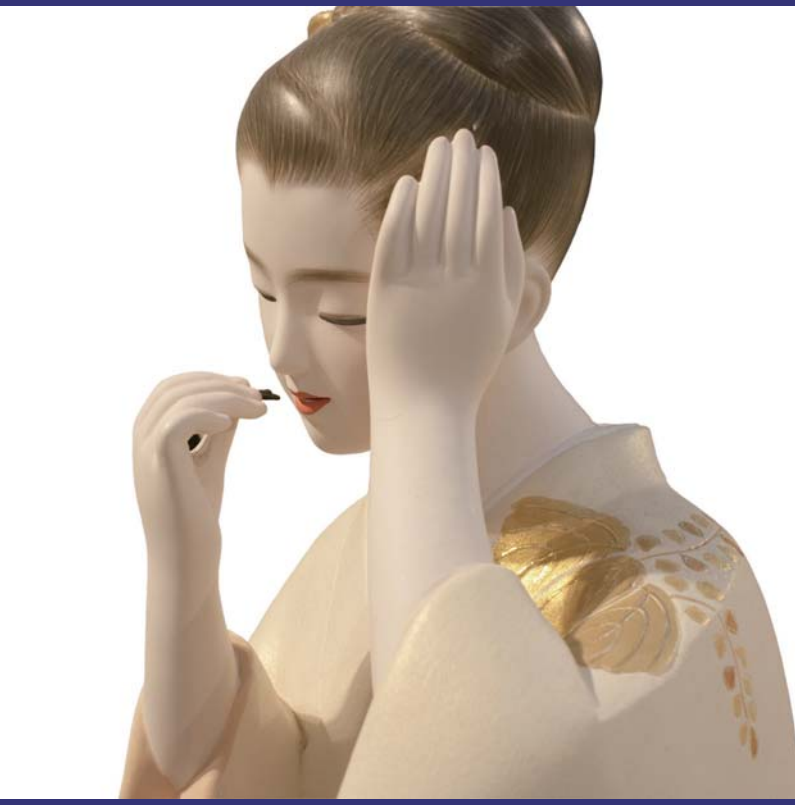
ITE

SID
SOCIETY FOR INFORMATION DISPLAY

IDW/AD'16

The 23rd International Display Workshops in conjunction with Asia Display 2016



Final Program

Fukuoka International Congress Center
Fukuoka, Japan
December 7 (Wed.) – 9 (Fri.), 2016

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PROGRAM HIGHLIGHTS

The 23rd International Display Workshops in conjunction with Asia Display 2016 will be held as IDW/AD '16 for encouraging aggressive research and development of display technologies throughout the world and especially in the Asian region. IDW/AD '16 focuses on the following 5 special topics and 1 topical session, which are extremely timely, as well as 14 active workshops.

Special Topics of Interest on
- Oxide-Semiconductor TFT
- AR/VR and Hyper Reality
- Lighting and Quantum Dot Technologies
- Printed Electronics
- Automotive Displays

Topical Session on
- User Experience and Cognitive Engineering

Workshops on
- LC Science and Technologies
- Active Matrix Displays
- FPD Manufacturing, Materials and Components
- Inorganic Emissive Display and Phosphors
- OLED Displays and Related Technologies
- 3D/Hyper-Realistic Displays and Systems
- Applied Vision and Human Factors
- Projection and Large-Area Displays and Their Components
- Electronic Paper
- MEMS and Emerging Technologies for Future Displays and Devices
- Display Electronic Systems
- Flexible Electronics
- Touch Panels and Input Technologies
- The 8th International Conference on 3D Systems and Applications

The three-day conference will feature 505 papers, including 3 keynote addresses, 103 invited presentations, 159 oral presentations, and 240 poster presentations. Following plenary session of keynote addresses in the Wednesday morning, presentations will begin and continue in 8 parallel oral sessions through Friday. Poster sessions, author interviews and demonstrations will enable participants to discuss topics in detail. Exhibits by universities and display industry-related businesses will also be featured from Wednesday to Friday in parallel with workshops. IDW/AD '16 should be of interest to not only researchers and engineers, but also managers of companies and institutions in the display community.

Special Topics of Interest on Oxide-Semiconductor TFT (OXT)
Currently, oxide semiconductor TFTs have been hugely successful in the industrial fields of flat panel displays. However, they are not yet a completed technology and we can find a lot of improvements day by day. In this IDW, not only the champion of the oxide semiconductor, IGZO, but also other finalists, including novel oxide materials, will be presented. New device structures and innovative deposition processes including solution processes will be also presented. By clarifying the operation mechanism, we can improve the performance stability. High resolution and large displays as well as challenging applications will be proposed. "Oxide semiconductors are the jewelry box in the information display world!" Don't miss it!

Special Topics of Interest on AR/VR and Hyper Reality (AR&VR)
In recent years, augmented reality (AR) and virtual reality (VR) applications have been making substantial progress with high-performance display devices and sensors including cameras with tracking capabilities and

computer graphics technologies.
There are several sessions for wearable devices such as head-mounted-displays. PRJ-WS introduces researches on hardware issues, LCT-WS on the quality of LCD, and VHF-WS on human perception side of wearable devices. We also introduce research about AR systems. PRJ-WS and DES-WS co-organize a session for introducing Spatial AR, which uses projector (s) for AR, while 3D-WS and 3DSA-WS introduce hyper realistic display systems and audio/haptic displays. A session organized by INP-WS introduces user interaction techniques used in AR systems.
Five oral and poster papers plan to present their works at I-DEMO. Please enjoy the state-of-the-art AR research.

Special Topics of Interest on Lighting and Quantum Dot Technologies (LIT)

The Lighting Technologies of STI will cover all aspects of science and technologies of lighting including LED lighting, OLED lighting, flexible lighting, manufacturing of lighting, lighting materials, device structures for lighting and internal or external efficiency enhancement technologies. A highlight for IDW/AD '16 will be the presentations on development of a high efficiency laser spotlight illuminator with a novel patterned phosphor structure and technological improvements in the phosphors for displays and high CRI lamps (PH-WS), applications of quantum dot materials, high brightness LED, energy-saving displays and lighting devices (MEET-WS) and OLED lighting technologies with stacked white OLED, lighting applications and advanced LED technologies including perovskite and quantum dots (OLED-WS).

Special Topics of Interest on Printed Electronics (PE)

Printing technologies are opening up a new era of electronic devices with their high productivity, low cost, large scale and low environmental-burden fabrication advantages. Printed Electronics, a Special Topics of Interest from IDW '14, will cover all aspects concerning printed electronics from scientific and technological viewpoints. This year, three workshops (FMC, OLED, and FLX) will hold sessions including standardization activities on printed electronics (FMC), solution-processed TFTs and OLEDs (OLED), and alignment technologies for printing process (FLX).

Special Topics of Interest on Automotive Displays (AUTO)

Under situations where a variety of display technologies are introduced into the automobile fields, a session "Automotive Displays (AUTO)" is newly scheduled as one of the Special Topics of Interest (STI) in 2016. There are many presentations related to the automotive technology in the IDW spreading across the workshops such as 3D, VHF, PRJ, DES, LCT, and INP. AUTO shares common features of automobile use in them. Sixteen oral or poster presentations are scheduled in the AUTO. For examples, much research into Head-Up Displays (HUD) that deal with Augmented Reality (AR), or 3-D display will be presented. Furthermore a technology that utilizes the lighting as the communication means and a study of an electronic tactile display will be presented besides HUD technology. These novel studies will surely attract your attention regardless of your position as a designer or a user of automobiles.

Topical Session on User Experience and Cognitive Engineering (UXC)

Displays are now diversified in its size from large ones to mobile and wearable ones. Displays are presently used in various situations from the office to towns to automobiles. Display technologies need to pay attention to the world where they are used. IDW will launch a new topic focusing on user studies and interaction design proposals to explore future display environments. This topic will cover all aspects of social studies, cognitive science, and human-computer interaction that aim to open up new use scenarios of displays.

Workshop on LC Science and Technologies (LCT)
The LCT workshop covers topics from fundamental studies to recent developments in LCD technologies and LC materials. Of special note this year are the four invited presentations related to high resolution LCDs, photo alignment technologies, new LC materials for FFS-mode LCDs and flexible LCDs. Moreover, new LC technologies, such as LC lenses, and photovoltaic system will be presented.

Workshop on Active Matrix Displays (AMD)
The AMD workshop covers Si-TFT, oxide TFT, organic TFT, OLED, sensors, memories, and the other devices. Recent paper presentations tend to focus on oxide TFT, which are expected to play a role in applications for higher definition LC and OLED displays than 8K4K or 800 ppi. We highlight the oxide TFT as a special topic of interest (STI-OXT) with six dedicated sessions covering a wide area from materials, physics, devices, and processes to applications. Furthermore, we have prepared two sessions for organic, printed, and flexible electronics mainly based on organic semiconductors. We look forward to your participation!

Workshop on FPD Manufacturing, Materials and Components (FMC)
The FMC workshop covers recent developments and achievements in the field of flat panel display technologies, including display optics, materials, components, display panel manufacturing and measurements technologies. The oral presentations contain more than 24 papers of which 9 are invited papers. In addition, more than 13 posters will be presented. In the FMC sessions, papers related to optical polarizer films, holographic waveguide display, retro-reflector for aerial display, micro-structured films for wide viewing, liquid crystal for space-variant polarization, flexible surface light sources, thin-film coatings on large size ultra-thin glass for flexible devices, phase change materials for reflective displays, thin film organic photodiodes on CMOS, and textured LTPS film by a single scanning CLC will be presented. The FMC-WS is supporting FLX-WS and PE of special topics of interest, in which the recent trends in these fields will be presented.

Workshop on Inorganic Emissive Display and Phosphors (PH)
The PH workshop presents the latest achievements in devices and phosphors for inorganic emissive displays, general lighting and liquid-crystal backlighting. Invited talks will be presented on emerging technologies such as high quality nanomaterials, quantum dots and laser spotlight illuminator.

Workshop on OLED Displays and Related Technologies (OLED)
The OLED workshop covers all aspects of the science and technologies of OLED, QLED, OTFT and other organic devices, ranging from material research, basic device physics for display including backplane technologies and other applications. The oral and poster sessions will cover OLED device technologies including OLED lighting technologies (LIT), OLED evaluation technologies and materials. Recent progress such as OLED displays, advanced OLED lighting, organic TFT and thermally activated delayed fluorescent (TADF) materials etc. will be reported on at IDW/AD ’16.

Workshop on 3D/Hyper-Realistic Displays and Systems (3D)
The 3D workshop focuses on recent progress in 3D and hyper-realistic displays and systems. It covers dual-/multi-view stereoscopic image, autostereoscopic display, 2D/3D image conversion, holography and holographic elements, integral photography, light field processing and analysis, volumetric images, aerial images, omni-directional images, immersive visualization system, depth and shape estimation, 3D scanner and printer, multi/hyper-spectral imaging, multi-color-primaries and hyperspectral display, crosstalk evaluation, visual depth and material

perception, image coding and transmission, standardization, new optical components, and more in the field of 3D/hyper-reality technologies. This year, the 3D workshop presents a lot of sessions in conjunction with 3DSA workshop to provide good opportunity for audiences to understand the trends in these fields.

Workshop on Applied Vision and Human Factors (VHF)

The VHF workshop covers all topics on vision, human factors, and image quality relating to information displays. We have six VHF oral sessions on Ergonomics for automotive applications, Display measurement and simulation, Human factors and applications, Visual comfort and motion sickness, Color vision and illumination, HDR and VR in addition to a VHF poster session. We also have a joint session with a 3D workshop on the theme of AR (Augmented Reality), a human factor session, and user experience and cognitive engineering session. Five invited talks will be given in the oral sessions, concerning LED Color targets Visual, 3D Educational Material, and Effects of Concave Curved Displays, Visually Induce Motion Sickness.

Workshop on Projection and Large-Area Displays and Their Components (PRJ)

The PRJ workshop covers the latest wearable applications, vehicle display technologies, head lights, solid-state light sources, holograms, short throw optics etc., projection mapping, Augmented Reality (virtual reality), 3D measurement, standardization of wearable/new light sources and all the projection technologies. This year, our session will focus on head light, wearable-related technologies, laser light sources, projection devices, projection mapping and standardization. A new session on standardization of wearable/new light sources has also been added. There will be 24 presentations, 20-oral and 4-poster, including 6 invited presentations in total.

Workshop on Electronic Paper (EP)

The EP workshop focuses on current topics in electronic paper including rewritable paper and flexible displays. Newly developed e-Paper technologies are now eagerly sought for emerging applications such as e-Books, e-Notes, electronic shelf labels, signage, and IoT. Various novel technologies will be presented in the following 3 sessions; 1. electrophoretic displays (4 pigment full color, 3 pigment color, and multi color), 2. flexible technologies and e-Paper for IoT, and novel material technologies such as electrochromism.

Workshop on MEMS and Emerging Technologies for Future Displays and Devices (MEET)

The MEET workshop is unique in covering all aspects of MEMS, nanotechnologies and emerging technologies concerning future displays, imaging devices, and emerging electron devices. It seeks to broaden the horizon of display and imaging technologies into cutting-edge technologies. Research areas such as materials, basic physics and fabrication processes are included. Among all the MEMS and display conferences in the world, this is the only opportunity for MEMS and cutting-edge technology researchers to gather and discuss such devices. Authorities from top research institutions around the world in this field have been invited. Invited speakers are from the University of Cambridge, Ecole Polytechnique, CEA-LETI, Brunel University, Seoul National University, Kyung Hee University, South China Normal University, Fuzhou University, Southern University of Science and Technology, Nanoco Technologies, Nanosys, X-Celeprint, Merck and Tohoku University. Together with contributed papers with high-quality content, this workshop is aimed at participants who wish to open up new fields in displays, imaging devices and emerging devices.

Workshop on Display Electronic Systems (DES)

The DES workshop covers all aspects of display electronic systems in

relation to video data processing, interface technologies, and cooperative operations between display components such as cells and backlights and sensors. This year, we will have 23 papers including 7 invited talks and 11 poster presentations (excluding late-news). We will organize one special session to celebrate the 10th anniversary of DES, and three normal sessions related to spatial augmented reality, 3D displays and sensors, and high image quality technology are planned.

Workshop on Flexible Electronics (FLX)

The FLX workshop focuses on advanced technologies for flexible electronics including displays, wearable sensors, and IoT technologies, which are composed of a wide range of fields from material science to practical applications. The sessions cover all aspects of the hottest flexible devices and material technologies including new TFT fabrication technologies, flexible substrates, encapsulation, innovative printing processes, new printing machines and evaluation techniques.

Workshop on Touch Panels and Input Technologies (INP)

Interface technologies such as touch panels and interactive technologies are the stars of the session. AR/Interactive systems such as haptics and AR are special topics of INP. Computer vision and natural interface technologies are still important research topics of INP. This year, new topics will be presented: automotive application and force sensing are special topics. INP papers will open a new window in displays and interactive technologies, not only for devices but also for systems, making them essential viewing.

Workshop on the 8th International Conference on 3D Systems and Applications (3DSA)

The 8th International Conference on 3D Systems and Applications (3DSA) is an international conference on audio-visual 3D technologies, systems, applications and other hyper-realistic systems, such as 3D capturing and processing, 3D coding and transmission, 3D displays and systems, 3D contents and applications, holographic technology, human vision, augmented reality, virtual reality, immersive display systems, free viewpoint image systems, ultra-realistic audio systems, and interactive systems. It will be held as 3DSA workshop this year. It is organized by the Ultra Realistic Communication Forum (URCF) / The Virtual Reality Society of Japan (VRSJ) in Japan, 3D Interaction Display Alliance (3DIDA) / Industrial Technology Research Institute (ITRI) / Society for Information Display (SID) Taipei Chapter in Taiwan, and the Association of Realistic Media Industry (ARMI) / Electronics and Telecommunications Research Institute (ETRI) and Korean Society of Broadcast Engineers (KSBE) in Korea.
This year, it is held in conjunction with IDW/AD '16 as 3DSA workshop in IDW/AD '16.

IDW Best Paper Award and IDW Outstanding Poster Paper Award

IDW will present "IDW Best Paper Award" and "IDW Outstanding Poster Paper Award". The award committee of IDW will select the most outstanding papers from those presented at IDW/AD '16. The award winners will be announced on the IDW website and given a plaque after the conference.

I-DEMO (Innovative Demonstration Session)

I-DEMO will be held on December 8 at Multipurpose Hall (2F). IDW provides the opportunity for an interdisciplinary technical demonstration/ discussion in a larger space, more preparation and demonstration time than in the "Author Interviews". Demonstration Award will be awarded to the demonstration that has the biggest impact on the audience.

Exhibition

The IDW/AD '16 Exhibition, which will be held from December 7 through December 9, covers materials, components, manufacturing and measuring equipment, software systems and other related products

for display devices. Please join in and enjoy discussions at exhibitors' booths (Lobby, 2F and 4F).

December 7 (Wed.) 12:40 – 18:00
December 8 (Thu.) 10:00 – 18:00
December 9 (Fri.) 10:00 – 14:00

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by Oral and Poster Presenters
Thursday, Dec. 8, 2016
10:30-16:40
Multipurpose Hall (2F)
Fukuoka International Congress Center

3DSA 2016

The 8th International Conference on 3D Systems and Applications
Held in conjunction with IDW/AD '16

Fukuoka International Congress Center
December 7-9, 2016
See page 133 for details
Free admission with your IDW/AD '16 registration name tag
http://www.3dsa.org/

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers selected from those presented at IDW/AD '16.
The 2016 award winners will be announced on the IDW website: http://www.idw.or.jp/award.html

GENERAL INFORMATION

SPONSORSHIP
IDW/AD '16 is sponsored by the Institute of Image Information and Television Engineers (ITE) and the Society for Information Display (SID).

CONFERENCE SITE
Fukuoka International Congress Center
2-1, Sekijo-machi
Hakata-ku, Fukuoka-shi
Fukuoka, 812-0032, Japan
Phone: +81-92-262-4111 Fax: +81-92-262-4701

ON-SITE SECRETARIAT
Telephone and fax machines for IDW/AD '16 will be temporarily set up in the secretariat room (Room 405) at Fukuoka International Congress Center (December 7-9). Phone/Fax: +81-92-282-8878

RECEPTION
A buffet style reception will be held on December 7 from 19:00 to 21:00 at the Crowne Grand Ball Room (2F) in ANA Crowne Plaza Fukuoka. As the number of tickets is limited, you are urged to make an advance reservation through the registration website.

EVENING GET-TOGETHER WITH WINE
A get-together will be held on December 6 from 18:00 to 20:00 at RACONTER 1F in Fukuoka International Congress Center. Wine (sponsored by Merck Ltd.) will be served to participants in a relaxed atmosphere for networking.

REGISTRATION
Registration is available in advance and also on-site. However, advance registration is strongly recommended to speed up the arrival procedure at the conference site.

Registration Fees
The registration fee for IDW/AD '16 includes admission to the conference and a USB Flash Drive of the proceedings. Detailed information will be announced on the website.

	Until Oct. 28	On and After Oct. 29
Individual Member (ITE/SID/ASO*)	¥ 40,000	¥ 50,000
Non-Member**	¥ 50,000	¥ 60,000
Student***	¥ 13,000	¥ 15,000
Life Member of ITE/SID	¥ 13,000	¥ 15,000
Reception	¥ 8,000	¥ 10,000

*ASO: Academic Supporting Organizations
(See p.16 as well as "Supporting Organizations and Sponsors" at the end of each workshop section.)
**Non-Member: If you intend to join either ITE or SID, the one year membership fee will be subsidized by IDW/AD '16 committee.
***Photocopy of student ID is required.

Please note that the payment of reduced registration fee is accepted until October 28. The full fee will be charged for payments made on and after October 29. Also note that the number of reception tickets to register on site is limited.

Proceedings Data at the Conference Site
Proceeding data can be accessed from the web-server via the wireless network only in the Free Wi-Fi Area at the conference site.

Additional proceedings (USB Flash Drive)

At the conference site	¥ 8,000
Airmail after the conference	¥ 12,000
Domestic mail after the conference	¥ 10,000

Payment
Three ways are provided for registration.

(1) e-Registration
Access the following URL.
http://www.idw.or.jp/regist.html
e-Registration will be accepted until November 25, 2016.

(2) Mail or Fax Registration
Complete the registration form (download from the website) and send it to the secretariat shown below together with the proof of payment no later than November 25, 2016.

IDW/AD '16 Secretariat
c/o Bilingual Group Ltd.
3-3-6 Kudan Minami, Chiyoda-ku, Tokyo 102-0074, Japan
Phone: +81-3-3263-1345 Fax: +81-3-3263-1264
E-mail: idw@idw.or.jp

The registration fee should be paid by one of the following methods.
1. Credit Card (VISA, MasterCard, JCB, AMEX or Diners)
2. Bank Transfer to:

Bank:	Bank of Tokyo-Mitsubishi UFJ (Swift Code: BOTKJPJT)
Branch:	Ichigaya Branch (Branch No. 14)
Account No.:	0167640 (Ordinary Account)
Account:	IDW

Please attach a copy of the bank receipt to the registration form to avoid any confusion. Please note that **the remittance charges, including that of Bank of Tokyo Mitsubishi UFJ, should be paid by the payer**.

All above payments should be made in **JAPANESE YEN**.
Also, please note that personal and traveler's checks are not accepted.

(3) On-site Registration
Conference registration desk will open:

December 6 (Tue.)	17:00 – 20:00
December 7 (Wed.)	8:00 – 18:00
December 8 (Thu.)	8:00 – 18:00
December 9 (Fri.)	8:00 – 13:00

On-site registration fee will be payable by:
1. Cash (JAPANESE YEN only)
2. Credit Card (VISA, MasterCard, JCB, AMEX or China Union Pay)

Bank transfer, bank checks, or personal/traveler's checks are not accepted.

Cancellation Policy
Until **October 28**, cancellation is accepted by writing to IDW/AD '16 Secretariat to obtain refunds for registration and reception. All bank services charges will be deducted from the refunds. Please note that refunds will not be made under the following conditions:
* Cancellations received on and after October 29
* No-shows
* Cancellations by presenters
* Cancellations by VISA invitation letter applicants who have already received a VISA invitation letter.

However, after IDW/AD '16 closes, a USB Flash Drive of the proceedings will be sent to the registrants who have paid the registration fees. If it becomes difficult to hold IDW/AD '16 due to the outbreak of infectious diseases and other unavoidable factors, we will substitute the IDW with the mail delivery of the IDW/AD '16 proceedings at a later date to all those who have registered and completed payment.

INQUIRIES

IDW/AD '16 Secretariat
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3-3-6 Kudan Minami, Chiyoda-ku, Tokyo 102-0074, Japan
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Academic Supporting Organizations (ASO)

- The Chemical Society of Japan
- The Electrochemical Society of Japan
- The Illuminating Engineering Institute of Japan
- The Imaging Society of Japan
- The Institute of Electrical Engineer of Japan
- The Institute of Electronics, Information and Communication Engineers (IEICE)
- The Institute of Image Electronics Engineers of Japan
- International Electrotechnical Commission
- The Japan Ergonomics Society
- The Japan Society of Applied Physics
- The Japanese Liquid Crystal Society
- The Optical Society of Japan
- The Society of Automotive Engineers of Japan
- The Society of Polymer Science, Japan
- The Virtual Reality Society of Japan
- Vision Society of Japan

FUNDS

- Fukuoka Convention and Visitors Bureau
- JSPS KAKENHI Grant Number 16HP0304

For final updated information, please visit our website, http://www.idw.or.jp/

IDW/AD '16 Tutorial in Japanese

Organized by SID Japan Chapter
Tuesday, Dec. 6, 2016
12:20-16:30
Room 501
Fukuoka International Congress Center
Detailed information will be announced at
http://www.sid-japan.org/

TRAVEL INFORMATION

ACCOMMODATIONS
JTB Convention Support Center will handle arrangements for your hotel reservations.

Hotel reservations can be made at the IDW official website.
http://www.idw.ne.jp/accommodation.html

JTB Convention Support Center

Phone: +81-92-751-2102 Fax: +81-92-751-4098
Office Hours: 9:30-17:30 (Weekdays only)
E-mail: Travel_idw2016@kys.jtb.jp

There will be an on-site travel information desk during the conference period to handle arrangements for transportations.

VISAS
Visitors from countries whose citizens must have visas should apply to Japanese consular office or diplomatic mission in their respective country. For further details, please contact your travel agency or the local consular office in your country.
Attention: For some countries' citizens, official documents prepared by the secretariat will be needed. Please ask the secretariat at least two months before the conference.

CLIMATE
The average temperature in Fukuoka during the period is around 12°C in the daytime and 4°C at night.

JAPAN RAILWAY PASSES
Japan Railway (JR) provides the following economical passes. They are the most economical and flexible rail passes to travel from around Osaka to Hakata (Sanyo-San'in Area Pass) and Kyushu area by Bullet Train and rail. They should be purchased before you leave your country. Please contact your travel agency. Visit following sites for the details.

(1) Sanyo-San'in Area Pass (Shin-Osaka⇔Hakata)：
http://www.westjr.co.jp/global/en/ticket/pass/sanyo_sanin/

(2) JR Kyusyu Pass (Northern Kyushu Area and All Kyushu Area)：
https://www.jrkyushu.co.jp/english/railpass/railpass.jsp

FUKUOKA

Fukuoka City (also known as “Hakata”) lies on the northern coast of Kyushu, the southernmost of the four main islands of Japan. The population of the city is approximately 1.5 million people, making it the 5th largest city in Japan.

Being the closest major city in Japan to the Korean Peninsula and China, Fukuoka has from ancient times been a gateway for economic and cultural exchanges with its Asian neighbors. On the basis of these historical and geographical links, the city is working on many levels to strengthen its relationships with the rest of Asia, towards the goal of becoming a “focal point for exchange in Asia”.

PLACES OF INTEREST

Dazaifu Tenmangu Shrine

Nishitetsu trains are available from Tenjin to Dazaifu Tenmangu (about 20 minutes by train and then 5 minutes on foot). Here, at the head shrine of all the Tenmangu Shrines in Japan, the god of learning, Michizane Sugawara, is worshipped. The plum tree to the right of the main building as you face it is called Tobiume (the flying plum tree), because it is said that the tree flew here to be with Michizane.

Kyushu National Museum

This museum is located a 5-minute walk from Dazaifu Tenmangu Shrine, and is Japan’s newest National Museum after Tokyo, Kyoto, and Nara. Based on the concept of “Understanding Japanese culture from an Asian viewpoint”, various valuable exhibits depict Japan’s blossoming relationships with other Asian countries over a long time.

Fukuoka City Museum

Covered with half-mirrored windows, this museum stands with the Fukuoka Tower rising behind it (about 15 minutes by bus from Hakata Station). There are 4 different exhibition rooms and a special exhibition room for visiting exhibitions. The Gold Seal, one of Japan’s national treasures, is exhibited in the Permanent Exhibition Room.

Uminonakamichi

Uminonakamichi is a peninsula connecting Shikanoshima Island in Higashi Ward to mainland Fukuoka. A large peninsula measuring about 8 km in length and about 2.5 km in width at its widest point, Uminonakamichi is a recreation area with a park in its central to north-western region. The JR Kashii Line and prefectural roads run parallel through Uminonakamichi, providing a popular scenic route. Those who prefer a boat ride can catch a ferry operated by Fukuoka City at the Bayside Place Hakata Futoh.

Nakasu-Tenjin Area

“Hakata” is famous for “Hakata Ramen”. One of the special features of nighttime Hakata is “Yatai (Street Stalls)”, street stalls that appear on the streets in the evening in Nakasu, Tenjin, and other areas. Yatai offer a range of hot tasty foods including Hakata Ramen, and a chance to rub shoulders with the locals.

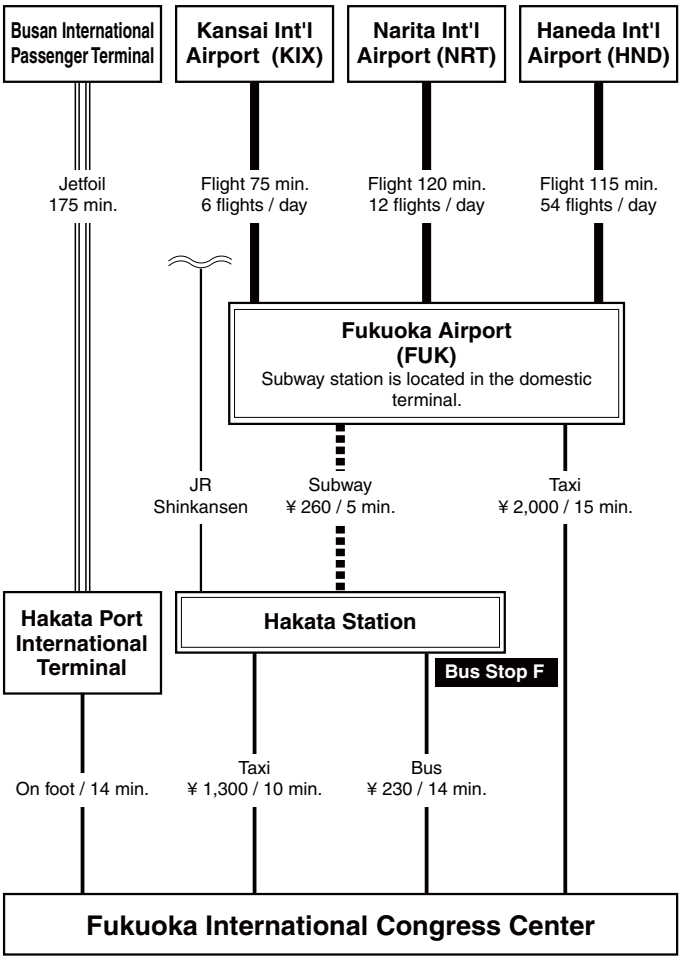
More information is available at the following websites:

http://www.city.fukuoka.lg.jp/english/

http://www.welcome-fukuoka.or.jp/english/

https://yokanavi.com/en/

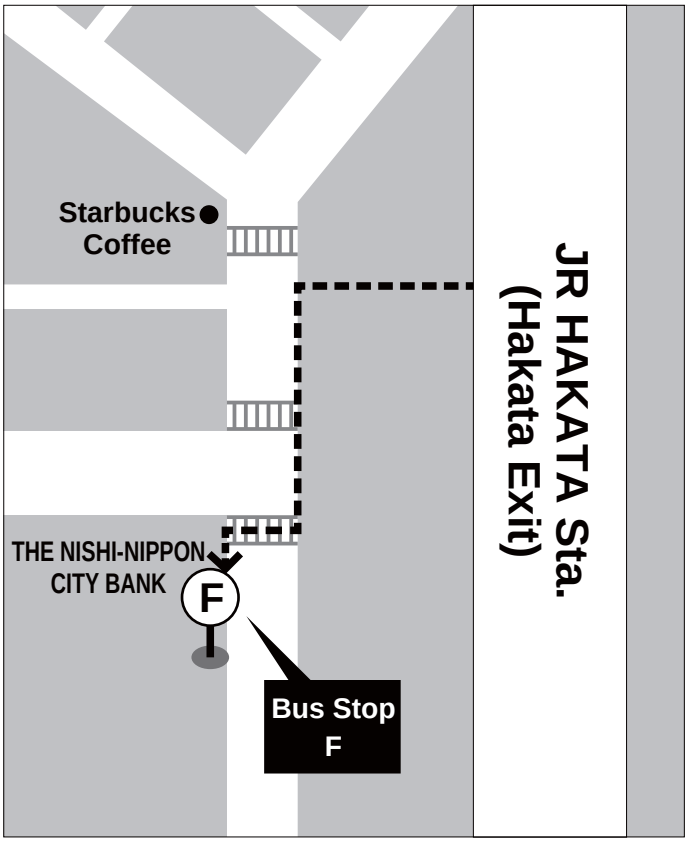
Access to Conference Site



Flight information on this page may be changed in December. Please confirm the details with each airline company.

(as of Oct., 2016)

Bus Stop at Hakata Station



In front of THE NIPPON CITY BANK, you will find the bus stop, Hakata-ekimae F.

Three kinds of buses are available to get to Fukuoka International Congress Center.

-No.88 and BRT*: bound for Hakata Port INT'L Terminal, get off at Kokusai Kaigijo Sun Palace-mae.

-No. 99: bound for Hakata Wharf, get off Kokusai Center Sun Palace-mae.

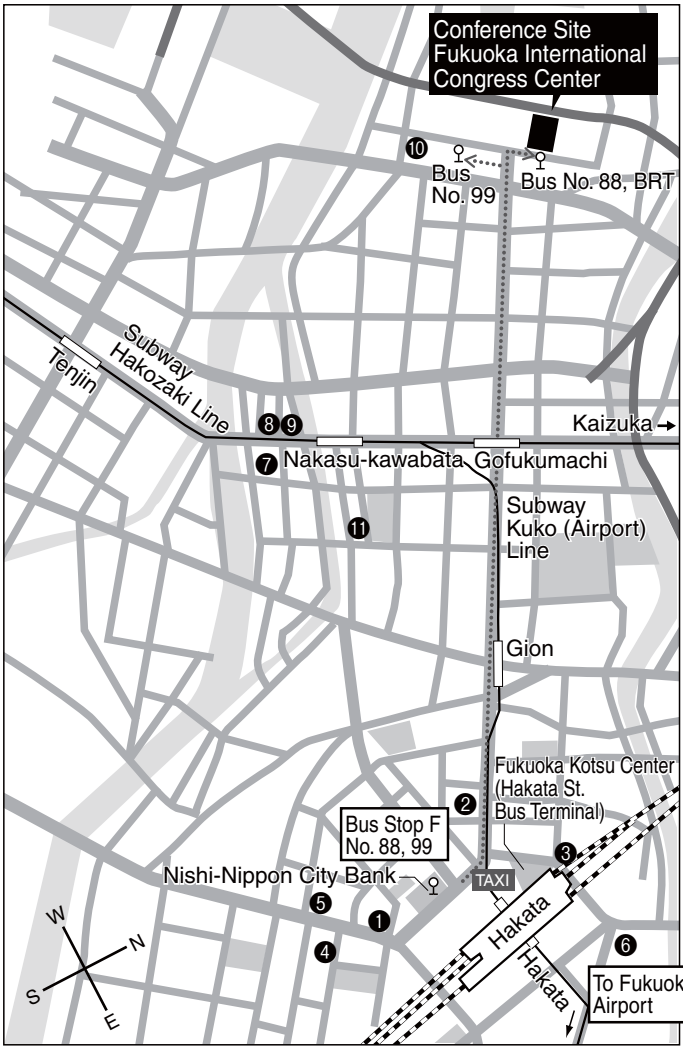
For more information, please check the detail below.

http://jik.nishitetsu.jp/menu?lang=en

*BRT, which is the Articulated Bus is available. Please find the detailed information from the below.

http://idw.or.jp/

HOTEL MAP



❶ Ana Crowne Plaza Fukuoka	❼ HAKATA EXCEL HOTEL TOKYU
❷ Hotel Nikko Fukuoka	❽ Imperial Palace CITY HOTEL
❸ NISHITETSU HOTEL CROOM HAKATA	❾ VESSEL INN HAKATA NAKASU
❹ YAOJI HAKATA HOTEL	❿ HOTEL HAKATA PLACE
❺ SUTTON HOTEL HAKATA CITY	⓫ Reisenkaku Hotel Kawabata
❻ TOYO HOTEL	

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by Oral and Poster Presenters
Thursday, Dec. 8, 2016
10:30-16:40
Multipurpose Hall (2F)
Fukuoka International Congress Center

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers selected from those presented at IDW/AD '16. The 2016 award winners will be announced on the IDW website: http://www.idw.or.jp/award.html

IDW '17

The 24th International Display Workshops

Dec. 6 – 8, 2017

Sendai International Center
Sendai, Japan

http://www.idw.or.jp/

Plenary Sessions

Wednesday, December 7

9:30 - 9:50 **Main Hall**

Opening

Master of Ceremony: M. Date, Executive Chair, IDW

Opening Remarks
9:30

M. Kimura, General Chair, IDW
Y.-S. Kim, President, SID
H. Oka, Vice President, ITE
R. Hattori, Program Chair, IDW

9:50 - 11:50 **Main Hall**

Keynote Addresses

Chair: R. Hattori, Program Chair, IDW
Co-Chair: M. Kimura, General Chair, IDW

Keynote Address - 1 **Future Trends of Display Technology**
9:50

C.-C. Lee

BOE Tech. Group, China

In this talk, the historical milestones and future vision of BOE display business will be described. Some updated status of advanced technology will be discussed. As the most rapidly growing display supplier, BOE strategy will also be introduced.

Keynote Address - 2 **Breaking the Barriers to True Augmented Reality**
10:30

C. Sandor

NAIST, Japan

In recent years, Augmented Reality (AR) and especially Virtual Reality have gained considerable commercial traction. I believe that soon, AR can become indistinguishable from reality; a concept I call True AR. This keynote addresses questions including: Why is True AR desirable? How can we test if something is True AR? How can we implement True AR?

Keynote Address - 3 **OLED Displays – Retrospection and Outlook**
11:10

C. W. Tang

Hong Kong Univ. of S&T, Hong Kong

EXHIBITION

12:40 – 18:00 Wednesday, Dec. 7
10:00 – 18:00 Thursday, Dec. 8
10:00 – 14:00 Friday, Dec. 9
Lobby (2F, 4F)
Fukuoka International Congress Center
Free admission with your IDW/AD '16 registration name tag

Evening Get-Together with Wine

Tuesday, Dec. 6, 2016
18:00 – 20:00
RACONTER (1F)
Fukuoka International Congress Center
(Sponsored by Merck Ltd.)
See page 14 for details

Reception

Wednesday, Dec. 7, 2016
19:00 – 21:00
Crowne Grand Ball Room (2F)
ANA Crowne Plaza Fukuoka
See page 14 for details

Special Topics of Interest on Oxide-Semiconductor TFT

Wednesday, December 7

13:00 - 14:25 **409**

AMD1: Oxide TFT: High-Stability TFTs

Chair: J. Jang, Kyung Hee Univ., Korea
Co-Chair: H. Kumomi, Tokyo Tech, Japan

AMD1 - 1: 13:00 ***Invited*** **Importance of Oxygen- and Hydrogen-Related Defects to Develop New Amorphous Oxide Semiconductor Materials**

T. Kamiya, J. Kim, K. Ide, H. Kumomi, H. Hosono
Tokyo Tech, Japan

First, defects and impurity in a-IGZO are reviewed focusing on oxygen- and hydrogen-related defects, which are strongly correlated and competing. We will also show that new materials are created by utilizing the above knowledge about defects in AOSs.

AMD1 - 2 13:25 **Electrical Characteristics of Si-Doped IGZO TFTs Fabricated Using Ion Implantation**

T. Goto, F. Imaizumi, S. Sugawa
Tohoku Univ., Japan

Si was doped to a-IGZO films by ion implantation. Hall effect measurement shows that electron carrier density increased by Si doping. For the Si-implanted IGZO TFT, gate bias stability against negative bias temperature illumination stress was improved, while the mobility was almost the same level as that without Si doping.

AMD1 - 3 13:45 **High Reliability Fluorine-Containing Polysilsesquioxane Passivation Layer for a-InGaZnO Thin-Film Transistors**

N. Yoshida[,**], J. P. Bermundo[**], Y. Ishikawa[**], T. Nonaka[*], K. Taniguchi[*], Y. Uraoka[**]*
[*]Merck Performance Materials Manufacturing G.K., Japan
[**]NAIST, Japan

We investigated the effect of fluorine-containing polysilsesquioxane passivation layer fabricated by solution process for InGaZnO (α-IGZO) thin-film transistors. This passivation layer greatly improves the stability of α-IGZO device even after being subjected to bias stress. Here, we demonstrate the photolithography properties, electrical properties and the state of the α-IGZO layer.

AMD1 - 4 14:05 **Achievement of High-Performance and Environmentally Stable TFTs by Introducing Hybrid-Phase Microstructure into InSnZnO Channels**

S. Deng[*], R. Chen[,**], G. Li[*], Z. Xia[*], K. Wang[***], M. Zhang[*], W. Zhou[*], M. Wong[*], H.-S. Kwok[*]*

[*]Hong Kong Univ. of S&T, Hong Kong
[**]South China Univ. of Tech., China
[***]Jinan Univ., China

We proposed the hybrid-phase microstructural InSnZnO thin films, where a number of nanocrystals were embedded in an amorphous matrix. The corresponding bottom- and top-gate TFTs with remarkable and uniform electrical characteristics were successfully fabricated. Additionally, such devices were air-stable owing to in situ passivation of hybrid-phase microstructure for InSnZnO channels.

----- Break -----

14:40 - 16:15 **409**

AMD2: Oxide TFT: High-Performance TFTs

Chair: T. Kamiya, Tokyo Tech, Japan
Co-Chair: H. Hamada, Kinki Univ., Japan

AMD2 - 1: 14:40 ***Invited*** **High Yield, High Drain Current Oxide TFTs for Display Manufacturing**

S. Lee, J. G. Um, D. Geng, J. Jang
Kyung Hee Univ., Korea

We report the high drain current amorphous indium-gallium-zinc-oxide (a-IGZO) thin-film transistors (TFTs) with excellent performance uniformity by using bulk accumulation (BA) mode. The high performance BA-TFTs could be applied to high yield and fast response integrated gate drivers for AMOLED and AMLCD.

AMD2 - 2: 15:05 ***Invited*** **Top Gate High Mobility Oxide TFT with Double Layered Gate Insulator**

Y. Kim, K. Park, J.-B. Ko, G. Mun, S.-H. K. Park
KAIST, Korea

We report top gate structured high mobility oxide TFT with high stability under the bias and current stress by using double layered gate insulator. Alumina gate insulator deposited by ALD plays key role both as the H barrier and in the formation of defects less interface with active layer.

AMD2 - 3: 15:30 ***Invited*** **Boosting the Field-Effect Mobility of Metal Oxide Thin Film Transistor by a Microstructure Modification**

J. K. Jeong, Y. Shin, S. T. Kim, I. J. Chung
Hanyang Univ., Korea

The metal reaction method is proposed to improve the mobility of IZO and IGZO TFTs. The high mobility exceeding 49.0 cm^2/Vs can be achievable in the resulting IZO and IGZO TFTs, which can be attributed to the affirmative effect of loosely bonded oxygen scavenge and M-O lattice ordering, respectively.

AMD2 - 4 15:55 **Double-Channel Oxide Semiconductor Vertical TFTs with Mo Source/Drain Layer**

*C.-S. Hwang, J. H. Choi, S. H. Cho, J.-H. Yang, J.-E. Pi, O.-S. Kwon, E.-S. Park, H.-O. Kim, S.-H. K. Park**

ETRI, Korea
**KAIST, Korea*

Vertical channel oxide semiconductor TFT was fabricated with convention metal source/drain layer, sputtered active layer and PECVD deposited gate insulator. Double-channel active structure was adopted for preventing non-ohmic contact resistance between active layer and metal source/drain layer. This structure is desirable for applying VTFTs to display panel with large area.

----- Break -----

16:20 - 17:50 **409**

AMD3: High-Resolution Displays

Chair: S.-H. K. Park, KAIST, Korea
Co-Chair: K. Takatori, NLT Techs., Japan

AMD3 - 1: 16:20 ***Invited*** **Advanced OLED Display Technologies for Large-Size UHD TVs**

H. J. Shin, S. Takasugi, H. D. Choi, C. K. Ha, J.-M. Kim, H. S. Kim, C. H. Oh

LG Display, Korea

Advanced OLED display technologies have been developed for large-size UHD OLED TVs. Self-aligned coplanar TFT is employed as panel backplane. The maximum difference of threshold voltages of a-IGZO TFTs on Gen. 8.5 glass is approximately 0.57 V. By applying novel compensation methods and a high dynamic range technology, we can enhance image quality of the OLED display.

AMD3 - 2: 16:45 ***Invited*** **LCD with Ultra High Resolution and Super Fast Response Giving Super Reality to VR Application**

N. Ueda, K. Okada, S. Uchida, K. Yamamoto, K. Yamamoto, H. Yoshida

Sharp, Japan

We will discuss our approach for the emerging Virtual Reality HMDs. We developed a 1008 ppi LCD with 2k2k resolution, realizing ultra-high definition and fast response at the same time. Advanced Oxide Pixel technology, super fast response LC technology, and advanced backlight for motion blur rejection have been adopted successfully.
Also presented in Innovative Demonstration Session (see p. 262)

AMD3 - 3
17:10
12.5-in. Real RGB Pixel High 4K Resolution a-Si TFT- LCD with Advanced Design to Reduce the Loss of High-Frequency Data Signal

S.-Y. Wu, C.-C. Chang, H.-H. Chen, H.-M. Su, W.-Z. Zeng
Chunghwa Picture Tubes, Taiwan

CPT research the parameters about printed circuit board (PCB) layer structure or metal trace etc. in layout design of eDP and P2P interface for high-resolution signal transmission, and finally we reached to decrease the loss of signal and having better signal integrity.

AMD3 - 4
17:30
19.5-in. 4K LCD Fabricated with Novel LTPS Technology at Gen10 Line

N. Nodera, S. Ishida, T. Matsumoto, K. Kobayashi
Sakai Display Prods., Japan

We developed Partial Laser Anneal Silicon (PLAS) TFT of novel LTPS technology for large substrate, which had the mobility of 28.1 cm^2/Vs in bottom-gate structure. A 19.5-in. prototype 4K LCD has been fabricated at Gen10 line. Photo-stability of PLAS will be suitable to OLED backplane, HDR TV, and outdoor IDP.

Author Interviews
17:50 – 18:20, Multipurpose Hall

Thursday, December 8

10:30 - 13:00 **Multipurpose Hall**

Poster FMCp2: Oxide TFT Manufacturing

FMCp2 - 1
Influence of Oxygen Ratio in Gate Bias Instability of Amorphous InGaZnO Thin Film Transistor

N. On, H. Seul, S. Kim, K. Lee, J. K. Jeong
Hanyang Univ., Korea

The PBTS dependent Vth variations for the self-aligned IGZO TFTs were examined. The activation energy barrier for the PBTS induced instability was found to be strongly dependent on the oxygen partial pressure during IGZO preparation, which was discussed on basis of the various degradation mechanisms.

FMCp2 - 2
Structural Characteristics of Nickel-Zinc Oxide Nanostructures

Y. Yoshihara, K. H. Kim, Y. Abe, M. Kawamura, T. Kiba
Kitami Inst. of Tech., Japan

We fabricated nanolayered nickel-zinc oxide nanostructures prepared via a simple one-pot solution process using aqueous solution dissolving nickel acetate, zinc nitrate, hexamethylenetetramine, and investigated their structural properties without and with annealing treatment of temperature at 700°C. After annealing, the nanolayers were composed of nanoparticles of several tens nanometers.

FMCp2 - 3 **Soluble-Processed SiO_2 Gate Insulator Fabrication via Deep UV Curing for Amorphous Oxide Transistors**

H. Seul, N. On, K. Lee, S. Kim, J. Jeong

Hanyang Univ., Korea

High-temperature annealing (> 300°C) required to obtain reasonable insulating properties still limits for the flexible electronics. This paper suggests that a perhydropolysilazane (PHPS) solution added VTES coupling agent can reduce the annealing temperature by using UV process.

FMCp2 - 4L **Withdrawn**

FMCp2 - 5L **Effect of Nitridation Pretreatment on the Electrical Properties of Low-Temperature (100°C) Silicon Nitride Films**

S. M. Noh, W.-S. Hong

Univ. of Seoul, Korea

Nitridation pretreatment with a mixture of NH_3 and N_2 has been attempted to improve electrical properties of silicon nitride films deposited at 100°C. The nitridation process for 1 minute at the substrate temperature of 50°C reduced drastically the capacitance-voltage hysteresis window and the threshold voltage shift.

10:30 - 13:00 **Multipurpose Hall**

***Poster* FLXp2: Oxide TFT for Flexible Devices**

FLXp2 - 1L 10:30 **Low-Temperature (150°C) Processed Self-Aligned InGaZnO Hybrid Thin-film Transistor with an Organic Gate Insulator**

M. Furuta, Y. Krieg, G. Tatsuoka, S. G. M. Aman, Y. Hirota, N. Frühauf**

Kochi Univ. of Tech., Japan
**Univ. of Stuttgart, Germany*

High performance, top-gated, and self-aligned In-Ga-Zn-O thin-film transistor was demonstrated at 150°C using an organic gate insulator. Fabricated hybrid TFT exhibited excellent electrical properties with the field effect mobility of 10.2 cm^2/Vs, subthreshold swing of 0.19 V/dec. The hybrid TFT is one good candidates for flexible and/or printed electronics.

FLXp2 - 2L **Multi-Functional Indium Tin Oxide Thin Films for Flexible Device**

S. H. Kim, J. N. Jang, S. Yi, M. P. Hong

Korea Univ., Korea

We introduce magnetic field shielded sputtering to block negative oxygen ion bombardments. The ITO thin films formed by MFSS at RT, a nanocrystalline phase is formed which leads to superior electro-optical characteristics. The ITO films also possessed low water permeability therefore, they are suitable for flexible devices.

----- Lunch -----

14:10 - 16:40 **Multipurpose Hall**

***Poster* AMDp1: Oxide TFTs**

AMDp1 - 1 **AC Stress Stability Study with Different Channel Length in BCE IGZO TFT for 32-in. 8K4K GOA LCD**

L.-Q. Shi, S.-J. Chen, Y.-F. Chou, L.-M. Zeng, T.-H. Wang, W.-Y. Li, X.-W. Lv, R.-L. Chen, C.-W. Liao, M. Zeng, S.-M. Ge, M. Wang, C. K. Zhang, C.-Y. Chiu, X. Liu, C.-Y. Lee

Shenzhen China Star Optoelect. Tech., China

AC stress stability study with different channel length in BCE IGZO TFT was investigated. It showed the threshold voltage shift is not sensitive to the AC frequency and channel length compared with the duty ratio. Based on the study, 32-in. 8K4K LCD was demonstrated by using GOA technology.

AMDp1 - 2 **Bias and Temperature Reliability of Amorphous Indium Tin Zinc Oxide Thin Film Transistor on SiO_2, SiN_x Gate Dielectric**

S. Kim, B. Choi

Sungkyunkwan Univ., Korea

In this study, we fabricated ITZO thin film transistor using oxide semiconductor that is mixed metal oxide- indium (In), tin (Sn), zinc (Zn). We investigated gate bias stress and temperature reliability of ITZO by comparison with gate dielectric SiO_2 and SiN_x respectively.

AMDp1 - 3 **Low-Power Gate Driver Circuit Using Depletion Mode a-IGZO TFTs**

J.-H. Kim, S. Wang, J. Oh, K. Park[*]*, Y.-S. Kim*

Sungkyunkwan Univ., Korea
[*]*Konkuk Univ., Korea*

This paper proposes a new gate driver using depletion mode a-IGZO TFTs. First, the proposed circuit is possible to decrease discharging of Q node due to leakage current. Second, the driving TFT V_{gs} of the inverter has zero less using two low supplies.

AMDp1 - 4 **Effects of Activation Annealing on the Reliability of Indium-Gallium-Zinc Oxide Thin-Film Transistors with Thermal Induced Source/Drain Regions**

J. Li, L. Lu, Z. Feng, H. S. Kwok, M. Wong

Hong Kong Univ. of S&T, Hong Kong

With respective gas-permeable and impermeable covers in the channel and source/drain regions, indium-gallium-zinc oxide thin-film transistors with thermally-induced homojunctions exhibit superior characteristics and small device footprint. Presently reported is the dependence of the reliability of the transistors on the junction-activation heat-treatment process.

AMDp1 - 5 **Low Subthreshold Swing InGaZnO Thin Film Transistors with UV-Ozone-Treated $BaTiO_3$ Dielectric Layers**

H.-Y. Liou, A.-H. Cheng, S.-Y. Chu

Nat. Cheng Kung Univ., Taiwan

We developed a method to improve the electrical performance of amorphous $BaTiO_3$ thin film by UV-ozone treatment. The treatment promoted densification of the dielectric layer by decreasing oxygen-vacancy and increasing metal–oxide bonds. The InGaZnO-TFTs exhibited high on/off ratio of 1.46×10^7 and the low sub-threshold swing of 0.069 V/dec.

AMDp1 - 6 **High Mobility Thin Film Transistors Formed by Metal-Induced Crystallization of Amorphous Zinc Tin Oxide Semiconductors**

S. T. Kim, K. J. Lee, N. On, H. J. Seul, J. K. Jeong

Hanyang Univ., Korea

Transition tantalum induced crystallization of amorphous zinc tin oxide (a-ZTO) was observed at low temperature annealing of 300°C. A significant improvement in the field-effect mobility (up to ~33.5 cm^2/Vs) was achieved for crystallized ZTO TFTs.

AMDp1 - 7 **Structure Engineering with ZrO_2 Thin Film for Highly Conducting Electrospun In_2O_3 Nanowire Field Effect Transistors**

H. Park, I. Lee, Y. H. Kim, B.-S. Bae

KAIST, Korea

In O_2 atmosphere, 600°C-annealed electrospun In_2O_3 nanowire field-effect transistor (NWFET) exhibits conductive behavior with large off-current (I_{off}) and high subthreshold slope (S.S.). Solution-processed ZrO_2 thin film is utilized to control and optimize conducting In_2O_3 NWFET and underlying mechanism is studied.

AMDp1 - 8 **New p-Type Thin-Film Transistor**

K. Lee, S. Kim, H. Seul, N. On, J. Jeong

Hanyang Univ., Korea

In recent developments, p-type oxide still lag in performance behind their n-type counterparts. In this paper, we demonstrated a new p-type thin-film transistor. XON has high hall mobility more than 200 cm^2/Vs. This study examined electrical properties, electronic structures, and chemical compositions of XON.

AMDp1 - 9 **De-Mux Circuit on the FFS-Mode LCD with a-IGZO TFTs**

Y.-K. Chen, C.-C. Tsai, E.-C. Liu, K.-Y. Lai, Y.-H. Chen, S.-C. Chiang, F.-C. Lu, Y.-J. Lu, W.-K. Tsao, C.-H. Huang, Y.-Y. Huang

Chunghwa Picture Tubes, Taiwan

We successfully developed the 5.5-in. narrow bezel FFS-mode LCD with the ESL type a-IGZO TFTs and the de-mux circuits. The de-mux circuits can narrow the bezel and reduce the number of IC chips on the display. The I_{on}/I_{off} of the ESL type TFTs are more than 10^9.

AMDp1 - 10 **New AMOLED Pixel Circuit with Concise 3-T Structure for Normally-off and Normally-on Amorphous IGZO TFTs**

P.-S. Chen, C.-E. Lee, C.-L. Lin

Nat. Cheng Kung Univ., Taiwan

A pixel circuit with V_{TH} compensation for AMOLED displays is proposed. By source-follower structure, the proposed circuit can detect V_{TH} shift of normally-off/on TFTs. Simulations show that the proposed circuit successfully senses V_{TH} shift of driving TFT during programming, and produces uniform current in range of 60 to 500 nA.

AMDp1 - 11 **Inkjet-Printed InGaZnO Thin Film Transistor on Flexible Substrate**

H. Hu, H. Huang, F. Li, T. Guo

Fuzhou Univ., China

Uniform IGZO films were inkjet-printed as active layer of TFT on a polyimide substrate. Laser spike annealing was conducted to improve the device performance.

AMDp1 - 12 **Investigation of Annealing Temperature and Atmosphere Effect on Solution Process ZTO Transistors with Different Metal Composite Doping**

N.-X. He, W.-X. Cheng, W.-A. Cheng, S.-J. Cheng, Y.-W. Wang

Nat. Chagnhua Univ. of Education, Taiwan

We investigated the characteristics transition of sol-gel processed Zinc-Tin-Oxide transistors with different metal dopant. The annealing conditions conducted different temperature and atmospheres. The result showed that moderate metal dopant could lower down the process temperature and increase its stability in ambient air. The highest mobility ~2.4 cm^2/Vs was achieved.

AMDp1 - 13L **Characteristic Analysis of IGZO Thin Films Using Planar and Stacked Devices - Evaluation of Electrical Resistivity and Current Density -**

M. Kimura[,**], Y. Koga[*], T. Matsuda[*], Y. Nakashima[**]*

[*]Ryukoku Univ., Japan
[**]NAIST, Japan

Electrical characteristics of IGZO Thin Films are analyzed using planar and stacked devices. The contact resistance is high but doesn't influence on the transistor characteristics. The current density in the planar device is higher than that in the stacked device owing to the high contact resistance and large electrode area.

AMDp1 - 14L Thermal Analysis and Device Simulation of Heat Suppressed Structure for Oxide Thin-Film Transistor

K. Kise, M. N. Fujii, J. P. Bermundo, Y. Ishikawa, Y. Uraoka

NAIST, Japan

Self-heating degradation in TAOS TFTs generated by driving voltage is a serious problem for development of highly reliable flexible displays. In this work, we suggested heat suppressed TFT structure in order to improve the reliability of TAOS TFTs by using device simulator and thermal analysis system.

AMDp1 - 15L Oxide TFTs Characteristic Optimize for Gate Driver on Array

S. J. Choi, Y. S. Song, C. W. Jeong, W. S. Li, F. Z. Zhang, G. C. Yuan, J. I. Ryu

BOE Tech. Group, China

We judged that, to adopt Oxide TFT on gate driver on array, the positive (+) position of initial V_{th} is advantageous for the reliability of GOA. Therefore, in this paper, we had studied which process conditions affect the initial V_{th} of Oxide TFT. As a result, the amount of O_2 in IGZO, N_2O treatment on IGZO film and ESL deposition condition are those.

AMDp1 - 16L Aluminum Doping Effect in Solution-Processed Indium Oxide TFTs

S.-H. Lee, T. Kim, C. Avis, J. Jang

Kyung Hee Univ., Korea

Aluminum as a carrier suppressor for solution-processed In_2O_3 TFTs was investigated. With increasing Al concentration from 0 to 5, and 10 % in In_2O_3 TFTs, the linear mobility decreased from 10.88 to 3.74, and 1.65 cm^2/Vs, and the threshold voltage increased from -3.35 to -0.5, and 0.85 V.

AMDp1 - 17L Improvement of Device Performance of Solution Processed IZTO TFT by Ar/O_2 Plasma Treatment

J. Lee, T. Kim, S.-H. Lee, C. Avis, J. Jang

Kyung Hee Univ., Korea

We investigated the effect of Ar/O_2 plasma treatment on the performance of solution processed indium-zinc-tin-oxide (IZTO) thin-film transistors (TFTs). The hysteresis voltage of the IZTO TFT dramatically decreased from -2.55 to -0.3 V by exposing IZTO surface to Ar/O_2 plasma. The linear mobility was improved from 48.89 to 129.84 cm^2/Vs.

AMDp1 - 18L Influence of N_2O Back-Channel Treatment on Copper S/D Metal BCE IGZO TFTs

C.-Y. Hou, Y.-T. Chiang, C.-J. Li, S.-F. Wu, S.-C. Lee, W.-C. Tsai

AU Optronics, Taiwan

Copper BCE_structure IGZO TFT using N_2O plasma treatment to passivate back-channel, we have modified the treatment process to prevent the metal from oxidation and improve the PV/metal interface. The PV/metal interface and device characteristics of Cu BCE IGZO TFT can be improved by modifying the N_2O back-channel treatment process.

AMDp1 - 19L Effects of Magnetic Field Shielded Sputtering Process on the Properties of IGZO TFT

K. D. Kim, D. H. Lee, S. G. Kim, M. H. Hong

Korea Univ., Korea

In this study, we will introduce our novel technology named as Magnetic Field Shielded Sputtering (MFSS) process to prevent the negative oxygen ions (NOIs) bombardment effects and present how much to be improved the properties of InGaZnO thin films transistor (IGZO TFT) by this new deposition method.

----- Break -----

16:50 - 18:20 **409**

AMD4/LCT4: Super-High-Resolution LCDs

Chair: M. Inoue, Huawei Techs., Japan
Co-Chair: M. Inoue, Apple, Japan

AMD4/LCT4 - 1: 16:50 ***Invited*** **510-ppi 8K4K LTPS-TFT LCD with 30 to 120 Hz Frame-Rate Driving**

H. Miki, D. Suzuki, M. Okita, K. Mochizuki, H. Hayashi, T. Nakamura, H. Kato, A. Oyama, Y. Matsui, K. Nishiyama, H. Kimura

Japan Display, Japan

On the basis of the low temperature polysilicon (LTPS) technology, a 510-ppi 8K4K LCD driven at frequency from 30 to 120 Hz has been developed, which provides a higher image quality without the uncomfortable feeling of crosstalk and the flicker caused by frequencies in practical use.

AMD4/ LCT4 - 2: 17:15 ***Invited*** **Development of a 27-in. 8K4K LCD Prototype Using an IGZO TFT Backplane**

S. Yamada, F. Shimoshikiryoh, Y. Itoh, A. Ban

Sharp, Japan

We have successfully developed 27-in. 8K4K Liquid Crystal Display by utilizing BCE IGZO (Back Channel Etched InGaZnO) transistor. BCE IGZO-TFT realizes low resistance wiring material because of its low process temperature. Because of this, we can enlarge the screen size to desktop monitor class, while keeping smartphone-class fine resolution.

Also presented in Innovative Demonstration Session (see p. 262)

AMD4/ LCT4 - 3 17:40 **Development of Cu BCE-Structure IGZO TFT for High ppi 32-in. 8K4K LCD**

S.-M. Ge, S. Li, S.-J. Chen, X.-Y. Kong, W. Shi, H.-J. Zhang, Y.-H. Meng, L.-Q. Shi, X. Liu, M. Wang, C. K. Zhang, C.-Y. Chiu, C.-Y. Lee

Shenzhen China Star Optoelect. Tech., China

The electrical characteristics of the BCE-structure IGZO TFT using copper as the gate and source/drain metal were studied. Through modifying the GI layer and annealing temperature, Cu BCE-structure IGZO TFT exhibited good subthreshold swing, threshold voltage and BTS reliability. Finally, a high performance 32-in. 8K4K IGZO LCD was demonstrated.

AMD4/ LCT4 - 4 18:00 **Fast-Response Fringe Field Switching LCD for Virtual Reality**

L. Fang, Y. Chen, Y. Liang, L. Wu, P. Shen, C. Tseng

XiaMen Tianma Microelect., China

We have achieved a fast response fringe field switching LCD of 847 ppi, which could be a competitive choice for virtual display. The maximal gray to gray response time was decreased dramatically from 19 ms to 7 ms. An advanced color filter was also proposed to optimize the white coordinates.

Author Interviews
18:20 – 18:50, Multipurpose Hall

Friday, December 9

10:40 - 12:00 **409**

AMD6: Flexible Devices

Chair: M. Kitamura, Kobe Univ., Japan
Co-Chair: Y. Fujisaki, NHK, Japan

AMD6 - 1: 10:40 ***Invited*** **Flexible TFT and Devices Manufacturing Using Advanced Printed Electronics Technology**

T. Kamata[,**], M. Yoshida[*], S. Uemura[*], K. Suemori[*], S. Nishi[**], Y. Mishima[**]*

[*]AIST, Japan
[**]JAPERA, Japan

High resolution flexible large-area sheet sensor and display with TFT backplane were investigated. The flexible devices were prepared by all-print process. Advanced flexible alignment technology and stretchable wiring technology were developed to improve the flexible device performance.

AMD6 - 2: 11:05 ***Invited*** **Megahertz Organic Thin-Film Transistors for Flexible Active-Matrix Displays**

U. Zschieschang, U. Kraft, R. Rödel, H. Klauk

Max Planck Inst. for Solid State Res., Germany

A process for the fabrication of organic thin-film transistors (TFTs) with channel lengths as short as 0.5 µm on flexible plastic substrates has been developed. The TFTs are fabricated in the bottom-gate, top-contact (inverted staggered) architecture and employ a thin, low-temperature-processed gate dielectric and vacuum-deposited small-molecule semiconductors.

AMD6 - 3L 11:30 **Highly Reliable Solution Processed Oxide TFT with Doped Semiconductor, High-k Gate Insulator, and Oxide Passivation Layers Patterned by Standard Photolithography Process**

Y. Hirano, M. Kusayanagi, S. Arae, R. Saotome, Y. Sone, S. Matsumoto, Y. Nakamura, Y. Ando, N. Ueda, K. Yamada

Ricoh, Japan

We have developed solution-processed oxide TFT. Doped-oxide semiconductor, high-k oxide gate insulator, and two oxide passivation layers were formed by spin-coating and standard photolithography process using original inks. The mobility reached over 10 cm^2/Vs. Reliability was remarkable with ΔV_{th} less than 0.2 V after 10^5 seconds under bias-temperature stress.

AMD6 - 4L 11:45 **Analysis of High Mobility Oxide Thin-Film Transistors after a Low Temperature Annealing Process**

J. P. Bermundo, Y. Ishikawa, M. N. Fujii, C. Kulchaisit, H. Ikenoue[*], Y. Uraoka

NAIST, Japan
[*]Kyushu Univ., Japan

High mobilities of more than 40 cm^2/Vs in amorphous InGaZnO (a-IGZO) thin-film transistors (TFT) were achieved through a low temperature excimer laser annealing process (ELA). The improvement mechanism was determined by analyzing the changes in electrical characteristics, composition, structure, and chemical bonding of the oxide semiconductor.

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 14:50 **409**

AMD7: Oxide TFT: Solution-Processed TFTs

Chair: T. Kamata, AIST, Japan
Co-Chair: H. Kumomi, Tokyo Tech., Japan

AMD7 - 1: 13:30 ***Invited*** **Large-Scale Printed Sol-Gel Metal Oxide Dielectrics**

W.-J. Lee, S. Park, M.-H. Yoon

Gwangju Inst. of S&T, Korea

A simple large-area sol-gel bar-printing of metal oxide dielectric layers was successfully demonstrated in order to control ultrathin film thickness with the excellent dielectric performance and physical properties. Both dielectric and semiconductor films were successfully fabricated by direct-bar-patterning process using surface wetting, leading to high-performance low-voltage sol-gel metal-oxide transistors.

AMD7 - 2 13:55 **Uniform Large-Area Slot-Die Coating of Soluble Metal Oxide Semiconductor towards Mass Production of High-Performance TFT Backplanes**

I. Katsouras[*], J. Maas[*], J.-L. van der Steen[*], G. Gelinck[,**], R. Takata[***], M. Marinkovic[***], A. Neumann[***], D.-V. Pham[***], R. Anselmann[***], T. H. Ke[****], S. Smout[****], S. Schols[****]*

[*]Holst Ctr., The Netherlands
[**]Eindhoven Univ. of Tech., The Netherlands
[***]Evonik Resource Efficiency, Germany
[****]imec, Belgium

ESL TFT backplane with solution type metal oxide semiconductor was completely processed on mass-production ready equipment. High mobility TFTs with excellent uniformity were obtained over the complete Gen1 glass substrate (320 mm x 352 mm), with good TFT bias stress reliability. An 85 ppi QVGA AMOLED display is demonstrated.

AMD7 - 3 14:15 **5.8-in. Ultra-Narrow Border LCD with Soluble Metal-Oxide TFTs and Integrated with GIP Circuit**

W.-K. Tsao, S.-C. Chiang, Y.-H. Chen, D.-C. Wu, K.-H. Tseng, Y.-H. Lin, H.-M. Chang, Y.-Y. Huang, D.-V. Pham, K.-H. Su*, M. Marinkovic*, D. Weber*, A. Merkulov*, R. Anselmann**

Chunghwa Picture Tubes, Taiwan
**Evonik Resource Efficiency, Germany*

In this paper, the soluble metal oxide-TFT fabricated with coating process and electrical stability of TFT device is investigated. We can integrate not only GIP-circuits but also solution-process OTFT to fabricate a 5.8-in. TFT-LCD with ultra-narrow-border (< 1 mm). The demonstrated panel is the first panel closed to the commercial product.

AMD7 - 4L 14:35 **Hydrogen and Subgap State in Amorphous IGZO Thin Films**

J. Bang, S. Matsuishi, H. Hosono

Tokyo Tech, Japan

Infrared absorption spectra of self-standing amorphous IGZO thin films deposited by conventional sputtering reveals the presence of hydride ions as a main hydrogen species. DFT calculations show these hydride species give rise to subgap states above the valence band top, suggesting the crucial role of hydride ions in NBIS.

----- Break -----

15:10 - 16:30 **409**

AMD8: Oxide TFT: Novel Processes and Applications

Chair: M.-H. Yoon, Gwangju Inst. of S&T, Korea
Co-Chair: N. Morosawa, Samsung Display, Korea

AMD8 - 1: 15:10 ***Invited*** **Transparent and Flexible Memory Thin-Film Transistors Using Oxide Semiconductors**

S.-M. Yoon, S.-J. Kim, D.-J. Yun, M.-J. Park, W.-H. Lee, G.-H. Seo

Kyung Hee Univ., Korea

Flexible charge-trap memory thin-film transistors (f-MTFTs) using oxide semiconductors were fabricated on plastic poly(ethylene naphthalate) substrate. The gate-stack was composed of all oxide layers such as In-Ga-Zn-O active channel, oxide charge-trap layer, Al_2O_3 blocking/tunneling layers, and In-Sn-O electrodes. The fabricated f-MTFTs exhibited stable and excellent device performance.

AMD8 - 2
15:35

Narrow-Pitch Low-Voltage-Driven and High-Speed Gate Driver with BA-IGZO TFTs for High-Resolution and Narrow-Bezel Displays

H. Seo, D. Geng, J. Jang

Kyung Hee Univ., Korea

We report the fabrication of a high-speed and narrow-pitch gate driver with BA-IGZO TFTs. By taking the advantage of higher current and zero turn-on voltage, BA-IGZO TFTs based gate driver has faster rising and falling edge compared to SG-IGZO TFTs based one.

AMD8 - 3
15:55

Novel Back-Channel-Etch Type In-Ga-Zn-Sn-O Thin Film Transistor with 4-Mask Technology

J. Li[*], X. Hu[*], Y. Zhai[*], H. Yu[*], J. Liu[*], T. Sun[*], S. Qin[*], C. Lee[*], F. Wang[,**]*

[*]Shenzhen China Star Optoelect. Tech., China
[**]TCL Corporate Res., China

This paper firstly demonstrates a novel back-channel-etch type In-Ga-Zn-Sn-O thin film transistor with 4-Mask technology. It seems that wet etch process do little damage to the back channel during the fabrication. The a-IGZTO TFT reveals a high uniformity and stability and is potential for mass production.

AMD8 - 4 **Withdrawn**

AMD8 - 5L
16:15

Development of 65-in. 4K UHD OLED TV with High Reliability Improvement of InGaZnO Thin-Film Transistors

S. J. Yun, J. Y. Noh, Y. H. Choi, W. C. Jeong, J. W. Kim, S. Y. Cha

LG Display, Korea

To improve PBTS of a-IGZO TFT we have been optimized the oxygen in SiO_2 insulators and developed the controllable H-incorporation for defect passivation. In this study, we achieved that Vth shift was Δ0.11 V after 236-hour long-term PBTS stress. Furthermore, we demonstrated the 65-in. 4K OLED TV with high reliability improvement.

Author Interviews
16:30 – 17:10, Multipurpose Hall

Special Topics of Interest on Lighting and Quantum Dot Technologies

Wednesday, December 7

14:40 - 16:00 **501**

OLED2: OLED for Lighting Applications

Chair: Y. Kijima, Huawei Techs. Japan
Co-Chair: S. Naka, Univ. of Toyama, Japan

OLED2 - 1: 14:40 ***Invited*** **Recent Advances in White OLED Technologies for OLED TV and Lighting**

C.-W. Han, H.-S. Choi, S.-S. Jang, M.-S. Kang, S.-S. Park, H.-C. Choi, I.-B. Kang

LG Display, Korea

The brightness of 55-in. UHD OLED TV embedded with the 3-stacked WOLED showed 150 cd/m^2 at full white screen and 500 cd/m^2 at peak white screen. With the application of light extraction structures and 3-stacked devices, PE of 90 lm/W in OLED lighting was achieved.

OLED2 - 2 15:00 **High Efficiency $FAPbBr_3$ Perovskite Light-Emitting Diode**

B. Xu, X. Zhang, W. Wang, J. Hao, W. Chen, D. Wang, J. Qin, W. Cao[*], *P. Liu*[**], *S. Chen, K. Wang, X.-W. Sun*

Southern Univ. of S&T, China
[*]Tianjin Univ., China
[**]Hubei Univ., China

Light-emitting diodes (LEDs) based on organometal halide perovskite are emerging light source for display and lighting. Here, we report high efficiency $FAPbBr_3$ perovskite LEDs with structures of ITO/PEDOT: PSS/$FAPbBr_3$/TPBi/LiF/Al. We demonstrate high electroluminescence performance with luminance of 9000 cd/m^2, external quantum efficiency of 0.82%, and current efficiency of 2.7 cd/A.

OLED2 - 3 15:20 **OLED Lighting for Photorejuvenation**

M.-Z. Dai, Y.-H. Chen, C.-C. Chen, H.-C. Hu, W.-L. Hung, T.-Y. Lin, J. H. Tao, W.-Y. Wang, C.-C. Chen, M.-T. Lee

AU Optronics, Taiwan

A flexible OLED photorejuvenation mask with non-regular face-shape design was delivered. The emitted light of wavelength from 520 nm through 680 nm, which covered most of cosmetic light therapies requirement. The functional silicone film is skin-friendly and can enhance light extraction of OLED.

OLED2 - 4 15:40 **Inkjet-Printed Flexible Quantum Dot Light-Emitting Diodes for Next Generation Display**

J. Zhuang, C. Wei, W. Su, Z. Cui

Chinese Ac. of Sci., China

We have fabricated flexible PM-QLEDs based on PET/Ag grid substrate by inkjet printing. The ink we developed is pure QDs without any other additives, and free of halogen solvents. The red, green and blue QDs inks are all stable even after 2 months with high quantum yields.

----- Break -----

16:20 - 17:45 **502**

PH1: Phosphors for Lighting Application

Chair: J. Silver, Brunel Univ. London, UK
Co-Chair: T. Kusunoki, Dexerials, Japan

PH1 - 1: 16:20 ***Invited*** **Highly Efficient Laser Spotlight Illuminator with a Novel Check-Patterned Phosphor Structure**

K. Morimoto, Y. Nagasaki, K. Okuyama, T. Miwa[*]*, A. Takamori*[**]*, T. Tanaka*

Panasonic AIS, Japan
[*]IDEC, Japan
[**]Osaka Univ., Japan

The first blue-violet laser-diode pumped phosphor spotlight illuminator is demonstrated, having a novel check-patterned blue/yellow phosphor structure with high conversion efficiency under high power excitation. The spotlight prototype achieves an excellent luminous efficacy 51.3 lm/W at high luminous flux 861 lm and uniform illuminance distribution on the target illumination area.

PH1 - 2 16:50 **Improvement of Photodegradation of Nitridosilicate Phosphors by Composition Change and Realization of High CRI White-LEDs**

M. Kanno, M. Abe, T. Kusunoki

Dexerials, Japan

Nitridosilicates $(Ca,Sr)_{2(1-x)}(Al_y,Si_{1-y})_5(O,N)_8:Eu_x$ are efficient andaffordable red-emitting phosphors. In this study in order to improve photodegradation of these phosphors we changed the composition of their alkaline-earth ions and had good results. We also used these phosphors as red-emitting phosphors for white-LEDs and could obtain high CRI successfully.

PH1 - 3
17:10

Commercialized, Narrow Band, Red Emitting Phosphors for Wide Color Gamut Display Applications and LED Lighting

S. P. Sista, F. Garcia-Santamaria, J. E. Murphy, A. Setlur, P. N. Kumar[*], D. G. Porob[*], J. M. Baldesare[**], W. W. Beers[**], A. I. Chowdhury[**], W. E. Cohen[**], F. Du[**], C. D. Nelson[**]

GE Global Res., USA
[*]GE Global Res., India
[**]GE Lighting, USA

Commercialized GE TriGain phosphors are narrow red line emitters that offer an effective on-chip solution to wide color gamut displays with increased brightness. We discuss the significant improvements in efficiency, phosphor reliability and absorption that TriGain phosphors show compared to typical KSF phosphor.

PH1 - 4L
17:30

White LED Using Narrow-Band γ-AlON:Mn,Mg Green Phosphor for Super Wide-Color Gamut Display

K. Yoshimura, M. Izumi, R.-J. Xie[*], H. Fukunaga, K. Takahashi[*], N. Hirosaki[*]

Sharp, Japan
[*]NIMS, Japan

The display backlight using sharp β-sialon:Eu (green) and K_2SiF_6:Mn (red) phosphors shows a very wide-color gamut that mostly covers the whole NTSC triangle. In this work, γ-AlON:Mn,Mg green phosphor is investigated as an alternative green phosphor with the purpose of the further improvement of the display color gamut.

Author Interviews
17:45 – 18:20, Multipurpose Hall

Thursday, December 8

10:30 - 13:00 **Multipurpose Hall**

***Poster* OLEDp2: OLED/LIT Poster**

OLEDp2 - 1

Efficiency Enhancement of Blue Organic Light-Emitting Diodes Using a Corrugated Structure

M. Hwang, H. Lee, S. M. Cho

Sungkyunkwan Univ., Korea

Silver-nanowire embedded flexible transparent electrode was fabricated via fully roll-to-roll process. Silver-nanowire was coated with mayer rod and embedded with NOA63. Sheet resistance of fabricated electrode was below 8 ohm/sq and transmittance was over 85%. The RMS value of surface roughness was below 10 nm.

OLEDp2 - 2 **Quantum Dot Light-Emitting Diode with Ligand-Controlled $CuInS_2$/ZnS Quantum Dot**

M. Hishinuma, J. Maki, T. Fukuda, N. Kamata, Z. Honda

Saitama Univ., Japan

The organic ligand of the semiconductor quantum dot prevents the reduced current efficiency of the quantum dot light-emitting diode. In this research, we investigated the inverted structure with the $CuInS_2$/ZnS quantum dots, and achieved the reduced threshold voltage by the decompression annealing to remove the organic ligand.

OLEDp2 - 3 **Reduced Exciton Lifetime in TADF Materials for Blue OLEDs**

Y. C. Kim, G. H. Kim, G. W. Kim, J. B. Im, J. H. Kwon

Kyung Hee Univ., Korea

We report newly designed and synthesized TADF molecule, KHU-TB-1. The KHU-TB-1 demonstrated a short exciton lifetime of 7.2 μs compared to the reference TADF emitter molecule (TCzTRz:9.5 μs). The fabricated blue OLED with KHU-TB-1 emitter exhibits maximum EQE and luminance of 22.0% and 13,630 cd/m^2. It also demonstrated an improved roll-off characteristic and color-quality.

OLEDp2 - 4L **Integration of Patterned Quantum Dot Film with Blue OLED for the Realization of Rec. 2020 Color Gamut**

H.-J. Kim, M.-H. Shin, S.-E. Kim, S.-J. Park, Y.-J. Kim

Yonsei Univ., Korea

We applied patterned red and green quantum dot (QD) to blue organic light emitting diode (OLED) as light converting component and found optimized characteristics of patterned QD for wide color gamut by simulation and realized 97% of Rec. 2020 standard that is NTSC 130% in CIE 1931 by experiments.

10:30 - 13:00 **Multipurpose Hall**

Poster VHFp2: Applied Vision and Human Factors - Lighting Technologies

VHFp2 - 1 **Quantification of LCD's Light Leakage of Each Corner Using 2D FFT and 2D CSF**

S. W. Jung, J. Y. Kim

LG Display, Korea

The light leakage has been known as one of the chronic LCD's defects. The display manufactures are continuously developing a new method for the improvement of light leakage. Therefore the needs of quantitative evaluation between the human's perception and the measurement system which can be practical in the field have been emphasized.

----- Lunch -----

14:10 - 16:40 **Multipurpose Hall**

Poster **PHp1: Phosphors for Lighting Application**

PHp1 - 1 **New Structure of Phosphor Layer in pc-WLEDs Package for Optical Properties Improving**

L.-F. Nien, T.-S. Zhan, S.-Y. Chu

Nat. Cheng Kung Univ., Taiwan

In this article, a new package method was investigated to solve the problems, which caused by conventional fabrication of phosphor-converted white LED (pc-WLED), like yellow-ring and uneven intensity of different view angles. This method can not only improve the color uniformity, but the luminous efficiency of pc-WLED.

PHp1 - 2 **Structural Equation Approach for Designing of LED Cup Reflector and the Future Prospect**

C.-J. Ou, Z.-W. Huang, Y.-J. Hsu, C.-R. Ho

Hsiuping Univ. of S&T, Taiwan

For the designing of the LED secondary lens, the solely effects of the reflectors should be familiar with the optical designers, such that the appropriate lens design can be integrated with the reflectors. This report setting up an analytical process to explore the effects of LED reflectors on energy distribution.

PHp1 - 3 **Electron Emission Properties of Cold Cathode Based on Silicon-Rich Silicon Dioxide Films Prepared by Magnetron Reaction Sputtering**

W. Zhao, M. Zhou, W. Hu

Xi'an Jiaotong Univ., China

Silicon-rich silicon dioxide (SRSO) films were formed through deposition of SiO_x films by magnetron reaction sputtering together with subsequent rapid temperature annealing treatment. The emission efficiency and emission current density of a cold cathode based on SRSO film reach 10.88% and 25.78 μA/cm^2 at the applied voltage of 19 V.

PHp1 - 4 **Synthesis and Luminescence Properties of Novel Eu^{2+}-Doped $BaGa_2SiS_6$ and $Ba_2Ga_8SiS_{16}$ Thiogallate Phosphors for White LEDs**

S. P. Lee, S. D. Liu, T. M. Chen

Nat. Chiao Tung Univ., Taiwan

Novel Eu^{2+}-doped $BaGa_2SiS_6$ and $Ba_2Ga_8SiS_{16}$ thiogallate phosphors were prepared by solid-state reaction. The $BaGa_2SiS_6$:Eu^{2+} phosphor generates a green emission upon excitation at 405 nm, whereas the $Ba_2Ga_8SiS_{16}$:Eu^{2+} phosphor could be tuned from cyan to green range with increasing Eu^{2+} concentration upon excitation at 365 nm.

PHp1 - 5 **Rare-Earth-Free Organic-Inorganic Hybrid Phosphor Made from APTES for White Light LED Application**

K. Hasegawa, K. Komatsu, A. Kato

Nagaoka Univ. of Tech., Japan

Organic-inorganic hybrid phosphors made from malic acids and APTES which shows strong green emission were synthesized by sol-gel method. The emission wavelength and intensity were found to depend on heating treatment temperature, which may be due to local structural change. This phosphor has a potential for rare-earth free UV-LEDs application.

PHp1 - 6 **Eu Concentration Dependence of Morphology and Emission Characteristics of Y_2WO_6:Eu Nano-Rod Phosphor**

S. Matsumoto, R. Kanai, M. Kimura, A. Kato

Nagaoka Univ. of Tech., Japan

Y_2WO_6:Eu nano-rod phosphors with various Eu concentration were synthesized by flux method using LiCl flux. The diameter of the nano-rod was kept around ~200 nm with Eu concentration lower than 10%. The emission characteristics were drastically improved by introduction of seed crystals in the flux.

PHp1 - 7L **Characteristics of Phosphor-Converted White Light-Emitting Diodes with Tunable Color Temperature and High CRI Fabricated by Near-Ultraviolet Light-Emitting Diodes**

C.-H. Chiang, S.-J. Gong, S.-Y. Chu

Nat. Cheng Kung Univ., Taiwan

The phosphor-converted white light-emitting diodes were fabricated by combining the tri-color phosphors and silicone gel with the near-ultraviolet light-emitting diode chips. Using the separated phosphor layer structure can reduce the loss of re-absorption. The CRI increase with increasing percentage of overlapping area between the spectra deconvoluted from the electroluminescence spectrums.

14:10 - 16:40 **Multipurpose Hall**

Poster MEETp1: Quantum Dots and Nanotechnologies

MEETp1 - 1 **$CsPbBr_3$ Based Perovskite Nanocrystals for Light-Emitting Diodes**

S.-Y. Cho, H.-M. Kim, E. Moyen, J. Jang

Kyung Hee Univ., Korea

We have synthetized $CsPbBr_3$ based perovskite nanocrystals (NCs) for light-emitting diodes. The $CsPbBr_3$ NCs solution shows a photo-luminescence (PL) peak at 517 nm under UV illumination with a narrow full-width half maximum (FWHM) of less than 24 nm. The highest PL intensity can be obtained at a 1:1 molar ratio of $PbBr_2$:CsBr.

MEETp1 - 2 **All Solution Processed Charge Generation Junction for Quantum-Dot Light Emitting Diodes**

E. Hwang, H.-M. Kim, J. Kim, J. Jang

Kyung Hee Univ., Korea

In this study, all-solution processed inverted yellow-emitting tandem quantum-dot light emitting diodes (QLEDs) are suggested. The solution processed p-n junctions are used to generate charges between bottom and top cells of tandem QLEDs. The tandem QLEDs with triple charge generation junctions by solution processing is fabricated for low-cost QLED manufacturing.

----- Break -----

Friday, December 9

10:40 - 12:00 **201**

PRJ3: Projection Components and Devices

Chair: S. Shikama, Setsunan Univ., Japan
Co-Chair: J. W. Pan, Nat. Chiao Tung Univ.,Taiwan

PRJ3 - 1: 10:40 ***Invited*** **Experimental Characterization of Oxide Semiconductors-Based SLM for Practical Use**

S. Nakashima, W. Nomura, N. Tate

Kyushu Univ., Japan

We have been studying the implementation of a zinc-oxide spatial light modulator (ZnO-SLM) using a light-assisted annealing method. It reveals novel performance as an optical switch based on surface current-induced magneto-optical effect. As a step toward practical use, we experimentally verified possible integration densities and wavelength characteristics.

PRJ3 - 2 11:00 **Improvement of Output Power Dependence on Temperature in 638-nm BA-LD**

T. Yagi, K. Kuramoto, S. Abe, M. Kusunoki, M. Miyashita

Mitsubishi Elec., Japan

Epitaxial growth technology for 638-nm LDs was improved. It was revealed that the technology suppressed carrier overflow from an active layer of the LD. By using the technology, the newly designed BA-LD for CW operation emitted 1.74 W under 55°C, CW with wall plug efficiency of 20.0%.

PRJ3 - 3 11:20 **Liquid Crystal Based Beam Deflectors**

D. Cuypers, X. Shang, H. De Smet

imec, Belgium

Devices consisting of micro grating structures combined with liquid crystals offer interesting applications as electrically tunable photonic devices for beam steering. Both linear and circular types are constructed using soft lithography and evaluated.

PRJ3 - 4 11:40 **Very Compact Waveguide-Type RGB Coupler with Multimode Converter**

J. Sakamoto, S. Katayose, K. Watanabe, M. Itoh, T. Hashimoto

NTT, Japan

We developed an optical-waveguide-type red-green-blue (RGB) multiplexer that uses additional waveguides for mode conversion to reduce circuit length and enhance isolation among colors. The coupler circuit is about 2.5-mm long and 1-mm thick, and the loss, excluding that of input/output routing circuits, is less than 1.2 dB for each color.

Author Interviews
12:00 – 12:40, Multipurpose Hall

13:30 - 14:50 **413**

MEET4: EL Quantum Dots Technologies

Chair: K. C. Park, Kyung Hee Univ., Korea
Co-Chair: X. W. Sun, Southern Univ. of S&T, China

MEET4 - 1: 13:30 ***Invited*** **Tandem QLED with Oxide Charge Generation Junction**

J. Jang, H.-M. Kim, E. Hwang

Kyung Hee Univ., Korea

This paper reviews the solution-processed charge generation junctions (CGJs) which can be used for single and tandem quantum-dot light emitting diodes (QLEDs) and organic light emitting diodes (OLEDs). Organic charge-generation layer by thermal evaporation, solution processed charge-generation junction and tandem QLED with oxide-oxide CGJ is introduced.

MEET4 - 2: 13:50 ***Invited*** **Full-Color Patterning of Quantum Dot Displays Based on Transfer Printing and Inkjet Printing**

J. Han, D. Ko, J. Roh, H. Jung, Y. Lee, J. Sohn, W. K. Bae[*]*, C. Lee*

Seoul Nat. Univ., Korea
[*]*KIST, Korea*

To realize the full-color QLED display, the QD emissive layer should be patterned to red, green, and blue subpixels. Here, we resent two full-color patterning methods such as transfer printing and inkjet printing and discuss key issues that must be solved for realizing practical QLED displays.

MEET4 - 3: ***Invited*** **Solution-Processable Hybrid Light-Emitting**
14:10 **Devices Based on Organic/Inorganic Nanocomposites**

Y. Liu, F. Li, J. Lin, H. Hu, T. Guo

Fuzhou Univ., China

By combining the unique advantages of organic and inorganic materials, hybrid light-emitting devices could exhibit superior device performances based on low cost solution processes. In this speak, we present our recent works regarding the design, fabrication and performance optimization of hybrid light-emitting devices based on semiconductor quantum dots, etc.

MEET4 - 4: ***Invited*** **Quantum Dot Electroluminescence**
14:30

P. Kathirgamanathan, M. Kumaraverl, N.Bramananthan, S. Ravichandran, L. M. Bushby, S. Surendrakumar

Brunel Univ. London, UK

Colloidal quantum dots have the potential to offer saturated colours satisfying the new REC 2020 (ITU-R-BT 2020) standard. By using suitable device architecture and quantum dot size, we achieved a very high efficiency of 4 cd/A for CIE (x, y) of (0.708, 0.292) meeting the REC 2020 specification. A world record efficiency of 16 cd/A and 11 lm/W for (0.704, 0.296) has been achieved by employing a novel hole transporter.

----- Break -----

15:10 - 16:30 **413**

MEET5: Emerging Quantum Dots and Nanotechnologies

Chair: J. Jang, Kyung Hee Univ., Korea
Co-Chair: Y. Bonnassieux, Ecole Polytechnique, France

MEET5 - 1: ***Invited*** **What's Next for Quantum Dots? Delivering**
15:10 **the Ultimate Visual Experience to the Mainstream**

H. Kim

Nanosys, USA

Display engineers strived for decades to produce displays that deliver immersive, life-like visual experiences – so-called Ultimate Visual Experience (UVE). Quantum Dot Enhancement Film (QDEF) makes UVE possible and affordable. This paper covers the latest Quantum Dot technology and supply chain developments for delivering UVE-capable LCD products to mainstream consumers.

MEET5 - 2: 15:30 ***Invited*** **Heavy Metal-Free Quantum Dots for Consumer Applications**

N. L. Pickett, N. C. Gresty, I. Naasani

Nanoco Techs., UK

In recent years, display products containing quantum dots have begun to appear on the consumer market. However, many products still contain toxic cadmium. Herein, we report on the synthesis and development of heavy metal-free quantum dots, with a particular focus on displays, lighting and biological imaging applications.

MEET5 - 3: 15:50 ***Invited*** **Luminescent Nanocrystals and Devices for Energy-Saving Quality Displays and Lighting**

K. Wang, X. W. Sun

Southern Univ. of S&T, China

We introduce a new kind of quantum dot composites as luminescent microspheres featuring high efficiency, narrow FWHM and excellent long-term operation stability for PL application. Moreover, very bright and efficient hybrid perovskite QLEDs based on $FA_{0.8}Cs_{0.2}PbBr_3$ perovskite nanocrystals with organic-inorganic mixed cations were also demonstrated.

MEET5 - 4: 16:10 ***Invited*** **Optical Characteristics of Quantum Rod Color Pixel Converter Combined with Twisted Nematic LCD**

M. Hasegawa, Y. Hirayama

Merck, Japan

We fabricated quantum rod-based color conversion subpixels by ink jet printing. We stacked these subpixels on a twisted nematic liquid crystal (TN-LC) panel, and evaluated their optical properties, including color gamut, contrast ratio, and viewing angle. The panel covers 80% of the BT.2020 standard color gamut. The TN LC panel with collimated blue LED showed the effects of polarizers and the alignment of LC. However, combination with the QR emission layer eliminated the effects of polarizer and LC, and led to a very wide viewing angle even in a grey level.

Author Interviews
16:30 – 17:10, Multipurpose Hall

Special Topics of Interest on AR/VR and Hyper Reality

Wednesday, December 7

13:05 - 14:20 **201**

INP1: AR and Interactive Systems

Chair: M. Sato, Tokyo Tech, Japan
Co-Chair: N. Hashimoto, Citizen Holdings, Japan

INP1 - 1: 13:05 ***Invited*** **Somatic Interfaces to Interact with Image Information**

*Y. Kume, T. Mizuno**

Tokyo Polytechnic Univ., Japan
**Univ. of Electro-Commun., Japan*

Multimodal interfaces for portable/wearable image displays are required to enhance realities and interactivities. We are currently developing several somatic interfaces for this purpose. These include handheld display to provide visual–tactile–force sensations, force-like sensations by mechanical vibration, and wearable system measuring nasal skin temperature to estimate mental workload.

Also presented in Innovative Demonstration Session (see p. 263)

INP1 - 2: 13:30 ***Invited*** **Retinal Imaging Laser Eyewear with Focus-Free and Augmented Reality**

M. Sugawara, M. Suzuki, H. Miyauchi

QD Laser, Japan

Retinal Imaging Laser Eyewear has a miniature laser projector inside the frame which provides the wearer with digital image information through the pupil using the retina as a screen. This compact universal-design eyewear features focus-free and augmented-reality image independent of the wearers' visual acuity and point of focus.

Also presented in Innovative Demonstration Session (see p. 263)

INP1 - 3: 13:55 ***Invited*** **String-Based Haptic Interface for Mobile Devices**

K. Honda, S. Ma[*]*, Y. Qian*[*]*, M. Sato*[*]

Tokyo Univ. of Marine S&T, Japan
[*]*Tokyo Tech, Japan*

In this research, a haptic device, which is able to be attached to mobile devices, has been proposed. The proposed device provides one degree of freedom force feedback. It is considered that the proposed device may be able to be adapted as a handy tool for creating multi-modal experiences.

Also presented in Innovative Demonstration Session (see p. 263)

----- Break -----

14:40 - 16:00 **Main Hall**

3D2/3DSA2: Visualization and AR

Chair: J.-W. Kim, ETRI, Korea
Co-Chair: H. Kakeya, Univ. of Tsukuba, Japan

3D2/ 3DSA2 - 1: 14:40 ***Invited*** **Progress on Head-Worn Display Technology for Augmented Reality**

Y. Wang, D. Cheng, C. Xu

Beijing Inst. of Tech., China

Several problems with significant impact on the development of head-worn displays for augmented reality are discussed, including the size and weight, the contradiction between large field-of-view and high resolution, and accommodation and convergence disparity. Methods proposed by Beijing Institute of Technology to solve or alleviate these problems are presented.

3D2/ 3DSA2 - 2 15:00 **Efficiency Balance for a See-Through Head-Mounted Display with Microstructures**

X.-C. Wang, K.-W. Zhao, Y.-D. Lu, C.-Y. Chuang, M.-C. Chan, J.-W. Pan

Nat. Chiao Tung Univ., Taiwan

The efficiency balance phenomenon for see-through head-mounted displays with different microstructure conditions can be found both theoretically and using optical simulation software. The simulation is based on factors taken from previous research studies. It's found that the balance value of the optical efficiency remains almost constant under different microstructure conditions.

3D2/ 3DSA2 - 3 15:20 **Changing Perceived Leg Length and Motion on Virtual Walking Generator**

T. Hamada, K. Yoshiho, R. Kondo, Y. Ikei[*], K. Hirota[**], T. Amemiya[***], M. Kitazaki

Toyohashi Univ. of Tech., Japan
[*]Tokyo Metropolitan Univ., Japan
[**]Univ. of Electro-Commun., Japan
[***]NTT, Japan

Disabled people cannot freely walk around. To overcome it, we developed a virtual walking generator that users can feel realistic walking sensations based on their body shape, and found that perceived leg length and walking motion were changed by altering timings of foot vibrations as a temporal factor of footsteps.

3D2/ 3DSA2 - 4 15:40 **Sparse Registration for Small Amount of Overlap between Point Clouds**

L. Sun, Y. Manabe, N. Yata

Chiba Univ., Japan

This paper proposes a framework for point clouds registration of small amount of overlap. This proposed method resamples point clouds into a large number of small point cloud groups, then matches the group between point clouds by Plane Distance histogram (PAD) of each groups based on sparse representation.

----- Break -----

Author Interviews
17:40 – 18:20, Multipurpose Hall

Thursday, December 8

9:00 - 10:20 **Main Hall**

3DSA4/VHF4: Human Vision

Chair: S. Yano, Shimane Univ., Japan
Co-Chair: S. Uehara, Asahi Glass, Japan

3DSA4/ VHF4 - 1: 9:00 ***Invited*** **Brain Function Analysis of Visual and Cross-Modal Information**

H. Ando[,**]*

[*]NICT, Japan
[**]Osaka Univ., Japan

To clarify how visual information is processed in the human visual system and how visual information interacts with other sensory modalities, we have investigated human brain functions using functional Magnetic Resonance Imaging (fMRI) techniques. Recent results of our fMRI experiments are described in this paper.

3DSA4/ VHF4 - 2: 9:20 ***Invited*** **Human Vision Response in AR & VR**

Y.-S. Chen, Y.-P. Huang[*], C.-Y. Chen[**]

Cathay General Hospital, Taiwan
[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Taiwan Univ. of S&T, Taiwan

The human vision response in AR & VR is definitely different from stereoptic images created by human macula of the real world. The index of physiological measurement for visual response should be developed and standardized in order to improve the AR & VR display in the future.

3DSA4/ VHF4 - 3 9:40 **Attentive Tracking of Moving Objects in Stereoscopic Viewing**

A. U. Rehman, Y. Nosaki[*], K. Kihara[*], S. Ohtsuka[*]

Kagoshima Nat. College of Tech., Japan
[*]Kagoshima Univ., Japan

This experiment examines the attentive tracking of moving objects in stereoscopic viewing. Participants could successfully track moving objects in an attentive task by ignoring the distractors' plane. In addition, they were able to divide attention equally among a range of depth planes.

3DSA4/ VHF4 - 4 10:00 **Subjective Experiment Study on Binocular Overlap Effect of Different Colors for the Augmented Reality Near-Eye Display**

H. Zhang, Y. Tang, Y. Zheng, Y. Xie[*], B. Wang

Southeast Univ., China
[*]S&T on Electro-optic Control Lab., China

The binocular overlap effect of different colors for the augmented reality near-eye display was studied. This experiment included 10 participants to observe and grade on the influence of the different colors on the binocular overlap effect. The results indicate that different colors have an impact on the binocular overlap effect.

Author Interviews
10:30 – 11:10, Room 201

----- Break -----

10:30 - 13:00 **Multipurpose Hall**

Poster **3Dp1/3DSAp1: 3D and Hyper-Realistic Systems and Applications 1**

3Dp1/3DSAp1 - 2 **Does Eye Strain Decrease after Observing 3D Imaging on the Light Field Display?**

M. Shoda, T. Iwane, R. Niimi[*]

Nikon, Japan
[*]*Niigata Univ., Japan*

We examined whether observing light field display decreases eye strain than lenticular display. Light field display did not alter eye strain, though it enhanced accommodation at far location. We concluded that light field display enhanced stereognostic sense without heavier eye strain.

3Dp1/3DSAp1 - 3 **Developing a Photometric Device for Generating Quality Texture and Normal Map**

Y.-C. Chen, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

We develop a 3D image capturing device for estimating the surface normals and capturing the texture from target object simultaneously. Several experiments are carried out. In addition, we not only analyse different arrangements of illuminants may cause distinguishing result, but also discuss how to refine by the proposed approach.

3Dp1/3DSAp1 - 5 **CNN-Based Pedestrian and Vehicle Detection Using Stereo Camera**

G.-C. Lee, J. Yoo

Kwangwoon Univ., Korea

In this paper, we propose a pedestrian and vehicle detection algorithm based on CNN using a stereo camera. In the proposed algorithm, object candidates are first obtained by using the disparity from the stereo camera. Then, the objects are recognized by the CNN which has a similar architecture of AlexNet.

3Dp1/3DSAp1 - 10 **Study on Compact Holographic Head-Mounted Display for Augmented Reality**

E. Murakami, Y. Oguro, Y. Sakamoto

Hokkaido Univ., Japan

This paper proposes a compact holographic HMD system for AR. The holographic HMD system can reconstruct the images at a free depth with lightweight and compact structure. The experimental result shows that an AR scene is correctly displayed by the holographic HMD system.

Also presented in Innovative Demonstration Session (see p. 262)

3Dp1/ 3DSAp1 - 17 **Evaluation of Perceived 3D Structure of Multi-View 3D Medical Image Based on Transparent Visualization: A Psychophysical Study**

Y. Sakano[,**], Y. Kitaura[***], K. Hasegawa[***], R. Lopez-Gulliver[***], H. Ando[*,**], S. Tanaka[***]*

[*]NICT, Japan
[**]Osaka Univ., Japan
[***]Ritsumeikan Univ., Japan

As an efficient transparent-rendering method, a stochastic point-based rendering method was proposed recently. In the present study, we found that by applying luminance gradient inherent in this method in addition to the traditional Phong shading to a medical data, perceived 3D structure gets closer to the ground truth.

3Dp1/ 3DSAp1 - 18 **Accommodation Measurement in VR Device of Google Cardboard Type**

H. Kang, H. Hong

Seoul Nat. Univ. of S&T, Korea

Virtual image by VR device was shown only to left eye of the user and the white uniform background was shown to right eye. The accommodation of right eye was measured to change in accord with the position of virtual image seen by left eye.

3Dp1/ 3DSAp1 - 19 **Head Tracking Based Immersive Sound Reproduction for Virtual Reality Display**

C. J. Chun, K. M. Jeon, J. M. Moon, H. K. Kim, J. Yoo[*]

Gwangju Inst. of S&T, Korea
[*]Kwangwoon Univ., Korea

This paper proposes a head tracking-based sound reproduction method to improve auditory realism in a virtual reality environment. To this end, a 4-channel omnidirectional microphone array is used for capturing ambient sounds. Then, a delay-and-sum beamformer is applied to the sounds for estimating the direction of the source.

3Dp1/ 3DSAp1 - 20 **Audio-Haptic Display for a Sense of Walking: Influence of Arm-Swing Interaction and User's Posture on Reproduced Walking in Real Space**

Y. Okuya, Y. Ikei[*], Y. Kamishohara[*], K. Hirota[**], T. Amemiya[***], M. Kitazaki[****]

Univ. Paris-Sud, France
[*]Tokyo Metropolitan Univ., Japan
[**]Univ. of Electro-Commun., Japan
[***]NTT, Japan
[****]Toyohashi Univ. of Tech., Japan

We present techniques to enhance a sense of walking without user's leg motion in 3D soundscape environment. Sound of footsteps and vibratory stimulus at the sole are simulated with physical models, responding to virtual walking steps. A sense of walking was investigated with user's reproduced walk in a real space.

3Dp1/ 3DSAp1 - 22 **Bodily Reliving Experience Based on Multisensory Passive Stimulation**

R. Koide, S. Imao, K. Yamada, N. Saka, K. Tashiro, M. Kurosawa, Y. Ikei, K. Hirota[*], T. Amemiya[**], M. Kitazaki[***]

Tokyo Metropolitan Univ., Japan
[*]Univ. of Electro-Commun., Japan
[**]NTT, Japan
[***]Toyohashi Univ. of Tech., Japan

This paper describes characteristics of a passive stimulation method using a vestibular and proprioceptive device for presentation of body motion sensation while the real body of the user is sitting. The motion of a seat and pedals/sliders was controlled to produce the sensation of a real walking motion.

3Dp1/ 3DSAp1 - 23L **Symmetricity in Perceptual Limit of Doubled Image Induced by Linearly Blended Images**

M. Date, K. Takeuchi, K. Okami, H. Fujii, H. Kimata, R. Kimura[*], K. Iwata[*], T. Kojima[*], M. Miyao[*]

NTT, Japan
[*]Nagoya Univ., Japan

Linear blending is a useful technique to produce an interpolated image from multiple camera images, especially in real time applications using smooth motion parallax. In this paper we evaluated the symmetricity of perceptual limit in a doubled image induced by linear blending and confirmed the suitability of symmetrical camera alignment.

3Dp1/ 3DSAp1 - 24L **Study on Rendering Ultra High-Resolution Image for 3D Models**

C.-C. Lee, Y.-L. Liu, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

With the innovation of emerging technologies, museums can reinterpret artifacts. Therefore, it's important to efficiently render high resolution images. We propose a practical solution to render an ultra high resolution image, which has almost no limitation in image size, for 3D digital heritage model based on OpenGL.

10:30 - 13:00 **Multipurpose Hall**

Poster PRJp1: Projection Displays

PRJp1 - 4L **See-Through Near-Eye Displays for Visual Impairment**

L. Zhou, C. P. Chen, Y. Wu, K. Wang, Z. Zhang

Shanghai Jiao Tong Univ., China

We propose a see-through near-eye display, which is dedicated to the users who are visually impaired. Our design is characterized by a pair of corrective lenses coated with holographic volume gratings. Its key optical performance include FOV of 14°, MTF above 0.4 at 5 cycles/mm, and distortion less than 5%.

----- Lunch -----

14:10 - 16:40 **Multipurpose Hall**

***Poster* INPp1: Interactive Technologies**

INPp1 - 1 **Single Pixel Imaging with a High-Frame-Rate LED Digital Signage**

S. Onose[*], M. Takahashi[*], H. Yamamoto[,**], Y. Mizutani[**,***], T. Yasui[**,****]*

[*]Utsunomiya Univ., Japan
[**]JST, Japan
[***]Osaka Univ., Japan
[****]Tokushima Univ., Japan

This paper proposes a single-pixel imaging by use of a high-frame-rate LED display. Ghost imaging algorithm is applied to reconstruct an image under randomly modulated illuminations with a point detector. We have constructed spatio-temporal codes to embed random-dot patterns in an apparent image and conducted numerical experiments on single-pixel imaging.

INPp1 - 3 **Gesture Recognition Using RGB-D Camera for 3D Virtual Reality and Interaction System**

Y.-Y. Hsu, L.-J. Zheng, H.-I Ning, Y.-C. Fan

Taipei Univ. of Tech., Taiwan

Virtual Reality technology becomes very important recently. We proposed the gesture recognition using RGB-D camera for 3D virtual reality and interaction system. The computer graphics establishes the 3D objects and the RGB-D camera performs accurate gesture recognition. Finally, we integrate and generate functions by different depth distance in 3D environment.

----- Break -----

14:10 - 16:40 **Multipurpose Hall**

***Poster* 3DSAp2/3Dp2: 3D and Hyper-Realistic Systems and Applications 2**

3DSAp2/ 3Dp2 - 15 **Colorizing 3D Objects in Free-Viewpoint Through a Transparent LCD**

Y.-P. Pi, P.-L. Sun, H.-P. Chien, H.-C. Li, Y.-C. Su

Nat. Taiwan Univ. of S&T, Taiwan

A method to colorize 3D objects through a transparent LCD in free-viewpoint is proposed. It uses a video camera to detect eye-sight of a viewer in real-time, and then displays the geometric corrected shadow-less color projection of the 3D objects (achromatic 3D prints or plaster models) onto the transparent LCD.

3DSAp2/ 3Dp2 - 28L **High Definition Spatiotemporal Division Multiplexing Electroholography Using DMD**

M. Fujiwara, N. Takada, C. W. Ooi, Y. Maeda, H. Nakayama[*], T. Kakue[**], T. Shimobaba[**], T. Ito[**]

Kochi Univ., Japan
[*]Nat. Astronomical Observatory of Japan, Japan
[**]Chiba Univ., Japan

We propose high-speed computer-generated hologram reproduction using digital mirror device for high-definition spatiotemporal division multiplexing electroholography. Finally, we succeeded to play high-definition 3D movie of 3D object comprised about 900,000 points at 60 fps when each frame was divided into twelve.

Friday, December 9

9:00 - 10:20 **201**

PRJ2: Wearable Display

Chair: D. Cuypers, imec, Belgium
Co-Chair: T. Suzuki, JVC KENWOOD, Japan

PRJ2 - 1 9:00 **Wearable See-Through Retinal Projector Using Optical Simulation Design**

H. A. Chen, W. S. Sun[*], Y. C. Chiang[*], Z. P. Yang, J. W. Pan

Nat. Chiao Tung Univ., Taiwan
[*]Nat. Central Univ., Taiwan

This study proposes a new simulation design for a wearable see-through retinal projector combined with a compact camera. The see-through retinal projector is composed of an illumination system and eyepiece system. In this eyeglass-mounted design, all the information is projected directly into the user's eyes using a see-through retinal projector.

PRJ2 - 2 9:20 **Optical Design of Wide Viewing Eyeglass-Type Wearable Device Using Multiple Reflection Element**

S. Sawada, A. Moriya, T. Sasaki, J. Yamaguchi, M. Baba

Toshiba, Japan

We propose an optical design of an eyeglass-type wearable device using a multiple reflection element (MRE) composed of multiple reflectors arranged in parallel. It gives the wearer a digital image with wide viewing angles while maintaining the size by reflecting an image projected from a projector at a MRE.

PRJ2 - 3
9:40 **Optimization and Verification of Viewing Angle for Wearable Display Device for Outdoor Use**

J. Iwai, H. Kimura

Telepathy Japan, Japan

We have studied optimized way of increasing a viewing angle of optics for our wearable display device. As a result, we have maintained the eye box of the optical unit with bigger viewing angle by adjusting the best viewing angle of exit light of the optical unit.

Also presented in Innovative Demonstration Session (see p. 263)

PRJ2 - 4
10:00 **Common Platform for Maintenance System with Wearable Device**

T. Fujiwara, R. Kabata[*]*, Y. Narita*[*]*, K. Kikuchi*[*]*, K. Oonishi*[*]

Hitachi, Japan
[*]*Hitachi Syss., Japan*

The purpose of our research is that we develop a common platform with various OS. In this study, we developed the abstraction layer between HTML5 and OS native functions. Our method can adapt four times OS than previous research method. Generally, communication between them is difficult.

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 15:05 **201**

PRJ4/DES3: 3D and Near Eye Displays

Chair: J. Reitterer, TriLite Techs., Austria
Co-Chair: T. Hayashi, Okamoto Glass, Japan

PRJ4/
DES3 - 1:
13:30 ***Invited*** **Projection Mapping Technologies for AR**

D. Iwai

Osaka Univ., Japan

This invited talk will present recent projection mapping technologies for augmented reality. First, fundamental technologies are briefly explained, which have been proposed to overcome the technical limitations of ordinary projectors. Second, augmented reality (AR) applications using projection mapping technologies are introduced.

PRJ4/
DES3 - 2:
13:50 ***Invited*** **Animating Static Objects by Illusion-Based Projection Mapping**

S. Nishida, T. Kawabe, T. Fukiage, M. Sawayama

NTT, Japan

In this presentation, we will explain a light projection technique that we recently developed. Based on the scientific knowledge about human visual processing, this technique, called Deformation Lamps (HenGenTou), is able to add a variety of illusory, yet realistic, distortions to a wide range of static projection targets.

Also presented in Innovative Demonstration Session (see p. 263)

PRJ4/ DES3 - 3: 14:10 ***Invited*** **3D Billboards without Glasses**

J. Reitterer, F. Fidler, G. Schmid, C. Hambeck, F. S. Julien-Wallsee, W. Leeb[*], U. Schmid[*]

TriLite Techs., Austria
[*]Tech. Univ. Wien, Austria

We have developed a technology enabling autostereoscopic billboards which provide outdoor-compatible luminance and are scalable to practically any desired display size. Each display element consists of a MEMS laser scanner that deflects the emitted light beams to the left and right eyes of multiple viewers in a time-multiplexed manner.

PRJ4/ DES3 - 4 14:30 **Smart Contact Lens Platform with a Deformed Active Artificial Iris**

A. V. Quintero[,**], S. Delcour[*,**], R. Verplancke[*,**], J. Vanfleteren[*,**], H. De Smet[*,**]*

[*]Ghent Univ., Belgium
[**]imec, Belgium

This paper explores the challenges regarding the thermoforming of a deformable guest-host liquid crystal display within a smart contact lens. Focus was given to the finite element modelling of its fabrication, to find respective design rules. Such displays are thought to be used in vision correction applications (i.e. artificial iris).

----- Break -----

15:15 - 16:45 **Main Hall**

DES4/3D8: 3D Display and Sensor

Chair: Y. Oyamada, Tottori Univ., Japan
Co-Chair: H. Yamamoto, Utsunomiya Univ., Japan

DES4/ 3D8 - 1: 15:15 ***Invited*** **Displaying Real World Light Fields Using Stacked LCDs**

K. Takahashi, Y. Kobayashi, T. Fujii

Nagoya Univ., Japan

We have developed a prototype of a layered light-field (3D) display, where three LCD panels are stacked in front of a backlight. We have also created an end-to-end system where a real 3D scene captured by a multi-view camera is reproduced in 3D on this prototype display.
Also presented in Innovative Demonstration Session (see p. 263)

DES4/ 3D8 - 2: 15:40 ***Invited*** **Lock-in-Detection Based Time-of-Flight CMOS Image Sensors**

K. Yasutomi, S. Kawahito

Shizuoka Univ., Japan

This paper reviews recent time-of-flight (TOF) range imagers particularly for indirect TOF measurement by using lock-in pixels. Lateral Electric Field charge Modulators (LEFM) in the lock-in pixel is a key component to achieve higher range resolution. In this paper, different implementations of TOF range imagers for various applications are described.

DES4/ 3D8 - 3 16:05 **Holographic Augmented Reality Head-Up Display with Eye Tracking and Steering Light Source**

Y.-T. Kim, J. Seo, W. Seo, G. Sung, Y. Kim, H. Song, J. An, C.-S. Choi, S. Kim, H. Kim, Y. Kim, Y. Kim, H.-S. Lee

Samsung Elect., Korea

We realized a holographic head-up display using a steering light source with eye position tracking. It can represent a real augmented reality which perfectly matches virtual graphic images to the real world. Further, for the determination of the position of the light source, 3D calibration method is proposed.

DES4/ 3D8 - 4 16:25 **Flat Autostereoscopic 3D Display with Enhanced Resolution Using a Wavelength Selective Filter Barrier**

S. Jurk, M. Kuhlmey, R. Bartmann, B. Duckstein, R. de la Barré

Fraunhofer HHI, Germany

A spatially multiplexed autostereoscopic 3D display design with lamellar parallax barrier consisting of wavelength-selective color filters is presented. In comparison to conventional similar parallax barriers the resolution, brightness and crosstalk are enhanced. The filtering of single colors enhances a separation of stereo images.

Author Interviews
16:45 – 17:10, Multipurpose Hall

Special Topics of Interest on Printed Electronics

Thursday, December 8

9:00 - 10:20 **413**

FMC4: Standardization on Printed Electronics

Chair: K. Käläntär, Global Optical Solutions, Japan
Co-Chair: Y. Inoue, Corning Japan, Japan

FMC4 - 1: 9:00 ***Invited*** **Standardization Activities on Printed Electronics of IEC TC 119**

K. Suganuma, S. Maeda[*,**]

Osaka Univ., Japan
[*]Chem. Materials Evaluation & Res. Base, Japan
[**]Mitsubishi Chem., Japan

Printed Electronics (PE) is one of the fastest growing technologies expected to lead IoT industry. Japan National committee and PE committee in JEITA are working very closely with IEC TC 119, Printed Electronics. This paper gives a brief overview of the organization of IEC TC 119 and the International Standards progress.

FMC4 - 2: 9:20 ***Invited*** **Overview of Standardization Activities for Stretchable Materials in IEC TC 119, Printed Electronics**

S. Maeda

Toyobo, Japan

Technologies for WSDs (wearable smart devices), and standardization activities related to each them were reviewed by TC 119 / WG 2. These results are summarized in the technical report "IEC 62899 Printed Electronics -Part 250: Material technologies required in Printed Electronics for Wearable Smart Devices". Stretchable electric materials have high priority for the standardization.

FMC4 - 3: 9:40 ***Invited*** **World First International Standard for Printed Electronics Materials**

C. Sekine, M. Oda[*]*, S. Maeda*[**]*, T. Sato*[***]

Sumitomo Chem., Japan
[*]Japan Advanced Printed Elect. Tech. Res. Assn., Japan
[**]Toyobo, Japan
[***]FUJIFILM, Japan

The world first International Standards for printed electronics (PE) materials regarding substrate and conductive ink were issued in February 2016 via IEC/TC119. This has led further international standardizations to match the trend of ItoT, wearable smart devices, etc. Such activities are expected to accelerate growing of PE industry.

FMC4 - 4: 10:00 ***Invited*** **Standardization Activities on Printed Electronics Devices in IEC TC 119**

T. Minakata, K. Hyodo[*]

Asahi Kasei, Japan

[*]Konica Minolta, Japan

New way of manufacturing process, called printed electronics, is getting popular. By using this new process, we could realize new devices that has unique characteristics such as flexibilities. Through this presentation, we would like to explain new standard ways of evaluating devices produced by printed electronics process.

Author Interviews
10:30 – 11:10, Room 201

10:30 - 13:00 **Multipurpose Hall**

Poster **OLEDp3: OLED/PE Poster**

OLEDp3 - 1 **Investigation on Poly(3-Hexylthiophene) Nano-Fiber Transistors with Hybrid Nano Compositor**

M.-H. Chih, C.-E. Tsai, Y.-T. Chen, Y.-J. Li, Y.-W. Wang

Nat. Changhua Univ. of Education, Taiwan

We investigated Poly(3-hexylthiophene)(P3HT) transistors characteristics with different nano material compositors. Moderate doping would enhance P3HT device properties and their resist to water/oxygen, even increase the ordering of molecule structure. In this article, we choose water absorbent/resist polymers, well-order liquid crystal, and metal oxide nanoparticles to modulate P3HT transistors' properties.

OLEDp3 - 2 **Investigation of Solution Process Rubrene Transistors under Different Annealing Conditions**

Y.-H. Cheng, P.-C. Lai, P.-Y. Tsai, K.-C. Fan, Y.-W. Wang

Nat. Changhua Univ. of Education, Taiwan

We investigated the characteristics transition of solution processed Rubrene transistors under various annealing temperature and concentrations. Rubrene has been proven as a high potential organic semiconductor. Solution process promises its application in large area coating and cost down. The fabricated device achieved a mobility ~10^{-4} cm^2/Vs and on/off ratio ~10^3.

OLEDp3 - 3 **Multiple Horizontal-Dip-Coating of Small Molecular Emission Layers for Solution-Processable Organic Light-Emitting Devices**

H. G. Jeon, W. S. Lee, J. N. Huh, Y. Aggarwal, B. Park

Kwangwoon Univ., Korea

We report an investigation of small molecular organic light-emitting diodes, consisted of solution-processable light-emitting layers (EMLs) using a horizontal-dip coating method with multiple coating cycles. It was shown that the formation of nano-pinhole defects in the EMLs was found to decrease with an increase in the number of coating cycles.

OLEDp3 - 4L Low Cost Process for Integrated Substrates of Flexible OLEDs using Printing and Plating

D.-H. Cho, O. E. Kwon, Y.-S. Park, B. G. Yu, J. Lee, J. Moon, H. Cho, H. Lee, N.-S. Cho

ETRI, Korea

We have developed cost-effective process for a flexible integrated substrate of OLEDs with a screen printing, an electroless copper plating, and a deboding process. A photolithographic method and expensive materials such as polyimide and silver did not used. The OLED devices with the integrated substrates were successfully fabricated.

----- Lunch -----

Friday, December 9

13:30 - 14:45 **501**

FLX5: Flexible Printed Electronics 1

Chair: H. Maeda, Dai Nippon Printing, Japan
Co-Chair: H. Endo, NEC, Japan

FLX5 - 1: 13:30 ***Invited*** **Organic Complementary Circuits Based on Solution-Processed Organic Transistors: Toward Flexible Electronics**

M. Uno

Tech. Res. Inst. of Osaka Pref., Japan

We present our recent progress on organic complementary logic circuits based on solution-processed high-mobility organic transistors. Flexible temperature sensors and their read-out circuits of analog-to-digital converters are developed on plastic films, demonstrating the extreme high yield of organic transistors.

FLX5 - 2: 13:55 ***Invited*** **High Mobility and Operational Stability of Top-Gate Organic Transistors Based on Solution-Processable Organic Semiconductors**

T. Nagase, K. Takagi, R. Nakamichi, T. Kobayashi, H. Naito

Osaka Pref. Univ., Japan

We report that the use of top-gate configuration for OTFTs based on solution-processable organic semiconductors allows enhancing field-effect mobility as well as operational stability. The roles of the surface of solution-processed organic semiconductor thin films and their interfaces with polymer gate insulators for enhanced performances in top-gate OTFTs are discussed.

FLX5 - 3: 14:20 ***Invited*** **Flexible/Stretchable Electronics Based on Carbon Nanotube Thin Films**

Y. Ohno

Nagoya Univ., Japan

Among various kinds of semiconductor thin films, carbon nanotube (CNT) thin film provide high-performance devices on flexible polymer films at low cost process such as printing technologies. Here, recent progresses CNT-based flexible devices, including high-mobility thin-film formation, wafer-scale device fabrication and characterization, and electrical and mechanical characteristics, are reported.

----- Break -----

15:10 - 16:15 **501**

FLX6: Flexible Printed Electronics 2

Chair: T. Furukawa, Yamagata Univ., Japan
Co-Chair: T. Shiro, Teijin, Japan

FLX6 - 1: 15:10 ***Invited*** **Printing Ultrafine Conductive Pattern Through Ligand Conversion of Metal Nanoparticles on Photoactivated Surface**

T. Yamada

AIST, Japan

We have succeeded in manufacturing ultrafine conductive pattern through reactive sintering of metal nanoparticles on photoactivated surface at almost room temperature. VUV light can produce photoactivated patterned surface on perfluorinated polymer with carboxylate group, and subsequent coating of alkylamine-encapsulated silver nanocolloids, which triggers to form self-fused solid silver layer.

FLX6 - 2 15:35 **New Alignment Technology for Printed Electronics over Large Flexible Substrates**

Y. Mishima, M. Akiyama, T. Noudou, K. Hashimoto, N. Watanabe, T. Kamata

Japan Advanced Printed Elect. Tech. Res. Assn., Japan

Using newly developed high precision alignment technology, we have realized printed wiring patterns with a high accuracy of less than 2 µm on a G1-size deformed plastic film without fixing on the supporting substrate. 5 µm gate-overlapped TFTs array with a cut-off frequency of 1.1 MHz is confirmed.

FLX6 - 3
15:55

Inkjet Printing Equipment for Multiple Layered Electronics Devices on Roll-to-Roll Flexible Substrates

S. Tomoeda, Y. Goto[*]*, D. Kumaki*[*]*, S. Tokito*[*]*, H. Hirata, T. Hatakeyama*

Toray Eng., Japan
[*]*Yamagata Univ., Japan*

Distortions of flexible substrates make it difficult for the conventional means, e.g. photolithography using masks, to be applied to the manufacturing of patterned layers. Utilizing inkjet technology, Toray Engineering has developed the equipment which overcomes the problems of the substrate distortion.

Author Interviews
16:30 – 17:10, Multipurpose Hall

EXHIBITION

12:40 – 18:00 Wednesday, Dec. 7
10:00 – 18:00 Thursday, Dec. 8
10:00 – 14:00 Friday, Dec. 9
Lobby (2F, 4F)
Fukuoka International Congress Center
Free admission with your IDW/AD '16 registration name tag

SPECIAL EXHIBITION

Presented by NHK

Reception of
Super Hi-Vision Test Satellite Broadcasting

Tuesday, Dec. 6 – Friday, Dec. 9, 2016
Lobby (5F)
Fukuoka International Congress Center

Special Topics of Interest on Automotive Displays

Wednesday, December 7

13:05 - 14:20 **502**

VHF1: Ergonomics for Automotive Applications

Chair: Y. Shimodaira, Shizuoka Univ., Japan
Co-Chair: K. Sakamoto, Panasonic, Japan

VHF1 - 1
13:05

Influence of Image Position and Visual Target on Depth Perception When Using Automotive 3D Head-Up Display

R. Noguchi, T. Daimon, T. Mori[*]*, K. Kasazumi*[*]

Keio Univ., Japan
[*]*Panasonic, Japan*

We previously proposed a three-dimensional (3D) head-up display (HUD) that places virtual images in the appropriate 3D position based on virtual image focal depth and image plane angle. Here, we compare the 3D-HUD with a conventional augmented reality HUD and investigate how image position and visual target influence depth perception.

VHF1 - 2
13:25

Traffic Signal with PWM Coding for Visible Light Communication

C.-J. Ou, M.-Y. Cheng, Z.-W. Huang, C.-H. Ou[*]*, H.-E. Lu*

Hsiuping Univ. of S&T, Taiwan
[*]*Dougshan High School, Taiwan*

LED with PWM control can improve the broadcasting information. Simulation through the dynamic routing program, results suggest that through this device, a 40% traffic jam situation can be amended, which manifest the ability of the information display system to improve not just the information qualities, but besides the existing parts.

VHF1 - 3
13:45

Key Perceptual Factors for Smart Garnish Light/ Display

J. K. Ko, S. Y. Choi, M. S. Noh, S. S. Kim[*]*, G. H. Kim*[*]*, W. K. Song*[*]*, K.-G. Seok*[**]

Korea Inst. of Lighting & Tech., Korea
[*]*Seoyon Elect., Korea*
[**]*Dilussion, Korea*

The important perceptual factors are investigated for a smart garnish considering that a conventional garnish can be replaced by lights or displays. The color and pattern stimuli determined to satisfy key emotional requirements can be utilized to deliver various visual messages as well as interior lighting mood options for automobile.

Note : One More Paper out of the scope of this STI will be presented in the session (see P.175)

----- Break -----

14:40 - 16:05 **201**

INP2: Automotive HMI

Chair: N. Haneda, DENSO, Japan
Co-Chair: H. Haga, NLT Techs., Japan

INP2 - 1: 14:40 ***Invited*** **Communication System Using Lights for Automobile**

N. Haneda

DENSO, Japan

This research is about three optical systems for communicating between people and automobiles. A Head-Up Display that directly projects images within a human's eye; an optical camouflage display that makes physical obstacles to the driver's vision and an external vehicle communication system to facilitate communication between passengers and road users.

INP2 - 2 15:05 **Automotive Grade Haptic Feedback System Based on Automotive Grade Embedded Operating System**

F.-H. Tsao, C.-L. Li, W.-F. Chang, H.-H. Chen, H.-M. Su, W.-T. Tseng

Chunghwa Picture Tubes, Taiwan

Based on automotive grade embedded operating system "Automotive Grade Linux" (AGL) and CPT's automotive grade liquid crystal display (LCD) panel with piezo vibrator, we have developed a automotive haptic feedback system successfully. In this paper, we applied different vibration patterns and vibration strength corresponding to function separately.

INP2 - 3 15:25 **Smart Steering Wheel with Swept Frequency Capacitive Sensing**

Y. Ono, Y. Morimoto, R. Hattori, M. Watanabe[*]*, N. Michida*[*]*, K. Nishikawa*[*]

Kyushu Univ., Japan
[*]*Mazda Motor, Japan*

We present a smart steering wheel that detects the gripping position and area, and the distance to the approaching driver's hands by measuring the resonant frequency and its resistance value in an LCR circuit composed of the floating capacitance of the gripping hand and the body resistance.

Also presented in Innovative Demonstration Session (see p. 264)

INP2 - 4 **Electrostatic Tactile Display for Interaction with**
15:45 **Multiple-Unique Sensations**

D. Sugimoto, H. Haga, K. Shigemura

NLT Techs., Japan

An electrostatic tactile display that presents multiple, unique sensations concurrently on a touch surface has been demonstrated. A beat frequency created by a pair of driving frequencies supplied to adjacent electrodes, which is the origin of the tactile sensation, is modulated using a frequency-variable voltage source.

Also presented in Innovative Demonstration Session (see p. 264)

----- Break -----

Author Interviews
17:40 – 18:20, Multipurpose Hall

Thursday, December 8

10:30 - 13:00 **Multipurpose Hall**

Poster **VHFp1: Applied Vision and Human Factors - Automotive applications**

VHFp1 - 1 **Evaluation of Specular Reflectance for Automotive Display**

K. Mo, B. Choi

LG Display, Korea

Reflection is one of the most important factors for the automotive display. Therefore, a measuring method of reflection must be defined properly for correct reflectance data. We suggest a new method of specular reflectance only void of diffuse components. It shows a correlation between measured data and human eye.

14:10 - 16:40 **Multipurpose Hall**

Poster **3DSAp2/3Dp2: 3D and Hyper-Realistic Systems and Applications 2**

3DSAp2/ **Wide-Screen Head-Up Display with a Projection**
3Dp2 - 12 **Lens Array**

T.-S. Yeh, W.-C. Su

Nat. Changhua Univ. of Education, Taiwan

The optical design for a virtual image system in a vehicle is presented. We use a lens array to implement a wide-screen virtual image projection display system. In this system, the virtual image location is in front of the eyebox with a distance of 1500 mm.

Friday, December 9

15:30 - 16:30 **201**

PRJ5: Automotive Displays

Chair: V. R. Bhakta, Texas Instrs., USA
Co-Chair: K. Ohara, Texas Instrs., Japan

PRJ5 - 1: 15:30 ***Invited*** **Adaptive High Resolution Headlight Using Texas Instruments DLP Technology**

V. R. Bhakta, B. Ballard

Texas Instrs., USA

Glare-free high beam solutions on the road support resolutions up to 100 pixels. To improve throughput and functionality, we propose a high resolution (>100k pixels) glare-free high beam using Texas Instruments DLP chipsets. We will present an optical design of an LED illuminated headlight and share performance measurements.

PRJ5 - 2 **Withdrawn**

PRJ5 - 3 15:50 **Integrated RGB Laser Light Module for Augmented and Virtual Reality Applications**

J. Reitterer, F. Fidler, G. Schmid, C. Hambeck, F. S. Julien-Wallsee, W. Leeb[*]*, U. Schmid*[*]

TriLite Techs., Austria
[*]*Tech. Univ. Wien, Austria*

We have developed an integrated, hermetically sealed RGB laser light module comprising three bare die semiconductor laser diodes (one each for red, green, and blue) with associated monitor photodiodes and a common microlens.

PRJ5 - 4 16:10 **Development of Head-Up Display for Railway Vehicle**

A. Michimori, J. Kondo, S. Nakahara, A. Heishi, T. Yamamura, S. Ohashi, H. Yokoyama[*]*, H. Horiuchi*[*]

Mitsubishi Elec., Japan
[*]*East Japan Railway, Japan*

We have developed a head-up display (HUD) for railway vehicles. We conducted stationary tests and running tests of the head-up display using actual vehicles and confirmed its good visibility and effectiveness in railway vehicles.

Author Interviews
16:30 – 17:10, Multipurpose Hall

Topical Session on User Experience and Cognitive Engineering

Wednesday, December 7

13:00 - 13:05 **503**

Opening

Opening Remarks
13:00

H. Shibata, Fuji Xerox, Japan

13:05 - 14:25 **503**

UXC1: User Study

Chair: H. Shibata, Fuji Xerox, Japan
Co-Chair: T. Matsui, Osaka Univ., Japan

UXC1 - 1: ***Invited*** **How People Change Their Social Behaviors around Different Public Displays?**
13:05

J. Ichino

Kagawa Univ., Japan

We investigated through a field study how the angles of displays deployed at a museum impact the social behaviors of the people around the display. We collected quantitative and qualitative data of around 700 visitors and examined how the three display angles impact visitors' attention, sharing of space, and communication.

UXC1 - 2: ***Invited*** **Interact with Art**
13:25

M. Tanaka, K. Isoda, I. Hisanaga

Dai Nippon Printing, Japan

We have been collaborating with the museums and the libraries, such as Musée du Louvre and Bibliothèque nationale de France, as Museum Lab, researching and developing myriad digital contents to install interactive systems for art appreciation. In this session, several examples of our installations and research results will be presented.

UXC1 - 3: ***Invited*** **The Effect of Conference Using Table with Display and Touch Interface**
13:45

T. Nishino, Y. Yagi, K. Fujita

Itoki, Japan

We have developed a big-size screen table with touch panel, named Face-up Table, and considered user interactions of group meetings by observing users interacting with it. Comparing with upright display setting, we confirmed that the face-up display setting made users remark more equally.

UXC1 - 4
14:05

VR Simulation Verification for the Space Design with the Tactile Reaction

T. Ainoya, Y. Tanaka, K. Kasamatsu
Tokyo Metropolitan Univ., Japan

In this study, we set the living space is a familiar space as a specific place, were examined for elements needed to feel comforting. As a result, there is the combination of hardness and surface on floor which gives a feeling comforting.

----- Break -----

14:40 - 16:00 **503**

UXC2/VHF2: Human Factors

Chair: H. Shibata, Fuji Xerox, Japan
Co-Chair: N. Hiruma, NHK-ES, Japan

UXC2/ VHF2 - 1: 14:40

Invited **Development of Japanese Electronic Text Readers Based on Perceptual Mechanisms of Reading**

J. Kobayashi[,**], E. Shinbori[*], T. Kawashima[**]*
[*]Dai Nippon Printing, Japan
[**]Future Univ. Hakodate, Japan

We have proposed stepped-line and vibration text layouts to improve eye movement efficiency. The reading speeds obtained with the proposed layouts are faster compared to a conventional Japanese layout. This is primarily achieved by a reduction in the number of eye fixations.

UXC2/ VHF2 - 2

Withdrawn

UXC2/ VHF2 - 3
15:20

Experiment of Psychological Impact of LED Display

T. Matsui, T. Fukuda, S. Nagamachi[*]
Osaka Univ., Japan
[*]LEM Design Studio, Japan

LED display replace paper advertising as digital signage and create new light-scape in urban system. However, LED has impact on human mind and it should be researched to establish comfortable urban landscape. This paper shows results of psychological experiment investigated the relationship between luminance level and glaring and uncomfortable emotion.

UXC2/ VHF2 - 4 15:40 **Effects of Different Comfortable Binocular Disparities on the DP3 Signal-an Event-Related Potential Study Using an Oddball Task**

P. Ye, X. Wu, D. Gao, S. Deng, N. Xu, J. She, J. Chen

Sun Yat-Sen Univ., China

Displaying the stereoscopic 3D contents within the comfort zone could reduce the induced visual fatigue. We studied the EEG signal of DP3 (differential P3) elicited by the 3D contents possessing different disparities within the comfort zone. The proposed approach could facilitate accurately improving the definition of the comfort zone.

----- Break -----

Author Interviews
17:40 – 18:20, Multipurpose Hall

Thursday, December 8

9:00 - 10:25 **503**

UXC3: Interaction Design

Chair: J. Ichino, Kagawa Univ., Japan
Co-Chair: H. Shibata, Fuji Xerox, Japan

UXC3 - 1: 9:00 ***Invited*** **Interaction Techniques on Touchscreens with Elastic/Non-Flat Surfaces**

B. Shizuki

Univ. of Tsukuba, Japan

Touchscreens with elastic/non-flat surfaces have the potential to provide a set of new interaction techniques. This paper discusses three of our touchscreens, i.e., one with a gel sheet as the surface, one with silicone rubber panel as the surface, and one with a cylindrical surface, along with their interaction techniques.

UXC3 - 2 9:25 **Proposal of a Paper Book Type Input Device for Page Navigation for Digital Documents**

S. Masunaga, X. Xu, H. Terabe, K. Shibuta, H. Shibata

Fuji Xerox, Japan

We tried to use a paper book as a device to navigate pages for digital documents. As a result of experiments, we confirmed the proposed system is superior to conventional navigation methods especially in moving back and forth among pages.
Also presented in Innovative Demonstration Session (see p. 264)

UXC3 - 3 9:45 **Supporting Reading Itself: An Exploration of Temporal Ink Pen for Making Annotations**

X. Xu, H. Shibata

Fuji Xerox, Japan

We provide a new concept of a "temporal ink" pen for supporting reading itself instead of current normal pens, which retain permanent information for later use, and hypothesized this annotation style supports reading effectively. Preliminary experiments shown a prospect that our proposal would promote annotating.

Also presented in Innovative Demonstration Session (see p. xxx)

UXC3 - 4 10:05 **Implementation and Evaluation of a Design Support System Using Pen Device for Animation**

T. Maruya, S. Tano, T. Hashiyama, M. Iwata[*], J. Ichino[**]

Univ. of Electro-Commun., Japan
[*]Tokyo Metropolitan College of Ind. Tech., Japan
[**]Kagawa Univ., Japan

We analyzed different types of animations and determined the factors that inhibit intuitive and creative animation design. Moreover, we developed a design-support tool to solve animation problems and implemented a prototype. Experiments were conducted to evaluate the tool. Results of the experiments suggest that the tool works properly and effectively.

10:25 - 10:31 **503**

Short Presentation UXCp1: User Experience

All authors of poster papers for the UXCp1 session will give a brief 3-minute oral presentations with no discussion time in advance.

Author Interviews
10:31 – 11:10, Room 201

10:30 - 13:00 **Multipurpose Hall**

***Poster* UXCp1: User Experience**

UXCp1 - 1 **10:30** **Investigation of Effect of Bioluminescent Light on Human Using Electroencephalogram**

N. Thammasan, M. Iwano, K. Moriyama[*], K. Fukui, K. Kawintiranon[**], Y. Buatong[**], S. Inagaki, T. Wazawa, T. Nagai, M. Numao

Osaka Univ., Japan
[*]Nagoya Inst. of Tech., Japan
[**]Chulalongkorn Univ., Thailand

In this study, we evaluate scientifically whether bioluminescence functions as a soothing light source. Specifically, we examine how visual stimulation affects human brainwaves using the newly developed bioluminescent proteins and we found the different optical properties that bioluminescent light produced softer and more pleasant effects on human than LED light.

UXCp1 - 2 **Withdrawn**

UXCp1 - 3L **A Novel Input Modality for Smartphone Using Tapping Sound Recognition**

S.-J. Song, D. Kim, H. Nam

Kyung Hee Univ., Korea

This paper proposes a new tapping sound recognition technology that is a novel input modality utilizing only microphones in most mobile devices. Our technology extracts the positions of tapping sounds generated at the outside of a smartphone by means of frequency domain features and support vector machine.

----- Lunch -----

Friday, December 9

15:10 - 16:10 **503**

VHF8/UXC4: High Dynamic Range and Virtual Reality

Chair: Y. Hisatake, Japan Display, Japan
Co-Chair: H. Shibata, Fuji Xerox, Japan

VHF8/ UXC4 - 1L **15:10** **Effect of Variable System Gamma for Hybrid Log-Gamma HDR Video Production**

Y. Ikeda, Y. Kusakabe, K. Masaoka, Y. Nishida

NHK, Japan

We conducted an experiment of Hybrid Log-Gamma (HLG) high dynamic range (HDR) video production at different display peak luminance levels. The experiment confirmed that the HLG HDR video production with a variable system gamma yields more consistent video level management results regardless of the peak luminance of a master monitor than that with a fixed system gamma.

VHF8/ UXC4 - 2L **Global Dimming Strategies for Improving Subjective Visual Quality of HDR Video on Liquid Crystal Displays**

M. Choi, D. Hoffman

Samsung Display, USA

We examined five strategies of global dimming backlight control with video sequences and emulated their LCD contrast on an OLED panel. We performed a subjective study to rank preferences with cinematic content. Dynamic global dimming with temporal smoothing was preferred over static and frame-by-frame approaches.

VHF8/ UXC4 - 3L **Subjective Evaluation of See-Through Head Mounted Display**

R. Kimura, T. Totani[*]*, T. Miyao*[*]*, T. Kojima, M. Miyao*

Nagoya Univ., Japan
[*]*Seiko Epson, Japan*

We conducted an experiment easy work with 119 participants. Easy work is that participants assembled the LEGOs according to assembly layout with a see-through head mounted display (HMD). We tested the subjective evaluation of see-through HMD and working efficiency.

VHF8/ UXC4 - 4L **Comparison of the Readability of a Tablet Device and See-Through Smart Glasses**

K. Iwata, T. Totani[*]*, T. Miyao*[*]*, P.R. Lege, T. Kojima, M. Miyao*

Nagoya Univ., Japan
[*]*Seiko Epson, Japan*

We carried out experiments to evaluate the readability of two devices, a tablet device (iPad) and smart glasses (BT-300). In the experiments, participants were asked to make subjective evaluations and their reading time was measured. We also calculated their percentage of correct answers, and compared the readability of each device.

----- Break -----

Author Interviews
16:30 – 17:10, Multipurpose Hall

Workshop on LC Science and Technologies

Wednesday, December 7

13:00 - 14:20 **412**

LCT1: Photoalignment

Chair: K. Miyachi, JSR, Japan
Co-Chair: Y. Iwashita, DIC, Japan

LCT1 - 1 13:00 **Development of a Novel Azobenzene Diamine Compound for Photoalignment Film with High Transmittance**

Y. Tsukada, Y. Ooki, Y. Oguchi, D. Touma

JNC Petrochem., Japan

A novel azobenzene compound for isomerization type photoalignment film has been developed. It has 4-aminophenethyl groups at both sides of azobenzene core. Photoalignment film (PAF) containing it shows high transmittance and almost the same alignment-ability compared with our conventional isomerization type PAF.

LCT1 - 2 13:20 **Chromaticity Improvement of Novel Photoalignment Material for IPS-LCDs**

Y.-J. Song, C.-G. Yuan, W. Ren, C.-C. Hsieh, Y.-C. Zhao, R.-T. Zhao, X. Li, C.-Y. Chiu, C.-Y. Lee

Shenzhen China Star Optoelect. Tech., China

A new photo alignment material for in-plane switching (IPS) liquid crystal display has been presented. In this paper, the chromaticity performance has been improved and it has good alignment performance. Furthermore, an excellent image sticking property can be achieved.

LCT1 - 3 13:40 **High Anchoring Composite Photoalignment Material with High Photosensitivity**

I. Rushnova[,**], A. Murauski[**], V. Mikulich[**], A. Muravsky[**]*

[*]Belarusian State Univ., Belarus
[**]NAS of Belarus, Belarus

We developed new type of composite photoalignment material that combines non-rubbed Nylon-6 and AtA-2 azo-dye photoalignment sub-layers. Comparing to single azo-dye photoalignment layer the composite photoalignment material is 2 times more photosensitive (exposure dose 0.25-0.45 J/cm^2) and possesses 3~5 times higher azimuthal anchoring energy (peak value 6.2×10^{-4} J/m^2 is obtained).

LCT1 - 4 14:00 **Photo-Aligned Quantum Rods Enhancement Films for LCDs**

W. Zhang, A. K. Srivastava, J. Schneider, A. Susha*, A. Rogach*, V. G. Chigrinov, H. S. Kwok*

Hong Kong Univ. of S&T, Hong Kong
**City Univ. of Hong Kong, Hong Kong*

We disclose photo-aligned Quantum Rods Enhancement Films (QREFs) for liquid crystal displays. Quantum Rods (QRs) are aligned in thin liquid crystal polymer films by photo-alignment technology. The QREFs show QRs alignment with order parameter ~0.87 and degree of polarization ~0.82, which can improve color gamut and polarization efficiency of polarizers.

----- Break -----

14:40 - 15:55 **412**

LCT2: Evaluations

Chair: M. Suzuki, Merck, Japan
Co-Chair: T. Nose, Akita Pref. Univ., Japan

LCT2 - 1 **Withdrawn**

LCT2 - 4L 14:40 **Influence of Impurity Ions on the Measurement of Flexoelectric Coefficients Using the C-V Properties of HAN Cells**

K. Imina, Y. Kudoh, T. Takahashi

Kogakuin Univ., Japan

Flexoelectric coefficients of a hybrid alignment nematic cell's were measured using C-V characteristics evaluated for seven electrodes. The flexoelectric coefficient and the impurity ion density were measured at each electrode. The C-V characteristics were used to extrapolate the flexoelectric coefficient without it being influenced by impurity ions.

LCT2 - 2 15:00 **Optical Surface Profilometry with Dynamic Fringe Pattern Generator Using Multi-Domain LC Phase Array**

H. Park, K.-I. Joo, M. Kim, M.-K. Park, J. Hahn, H.-R. Kim

Kyungpook Nat. Univ., Korea

We implemented dynamic fringe pattern generator (DFPG) using multi-domain liquid crystal phase array to develop the optical surface profilometry. Our fringe pattern generator can enhance scanning response time and precision in 3D depth measurement, which can electrically generate multiple interference patterns with multi-spatial frequencies and four-step phase shifting.

LCT2 - 3
15:20

Reflection Wavefront Design with Cholesteric LCs

H. Yoshida[,**], J. Kobashi[*], M. Ozaki[*]*

[*]Osaka Univ., Japan
[**]JST PRESTO, Japan

Cholesteric LCs – materials with spontaneous helical order – have long been known to function as circularly-polarization-sensitive Bragg reflectors. We show that through orientation control, it is possible to control the reflected light phase from cholesteric LCs, and hence fabricate various types of holographic optical elements.

LCT2 - 5L
15:40

A Theoretical Explanation of High Speed Response in LCDs such as TB, IPS, FFS, and HV-FLC with Geometry Phase-Pancharatnam Phase Retarder for an Optical Compensation

S. Kobayashi, H. Akiyama[*]

Tokyo Univ. of Sci., Yamaguchi, Japan
[*]DIC. Japan

We report a theoretical explanation of high speed response in LCDs such as TB, IPS, FFS, and HV-FLCD in terms of advance of Geometry phase-Pancharatnam phase.

----- Break -----

16:20 - 17:45 **412**

LCT3/FLX1: Flexible LCDs

Chair: S. Oka, Japan Display, Japan
Co-Chair: M. Kimura, Nagaoka Univ. of Tech., Japan

LCT3/
FLX1 - 1:
16:20

Invited **Roll Plastic TFT-LCD with 20R Curvature Using Soft Backlight Unit**

N. Sugiura, P.-H. Chiu, W.-Y. Li, Z.-H. Chen, W.-J. Chiu, C.-R. Chang, T.-H. Huang, Y.-H. Lai, J.-K. Lu, Y.-C. Lin

AU Optronics, Taiwan

We have developed a roll plastic TFT-LCD with 20R curvature using an advanced hyper-viewing-angle mode, optically compensated colorless polyimide substrates, and a soft backlight unit with an optimized micro-surface-structure. This technology enables both high optical performance and high reliability of roll plastic TFT-LCDs.

LCT3/
FLX1 - 2:
16:45

Invited **Substrate and Polymer-Wall Technologies for Future Foldable LCD Applications**

T. Ishinabe, Y. Obonai, S. Honda, Y. Shibata, H. Fujikake

Tohoku Univ., Japan

Highly reliable foldable display has been crucial technology for future LCD applications such as large digital signages and automotive displays. We have developed foldable LCD using ultra-thin polyimide substrates with polymer walls structure by the coat-debond fabrication method and successfully achieved small curvature radius less than 2 mm.

LCT3/ FLX1 - 3 17:10 **Flexible LC Light Shutter with Polymer Wall Structure**

S.-M. Ji, J.-W. Huh, J.-H. Kim, Y.-G. Choi, B.-H. Yu, T.-H. Yoon

Pusan Nat. Univ., Korea

We fabricated an initially-transparent flexible LC light shutter with the wall structure. It uses light scattering and absorption at the same time so that it can hide objects behind it and provide black color. We expect that the light shutter can provide high visibility to a flexible see-through display.

LCT3/ FLX1 - 4L 17:30 **Solution-Processed Graphene/PEDOT:PSS Film as Alternative to ITO**

T. Hu, H. Wang, X. Zhang, G. Liu, H. Chen, Y. Lee

Shenzhen China Star Optoelect. Tech., China

An ITO alternative film was obtained from high conductivity graphene nanosheet combining with the PEDOT:PSS, and the film with 123 nm film thickness exhibited a sheet resistance of 185 Ω/□ and 95% light transmittance at 550 nm. Moreover, the film has good adhesive due to the addition of graphene.

Author Interviews
17:45 – 18:20, Multipurpose Hall

Thursday, December 8

10:30 - 13:00 **Multipurpose Hall**

***Poster* LCTp1: Evaluations**

LCTp1 - 1 **Withdrawn**

LCTp1 - 2 **Analysis of Gamma Variation in High ppi Mobile Displays**

J. Li, Z. Xu, H. Chu, Y. Guo, L. Wang, Q. Guo, M. Wang, S. Wang, K. H. Park, Y. B. Lee, C. Che, S. K. Lee

BOE HF, China

We investigated the influence factor of gamma variation in ADS mode LCD. According to the experimental results, some TFT parameters like pixel electrode width and passivation thickness are the main effect to gamma variation. The result is important to decrease gamma variation in high PPI mobile display.

LCTp1 - 3 **Simple Technique for Measuring Phase Modulation and Accelerating Response Time for Off-Axis System with Thick Spatial Light Modulator**

C. Wang

Jasperdisplay, Taiwan

We provide a simple method to measure phase curve for SLM (Spatial Light Modulator) in off-axis system and we also speed up the slow response time of thick SLM by choosing appropriate driving voltage range. These improve the performance of thick SLM in off-axis system.

LCTp1 - 4 **Computer Simulation for Dielectrophoresis in Nematic-Isotropic Mixtures on Honeycomb-Shaped Electrodes**

J.-S. Lee, B. Lee. J.-K. Song

Sungkyunkwan Univ., Korea

We have investigated the dielectrophoretic manipulation of isotropic droplets in nematic medium using computer simulations. The effects of electrode shapes, sizes, cell gap, applied voltages and addition of micro-deforming tips have been investigated in details.

LCTp1 - 5 **Study of Image Sticking of LC Cell with Dielectric Spectrum**

Y.-L. Tsai, A. Y.-G. Fuh, C.-Y. Huang[*], C.-Y. Chen[**], C.-Y. Huang[**]

Nat. Cheng Kung Univ., Taiwan
[*]Daxin Material, Taiwan
[**]Nat. Changhua Univ. of Education, Taiwan

We investigate dielectric spectrum (DS) of the LC cells. The DS of the cell shift to the low frequency region during DC voltage stress (DCVS), and restores to the original position after DCVS. The cell with image sticking restore slower than that of the cell without image sticking.

LCTp1 - 6 **Ellipsometric Characterization of the Surface of Rubbed Polyimide and Distribution of LC Molecules in TN Cells**

S. Y. Cho[*], S. U. Park[**], S. M. Yang[*], S. Y. Kim[,**]*

[*]Ajou Univ., Korea
[**]Ellipso Tech., Korea

Optical anisotropy of rubbed PI surfaces and distribution of liquid crystal molecules in TN cells are quantitatively addressed by using ellipsometry.

LCTp1 - 7 **Necessity and Efficacy of Inspecting a Minute Twist of LC Director Alignment in FFS/IPS LCDs**

A. Ikemura, M. Kitamura

SHINTECH, Japan

We show that a minute twist unexpectedly arising in the FFS/IPS LCD, in which a perfect parallel alignment is required, significantly degrades the contrast ratio both by numerical simulations and by experiments. We emphasize that the necessity and efficacy of inspecting the twist angle in FFS/IPS manufacturing process.

LCTp1 - 8 **Withdrawn**

LCTp1 - 9L **Continuous Change of Dispersive and Polar Components of Surface Energy: Irradiation on Reactive Mesogen**

S. Takahashi, Y. Kobayashi, M. Kimura

Nagaoka Univ. of Tech., Japan

It was reported that the molecular alignment of nematic liquid crystal can be fabricated by slit coater method. Pretilt angle can also be controlled by the UV irradiation energy. In this study, the relationship between the pretilt angle and dispersive and polar components of the surface energy is discussed.

10:30 - 13:00 **Multipurpose Hall**

Poster **LCTp2: Novel LC Applications**

LCTp2 - 1 **Imaging Performance Using a Large Aperture LC Lens Embedded a Floating-Ring Electrode**

C.-J. Hsu, J.-J. Jhang, C.-Y. Huang

Nat. Changhua Univ. of Education, Taiwan

A large aperture hole-patterned LC lens with low driving voltages and large lens power is realized by introducing a floating-ring electrode at the interface between the dielectric layer and LC layer. The well lens quality of the proposed LC lens is demonstrated on imaging system.

LCTp2 - 2 **Electrically Blind Window Based on Polymer Stabilized Cholesteric Texture Films**

S.T. Wu, Z. B. Shina, C. H. Yang, A. Y.-G. Fuh

Nat. Cheng Kung Univ., Taiwan

The study reports a novel LC film that can be applied on the transmissive substrates to upgrade the shield. The shadow area and transmittance can be adjusted according to the outer sunshine. The window maintains the transmittance after an once-off operation of pulse amplitude modulation (PAM) electric driving.

LCTp2 - 3 **Coaxially Bifocal LC Lens with Double Hole-Patterned Electrodes**

S.-Y. Chih, C.-J. Hsu[*]*, C.-Y. Huang*[*]*, J.-C. Jhang*[*]*, A. Y.-G. Fuh*

Nat. Cheng Kung Univ., Taiwan
[*]*Nat. Changhua Univ. of Education, Taiwan*

We fabricate the LC lens with two hole-patterned electrodes which have different aperture diameters. The proposed LC lens with two hole-patterned electrodes presents coaxially dual focal lengths. The phase retardation distribution is depicted by interference pattern to justify the coaxially dual focal characteristic.

LCTp2 - 4 **Measurement of Photoluminescence Spreading in an LC/Dye Cell**

S. Ozawa, M. Ohta, S. Itaya, I. Fujieda

Ritsumeikan Univ., Japan

Photoluminescence generated by a narrow laser beam spreads inside an LC/dye cell. This phenomenon is affected by the bias as well as the LC alignment configuration. We attribute it to self-absorption and re-emission processes. It can degrade the quality of an image displayed in a Display-Integrated Photovoltaic system.

LCTp2 - 5 **Polymer Stabilized LC Lens Using a Floating-Ring Electrode**

Y.-J. Liu, C.-J. Hsu, C.-Y. Huang

Nat. Changhua Univ. of Education, Taiwan

We demonstrate a polymer stabilized LC lens using a circular hole-patterned electrodes with a diameter of 6 mm and a floating-ring electrode with a diameter of 2 mm. By photopolymerization, the hole-type LC lens implanted a floating-ring electrode is constructed with free of disclination lines.

LCTp2 - 6 Model Incorporating Self-Absorption for a Display-Integrated Photovoltaic System

I. Fujieda

Ritsumeikan Univ., Japan

A two-dimensional model incorporating self-absorption is proposed to account for the photoluminescence (PL) fluxes inside a Luminescent Solar Concentrator (LSC). This model relates its power harvesting efficiency to its design parameters. It also gives an estimate on the degree of PL spreading in a Display-Integrated Photovoltaic system.

LCTp2 - 7 Thermal-Induced Black LC-Polymer Composite Display

S. Kim, W.-J. Lee, Y,-H. Kim, G. H. Kim

ETRI, Korea

The black dye-doped LC-polymer composites display (BD-LCCD) is developed by using the three dyes (R, G, B) blend for black color. BD-LCCD can be obtained by thermal polymerization induced phase separation method. The fabricated BD-LCCD exhibit good electro-optic behavior as low driving voltage and high contrast ratio.

LCTp2 - 8L Reduction of Driving Voltage in Polymer Stabilized Reverse Mode Cell: UV Absorption of LC and UV Light Source

K. Inoue, R. Yamaguchi

Akita Univ., Japan

We have fabricated a polymer stabilized reverse mode cell using Hg lamp (313 nm) and UV-LED (365 nm) light sources. A relationship between UV intensity profiles through the cell and electro-optical properties has been investigated. The driving voltage was successfully reduced by controlling the UV absorption.

LCTp2 - 9L Formation of Polymer Walls by Monomer Aggregation Control Utilizing Wettability of Substrate Surface for Flexible Displays

S. Kawamorita, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

We have proposed a novel fabrication process of polymer walls structure by monomer aggregation control utilizing wettability of substrate surface for high quality flexible LCDs. We clarified that separation of LC and monomer for forming polymer walls can be enhanced by decreasing temperature in UV light irradiation.

LCTp2 - 10L **Development of Dimming Glass Using Azobenzene Doped Gest-Host LC**

K. Goda, M. Omori, K. Takatoh

Tokyo Univ. of Sci., Yamaguchi, Japan

In this study, the optically switchable device between the vertically aligned nematic mode and the isotropic phase by the photoisomerization reaction of azobenzene is proposed. This device represents the transparent state and colored state by the unpolarized UV light.

----- Lunch -----

14:10 - 16:40 **Multipurpose Hall**

Poster LCTp3: Quality of LCDs

LCTp3 - 1 **Analysis of the Relationship between Pixel Electrode Design and LC Alignment in VA-LCD**

M. Li, L. Chen, H. H. Chen

Shenzhen China Star Optoelect. Tech., China

According to simulation and analysis of LC motion induced by electric field, we have deeply explained the relationship between pixel electrode design and LC alignment in VA-LCD, which is meaning for better understanding and controlling LC alignment to achieve high transmittance LCD.

LCTp3 - 2 **Research of Optimize LCD Quality in ADS Mode**

H. Zhang, Y. Qu, H. Zhao, D. Wang, S. Liu

Beijing BOE Display Tech., China

Mura is the key issue for quality of TFT LCD panel, and need to be overcome for long time. This paper introduces the research of improve tracing mura, and improvements on such problems that mainly through optimizing design to improve the image quality. In addition to the wider view angle characteristics, there is achieve higher transmittance characteristics.

LCTp3 - 3 **Novel Photo-Polymer Stabilization of Nano-Phase-Separated LCs with Fast Response**

T. Fujisawa, K. Jang, F. Kodera, Y. Iwashita, H. Hasebe, H. Takatsu

DIC, Japan

A Nano-Phase-Separated LCs (NPS-LCs), which is one of polymer/LC composite, realizes faster response than polymer sustained vertical aligned LC. Method of photo-polymer stabilization is devised to improve alignment of LC along both strip electrodes and slits in fishbone patterned electrodes.

LCTp3 - 4 **Improvement of the Off-Axis Gamma Distortion in 8-Domain Patterned Vertical Alignment Mode**

Y.-C. Shin, M.-K. Park, H. G. Kim, J.-S. Park, H.-R. Kim

Kyungpook Nat. Univ., Korea

The conventional multi-domain vertical alignment (MVA) technologies still have problems with the gray level distortion at oblique viewing angles. In this paper, to improve the gamma distortion at the off-axis, an 8-domain vertical alignment was adopted by using novel hybrid structure of pixel electrode without additional electronic circuits.

LCTp3 - 5 **Effects of Hollow Silica Nanoparticles on Ionic Properties of the LC Cells**

M.-K. Huang, C.-Y. Huang, K.-Y. Lo[*]*, H.-P. Lin*[*]

Nat. Changhua Univ. of Education, Taiwan
[*]*Nat. Cheng Kung Univ., Taiwan*

We investigate the low-frequency permittivity spectra and electro-optical properties of the hollow silica nanoparticles (HSNs)-doped LC cells. The addition of HSNs decreases the ion density and response time of the LC cell.

LCTp3 - 6 **Color Filter/Polarizer-Free LC Composite Display Having Color Dyes**

G. H. Kim, W. J. Lee, S. Kim, Y. H. Kim

ETRI, Korea

Thermally induced LC composite displays having color dyes were developed by doping color dyes into thermal-curable reactants and nematic LC mixtures. There are some advantages for light shutter and display such as low driving voltage and color expression without color filter and polarizers. The obtained devices exhibit good electro-optic behaviors.

LCTp3 - 7 **Stable Reverse TN-LCDs Using High Pretilt Angle Alignment Layers**

K. Takatoh, H. Uno, H. Taniguchi, I. Watanabe

Tokyo Univ. of Sci., Yamaguchi, Japan

RTN (Reverse TN)-LCDs can be driven by low driving voltage. However, the stabilization process had been indispensable. Stable RTN-LCDs could be realized by using high pretilt angle alignment layers. The obtained stable RTN-LCDs should be the optical switch which can be driven by lowest driving voltage.

LCTp3 - 8 **Viewing Angle Controllable LCDs with Hybrid Aligned Nematic LC**

L. Jiang, Z. Su, C. M. Yu, P. Liao, S. Chung

InfoVision Optoelect., China

We propose a viewing angle controllable FFS-TFT-LCD with hybrid alignment. From optical measured results, it was found that the horizontal viewing angle of the VAC device can be controllable from 120° to 50°, response behavior and color performance were also studied simultaneously in this work.

LCTp3 - 9 **Influence of LC Dielectric on TFT-LCD of UV2A LC Mode**

X. Li, Y.-J. Song, C.-C. Hsieh, Y.-C. Zhao, Y. Zhang, W. Ren, C.-G. Yuan, C.-Y. Chiu, C.-Y. Lee

Shenzhen China Star Optoelect. Tech., China

The Ultraviolet induced multi-domain vertically aligned (UV2A) LC mode has wide application for manufacturing large size LCD-TV panel. It needs to be well controlled for UV2A LC dielectric constant. In this study, we have investigated the effect of LC dielectric on the transmittance, image sticking and recovery time.

LCTp3 - 10 **Non-Contact LC Alignment by Using ZnO Films**

C.-C. Liu, C.-L. Lee, F.-J. Guo, S.-C. Jeng

Nat. Chiao Tung Univ., Taiwan

The process of dip-coating was applied to form the ZnO films by sol-gel method for LC alignment. The properties of homeotropically/homogenously aligned LC cells with ZnO alignment films were characterized and presented in this paper.

LCTp3 - 11 **Single-Layered Retardation Film with Negative Wavelength Dispersion Birefringence Using UV-Curable LC**

M. Yamamoto, K. Endou, Y. Kuwana, I. Nishiyama

DIC, Japan

We have investigated optical properties of retardation films with negative wavelength dispersion-birefringence (NWD) using UV-curable LC. We developed new liquid crystalline monomers suitable to a coating and optimized them to improve optical properties, solubility and durability of the retardation film. Besides, we succeeded +A-plate, +C-plate and O-plate with NWD.

LCTp3 - 12 Optical Performance of Twisted Nematic VS Twist Angle

B. Li, Z. Li, J. Jiang

InfoVision Optoelect., China

We have studied the optical performance of twist nematic display depends on different twist angle. The simulation results indicated that the twist angle strongly influence the gamma and center contrast ratio. Our actual measurement results agreed with the tendency of the simulation.

LCTp3 - 13 Method to Fundamentally Improve Edge Mura for Large LCD

Y. Xu, S. Zhang, X. Huang

InfoVision Optoelect., China

We analyzed the root cause and proposed a method to improve edge mura. Final the results testified that the liquidity of the photo resist and long distance between sealant and active area made the photo resist bad uniformity. Add the area of dummy RGB can improve the edge mura effectively.

LCTp3 - 14L Switching Mechanism of a VA-IPS LCD: Effect of 2D Confinement by Virtual Walls

J.-H. Woo, T.-H. Choi, Y. Choi, T.-H. Yoon

Pusan Nat. Univ., Korea

In a VA-IPS cell, LC molecules are two-dimensionally confined by virtual walls as well as the two substrates. Thus, the response time can be reduced simply by decreasing the pitch of the interdigitated electrodes as a result of enhanced anchoring provided by the virtual walls.

LCTp3 - 15L Optical Performance of Guest-Host-Type In-Cell Polarizer Using Polarization-Converting Film

H. Niwa, T. Itsukaichi, Y. Iimura

Tokyo Univ. of A&T, Japan

In order to improving low contrast in a gest-host-type in-cell polarizer, a polarization-converting film consisting of a $\lambda/4$ and a cholesteric layers have been added beneath the polarizer. About 100 times improvement in the contrast ratio is expected from simulated results, which is also confirmed semiquantitatively by experimental results.

----- Break -----

16:50 - 18:20 **409**

AMD4/LCT4: Super-High-Resolution LCDs
Special Topics of Interest on Oxide-Semiconductor TFT

Chair: M. Inoue, Huawei Techs., Japan
Co-Chair: M. Inoue, Apple, Japan

AMD4/LCT4 - 1: 16:50 ***Invited*** **510-ppi 8K4K LTPS-TFT LCD with 30 to 120 Hz Frame-Rate Driving**

H. Miki, D. Suzuki, M. Okita, K. Mochizuki, H. Hayashi, T. Nakamura, H. Kato, A. Oyama, Y. Matsui, K. Nishiyama, H. Kimura

Japan Display, Japan

On the basis of the low temperature polysilicon (LTPS) technology, a 510-ppi 8K4K LCD driven at frequency from 30 to 120 Hz has been developed, which provides a higher image quality without the uncomfortable feeling of crosstalk and the flicker caused by frequencies in practical use.

AMD4/LCT4 - 2: 17:15 ***Invited*** **Development of 27-in. 8K4K LCD Prototype Using an IGZO TFT Backplane**

S. Yamada, F. Shimoshikiryoh, Y. Itoh, A. Ban

Sharp, Japan

We have successfully developed 27-in. 8K4K Liquid Crystal Display by utilizing BCE IGZO (Back Channel Etched InGaZnO) transistor. BCE IGZO-TFT realizes low resistance wiring material because of its low process temperature. Because of this, we can enlarge the screen size to desktop monitor class, while keeping smartphone-class fine resolution.

Also presented in Innovative Demonstration Session (see p. 262)

AMD4/LCT4 - 3 17:40 **Development of Cu BCE-Structure IGZO TFT for High ppi 32-in. 8K4K LCD**

S.-M. Ge, S. Li, S.-J. Chen, X.-Y. Kong, W. Shi, H.-J. Zhang, Y.-H. Meng, L.-Q. Shi, X. Liu, M. Wang, C. K. Zhang, C.-Y. Chiu, C.-Y. Lee

Shenzhen China Star Optoelect. Tech., China

The electrical characteristics of the BCE-structure IGZO TFT using copper as the gate and source/drain metal were studied. Through modifying the GI layer and annealing temperature, Cu BCE-structure IGZO TFT exhibited good subthreshold swing, threshold voltage and BTS reliability. Finally, a high performance 32-in. 8K4K IGZO LCD was demonstrated.

AMD4/ LCT4 - 4 18:00 **Fast-Response Fringe Field Switching LCD for Virtual Reality**

L. Fang, Y. Chen, Y. Liang, L. Wu, P. Shen, C. Tseng
XiaMen Tianma Microelect., China

We have achieved a fast response fringe field switching LCD of 847 ppi, which could be a competitive choice for virtual display. The maximal gray to gray response time was decreased dramatically from 19 ms to 7 ms. An advanced color filter was also proposed to optimize the white coordinates.

Author Interviews
18:20 – 18:50, Multipurpose Hall

Friday, December 9

9:00 - 10:20 **412**

LCT5: Novel LC Applications

Chair: M. Ozaki, Osaka Univ., Japan
Co-Chair: H. Okada, Univ. of Toyama, Japan

LCT5 - 1: 9:00 ***Invited*** **Power Generating LCD for Advanced Energy-Harvesting Applications**

Y. H. Huh, H. G. Jeon, I.-G. Bae, B. Park
Kwangwoon Univ., Korea

We report power generating reflective-type LCDs, composed of a twisted nematic LC cell and a polymer solar cell, consisted of a low-band-gap photovoltaic layer. To improve the visibility, we used a giant birefringent optical film. The contrast ratio from the Solar-LCD was observed to be significantly improved.

LCT5 - 2 9:25 **Light Shutter Based on Electro-Hydrodynamic Effect in LCs Doped with TBAB**

J.-W. Huh, J.-H. Kim, S.-M. Ji, B.-H. Yu, T.-H. Yoon
Pusan Nat. Univ., Korea

We propose a LC light shutter based on the electro-hydrodynamic effect in LCs doped with tetra-n-butylammonium bromide (TBAB). It can simultaneously control absorption by dye and scattering by the electro-hydrodynamic effect. In the opaque state, it shows an excellent opaque state than other types of light shutters.

LCT5 - 3 9:45 **Tunable Optical LC Deflector and Lens with Fresnel Structure**

G. Shibuya, S. Yamano, H. Yoshida, M. Ozaki
Osaka Univ., Japan

A new type of tunable Fresnel deflector and lens composed of LC was developed. Novel structure of thin films induces a saw-tooth distribution of refractive index in the LC material. Maximum tilt angle of ±1.3 deg. and lens power of ±4.0 diopter were achieved with the tunable LC devices.

LCT5 - 4L **Fast Flexoelectro-Optic Device Based on Polymer-**
10:05 **Stabilized Cholesteric ULH**

A. Varanytsia, L-C. Chien

Kent State Univ., USA

We demonstrate a strong flexoelectro-optic behavior of LC dimer CB7CB. Flexoelectric properties of CB7CB experimentally characterized by measured angle of an in-plane rotation of helical axis (HA) in polymer stabilized uniform lying helix (PSULH) cholesteric LC. The 45˚ rotation of HA providing full intensity modulation of transmitted through a pair of crossed polarizers light, is achieved with 4.3 V/μm with a sub-millisecond electro-optic switching time. The PSULH is suitable for a electro-optic applications of the flexoelectric effect in LC materials.

----- Break -----

10:40 - 12:00 **412**

LCT6: Quality of LCDs

Chair: B. Park, Kwangwoon Univ., Korea
Co-Chair: S. Shibahara, Sony Visual Products, Japan

LCT6 - 1 **Method to Evaluate and Improve Photodegradation**
10:40 **By-products of Photo Alignment Material**

Y. Zhao, Y. Song, C.-C. Hsieh, W. Ren, C. Yuan, C.-Y. Chiu, C.-Y. Lee

Shenzhen China Star Optoelect. Tech., China

A new photo alignment material for in-plane switching has been presented. 254 nm PI (Polyimide) material is decomposition type. Thus before UV exposure, PI chains in the film are randomly oriented. PI chains parallel to the exposed UV polarization are selectively decomposed by UV exposure, and the corresponding photoproducts become randomly relocated in PI film. By-products of the photodegradation can produce ions and initiate the image sticking effect and flicker. So we should develop a method to remove by-products of the photo-degradation and know how much are remained.

LCT6 - 2
11:00

On the Black Level Luminance for Oblique Viewing Angle Due to Diffractions in LCDs

A. Yuuki, T. Tsuchiya, K. Yonemura, Y. Niwano

Mitsubishi Elec., Japan

We have calculated black level luminance of in-plane-switching-mode LCDs for oblique viewing angle considering the diffraction by LC panels. Results show that the influence of the diffraction significantly increases in the case of panels with pixels smaller than 0.1 mm and with the birefringence retardation film on its rear side.

LCT6 - 3
11:20

Method for Eliminating Color Filter Related Mura of Near-Eye Display

B. Zheng, Y. Lin, Y. Yang, L. Wu, B. Shen, C. Tseng

XiaMen Tianma Microelect., China

In high ppi color filter design, a regular dark spot Mura in TFT-LCD is observed, related to the black matrix area difference (ΔArea) at main and sub-photo spacer location. This study showed that MPS should be located between red and blue color pixel, and ΔArea should be less than 256 μm^2 .

LCT6 - 4
11:40

Correlation Analysis of Flicker Shift Phenomenon and Ion Accumulation Mechanism in FFS Mode LCD Panel

K.-T. Huang, Y.-W. Hung, R.-X. Fang, Y.-T. Chao, T. Lee, C. Lee, S.-C. Lin, C. Kuo, T.-S. Jen

HannStar Display, Taiwan

Flicker shift is a serious problem in FFS mode LCD, In this paper, we analysis the mechanism of Flicker shift phenomenon. Different PI material was compared and the flexoelectric effect, ion accumulation phenomenon, and optimum Vcom setting of FFS LCD panel was discussed.

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 14:50 **412**

LCT7: High Performance LC Mode

Chair: T. Ishinabe, Tohoku Univ., Japan
Co-Chair: F. Araoka, RIKEN, Japan

LCT7 - 1: 13:30 ***Invited*** **Photo-Alignment and N-FFS LCD Technologies for Low Refresh Rate Driving**

I. Miyake, H. Asagi, M. Shimizu, K. Matsumoto, Y. Nishihara, Y. Hashimoto, T. Matsushita, S. Shimada, Y. Ito

Sharp, Japan

We achieved a super low power consuming LCD panel with an n-FFS mode driven by IGZO-TFTs and report a new photo-alignment process and materials for n-FFS, which reduce flicker in low refresh rate driving. These technologies have already been applied to the generation eight factory.

LCT7 - 2 13:55 **Fast In-Plane Switching of LCs Aided by Two Dimensional Confinement with Virtual Walls**

T.-H. Choi, S.-W. Oh, Y.-J. Park, Y. Choi, T.-H. Yoon

Pusan Nat. Univ., Korea

When an in-plane electric field is applied to a zero-rubbing-angle cell, virtual walls are built. LC molecules in a zero-rubbing-angle cell are confined not only by two substrates but also by these virtual walls, and thereby the switching speed can be increased by several fold in an in-plane switching cell.

LCT7 - 3 14:15 **Polymer-Stabilized Blue Phase LCD with Enhancement Double Sided Protrusion Electrodes**

Z.-F. Su, T.-C. Chung, C.-T. Liao, C.-M. Yu, Y.-B. Qiao

InfoVision Optoelect., China

A PSBP-LCD with E-DSP electrodes is proposed. Based on Kerr effect, more isotropic-to-anisotropic transition is induced than using the IPS and DSP electrodes. At the same parameters, the transmittance of PSBP-LCD with the E-DSP electrodes is 36% and 12.6% higher than IPS and DSP electrodes at 29 V, respectively.

LCT7 - 4L 14:35 **Color Breakup Reduction Using Global Edge-FSC Method**

F.-C. Lin, K.-T. Teng, Y.-P. Huang, H.-P. D. Shieh
Nat. Chiao Tung Univ., Taiwan

This paper considers edge-dependent information of an input image to effectively suppress color breakup for a field-sequential-color (FSC) display. Only using a global backlight controlling, the proposed edge-FSC method can much reduce the computational complexity and make an FSC display more promising as next generation eco-displays.

----- Break -----

Author Interviews
16:30 – 17:10, Multipurpose Hall

Panel Discussion on Display Technologies for Sports in Japanese

Organized by International Display Workshops
General Incorporated Association
Tuesday, Dec. 6, 2016

16:45-18:00

Room 501 (5F)

Fukuoka International Congress Center
Detailed information will be announced at
http://sport.idw.or.jp/

Workshop on Active Matrix Displays

Wednesday, December 7

13:00 - 14:25 **409**

AMD1: Oxide TFT: High-Stability TFTs
Special Topics of Interest on Oxide-Semiconductor TFT

Chair: J. Jang, Kyung Hee Univ., Korea
Co-Chair: H. Kumomi, Tokyo Tech, Japan

AMD1 - 1: 13:00 ***Invited*** **Importance of Oxygen- and Hydrogen-Related Defects to Develop New Amorphous Oxide Semiconductor Materials**

T. Kamiya, J. Kim, K. Ide, H. Kumomi, H. Hosono

Tokyo Tech, Japan

First, defects and impurity in a-IGZO are reviewed focusing on oxygen- and hydrogen-related defects, which are strongly correlated and competing. We will also show that new materials are created by utilizing the above knowledge about defects in AOSs.

AMD1 - 2 13:25 **Electrical Characteristics of Si-Doped IGZO TFTs Fabricated Using Ion Implantation**

T. Goto, F. Imaizumi, S. Sugawa

Tohoku Univ., Japan

Si was doped to a-IGZO films by ion implantation. Hall effect measurement shows that electron carrier density increased by Si doping. For the Si-implanted IGZO TFT, gate bias stability against negative bias temperature illumination stress was improved, while the mobility was almost the same level as that without Si doping.

AMD1 - 3 13:45 **High Reliability Fluorine-Containing Polysilsesquioxane Passivation Layer for a-InGaZnO Thin-Film Transistors**

N. Yoshida[,**], J. P. Bermundo[**], Y. Ishikawa[**], T. Nonaka[*], K. Taniguchi[*], Y. Uraoka[**]*

[*]Merck Performance Materials Manufacturing G.K., Japan
[**]NAIST, Japan

We investigated the effect of fluorine-containing polysilsesquioxane passivation layer fabricated by solution process for InGaZnO (a-IGZO) thin-film transistors. This passivation layer greatly improves the stability of a-IGZO device even after being subjected to bias stress. Here, we demonstrate the photolithography properties, electrical properties and the state of the a-IGZO layer.

AMD1 - 4 14:05 **Achievement of High-Performance and Environmentally Stable TFTs by Introducing Hybrid-Phase Microstructure into InSnZnO Channels**

S. Deng[*], R. Chen[,**], G. Li[*], Z. Xia[*], K. Wang[***], M. Zhang[*], W. Zhou[*], M. Wong[*], H.-S. Kwok[*]*

[*]Hong Kong Univ. of S&T, Hong Kong
[**]South China Univ. of Tech., China
[***]Jinan Univ., China

We proposed the hybrid-phase microstructural InSnZnO thin films, where a number of nanocrystals were embedded in an amorphous matrix. The corresponding bottom- and top-gate TFTs with remarkable and uniform electrical characteristics were successfully fabricated. Additionally, such devices were air-stable owing to in situ passivation of hybrid-phase microstructure for InSnZnO channels.

----- Break -----

14:40 - 16:15 **409**

AMD2: Oxide TFT: High-Performance TFTs
Special Topics of Interest on Oxide-Semiconductor TFT

Chair: T. Kamiya, Tokyo Tech, Japan
Co-Chair: H. Hamada, Kinki Univ., Japan

AMD2 - 1: 14:40 ***Invited*** **High Yield, High Drain Current Oxide TFTs for Display Manufacturing**

S. Lee, J. G. Um, D. Geng, J. Jang
Kyung Hee Univ., Korea

We report the high drain current amorphous indium-gallium-zinc-oxide (a-IGZO) thin-film transistors (TFTs) with excellent performance uniformity by using bulk accumulation (BA) mode. The high performance BA- TFTs could be applied to high yield and fast response integrated gate drivers for AMOLED and AMLCD.

AMD2 - 2: 15:05 ***Invited*** **Top Gate High Mobility Oxide TFT with Double Layered Gate Insulator**

Y. Kim, K. Park, J.-B. Ko, G. Mun, S.-H. K. Park
KAIST, Korea

We report top gate structured high mobility oxide TFT with high stability under the bias and current stress by using double layered gate insulator. Alumina gate insulator deposited by ALD plays key role both as the H barrier and in the formation of defects less interface with active layer.

AMD2 - 3: 15:30 ***Invited*** **Boosting the Field-Effect Mobility of Metal Oxide Thin Film Transistor by a Microstructure Modification**

J. K. Jeong, Y. Shin, S. T. Kim, I. J. Chung

Hanyang Univ., Korea

The metal reaction method is proposed to improve the mobility of IZO and IGZO TFTs. The high mobility exceeding 49.0 cm^2/Vs can be achievable in the resulting IZO and IGZO TFTs, which can be attributed to the affirmative effect of loosely bonded oxygen scavenge and M-O lattice ordering, respectively.

AMD2 - 4 15:55 **Double-Channel Oxide Semiconductor Vertical TFTs with Mo Source/Drain Layer**

*C.-S. Hwang, J. H. Choi, S. H. Cho, J.-H. Yang, J.-E. Pi, O.-S. Kwon, E.-S. Park, H.-O. Kim, S.-H. K. Park**

ETRI, Korea
**KAIST, Korea*

Vertical channel oxide semiconductor TFT was fabricated with convention metal source/drain layer, sputtered active layer and PECVD deposited gate insulator. Double-channel active structure was adopted for preventing non-ohmic contact resistance between active layer and metal source/drain layer. This structure is desirable for applying VTFTs to display panel with large area.

----- Break -----

16:20 - 17:50 **409**

AMD3: High-Resolution Displays
Special Topics of Interest on Oxide-Semiconductor TFT

Chair: S.-H. K. Park, KAIST, Korea
Co-Chair: K. Takatori, NLT Techs., Japan

AMD3 - 1: 16:20 ***Invited*** **Advanced OLED Display Technologies for Large-Size UHD TVs**

H. J. Shin, S. Takasugi, H. D. Choi, C. K. Ha, J.-M. Kim, H. S. Kim, C. H. Oh

LG Display, Korea

Advanced OLED display technologies have been developed for large-size UHD OLED TVs. Self-aligned coplanar TFT is employed as panel backplane. The maximum difference of threshold voltages of a-IGZO TFTs on Gen. 8.5 glass is approximately 0.57 V. By applying novel compensation methods and a high dynamic range technology, we can enhance image quality of the OLED display.

AMD3 - 2: 16:45 ***Invited*** **LCD with Ultra High Resolution and Super Fast Response Giving Super Reality to VR Application**

N. Ueda, K. Okada, S. Uchida, K. Yamamoto, K. Yamamoto, H. Yoshida

Sharp, Japan

We will discuss our approach for the emerging Virtual Reality HMDs. We developed a 1008 ppi LCD with 2k2k resolution, realizing ultra-high definition and fast response at the same time. Advanced Oxide Pixel technology, super fast response LC technology, and advanced backlight for motion blur rejection have been adopted successfully.
Also presented in Innovative Demonstration Session (see p. 262)

AMD3 - 3 17:10 **12.5-in. Real RGB Pixel High 4K Resolution a-Si TFT- LCD with Advanced Design to Reduce the Loss of High-Frequency Data Signal**

S.-Y. Wu, C.-C. Chang, H.-H. Chen, H.-M. Su, W.-Z. Zeng

Chunghwa Picture Tubes, Taiwan

CPT research the parameters about printed circuit board (PCB) layer structure or metal trace etc. in layout design of eDP and P2P interface for high-resolution signal transmission, and finally we reached to decrease the loss of signal and having better signal integrity.

AMD3 - 4 17:30 **19.5-in. 4K LCD Fabricated with Novel LTPS Technology at Gen10 Line**

N. Nodera, S. Ishida, T. Matsumoto, K. Kobayashi

Sakai Display Prods., Japan

We developed Partial Laser Anneal Silicon (PLAS) TFT of novel LTPS technology for large substrate, which had the mobility of 28.1 cm^2/Vs in bottom-gate structure. A 19.5-in. prototype 4K LCD has been fabricated at Gen10 line. Photo-stability of PLAS will be suitable to OLED backplane, HDR TV, and outdoor IDP.

Author Interviews
17:50 – 18:20, Multipurpose Hall

Thursday, December 8

14:10 - 16:40 **Multipurpose Hall**

***Poster* AMDp1: Oxide TFTs**

Special Topics of Interest on Oxide-Semiconductor TFT

AMDp1 - 1 **AC Stress Stability Study with Different Channel Length in BCE IGZO TFT for 32-in. 8K4K GOA LCD**

L.-Q. Shi, S.-J. Chen, Y.-F. Chou, L.-M. Zeng, T.-H. Wang, W.-Y. Li, X.-W. Lv, R.-L. Chen, C.-W. Liao, M. Zeng, S.-M. Ge, M. Wang, C. K. Zhang, C.-Y. Chiu, X. Liu, C.-Y. Lee

Shenzhen China Star Optoelect. Tech., China

AC stress stability study with different channel length in BCE IGZO TFT was investigated. It showed the threshold voltage shift is not sensitive to the AC frequency and channel length compared with the duty ratio. Based on the study, 32-in. 8K4K LCD was demonstrated by using GOA technology.

AMDp1 - 2 **Bias and Temperature Reliability of Amorphous Indium Tin Zinc Oxide Thin Film Transistor on SiO_2, SiN_x Gate Dielectric**

S. Kim, B. Choi

Sungkyunkwan Univ., Korea

In this study, we fabricated ITZO thin film transistor using oxide semiconductor that is mixed metal oxide- indium (In), tin (Sn), zinc (Zn). We investigated gate bias stress and temperature reliability of ITZO by comparison with gate dielectric SiO_2 and SiN_x respectively.

AMDp1 - 3 **Low-Power Gate Driver Circuit Using Depletion Mode a-IGZO TFTs**

J.-H. Kim, S. Wang, J. Oh, K. Park[*]*, Y.-S. Kim*

Sungkyunkwan Univ., Korea
[*]*Konkuk Univ., Korea*

This paper proposes a new gate driver using depletion mode a-IGZO TFTs. First, the proposed circuit is possible to decrease discharging of Q node due to leakage current. Second, the driving TFT V_{gs} of the inverter has zero less using two low supplies.

AMDp1 - 4 **Effects of Activation Annealing on the Reliability of Indium-Gallium-Zinc Oxide Thin-Film Transistors with Thermal Induced Source/Drain Regions**

J. Li, L. Lu, Z. Feng, H. S. Kwok, M. Wong

Hong Kong Univ. of S&T, Hong Kong

With respective gas-permeable and impermeable covers in the channel and source/drain regions, indium-gallium-zinc oxide thin-film transistors with thermally-induced homojunctions exhibit superior characteristics and small device footprint. Presently reported is the dependence of the reliability of the transistors on the junction-activation heat-treatment process.

AMDp1 - 5 **Low Subthreshold Swing InGaZnO Thin Film Transistors with UV-Ozone-Treated $BaTiO_3$ Dielectric Layers**

H.-Y. Liou, A.-H. Cheng, S.-Y. Chu

Nat. Cheng Kung Univ., Taiwan

We developed a method to improve the electrical performance of amorphous $BaTiO_3$ thin film by UV-ozone treatment. The treatment promoted densification of the dielectric layer by decreasing oxygen-vacancy and increasing metal–oxide bonds. The InGaZnO-TFTs exhibited high on/off ratio of 1.46×10^7 and the low sub-threshold swing of 0.069 V/dec.

AMDp1 - 6 **High Mobility Thin Film Transistors Formed by Metal-Induced Crystallization of Amorphous Zinc Tin Oxide Semiconductors**

S. T. Kim, K. J. Lee, N. On, H. J. Seul, J. K. Jeong

Hanyang Univ., Korea

Transition tantalum induced crystallization of amorphous zinc tin oxide (a-ZTO) was observed at low temperature annealing of 300°C. A significant improvement in the field-effect mobility (up to ~33.5 cm^2/Vs) was achieved for crystallized ZTO TFTs.

AMDp1 - 7 **Structure Engineering with ZrO_2 Thin Film for Highly Conducting Electrospun In_2O_3 Nanowire Field Effect Transistors**

H. Park, I. Lee, Y. H. Kim, B.-S. Bae

KAIST, Korea

In O_2 atmosphere, 600°C-annealed electrospun In_2O_3 nanowire field-effect transistor (NWFET) exhibits conductive behavior with large off-current (I_{off}) and high subthreshold slope (S.S.). Solution-processed ZrO_2 thin film is utilized to control and optimize conducting In_2O_3 NWFET and underlying mechanism is studied.

AMDp1 - 8 **New p-Type Thin-Film Transistor**

K. Lee, S. Kim, H. Seul, N. On, J. Jeong

Hanyang Univ., Korea

In recent developments, p-type oxide still lag in performance behind their n-type counterparts. In this paper, we demonstrated a new p-type thin-film transistor. XON has high hall mobility more than 200 cm^2/Vs. This study examined electrical properties, electronic structures, and chemical compositions of XON.

AMDp1 - 9 **De-Mux Circuit on the FFS-Mode LCD with a-IGZO TFTs**

Y.-K. Chen, C.-C. Tsai, E.-C. Liu, K.-Y. Lai, Y.-H. Chen, S.-C. Chiang, F.-C. Lu, Y.-J. Lu, W.-K. Tsao, C.-H. Huang, Y.-Y. Huang

Chunghwa Picture Tubes, Taiwan

We successfully developed the 5.5-in. narrow bezel FFS-mode LCD with the ESL type a-IGZO TFTs and the de-mux circuits. The de-mux circuits can narrow the bezel and reduce the number of IC chips on the display. The I_{on}/I_{off} of the ESL type TFTs are more than 10^9.

AMDp1 - 10 **New AMOLED Pixel Circuit with Concise 3-T Structure for Normally-off and Normally-on Amorphous IGZO TFTs**

P.-S. Chen, C.-E. Lee, C.-L. Lin

Nat. Cheng Kung Univ., Taiwan

A pixel circuit with V_{TH} compensation for AMOLED displays is proposed. By source-follower structure, the proposed circuit can detect V_{TH} shift of normally-off/on TFTs. Simulations show that the proposed circuit successfully senses V_{TH} shift of driving TFT during programming, and produces uniform current in range of 60 to 500 nA.

AMDp1 - 11 **Inkjet-Printed InGaZnO Thin Film Transistor on Flexible Substrate**

H. Hu, H. Huang, F. Li, T. Guo

Fuzhou Univ., China

Uniform IGZO films were inkjet-printed as active layer of TFT on a polyimide substrate. Laser spike annealing was conducted to improve the device performance.

AMDp1 - 12 **Investigation of Annealing Temperature and Atmosphere Effect on Solution Process ZTO Transistors with Different Metal Composite Doping**

N.-X. He, W.-X. Cheng, W.-A. Cheng, S.-J. Cheng, Y.-W. Wang

Nat. Chagnhua Univ. of Education, Taiwan

We investigated the characteristics transition of sol-gel processed Zinc-Tin-Oxide transistors with different metal dopant. The annealing conditions conducted different temperature and atmospheres. The result showed that moderate metal dopant could lower down the process temperature and increase its stability in ambient air. The highest mobility ~2.4 cm^2/Vs was achieved.

AMDp1 - 13L Characteristic Analysis of IGZO Thin Films Using Planar and Stacked Devices - Evaluation of Electrical Resistivity and Current Density -

M. Kimura[,**], Y. Koga[*], T. Matsuda[*], Y. Nakashima[**]*

[*]Ryukoku Univ., Japan
[**]NAIST, Japan

Electrical characteristics of IGZO Thin Films are analyzed using planar and stacked devices. The contact resistance is high but doesn't influence on the transistor characteristics. The current density in the planar device is higher than that in the stacked device owing to the high contact resistance and large electrode area.

AMDp1 - 14L Thermal Analysis and Device Simulation of Heat Suppressed Structure for Oxide Thin-Film Transistor

K. Kise, M. N. Fujii, J. P. Bermundo, Y. Ishikawa, Y. Uraoka

NAIST, Japan

Self-heating degradation in TAOS TFTs generated by driving voltage is a serious problem for development of highly reliable flexible displays. In this work, we suggested heat suppressed TFT structure in order to improve the reliability of TAOS TFTs by using device simulator and thermal analysis system.

AMDp1 - 15L Oxide TFTs Characteristic Optimize for Gate Driver on Array

S. J. Choi, Y. S. Song, C. W. Jeong, W. S. Li, F. Z. Zhang, G. C. Yuan, J. I. Ryu

BOE Tech. Group, China

We judged that, to adopt Oxide TFT on gate driver on array, the positive (+) position of initial V_{th} is advantageous for the reliability of GOA. Therefore, in this paper, we had studied which process conditions affect the initial V_{th} of Oxide TFT. As a result, the amount of O_2 in IGZO, N_2O treatment on IGZO film and ESL deposition condition are those.

AMDp1 - 16L Aluminum Doping Effect in Solution-Processed Indium Oxide TFTs

S.-H. Lee, T. Kim, C. Avis, J. Jang

Kyung Hee Univ., Korea

Aluminum as a carrier suppressor for solution-processed In_2O_3 TFTs was investigated. With increasing Al concentration from 0 to 5, and 10 % in In_2O_3 TFTs, the linear mobility decreased from 10.88 to 3.74, and 1.65 cm^2/V s, and the threshold voltage increased from -3.35 to -0.5, and 0.85 V.

AMDp1 - 17L Improvement of Device Performance of Solution Processed IZTO TFT by Ar/O_2 Plasma Treatment

J. Lee, T. Kim, S.-H. Lee, C. Avis, J. Jang

Kyung Hee Univ., Korea

We investigated the effect of Ar/O_2 plasma treatment on the performance of solution processed indium-zinc-tin-oxide (IZTO) thin-film transistors (TFTs). The hysteresis voltage of the IZTO TFT dramatically decreased from -2.55 to -0.3 V by exposing IZTO surface to Ar/O_2 plasma. The linear mobility was improved from 48.89 to 129.84 cm^2/Vs.

AMDp1 - 18L Influence of N_2O Back-Channel Treatment on Copper S/D Metal BCE IGZO TFTs

C.-Y. Hou, Y.-T. Chiang, C.-J. Li, S.-F. Wu, S.-C. Lee, W.-C. Tsai

AU Optronics, Taiwan

Copper BCE_structure IGZO TFT using N_2O plasma treatment to passivate back-channel, we have modified the treatment process to prevent the metal from oxidation and improve the PV/metal interface. The PV/metal interface and device characteristics of Cu BCE IGZO TFT can be improved by modifying the N_2O back-channel treatment process.

AMDp1 - 19L Effects of Magnetic Field Shielded Sputtering Process on the Properties of IGZO TFT

K. D. Kim, D. H. Lee, S. G. Kim, M. H. Hong

Korea Univ., Korea

In this study, we will introduce our novel technology named as Magnetic Field Shielded Sputtering (MFSS) process to prevent the negative oxygen ions (NOIs) bombardment effects and present how much to be improved the properties of InGaZnO thin films transistor (IGZO TFT) by this new deposition method.

IDW/AD '16 Tutorial in Japanese

Organized by SID Japan Chapter
Tuesday, Dec. 6, 2016
12:20-16:30
Room 501
Fukuoka International Congress Center
Detailed information will be announced at
http://www.sid-japan.org/

14:10 - 16:40 **Multipurpose Hall**

Poster AMDp2: Active-Matrix Devices

AMDp2 - 1 **Organic Thin-Film Transistors Integrated Gate Driver Circuits for Low Power Consumption in Panel Application**

G.-T. Zheng, P.-T. Liu[*], I.-H. Lu[*], L. Quan[**], S.-I. Lin[**], Y.-C. Chang[**], C.-Y. Liu[**], A. Facchetti[**]

Nat. Tsing Hua Univ., Taiwan
[*]Nat. Chiao Tung Univ., Taiwan
[**]Polyera Taiwan, Taiwan

This paper presents integrated organic thin-film transistors (OTFT) gate driver circuit which is driven by DC voltage to lower the power consumption. Moreover, basic parasitic gate driver is used to couple the pre-charging node to stabilize the output performance.

AMDp2 - 2 **Robust Driving Method for Integrated Shift Register with Self-Total Resetting**

G. Shang[*], M. Han[*], S. Han[*], H. Zheng[*], X. Yao[*], Y. Zhang[**], L. Yuan[*], Z. Wang[*], Y. Im[*], J. Lv[*], Y. Huang[*], H. Qiu[,**], J. Jun[*], X. Dong[*]*

[*]BOE Tech. Group, China
[**]Chongqing BOE Optoelect., China

This paper proposes a Self-Total Reset driving method. It can prevent flickering phenomenon, which can be observed when missing shift register drive clocks in 1-frame period during system startup or display source switching. To solve this problem, an integrated circuit was simulated and successfully applied to 49-inch UHD TFT-LCD display.

AMDp2 - 3 **Amorphous Silicon 2-in. High Resolution Smart Watch with GIP**

Y.-H. Tai, W.-L. Sung, P.-S. Cheng, W.-C. Wang, C.-L. Kuo, Y.-H. Chang, W.-C. Wang

Chunghwa Picture Tubes, Taiwan

CPT demonstrated the wearable technology about 2-in. full-circle display by using a-Si (Amorphous Silicon). High resolution (480xRGBx480, 240PPI) and GIP circuits design is the characteristic in this display. The results of optical verification and reliability test show this 2-in. full-circle display has good performance.

AMDp2 - 4 **New 4T1C Pixel Compensation Circuit for AMOLED Display**

H. Zhu, S. Hu, X. Gao, X. Huang

Kunshan New Flat Panel Display Tech. Ctr., China

A new 4T1C active matrix organic light emitting diode (AMOLED) pixel circuit is proposed for improving the image quality of the display. Simulation results showed that the current variation through OLED decreased to 9% comparing with the conventional pixel structure when the threshold voltage of the driving TFT varied from –0.25 V to 0.25 V.

AMDp2 - 5 **LTPS Pixel Circuit for AMOLED Display**

J. Zhang, H. Zhu, S. Hu, N. Yang, Y. Song, T. Zhang, X. Gao, X. Huang

Kunshan New Flat Panel Display Tech. Ctr., China

A LTPS pixel circuit is developed, which can compensate both non-uniformity of Driving TFT threshold voltage and IR drop of power line. Compared with 2T1C circuit, it is found that the circuit has a better compensation for non-uniformity of threshold voltage and IR drop of power line through SPICE simulation.

AMDp2 - 6 **New 3T2C LTPS Pixel Circuit Compensate for Threshold Voltage Variation for AMOLED Displays**

M.-Y. Deng, Y.-T. Liu, C.-M. Lu, C.-L. Lin

Nat. Cheng Kung Univ., Taiwan

This work proposes a new low-temperature polycrystalline silicon pixel circuit for active-matrix organic light-emitting diode displays. This circuit compensates for the threshold voltage variation of driving thin-film transistor and utilizes a fixed V_{SS} to increase the operation stability. The simulated current error rates are all below 3% among entire range.

AMDp2 - 7 **Effect of Hydrogen Annealing of Si TFTs with Metal Source/Drain Using BLDA**

T. Harada, F. Gakiya, T. Ashitomi, T. Okada, T. Noguchi, O. Nishikata[*]*, A. Ota*[*]*, K. Saito*[*]

Univ. of the Ryukyus, Japan
[*]*ULVAC, Japan*

n-type top-gate TFT was fabricated with low temperature process below 490°C using BLDA without adopting ion-implantation. In place of impurity doping, Ti was used for source-drain region. Hydrogen annealing after forming Al electrodes, drastic improvement of n-type TFT has been observed.

AMDp2 - 8 **Anomalous Threshold Voltage Variation in Low-Temperature Polycrystalline-Silicon Thin-Film Transistors under Self-Heating Stress**

L. F. Zhang, Y. J. Hsu, Y. C. Wu, P. Lu

Shenzhen China Star Optoelect. Tech., China

This letter investigates the degradation behavior under self-heating stress in low-temperature polycrystalline-silicon (LTPS) thin-film transistors (TFT). Negative threshold voltage shift was observed after self-heating stress. To understand the causes of this phenomenon in depth, device with the different thickness of gate insulator under self-heating stress is also inspected.

AMDp2 - 9 **New Cu-Alloy Cap Layer with Anti-Oxidation Property for Cu Interconnections**

Y. Shida, H. Goto, H. Okuno[*]*, M. Kanamaru*[*]

Kobe Steel, Japan
[*]*Kobelco Res. Inst., Japan*

We have developed the new Cu-alloy film used for the cap layer in Cu interconnections. The oxidation of the Cu interconnections during CVD process for SiO_2 deposition was successfully suppressed. Moreover, it's thermally stable up to 500 °C and able to be patterned by a single step of wet etching.

AMDp2 - 10 **Withdrawn**

AMDp2 - 11L **Ultra-Low Temperature Si TFTs with Metal Source-Drain Using ELA for Flexible Sheet**

T. Harada, F. Gakiya, Y. Ishiki, T. Okada, T. Noguchi, K. Noda[*]*, A. Suwa*[*,**]*, H. Ikenoue*[**]

Univ. of the Ryukyus, Japan
[*]*GIGAPHOTON, Japan*
[**]*Kyusyu Univ., Japan*

n-type top-gate TFT was fabricated using ELA without adopting ion-implantation by adopting ultra-low temperature process below 200˚C. In place of impurity doping, Ti of metal was used for source-drain region. As a result of hydrogen annealing at 200˚C after forming Al electrodes, drastic improvement of n-type TFT has been realized.

AMDp2 - 12L **Dependences of Photo-Induced Current on Channel Dimensions in Thin-Film Phototransistors**

T. Tanaka, T. Kadonome, T. Fuchiya, S. Haruki, T. Matsuda, M. Kimura

Ryukoku Univ., Japan

Dependences of photo-induced current on channel dimensions in phototransistors are evaluated by experiments and simulations. The current is proportional to W, whereas it becomes maximum at a certain L for pin-type and increases as L decreases for n-type and p-type. These phenomena are analyzed by electric field and recombination rate.

AMDp2 - 13L **Effect of Low-Temperature Annealing of Sputtered SiO_2 for Gate Insulator in Poly-Si TFTs on Panel**

H. Tamashiro, K. Imura, T. Okada, T. Noguchi

Univ. of Ryukyus, Japan

Effective low-temperature Hydrogen annealing to sputtered SiO_2 film was studied. Hydrogen annealing after Al electrode forming is more effective. Towards PI substrate, TFT was annealed at low-temperature of 200°C, and satisfactory TFT characteristics was obtained. Since defects ware decreased in Si/SiO_2 and obtained S value was 0.3 V/dec.

----- Break -----

16:50 - 18:20 **409**

AMD4/LCT4: Super-High-Resolution LCDs
Special Topics of Interest on Oxide-Semiconductor TFT

Chair: M. Inoue, Huawei Techs., Japan
Co-Chair: M. Inoue, Apple, Japan

AMD4/ LCT4 - 1: 16:50 ***Invited*** **510-ppi 8K4K LTPS-TFT LCD with 30 to 120 Hz Frame-Rate Driving**

H. Miki, D. Suzuki, M. Okita, K. Mochizuki, H. Hayashi, T. Nakamura, H. Kato, A. Oyama, Y. Matsui, K. Nishiyama, H. Kimura

Japan Display, Japan

On the basis of the low temperature polysilicon (LTPS) technology, a 510-ppi 8K4K LCD driven at frequency from 30 to 120 Hz has been developed, which provides a higher image quality without the uncomfortable feeling of crosstalk and the flicker caused by frequencies in practical use.

AMD4/ LCT4 - 2: 17:15 ***Invited*** **Development of 27-in. 8K4K LCD Prototype Using an IGZO TFT Backplane**

S. Yamada, F. Shimoshikiryoh, Y. Itoh, A. Ban

Sharp, Japan

We have successfully developed 27-in. 8K4K Liquid Crystal Display by utilizing BCE IGZO (Back Channel Etched InGaZnO) transistor. BCE IGZO-TFT realizes low resistance wiring material because of its low process temperature. Because of this, we can enlarge the screen size to desktop monitor class, while keeping smartphone-class fine resolution.

Also presented in Innovative Demonstration Session (see p. 262)

AMD4/ LCT4 - 3 17:40 **Development of Cu BCE-Structure IGZO TFT for High ppi 32-in. 8K4K LCD**

S.-M. Ge, S. Li, S.-J. Chen, X.-Y. Kong, W. Shi, H.-J. Zhang, Y.-H. Meng, L.-Q. Shi, X. Liu, M. Wang, C. K. Zhang, C.-Y. Chiu, C.-Y. Lee

Shenzhen China Star Optoelect. Tech., China

The electrical characteristics of the BCE-structure IGZO TFT using copper as the gate and source/drain metal were studied. Through modifying the GI layer and annealing temperature, Cu BCE-structure IGZO TFT exhibited good subthreshold swing, threshold voltage and BTS reliability. Finally, a high performance 32-in. 8K4K IGZO LCD was demonstrated.

AMD4/ LCT4 - 4 18:00 **Fast-Response Fringe Field Switching LCD for Virtual Reality**

L. Fang, Y. Chen, Y. Liang, L. Wu, P. Shen, C. Tseng

XiaMen Tianma Microelect., China

We have achieved a fast response fringe field switching LCD of 847 ppi, which could be a competitive choice for virtual display. The maximal gray to gray response time was decreased dramatically from 19 ms to 7 ms. An advanced color filter was also proposed to optimize the white coordinates.

Author Interviews
18:20 – 18:50, Multipurpose Hall

Friday, December 9

9:00 - 10:25 **409**

AMD5: Organic TFTs

Chair: H. Klauk, Max Planck Inst. for Solid State Res., Germany
Co-Chair: H. Minemawari, AIST, Japan

AMD5 - 1: 9:00 ***Invited*** **Organic-Inorganic Perovskite Field-Effect Transistors**

T. Matsushima[,**], S. Hwang[*], A. S. D. Sandanayaka[*,**], C. Qin[*,**], S. Terakawa[*], T. Fujihara[***], M. Yahiro[***], C. Adachi[*,**,***]*

[*]Kyushu Univ., Japan
[**]JST, Japan
[***]Info. Techs. & Nano-techs., Japan

In field-effect transistors with an organic-inorganic perovskite semiconductor, we realized greatly improved hole mobilities of up to 15 $cm^2 V^{-1} s^{-1}$, the highest ever reported, by utilizing a top-contact top-gate structure with carrier injection layers and treating the substrate with a self-assembled monolayer before spin coating the perovskite.

AMD5 - 2: 9:25 ***Invited*** **Fundamental Technology for Organic Transistors and Their Application to Sensor Devices**

M. Kitamura

Kobe Univ., Japan

Fundamental technology for high-performance organic transistors is reviewed in the presentation. The technology contains threshold voltage control and surface-modified electrodes. The modification leads to the changes in work function and surface energy of electrodes. Also, the possibility of application of modified metals to vapor sensor is discussed.

AMD5 - 3 9:50 **Direct Photo-Patterning and High Mobility Materials for Flexible OTFTs for Advanced Processing**

D. Kaelblein, F. G. Brunetti, R. Pretot[*], P. Hayoz[*], M. Zhou, J. Brill, K. Exner[**]

BASF SE, Germany
[*]BASF Schweiz, Switzerland
[**]BASF New Business, Germany

Targeting flexible display backplanes and circuitry, BASF is developing high performance materials for Organic Thin Film Transistors (OTFTs). Here we present our development focusing on directly photo-patternable semiconductors and dielectrics, as well as new semiconductors for solution-processed transistors with mobilities of up to 4 cm^2/Vs.

AMD5 - 4L 10:10 **Ultra-High PPI and Fast Response TFT-LCDs for Head-Mounted Displays**

S.-H. Lu, C.-H. Li, S.-Y. Lin, C.-C. Su, M.-C. Hsien, H.-M. Hu, S.-H. Huang, Y.-T. Chen, S.-H. Lin, Y.-T. Li, S.-W. Jang, H.-C. Li, W.-H. Kuo, M.-H. Lee

AU Optronics, Taiwan

We demonstrated a head-mounted display using two 2.1-in. 1000PPI LTPS TFT-LCD. Good contrast ratio and fast response time were achieved. New pixel structure was also employed to increase Cst. In the near future other technologies such as higher frame rate driving and strobe backlight system will be also integrated.

----- Break -----

10:40 - 12:00 **409**

AMD6: Flexible Devices
Special Topics of Interest on Oxide-Semiconductor TFT

Chair: M. Kitamura, Kobe Univ., Japan
Co-Chair: Y. Fujisaki, NHK, Japan

AMD6 - 1: 10:40 ***Invited*** **Flexible TFT and Devices Manufacturing Using Advanced Printed Electronics Technology**

T. Kamata[,**], M. Yoshida[*], S. Uemura[*], K. Suemori[*], S. Nishi[**], Y. Mishima[**]*

[*]AIST, Japan
[**]JAPERA, Japan

High resolution flexible large-area sheet sensor and display with TFT backplane were investigated. The flexible devices were prepared by all-print process. Advanced flexible alignment technology and stretchable wiring technology were developed to improve the flexible device performance.

AMD6 - 2: 11:05 ***Invited*** **Megahertz Organic Thin-Film Transistors for Flexible Active-Matrix Displays**

U. Zschieschang, U. Kraft, R. Rödel, H. Klauk

Max Planck Inst. for Solid State Res., Germany

A process for the fabrication of organic thin-film transistors (TFTs) with channel lengths as short as 0.5 µm on flexible plastic substrates has been developed. The TFTs are fabricated in the bottom-gate, top-contact (inverted staggered) architecture and employ a thin, low-temperature-processed gate dielectric and vacuum-deposited small-molecule semiconductors.

AMD6 - 3L 11:30 **Highly Reliable Solution Processed Oxide TFT with Doped Semiconductor, High-k Gate Insulator, and Oxide Passivation Layers Patterned by Standard Photolithography Process**

Y. Hirano, M. Kusayanagi, S. Arae, R. Saotome, Y. Sone, S. Matsumoto, Y. Nakamura, Y. Ando, N. Ueda, K. Yamada

Ricoh, Japan

We have developed solution-processed oxide TFT. Doped-oxide semiconductor, high-k oxide gate insulator, and two oxide passivation layers were formed by spin-coating and standard photolithography process using original inks. The mobility reached over 10 cm^2/Vs. Reliability was remarkable with ΔV_{th} less than 0.2 V after 10^5 seconds under bias-temperature stress.

AMD6 - 4L 11:45 **Analysis of High Mobility Oxide Thin-Film Transistors after a Low Temperature Annealing Process**

J. P. Bermundo, Y. Ishikawa, M. N. Fujii, C. Kulchaisit, H. Ikenoue[*]*, Y. Uraoka*

NAIST, Japan
[*]Kyushu Univ., Japan

High mobilities of more than 40 cm^2/Vs in amorphous InGaZnO (a-IGZO) thin-film transistors (TFT) were achieved through a low temperature excimer laser annealing process (ELA). The improvement mechanism was determined by analyzing the changes in electrical characteristics, composition, structure, and chemical bonding of the oxide semiconductor.

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 14:50 **409**

AMD7: Oxide TFT: Solution-Processed TFTs
Special Topics of Interest on Oxide-Semiconductor TFT

Chair: T. Kamata, AIST, Japan
Co-Chair: H. Kumomi, Tokyo Tech., Japan

AMD7 - 1: 13:30 ***Invited*** **Large-Scale Printed Sol-Gel Metal Oxide Dielectrics**

W.-J. Lee, S. Park, M.-H. Yoon

Gwangju Inst. of S&T, Korea

A simple large-area sol-gel bar-printing of metal oxide dielectric layers was successfully demonstrated in order to control ultrathin film thickness with the excellent dielectric performance and physical properties. Both dielectric and semiconductor films were successfully fabricated by direct-bar-patterning process using surface wetting, leading to high-performance low-voltage sol-gel metal-oxide transistors.

AMD7 - 2 13:55 **Uniform Large-Area Slot-Die Coating of Soluble Metal Oxide Semiconductor towards Mass Production of High-Performance TFT Backplanes**

I. Katsouras[*], J. Maas[*], J.-L. van der Steen[*], G. Gelinck[,**], R. Takata[***], M. Marinkovic[***], A. Neumann[***], D.-V. Pham[***], R. Anselmann[***], T. H. Ke[****], S. Smout[****], S. Schols[****]*

[*]Holst Ctr., The Netherlands
[**]Eindhoven Univ. of Tech., The Netherlands
[***]Evonik Resource Efficiency, Germany
[****]imec, Belgium

ESL TFT backplane with solution type metal oxide semiconductor was completely processed on mass-production ready equipment. High mobility TFTs with excellent uniformity were obtained over the complete Gen1 glass substrate (320 mm x 352 mm), with good TFT bias stress reliability. An 85 ppi QVGA AMOLED display is demonstrated.

AMD7 - 3 14:15 **5.8-in. Ultra-Narrow Border LCD with Soluble Metal-Oxide TFTs and Integrated with GIP Circuit**

W.-K. Tsao, S.-C. Chiang, Y.-H. Chen, D.-C. Wu, K.-H. Tseng, Y.-H. Lin, H.-M. Chang, Y.-Y. Huang, D.-V. Pham[*], K.-H. Su[*], M. Marinkovic[*], D. Weber[*], A. Merkulov[*], R. Anselmann[*]

Chunghwa Picture Tubes, Taiwan
[*]Evonik Resource Efficiency, Germany

In this paper, the soluble metal oxide-TFT fabricated with coating process and electrical stability of TFT device is investigated. We can integrate not only GIP-circuits but also solution-process OTFT to fabricate a 5.8-in. TFT-LCD with ultra-narrow-border (< 1 mm). The demonstrated panel is the first panel closed to the commercial product.

AMD7 - 4L 14:35 **Hydrogen and Subgap State in Amorphous IGZO Thin Films**

J. Bang, S. Matsuishi, H. Hosono

Tokyo Tech, Japan

Infrared absorption spectra of self-standing amorphous IGZO thin films deposited by conventional sputtering reveals the presence of hydride ions as a main hydrogen species. DFT calculations show these hydride species give rise to subgap states above the valence band top, suggesting the crucial role of hydride ions in NBIS.

----- Break -----

15:10 - 16:30 **409**

AMD8: Oxide TFT: Novel Processes and Applications
Special Topics of Interest on Oxide-Semiconductor TFT

Chair: M.-H. Yoon, Gwangju Inst. of S&T, Korea
Co-Chair: N. Morosawa, Samsung Display, Korea

AMD8 - 1: 15:10 ***Invited*** **Transparent and Flexible Memory Thin-Film Transistors Using Oxide Semiconductors**

S.-M. Yoon, S.-J. Kim, D.-J. Yun, M.-J. Park, W.-H. Lee, G.-H. Seo

Kyung Hee Univ., Korea

Flexible charge-trap memory thin-film transistors (f-MTFTs) using oxide semiconductors were fabricated on plastic poly(ethylene naphthalate) substrate. The gate-stack was composed of all oxide layers such as In-Ga-Zn-O active channel, oxide charge-trap layer, Al_2O_3 blocking/tunneling layers, and In-Sn-O electrodes. The fabricated f-MTFTs exhibited stable and excellent device performance.

AMD8 - 2 15:35 **Narrow-Pitch Low-Voltage-Driven and High-Speed Gate Driver with BA-IGZO TFTs for High-Resolution and Narrow-Bezel Displays**

H. Seo, D. Geng, J. Jang

Kyung Hee Univ., Korea

We report the fabrication of a high-speed and narrow-pitch gate driver with BA-IGZO TFTs. By taking the advantage of higher current and zero turn-on voltage, BA-IGZO TFTs based gate driver has faster rising and falling edge compared to SG-IGZO TFTs based one.

AMD8 - 3 15:55 **Novel Back-Channel-Etch Type In-Ga-Zn-Sn-O Thin Film Transistor with 4-Mask Technology**

J. Li[*], X. Hu[*], Y. Zhai[*], H. Yu[*], J. Liu[*], T. Sun[*], S. Qin[*], C. Lee[*], F. Wang[,**]*

[*]Shenzhen China Star Optoelect. Tech., China
[**]TCL Corporate Res., China

This paper firstly demonstrates a novel back-channel-etch type In-Ga-Zn-Sn-O thin film transistor with 4-Mask technology. It seems that wet etch process do little damage to the back channel during the fabrication. The a-IGZTO TFT reveals a high uniformity and stability and is potential for mass production.

AMD8 - 4 **Withdrawn**

AMD8 - 5L 16:15 **Development of 65-in. 4K UHD OLED TV with High Reliability Improvement of InGaZnO Thin-Film Transistors**

S. J. Yun, J. Y. Noh, Y. H. Choi, W. C. Jeong, J. W. Kim, S. Y. Cha

LG Display, Korea

To improve PBTS of a-IGZO TFT we have been optimized the oxygen in SiO_2 insulators and developed the controllable H-incorporation for defect passivation. In this study, we achieved that Vth shift was Δ0.11 V after 236-hour long-term PBTS stress. Furthermore, we demonstrated the 65-in. 4K OLED TV with high reliability improvement.

Author Interviews
16:30 – 17:10, Multipurpose Hall

Supporting Organizations:
Technical Committee on Electronic Information Displays, Electronics Society, IEICE
Thin Film Materials & Devices Meeting

Workshop on FPD Manufacturing, Materials and Components

Wednesday, December 7

13:00 - 14:20 **413**

FMC1: Film Technologies

Chair: R. Yamaguchi, Akita Univ., Japan
Co-Chair: I. Amimori, A51Tech, Japan

FMC1 - 1: 13:00 ***Invited*** **Temperature-Independent Zero-Zero-Birefringence Polymers for Optical Films**

A. Tagaya, M. Shikanai, H. Nagahama, Y. Koike
Keio Univ., Japan

A polymer exhibiting no birefringence over the wide temperature range was designed and synthesized in a quaternary copolymer system based on the analysis of intrinsic birefringence, temperature coefficient of intrinsic birefringence and photoelastic coefficient of polymers.

FMC1 - 2 13:20 **Control of Three Dimensional Birefringence of Uniaxial Oriented Film by Using Smectite Nanoparticle**

*K. Takatoh, M. Kobayashi, K. Yonehara, T. Abo**
Tokyo Univ. of Sci., Yamaguchi, Japan
**Kaneka, Japan*

It was found that by adding flat plate smectite nanoparticles to the polymer films of negative ΔN_{xy} values, three dimensional birefringence of uniaxially stretched film can be controlled. In the film, flat plate smectite nanoparticles are considered to have the tendency to align parallel to the film plane.

FMC1 - 3 13:40 **Improvement of Display Unevenness of Display Device by Reduction of Shrinkage of Polarizing Film**

M. Katou, S. Murayama, K. Ikeshima, Y. Nakano
Nitto Denko, Japan

Every display device is becoming thinner, and so are the glasses, polarizing films and backlight systems. But thinning such components and minimizing the interspaces are increasing generation of display defects such as display unevenness. We worked on improvement of display defects by controlling shrinkage force of polarizing film.

FMC1 - 4 14:00 **Development of High Contrast Achromatic Dye-Type Polarizer Using New Dichroic Dye Systems**

N. Mochizuki, T. Higeta, Y. Hattori, M. Nakamura, N. Koma[*], J. Toda[*], T. Ishinabe[**], H. Fujikake[**]

Nippon Kayaku, Japan
[*]Polatechno, Japan
[**]Tohoku Univ., Japan

We have succeeded in developing new achromatic dye-type polarizers with high contrast ratio which is 14 times higher than conventional one. This achromatic polarizer was realized by the optimum combination of dichroic dyes and improvement of dichroic ratio of yellow dye.

----- Break -----

14:40 - 16:00 **413**

FMC2: Display Optics and Information Technologies

Chair: K. Käläntär, Global Optical Solutions, Japan
Co-Chair: H. Yamamoto, Utsunomiya Univ., Japan

FMC2 - 1: 14:40 ***Invited*** **Color Rendering in Holographic Waveguide Display System**

Z. Shen, Y. Zhang, Y. Weng, X. Li, Y. Tu, Y. Tang

Southeast Univ., China

Due to wavelength and angle dependency of volume holographic gratings, there are color dispersions when displaying a full color image. This paper reviews the spectrum transfer properties and color rendering performances. Methods to improve color uniformity in different incidence angles and approaches to enlarge field of view are separately discussed.

FMC2 - 2 15:00 **Preventing Surface Reflected Light on Retro-Reflector in AIRR**

R. Kujime[,**], H. Yamamoto[**]*

[*]Tokushima Univ., Japan
[**]Utsunomiya Univ., Japan

In AIRR (aerial imaging by retro-reflection), surface reflection on retro-reflector sometimes spoils aerial display quality. This paper proposes optical designs to prevent reflected light on retro-reflector in AIRR. One of the design employs a barrier to block reflected light. Another design is consisted of our original retro-reflectors in Venetian-blind-shape.
Also presented in Innovative Demonstration Session (see p. 262)

FMC2 - 3 **Development of Wide Viewing VA-LCD System by**
15:20 **Utilizing Microstructure Film**

S. Ochi, Y. Asaoka, T. Nango, Y. Tsuda

Sharp, Japan

We have developed a wide viewing VA-LCD system utilizing the microstructure film with internal air-micro cavities. LC alignment directions and BL distribution are optimized as well as the scattering profile of the film. The color shift and the CR at oblique angles are improved than the conventional 4D-VA LCD.

FMC2 - 4: ***Invited*** **Mechanism of Optical Vortex Generation**
15:40 **from Self-Assembled TFCD Array in Smectic LC and TFCD Application to Optical Devices**

K. Käläntär

Global Optical Solutions, Japan

An array of self-assembled defects using smectic liquid crystal can generate optical vortices. The horizontal and vertical graded index (GRIN) structure of a defect results in vortex. The characteristics of the GRIN layers and shells of a defect are formulated to realize an optical device with vortex generation function.

----- Break -----

16:20 - 17:40 **413**

FMC3: Manufacturing Technologies

Chair: T. Tomono, Toppan Printing, Japan
Co-Chair: Y. Yang, China Star Optoelect. Tech., China

FMC3 - 1 **Withdrawn**

FMC3 - 5L **Catalytic Effect of Trichloroethene on Deposition**
16:20 **Rate of Silicon Oxides Films Deposited by APCVD Using Silicone Oil and Ozone Gas**

P. Jain, S. Horita

JAIST, Japan

By chemical reaction between silicone oil and ozone, SiO_X films were deposited on Si substrates at temperatures < 250°C in atmosphere. It was found that adding trichloroethene enhances deposition rate due to its catalytic effect and that at higher temperatures, the deposition rate saturates or decreases by its effect.

FMC3 - 2
16:40

Integrated System of LCD Factory Service Automation

W.-C. Chiu, C.-W. Wu, Y.-C. Chu, C.-L. Lin

Nat. Cheng Kung Univ., Taiwan

This work presents an innovative system for replacing the conventional inspection on the liquid crystal display (LCD) production line which can clearly indicate assembly flaws of panel and save the inspection results for machine parameter adjustment. The results show proposed system can rise inspection efficiency and reduce personnel costs.

FMC3 - 3
17:00

New Formation of Multi-Layered n^+ Silicon Films for Image Sticking Improvement in 55-in. HVA TV Product

X.-W. Lyu, Y.-H. Meng, S.-J. Chen, X. Liu, C. Liao, L. Zeng, Y. Zhou, X. Liu, C. Lee

Shenzhen China Star Optoelect. Tech., China

A-Si:H TFT manufactured by using multi-layered n^+ silicon films instead of normal single layer n^+ silicon film to improve image sticking of our 55-in." HVA TV product. Compared to single n^+ layer, the leakage current of multi-layered n^+ decreased obviously without Vth variation and Ion degradation.

FMC3 - 4
17:20

Improvement on Two-Wet and Two-Dry Method in Four-Mask Process of G8.5 LCDs

X. D. Liu, X. Liu[*]*, C. Y. Lee, M. Zeng, L. M. Zeng, X.-W. Lv, J. X. Xie, Y. F. Yang, D. Luo, F. Long, X. Y. Kong, C. W. Liao, H. F. Xie, Z. W. Tan*

Shenzhen China Star Optoelect. Tech., China
[*]*Peking Univ., China*

Novel four-Mask process is provided to get less a-Si and N^+ tails, which decreases about 1.12/1.24 µm and 0.96/0.88 µm in Al/Cu process, respectively. Therefore, I_{on} was lower for larger channel length. Optimized O_2 ashing process had successfully cut in half the higher I_{off} and attained better stability.

Author Interviews
17:40 – 18:20, Multipurpose Hall

Thursday, December 8

9:00 - 10:20 **413**

FMC4: Standardization on Printed Electronics
Special Topics of Interest on Printed Electronics

Chair: K. Käläntär, Global Optical Solutions, Japan
Co-Chair: Y. Inoue, Corning Japan, Japan

FMC4 - 1: 9:00 ***Invited*** **Standardization Activities on Printed Electronics of IEC TC 119**

K. Suganuma, S. Maeda[,**]*

Osaka Univ., Japan
[*]Chem. Materials Evaluation & Res. Base, Japan
[**]Mitsubishi Chem., Japan

Printed Electronics (PE) is one of the fastest growing technologies expected to lead IoT industry. Japan National committee and PE committee in JEITA are working very closely with IEC TC 119, Printed Electronics. This paper gives a brief overview of the organization of IEC TC 119 and the International Standards progress.

FMC4 - 2: 9:20 ***Invited*** **Overview of Standardization Activities for Stretchable Materials in IEC TC 119, Printed Electronics**

S. Maeda

Toyobo, Japan

Technologies for WSDs (wearable smart devices), and standardization activities related to each them were reviewed by TC 119 / WG 2. These results are summarized in the technical report "IEC 62899 Printed Electronics -Part 250: Material technologies required in Printed Electronics for Wearable Smart Devices". Stretchable electric materials have high priority for the standardization.

FMC4 - 3: 9:40 ***Invited*** **World First International Standard for Printed Electronics Materials**

C. Sekine, M. Oda[*], S. Maeda[**], T. Sato[***]

Sumitomo Chem., Japan
[*]Japan Advanced Printed Elect. Tech. Res. Assn., Japan
[**]Toyobo, Japan
[***]FUJIFILM, Japan

The world first International Standards for printed electronics (PE) materials regarding substrate and conductive ink were issued in February 2016 via IEC/TC119. This has led further international standardizations to match the trend of ItoT, wearable smart devices, etc. Such activities are expected to accelerate growing of PE industry.

FMC4 - 4: 10:00 ***Invited*** **Standardization Activities on Printed Electronics Devices in IEC TC 119**

T. Minakata, K. Hyodo[*]

Asahi Kasei, Japan
[*]Konica Minolta, Japan

New way of manufacturing process, called printed electronics, is getting popular. By using this new process, we could realize new devices that has unique characteristics such as flexibilities. Through this presentation, we would like to explain new standard ways of evaluating devices produced by printed electronics process.

Author Interviews
10:30 – 11:10, Room 201

10:30 - 13:00 **Multipurpose Hall**

Poster **FMCp1: FPD Manufacturing, Materials and Components**

FMCp1 - 1 **Mechanism of TFT-LCD RGB Photoresist Wrinkle and Improvement Strategies**

J. Li, X. Yu, M. Tang, Y. Zeng, H. H. Chen

Shenzhen China Star Optoelect. Tech., China

we proposed a series of experiments to explore the mechanism of photoresist wrinkle issue and presented the strategies to solve the problem in different aspects such as material prescription, process recipe and mask design.

FMCp1 - 2 **Effect of Sintering Temperature on Piezoelectric and Ferroelectric Properties of NKLNTS Based Ceramics for Energy Harvesting Applications**

S.-M. Huang, H.-R. Chen[*], Y.-D. Juang[*], Y.-C. Lin, S.-Y. Chu, C.-C. Tsai[**], C.-S. Hong[***]

Nat. Cheng Kung Univ., Taiwan
[*]Nat. Tainan Univ., Taiwan
[**]Tung Fang Design Inst., Taiwan
[***]Nat. Kaohsiung Normal Univ., Taiwan

In this study, NKLNTS ceramics were prepared using a conventional mixed oxide method and the effects of sintering temperature on the electrical properties of the proposed samples are investigated. Furthermore, energy-harvesting devices based on proposed samples have been developed for driving LED.

FMCp1 - 3 **Withdrawn**

FMCp1 - 4 **Design of White Light LED for Multi-View Angle Display Application**

Y.-M. Weng, C.-C. Chiu, F.-L. Hsiao

Nat. Changhua Univ. of Education, Taiwan

We designed a two-dimensional photonic crystal periodic air holes array on LED surface. The split shape of light distribution relate to the periodic air holes array. The split angles can be control the directivity of light distribution. The results of research can apply to white light LED.

FMCp1 - 5 **Comparison of Divergence Angle of Retro-Reflectors for Aerial Imaging by Retro-Reflection**

K. Onuki[*], N. Kawagishi[,**], H. Yamamoto[*]*

[*]Utsunomiya Univ., Japan
[**]Yazaki, Japan

This paper reports comparisons of retro-reflectors for aerial imaging by retro-reflection (AIRR). We have evaluated sharpness of aerial images formed with AIRR by use of several types of retro-reflectors. We measured the divergence angle of retro-reflectors. Furthermore, we have obtained contrast-transfer functions of aerial images with polarized AIRR.

FMCp1 - 6 **Over 96% Visual Area LTPS-TFT LCD with Ultra-Slim Border (0.15 mm)**

B. P. Liu, J. Y. Yan, X. F. Zhou, Y. S. Huang, Y. F. Tang, X. A. Xu, X. X. Wu, S. J. Cai, B. P. Shen, G. Z. Chen, J. Y. Li, Z. Zeng

XiaMen Tianma Microelect., China

In this paper, we show a display with a left and right border (L/R border) of 0.15 mm, and the visual area is over 96%. Meanwhile, we indicate the technology of the ultra-slim border, which includes the difficulty and solution of process.

FMCp1 - 7 **Research on Pellicles for DUV Exposure to Improve CD Uniformity**

T. Ooyanagi, M. Ando, Y. Nagai, M. Hakko, N. Yabu, N. Izumi, K. Nagano

Canon, Japan

Shorter wavelength as exposure light is effective to achieve high resolution. A pellicle is one of the items which is affected by shorter wavelength. We investigate the effectiveness of shorter wavelength as exposure light for high resolution, and we also investigate the impact of pellicles.

FMCp1 - 8L Formation of C_8BTBT Single Crystal Thin Films by Coating Liquid Crystal and Organic Semiconductor Solution on Photo-alignment Layer

R. Takeda, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

We realized C_8BTBT single crystal growth and the control of the axis direction by coating solution of liquid crystal and semiconductor on photo-alignment layer. We clarified that single crystal is formed parallel to orientation direction of the liquid crystal even when the liquid crystal solvent oriented hybrid-aligned in coating process.

FMCp1 - 9L The Lifetime Estimation of 24.9-in. / 16:3 / 4K Free-Form Automobile Display with Quantum-Dot System

I.-H. Hsieh, S.C. Wang, A. Shiu, D. Wu, S. Hsieh, S. Liu, A. Chen

AU Optronics, Taiwan

We have developed a 24.9-in. free-form display concept enables various in-vehicle designs. The lifetime estimation method is followed the early work indicates that the backlight-unit should be responsible for 92% of brightness decay after 46,000 hours test time. We could expect the lifetime of 24.9-in. is about 20,000 hours currently.

FMCp1 - 10L Analysis of Transmission Property for Thin Wide-Viewing- Angle Reflective Polarizer Using Optically-Anisotropic Dielectric Multilayer

K. Akahane, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

We clarified that we can suppress light leakage of reflective polarizers for large incident angle light by increasing refractive index of thickness direction of anisotropic dielectric multilayer. We can also reduce thickness by optimizing film thickness distribution. These results were obtained from analysis using Interference-Included 2×2 Jones Matrix method.

10:30 - 13:00 **Multipurpose Hall**

***Poster* FMCp2: Oxide TFT Manufacturing**
Special Topics of Interest on Oxide-Semiconductor TFT

FMCp2 - 1 **Influence of Oxygen Ratio in Gate Bias Instability of Amorphous InGaZnO Thin Film Transistor**

N. On, H. Seul, S. Kim, K. Lee, J. K. Jeong
Hanyang Univ., Korea

The PBTS dependent Vth variations for the self-aligned IGZO TFTs were examined. The activation energy barrier for the PBTS induced instability was found to be strongly dependent on the oxygen partial pressure during IGZO preparation, which was discussed on basis of the various degradation mechanisms.

FMCp2 - 2 **Structural Characteristics of Nickel-Zinc Oxide Nanostructures**

Y. Yoshihara, K. H. Kim, Y. Abe, M. Kawamura, T. Kiba
Kitami Inst. of Tech., Japan

We fabricated nanolayered nickel-zinc oxide nanostructures prepared via a simple one-pot solution process using aqueous solution dissolving nickel acetate, zinc nitrate, hexamethylenetetramine, and investigated their structural properties without and with annealing treatment of temperature at 700°C. After annealing, the nanolayers were composed of nanoparticles of several tens nanometers.

FMCp2 - 3 **Soluble-Processed SiO_2 Gate Insulator Fabrication via Deep UV Curing for Amorphous Oxide Transistors**

H. Seul, N. On, K. Lee, S. Kim, J. Jeong
Hanyang Univ., Korea

High-temperature annealing (> 300°C) required to obtain reasonable insulating properties still limits for the flexible electronics. This paper suggests that a perhydropolysilazane (PHPS) solution added VTES coupling agent can reduce the annealing temperature by using UV process.

FMCp2 - 4L **Withdrawn**

FMCp2 - 5L **Effect of Nitridation Pretreatment on the Electrical Properties of Low-Temperature (100°C) Silicon Nitride Films**

S. M. Noh, W.-S. Hong

Univ. of Seoul, Korea

Nitridation pretreatment with a mixture of NH_3 and N_2 has been attempted to improve electrical properties of silicon nitride films deposited at 100°C. The nitridation process for 1 minute at the substrate temperature of 50°C reduced drastically the capacitance-voltage hysteresis window and the threshold voltage shift.

----- Lunch -----

16:50 - 18:10 **412**

FMC5/FLX2: Manufacturing and Equipment

Chair: A. Fujita, JNC, Japan
Co-Chair: M. Ito, Toppan Printing, Japan

FMC5/ FLX2 - 1: 16:50 ***Invited*** **Development of the Flexible Surface Light Source Using Luminous Array Film Technology**

K. Awamoto, H. Hirakawa, J. Takahashi[*]*, T. Hidaka*[*]*, T. Shinoda*

Shinoda Plasma, Japan
[*]*Shikoh Tech LLC, Japan*

We developed a new technology of a Luminous Array Film (LAFi) as a large screen, bendable, film-like, emissive display and we produced the 150-in. diagonal curved display. We applied the LAFi to a flexible light source and we developed the Hg-free high luminance deep-UV surface light source.

FMC5/ FLX2 - 2 17:10 **Fabrication of Thin-Film Coatings on Large Size Ultra-Thin Glass for Flexible Devices**

M. Junghaehnel, T. Preussner, J. Westphalen, S. Mogck

Fraunhofer Inst., Germany

Ultra-thin flexible glass is an emerging flexible substrate material for flexible displays, devices or lighting. 100 µm thick flexible glasses with a maximum dimension of 600 × 600 mm² were deposited with inorganic and organic thin-films in sheet-to-sheet and roll-to-roll processes.

FMC5/ FLX2 - 3 17:30 **Cutting Method for Electronic Device Made Using Ultra-Thin Glass**

N. Inayama, S. Miwa. T. Fujii

Nippon Elec. Glass, Japan

The simultaneous laser thermal stress cutting method (SLTSC) has been newly developed as cutting methods for an electronic device made using ultrathin glass. Compared with other methods, the novel cutting method is one path cutting of the display to achieve high bending strength due to high quality edge.

FMC5/ FLX2 - 4 17:50 **Direct Imaging Exposure Equipment with High Overlay Accuracy for Flexible Substrate in Roll-to-Roll Method**

Y. Kito, M. Hori, Y. Hayashida, T. Suzuki, H. Komiyama, T. Watanabe, T. Kurashige, M. Kato, K. Nara

Nikon, Japan

To fabricate TFTs on a flexible substrate, it is required to make overlay patterns with high alignment accuracy. We developed roll-to-roll exposure equipment with high overlay accuracy for flexible substrate. By a prototype, we succeeded to make patterns on a PET film directly, achieving overlay accuracy less than +/- 5 mm.

Author Interviews
18:10 – 18:50, Multipurpose Hall

Friday, December 9

13:30 - 14:50 **502**

FMC6: Materials and Components

Chair: T. Tsuzuki , NHK, Japan
Co-Chair: K. Kurokawa, Nihon Entegris, Japan

FMC6 - 1: 13:30 ***Invited*** **Reflective Displays - Are Phase Change Materials the New Modulator?**

P. Hosseini, C. Rios[*]*, H. Bhaskaran*[*]

Bodle Techs., UK
[*]*Univ. of Oxford, UK*

In this talk, our work on the use of phase change materials in novel reflective displays will be presented. This work involves the use of the electro-optical phase change materials modulating the refractive index of one layer of the material.

FMC6 - 2 13:50 **Thin Film Organic Photodiodes on CMOS Materials Structured via Orthogonal Photolithography for Sensor Applications**

M. Jahnel, M. Schober, K. Fehse, O. Hild, U. Vogel

Fraunhofer Inst., Germany

In this work we present an easy and cheap method to structure organic photodetectors integrated on an 200 mm silicon wafer in combination with a thin film encapsulation. A new top absorbing organic photodetector device is discussed, structured with the orthogonal photo- lithography, for light sensors and organic photodetector applications.

FMC6 - 3 14:10 **Investigation of Copper Metallization with New Titanium Barrier Layer**

J. H. Kim, B. O Kim, J. H. Seo

Korea Aerospace Univ., Korea

The effects of new titanium electrodes on the electrical performance of thin film transistors were studied. The new titanium alloy showed better thermal resistance properties compared to pure titanium. The mobility lied between 10~14 cm^2/Vs and the contact resistance was about 0.5 M-ohm. Both values were comparable to reported values.

FMC6 - 4 14:30 **(100) Textured LTPS Film by Single Scanning CW Laser Lateral Crystallization and Effect of Crystallization Conditions on Grain-Boundaries**

N. Sasaki, Y. Nieda[*]*, D. Hishitani*[*]*, M. Arif*[*]*, Y. Uraoka*[*]

Sasaki Consulting, Japan
[*]*NAIST, Japan*

A (100) textured LTPS film is obtained by a single scanning CLC of a-Si at low laser power levels. The film contains mainly low-angle grain boundaries. Observed CSL boundary is ∑3 boundary of 0.27%. Various CSL boundaries are generated at a higher power or a 80 times scan.

----- Break -----

Author Interviews
16:30 – 17:10, Multipurpose Hall

Supporting Organizations:
Japan Electronics Packaging and Circuits Association
Japan Society of Colour Material
The Japanese Research Association for Organic Electronics Materials
The Japanese Society of Printing Science and Technology
RadTech Japan
The Society of Photography and Imaging of Japan
The Technical Association of Photopolymers, Japan

Workshop on Inorganic Emissive Display and Phosphors

Wednesday, December 7

16:20 - 17:45 **502**

PH1: Phosphors for Lighting Application
Special Topics of Interest on Lighting and Quantum Dot Technologies

Chair: J. Silver, Brunel Univ. London, UK
Co-Chair: T. Kusunoki, Dexerials, Japan

PH1 - 1: 16:20 ***Invited*** **Highly Efficient Laser Spotlight Illuminator with a Novel Check-Patterned Phosphor Structure**

K. Morimoto, Y. Nagasaki, K. Okuyama, T. Miwa[*], A. Takamori[**], T. Tanaka

Panasonic AIS, Japan
[*]IDEC, Japan
[**]Osaka Univ., Japan

The first blue-violet laser-diode pumped phosphor spotlight illuminator is demonstrated, having a novel check-patterned blue/yellow phosphor structure with high conversion efficiency under high power excitation. The spotlight prototype achieves an excellent luminous efficacy 51.3 lm/W at high luminous flux 861 lm and uniform illuminance distribution on the target illumination area.

PH1 - 2 16:50 **Improvement of Photodegradation of Nitridosilicate Phosphors by Composition Change and Realization of High CRI White-LEDs**

M. Kanno, M. Abe, T. Kusunoki

Dexerials, Japan

Nitridosilicates $(Ca,Sr)_{2(1-x)}(Al_y,Si_{1-y})_5(O,N)_8:Eu_x$ are efficient andaffordable red-emitting phosphors. In this study in order to improve photodegradation of these phosphors we changed the composition of their alkaline-earth ions and had good results. We also used these phosphors as red-emitting phosphors for white-LEDs and could obtain high CRI successfully.

PH1 - 3
17:10

Commercialized, Narrow Band, Red Emitting Phosphors for Wide Color Gamut Display Applications and LED Lighting

S. P. Sista, F. Garcia-Santamaria, J. E. Murphy, A. Setlur, P. N. Kumar[*], D. G. Porob[*], J. M. Baldesare[**], W. W. Beers[**], A. I. Chowdhury[**], W. E. Cohen[**], F. Du[**], C. D. Nelson[**]

GE Global Res., USA
[*]GE Global Res., India
[**]GE Lighting, USA

Commercialized GE TriGain phosphors are narrow red line emitters that offer an effective on-chip solution to wide color gamut displays with increased brightness. We discuss the significant improvements in efficiency, phosphor reliability and absorption that TriGain phosphors show compared to typical KSF phosphor.

PH1 - 4L
17:30

White LED Using Narrow-Band γ-AlON:Mn,Mg Green Phosphor for Super Wide-Color Gamut Display

K. Yoshimura, M. Izumi, R.-J. Xie[*], H. Fukunaga, K. Takahashi[*], N. Hirosaki[*]

Sharp, Japan
[*]NIMS, Japan

The display backlight using sharp β-sialon:Eu (green) and K_2SiF_6:Mn (red) phosphors shows a very wide-color gamut that mostly covers the whole NTSC triangle. In this work, γ-AlON:Mn,Mg green phosphor is investigated as an alternative green phosphor with the purpose of the further improvement of the display color gamut.

Author Interviews
17:45 – 18:20, Multipurpose Hall

Thursday, December 8

14:10 - 16:40 **Multipurpose Hall**

***Poster* PHp1: Phosphors for Lighting Application**
Special Topics of Interest on Lighting and Quantum Dot Technologies

PHp1 - 1

New Structure of Phosphor Layer in pc-WLEDs Package for Optical Properties Improving

L.-F. Nien, T.-S. Zhan, S.-Y. Chu

Nat. Cheng Kung Univ., Taiwan

In this article, a new package method was investigated to solve the problems, which caused by conventional fabrication of phosphor-converted white LED (pc-WLED), like yellow-ring and uneven intensity of different view angles. This method can not only improve the color uniformity, but the luminous efficiency of pc-WLED.

PHp1 - 2 **Structural Equation Approach for Designing of LED Cup Reflector and the Future Prospect**

C.-J. Ou, Z.-W. Huang, Y.-J. Hsu, C.-R. Ho

Hsiuping Univ. of S&T, Taiwan

For the designing of the LED secondary lens, the solely effects of the reflectors should be familiar with the optical designers, such that the appropriate lens design can be integrated with the reflectors. This report setting up an analytical process to explore the effects of LED reflectors on energy distribution.

PHp1 - 3 **Electron Emission Properties of Cold Cathode Based on Silicon-Rich Silicon Dioxide Films Prepared by Magnetron Reaction Sputtering**

W. Zhao, M. Zhou, W. Hu

Xi'an Jiaotong Univ., China

Silicon-rich silicon dioxide (SRSO) films were formed through deposition of SiO_X films by magnetron reaction sputtering together with subsequent rapid temperature annealing treatment. The emission efficiency and emission current density of a cold cathode based on SRSO film reach 10.88% and 25.78 μA/cm^2 at the applied voltage of 19 V.

PHp1 - 4 **Synthesis and Luminescence Properties of Novel Eu^{2+}-Doped $BaGa_2SiS_6$ and $Ba_2Ga_8SiS_{16}$ Thiogallate Phosphors for White LEDs**

S. P. Lee, S. D. Liu, T. M. Chen

Nat. Chiao Tung Univ., Taiwan

Novel Eu^{2+}-doped $BaGa_2SiS_6$ and $Ba_2Ga_8SiS_{16}$ thiogallate phosphors were prepared by solid-state reaction. The $BaGa_2SiS_6$:Eu^{2+} phosphor generates a green emission upon excitation at 405 nm, whereas the $Ba_2Ga_8SiS_{16}$:Eu^{2+} phosphor could be tuned from cyan to green range with increasing Eu^{2+} concentration upon excitation at 365 nm.

PHp1 - 5 **Rare-Earth-Free Organic-Inorganic Hybrid Phosphor Made from APTES for White Light LED Application**

K. Hasegawa, K. Komatsu, A. Kato

Nagaoka Univ. of Tech., Japan

Organic-inorganic hybrid phosphors made from malic acids and APTES which shows strong green emission were synthesized by sol-gel method. The emission wavelength and intensity were found to depend on heating treatment temperature, which may be due to local structural change. This phosphor has a potential for rare-earth free UV-LEDs application.

PHp1 - 6 **Eu Concentration Dependence of Morphology and Emission Characteristics of Y_2WO_6:Eu Nano-Rod Phosphor**

S. Matsumoto, R. Kanai, M. Kimura, A. Kato

Nagaoka Univ. of Tech., Japan

Y_2WO_6:Eu nano-rod phosphors with various Eu concentration were synthesized by flux method using LiCl flux. The diameter of the nano-rod was kept around ~200 nm with Eu concentration lower than 10%. The emission characteristics were drastically improved by introduction of seed crystals in the flux.

PHp1 - 7L **Characteristics of Phosphor-Converted White Light-Emitting Diodes with Tunable Color Temperature and High CRI Fabricated by Near-Ultraviolet Light-Emitting Diodes**

C.-H. Chiang, S.-J. Gong, S.-Y. Chu

Nat. Cheng Kung Univ., Taiwan

The phosphor-converted white light-emitting diodes were fabricated by combining the tri-color phosphors and silicone gel with the near-ultraviolet light-emitting diode chips. Using the separated phosphor layer structure can reduce the loss of re-absorption. The CRI increase with increasing percentage of overlapping area between the spectra deconvoluted from the electroluminescence spectrums.

14:10 - 16:40 **Multipurpose Hall**

Poster PHp2: Phosphors for General

PHp2 - 1 **Synthesis and Properties of Luminescent Polymer-Silica Multilayer Encapsulated Perovskite Quantum Dots for Photoelectronic**

S. D. Liu, S. P. Lee, T. M. Chen

Nat. Chiao Tung Univ., Taiwan

We synthesized monodisperse colloidal nanocrystals of fully inorganic cesium lead halide perovskites ($CsPbX_3$, X = Br and I or mixed halide systems Cl/Br and Br/I) and SiO_2 coated $CsPbBr_3$. Perovskite QDs have potential to become a new of candidates for inexpensive optical communication applications.

PHp2 - 2 **Withdrawn**

PHp2 - 3 **Down-Conversion Luminescence with CdSe-Based Quantum Dots**

B. K. Kim, D. Jo, C. M. Lee, H. Chung, H. Chae

Sungkyunkwan Univ., Korea

Down-conversion luminescence of blue light emitting diodes (LEDs) was investigated with red (CdSe@CdZnS) and green (CdSe@ZnS/ZnS) quantum dots (QDs) in this work. Down-conversion films were applied to blue LEDs to obtain large color gamut.

PHp2 - 4 **Effect of Thiophenol-Based Ligands on Quantum Dot Light Emitting Diodes (QLEDs)**

H. Moon, W. Lee, H. Chung, H. Chae

Sungkyunkwan Univ., Korea

The effect of thiophenol-based ligands was investigated on CdSe quantum dot and quantum dot light emitting diodes (QLEDs). Oleic acid ligands were exchanged to 4-methylthiophenol, thiophenol, 4-(dimethylamino)thiophenol. Quantum yields of QDs with each ligands were 82%, 81% and 73%. Luminance of QLED show similar trends with QYs.

PHp2 - 5 **RoHS-Compliant and High Efficiency QD Backlight for BT.2020 LCD**

J. Fan, K. Hsiao, R. C. Chien, J. J. Wu

Shenzhen China Star Optoelect. Tech., China

By using the backlight with BR chips solution, the LCD was successfully developed with RoHS-compliant ,more than 90% BT.2020 color gamut and over 95% Pointer's gamut. The total efficiency of BR chips solution LCM was presented a high efficiency about 106.7% of the blue chip solution.

PHp2 - 6L **Local Structure Analyses of Cations in YVO_4:Eu,Bi Nanophosphor Prepared by Continuous Flow Reactor**

T. Kunimoto, Y. Fujita, H. Okura[*], T. Honma[**]

Tokushima Bunri Univ., Japan
[*]Merck, Japan
[**]JASRI, Japan

X-ray absorption fine structure measurements of all cation-species in YVO_4:Eu,Bi nanophosphors synthesized by continuous flow reactor were carried out. Structural disorder near the surface of nanoparticle, which leads a low quantum efficiency, was obviously observed.

PHp2 - 7L **Influence on Transition Metal Doping of Luminescent Properties of $SrTiO_3$:Pr Phosphors Prepared by Sol-Gel Method**

K. Akao, T. Tashiro, H. Kominami, K. Hara, Y. Nakanishi, O. Marchylo[*]

Shizuoka Univ., Japan
[*]V. E. Lashkaryov Inst. of Semiconductor Physics, Ukraine

We prepared $SrTiO_3$:Pr doped with transition metals, such as Fe, Co and Ni, by sol-gel method, to aim of investigation of the influence of the doping. As the results, the luminescence of $SrTiO_3$:Pr was improved by Fe addition, however, Co and Ni were a role of quenching center adversely.

PHp2 - 8L **Preparation of Deep UV Emitting $ZnAl_2O_4$ Thin Film by Thermal Diffusion of α-Al_2O_3/ZnO Multilayers**

T. Ito, H. Kominami, Y. Nakanishi, K. Hara

Shizuoka Univ., Japan

Deep UV emitting $ZnAl_2O_4$ thin film were prepared by α-Al_2O_3/ZnO multilayers on quartz substrate using sputtering system. $ZnAl_2O_4$ phase was formed by thermal annealing for above 2 hours. From CL measurements, UV emission of Al-rich $ZnAl_2O_4$ at 243 nm was obtained.

PHp2 - 9L **Luminescent Properties and Particle-Size Control of Eu Doped $Sr_4Al_{14}O_{25}$ Afterglow Phosphors**

K. Hada, T. Akahori, H. Kominami, K. Hara, Y. Nakanishi

Shizuoka Univ., Japan

To improve the absorption efficiency of visible light to phosphors, it is necessary to grow the phosphor particle larger. From this experiment, boron played a role as not only $Sr_4Al_{14}O_{25}$ phase formation but also crystal growth. According to increase of particle size, PL properties of powders were improved.

PHp2 - 10L **Organic-Inorganic Hybrid Materials for Light Emitting Diodes**

I. S. Young, D. H. Go, J. G. Ryu, Y. S. Kim

Hyosung, Korea

Generally, display phosphors are required to narrow bands width to meet the growing demands such as the high color uniformity, high brightness and high color gamut. Organic-inorganic hybrid materials used lanthanide ions (for example, Eu^{3+}, Sm^{3+} and Tb^{3+}) can emit high-performance luminescence.

----- Break -----

16:50 - 18:10 **503**

PH2: Phosphors for General

Chair: H. Zhong, Beijing Inst. of Tech., China
Co-Chair: R.-J. Xie , NIMS, Japan

PH2 - 1: 16:50 ***Invited*** **Light Emission from Solution-Processed High Quality Semiconductor Nanomaterials: Nanoparticles and Perovskites**

Y. Kanemitsu

Kyoto Univ., Japan

We have studied the optical responses of solution-processed nanoparticles and perovskites and discuss their radiative and nonradiative recombination processes with respect to low-cost and high-efficiency light-emitting diode, laser, and photovoltaic applications.

PH2 - 2: 17:20 ***Invited*** **Halide Perovskite Quantum Dots: New Generation Materials for Display Applications**

Q. Zhou, Z. Bai, F. Zhao[*]*, Q. Pei*[*]*, H. Zhong*

Beijing Inst. of Tech., China
[*]*Univ. of California, USA*

Halide perovskite quantum dots exhibit high photoluminescence quantum yields (60-90%), wide wavelength tenability (400-800 nm), and ultra-narrow band emissions (< 30 nm), the combination of these superior optical properties and low cost fabrication makes them to be potential candidates for lighting and display technology.

PH2 - 3 17:50 **Versatile Measuring Method of the Quantum Yield of Phosphor Systems with High and Low Photoluminescence**

J. Silver, T. G. Ireland, G. R. Fern, D. den Engelsen

Brunel Univ. London, UK

Methods of measuring quantum efficiencies are presented, many factors affect QE measurements. We demonstrate that nanoparticle YAG:Ce phosphors have lower QEs than micron sized phosphor powders. Depending on instrument choice for measurement different QE values can be obtained from the same phosphors. Extreme caution is needed for accurate measurement.

Author Interviews
18:10 – 18:50, Multipurpose Hall

Supporting Organizations:
The 125th Research Committee on Mutual Conversion between Light and Electricity, Japan Society for Promotion of Science
Phosphor Research Society, The Electrochemical Society of Japan

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by Oral and Poster Presenters
Thursday, Dec. 8, 2016
10:30-16:40
Multipurpose Hall (2F)
Fukuoka International Congress Center

Workshop on OLED Displays and Related Technologies

Wednesday, December 7

13:00 - 14:20 **501**

OLED1: OLED Displays

Chair: T. Ikuta, JNC Petrochem., Japan
Co-Chair: T. Wakimoto, Merck, Japan

OLED1 - 1: 13:00 ***Invited*** **Bi-directional Foldable AMOLED Display with Millions Repeat Folding Cycles**

M.-T. Lee, C.-L. Wang, C.-S. Chan, C.-C. Fu, W.-J. Su, Z.-X. Weng, Y.-H. Lin

AU Optronics, Taiwan

A bi-directional foldable AMOLED display with a 10 µm thin color-filter array (CFA) can pass millions repeat folding times with 4 mm folding radius. The design of the display allows the most fragile part of thin-film transistor (TFT) and thin-film encapsulation (TFE) to be placed at the neutral axis during folding process.

OLED1 - 2 13:20 **Introduction of New Transparent Conductive Oxide Film for Anode of OLED**

Y. Hayashi, Y. Toshimori, K. Kiuchi, I. Shiono, S. Komiyama, S. Zhang

Mitsubishi Materials, Japan

A multilayered film assuming the anode for OLED was fabricated by using new TCO film MMCZ. Reflectivity of MMCZ/Ag/MMCZ multilayer in the short wavelength region is improved compared with ITO/Ag/ITO multilayer, and this multilayer is etched with phosphoric acetic nitric acid.

OLED1 - 3 13:40 **Data-Counting Model for Empirical Prediction of OLED Degradation**

X. Jiang, C. Xu

Saarland Univ., Germany

We propose a data-counting model for the estimation of OLED degradation. The empirical model derived from degradation behavior in accelerated aging tests considers multi-operation conditions, such as current amplitude, and temperature. It is used to compensate loss of current efficiency and extend lifetime for OLED display application.

OLED1 - 4
14:00 **Highly Performant and Stable Thin-Film Encapsulated Inverted Top-Emitting Organic Diodes Based on MoO_x as Electron Injection Layer**

Y. Murat[,**], G. Wantz[*], J.-Y. Laurent[**], V. Gorge[**], L. Hirsch[*], T. Maindron[**]*

[*]Univ. of Bordeaux, France
[**]Univ. Grenoble-Alpes CEA, France

This work aims to understand the role of a thin MoO_X layer at the interface cathode/n-doped layer in top-emitting OLEDs. With this cathode/MoO_X/n-doped layer structure, a higher efficiency and a reduced voltage drift over lifetime during ageing have been demonstrated for the inverted as well as for equivalent direct structures.

----- Break -----

14:40 - 16:00 **501**

OLED2: OLED for Lighting Applications
Special Topics of Interest on Lighting and Quantum Dot Technologies

Chair: Y. Kijima, Huawei Techs., Japan
Co-Chair: S. Naka, Univ. of Toyama, Japan

OLED2 - 1: ***Invited*** **Recent Advances in White OLED**
14:40 **Technologies for OLED TV and Lighting**

C.-W. Han, H.-S. Choi, S.-S. Jang, M.-S. Kang, S.-S. Park, H.-C. Choi, I.-B. Kang

LG Display, Korea

The brightness of 55-in. UHD OLED TV embedded with the 3-stacked WOLED showed 150 cd/m^2 at full white screen and 500 cd/m^2 at peak white screen. With the application of light extraction structures and 3-stacked devices, PE of 90 lm/W in OLED lighting was achieved.

OLED2 - 2
15:00 **High Efficiency $FAPbBr_3$ Perovskite Light-Emitting Diode**

B. Xu, X. Zhang, W. Wang, J. Hao, W. Chen, D. Wang, J. Qin, W. Cao[*], P. Liu[**], S. Chen, K. Wang, X.-W. Sun

Southern Univ. of S&T, China
[*]Tianjin Univ., China
[**]Hubei Univ., China

Light-emitting diodes (LEDs) based on organometal halide perovskite are emerging light source for display and lighting. Here, we report high efficiency $FAPbBr_3$ perovskite LEDs with structures of ITO/PEDOT:PSS/$FAPbBr_3$/TPBi/LiF/Al. We demonstrate high electroluminescence performance with luminance of 9000 cd/m^2, external quantum efficiency of 0.82%, and current efficiency of 2.7 cd/A.

OLED2 - 3 **OLED Lighting for Photorejuvenation**
15:20

M.-Z. Dai, Y.-H. Chen, C.-C. Chen, H.-C. Hu, W.-L. Hung, T.-Y. Lin, J. H. Tao, W.-Y. Wang, C.-C. Chen, M.-T. Lee

AU Optronics, Taiwan

A flexible OLED photorejuvenation mask with non-regular face-shape design was delivered. The emitted light of wavelength from 520 nm through 680 nm, which covered most of cosmetic light therapies requirement. The functional silicone film is skin-friendly and can enhance light extraction of OLED.

OLED2 - 4 **Inkjet-Printed Flexible Quantum Dot Light-Emitting**
15:40 **Diodes for Next Generation Display**

J. Zhuang, C. Wei, W. Su, Z. Cui

Chinese Ac. of Sci., China

We have fabricated flexible PM-QLEDs based on PET/Ag grid substrate by inkjet printing. The ink we developed is pure QDs without any other additives, and free of halogen solvents. The red, green and blue QDs inks are all stable even after 2 months with high quantum yields.

----- Break -----

16:20 - 17:15 **501**

OLED3: OLED Devices

Chair: K. Nakayama, Osaka Univ., Japan
Co-Chair: Y. Sakai, Mitsubishi Chem., Japan

OLED3 - 1 **Flexible Active Matrices with Solution-Processed**
16:20 **High Mobility Organic TFTs for Large Area Displays**

M. Ikawa[*], M. Kishi[**], Y. Tanaka[**], S. Kumagai[**], K. Ueji[**], A. Yamamura[**], Y. Tanaka[*], M. Tanabe[*], M. Ito[*], M. Uno[**],[***], J. Takeya[*],[**],[***],[****]

[*]Pi-Crystal, Japan
[**]Univ. of Tokyo, Japan
[***]Tech. Res. Inst. of Osaka Pref., Japan
[****]Organo-Circuit, Japan

This paper presents flexible active matrices with solution-processed organic single-crystal transistors with the mobility around 10 cm^2/Vs. We demonstrate a new methodology to fabricate large-area displays due to the high on-current density of the crystal TFTs, drastically reducing total area of the TFTs in a whole active matrix sheet.

OLED3 - 2
16:40

Gate-Bias and Temperature Dependence in C8-BTBT Thin Film Transistor with MoO_3/Au Electrodes

S. Shaari[,**], S. Naka[*], H. Okada[*]*

[*]Univ. of Toyama, Japan
[**]Univ. Malaysia Perlis, Malaysia

We have investigated gate-bias and temperature dependence of drain voltage-drain current (V_D-I_D) characteristics in C8-BTBT thin film transistor (TFT) using MoO_3/Au electrodes. Temperature dependence V_D-I_D characteristics can be fitted with two possible charge injection mechanism which are Schottky thermionic emission model and Polycrystalline model.

OLED3 - 3 **Moved to OLEDp1-23L poster presentation, see p.145**

OLED3 - 4L
17:00

Effect of Integrated Protection Layer on Photolithographic Patterned Organic Light Emitting Diodes (OLEDs)

T.-H. Ke[*], P. Malinowski[*], A. Nakamura[**], M. Wuyts[,****], D.-l. Gu[*], J.-H. Lee[*,****], S. Steudel[*], D. Janssen[**], Y. Kamochi[***], I. Koyama[***], Y. Iwai[***], P. Heremans[*,****]*

[*]imec, Belgium
[**]FUJIFILM Elect. Materials, Belgium
[***]FUJIFILM, Japan
[****]KU Leuven, Belgium

A small molecule OLED (SMOLED) stack under different photolithography processes is investigated. The effect of the protection layer in OLEDs is studied. The device with protection layer shows lower degradation in efficiency and also higher lifetime (T50) after photolithography. The critical parameters of patterned OLED are discussed.

Author Interviews
17:40 – 18:20, Multipurpose Hall

Thursday, December 8

9:00 - 10:15 **501**

OLED4: OLED Materials I

Chair: H. Kuma, Idemitsu Kosan, Japan
Co-Chair: T. Uchida, Tokyo Polytech Univ., Japan

OLED4 - 1: 9:00 ***Invited*** **Efficient HOMO-LUMO Separation by Multiple Resonance Effect Toward Ultra Pure Blue Thermally Activated Delayed Fluorescence**

T. Hatakeyama, K. Shiren[*]*, K. Nakajima, S. Nomura*[*]*, J. Ni*[*]*, T. Ikuta*[*]

Kwansei Gakuin Univ., Japan
[*]*JNC Petrochem., Japan*

Organic molecules that exhibit ultrapure blue fluorescence based on TADF were synthesized. These molecules consist of three benzene rings connected by one boron and two nitrogen atoms, which establish a rigid polycyclic framework and significant localization of the highest occupied and lowest unoccupied molecular orbitals by a multiple resonance effect.

OLED4 - 2: 9:20 ***Invited*** **High Efficiency Deep Blue Fluorescent Organic Light-Emitting Diodes with Thermally Activated Delayed Process**

D. H. Ahn, G. H. Kim, J. H. Kwon

Kyung Hee Univ., Korea

We report highly efficient deep blue organic light-emitting diodes (OLEDs) using thermally activated delayed fluorescence (TADF) assistant host. The fabricated deep blue OLED device has maximum external quantum efficiency of 19.0% and CIE color coordinates of (0.14, 0.15).

OLED4 - 3 9:40 **Recent Development of the Performance of Blue TADF Emitters for Display Applications**

G. Liaptsis

CYNORA, Germany

We demonstrate our recent development in device performance of our sky-blue and deep-blue dopants which are based on thermally activated delayed fluorescence (TADF) technology. Both emitter systems reach state-of-the-art efficiency. Durable operational device stability is shown by our sky-blue dopants.

OLED4 - 4L: ***Invited*** **Recent Advances in Solution Processed Fluorescent Blue OLEDs - Closing the Gap to Vapor Processed Devices**
10:00

S. Meyer, M. Engel, H. Heil, L.-I. Rodríguez, R. Linge, A. Lackner, B. Burkhart, K. Stegmaier, C. Pflumm, E. Böhm, H. Buchholz

Merck, Germany

We report on preferential horizontal orientation as well as optimized triplet harvesting by triplet-triplet annihilation for fluorescent blue emissive materials processed out of solution. Incorporating latest progress on adjacent layers of hole and electron transport leads to an EQE of ~10% and improved lifetime; thereby approaching today's vapor device performance.

Author Interviews
10:30 – 11:10, Room 201

10:30 - 13:00 **Multipurpose Hall**

Poster **OLEDp1: OLED Poster**

OLEDp1 - 1 **Depth-Sensitive Analysis of Organic Thin Film by GCIB and XAS**

E. Takahashi, D. Yamauchi, K. Imanishi, S. Suehiro, Y. Suzuri[*], Y. Muramatsu[**], E. M. Gullikson[***]

Sumika Chem. Analysis Service, Japan
[*]Yamagata Univ., Japan
[**]Univ. of Hyogo, Japan
[***]Lawrence Berkeley Nat. Lab., USA

We developed a method for analyzing molecular orientation in thin film by soft X-ray absorption spectroscopy (XAS) and argon gas cluster ion beam (GCIB) sputtering technique. The method enabled the analysis of multilayered organic thin films with depth information, which will contribute to the optimization of manufacturing process.

OLEDp1 - 2 **Orthogonally Polarized OLED for High Brightness 3D Display**

J.-H. Jung, D.-M. Lee, H. B. Park, Y.-J. Lee, G.-D. Lee,[*] C.-J. Yu, J.-H. Kim

Hanyang Univ., Korea
[*]Dong-A Univ., Korea

We proposed a polarized organic light emitting diode (pOLED) with patterned with orthogonal directions for high brightness three-dimensional (3D) display. The orthogonally patterned pOLED makes right- and left-handed circularly polarization with a conventional quarter wave plate without any loss of light.

OLEDp1 - 3 **Withdrawn**

OLEDp1 - 4 **Hybrid White OLEDs with Color Stability Utilizing Blue Emission Supporting Layer**

G. J. Yun[*], Y. K. Jeong[*], J. C. Han[*], T. J. Yoon[**], H. J. Baek[**], S. E. Lee[**], Y. K. Kim[**], W. Y. Kim[,***]*

[*]Hoseo Univ., Korea
[**]Hongik Univ., Korea
[***]McMaster Univ., Canada

We fabricated hybrid WOLEDs with emission supporting layer (ESL) composed of TPBi as electron transport layer (ETL) with blue fluorescent emitting material such as 4P-NPD. The hybrid WOLED has single-emissive layer (SEL) with doping 4P-NPD into ETL additionally. We investigated electro-optical characteristics of hybrid WOLEDs.

OLEDp1 - 5 **Effects of Electron Transport Layer in High Efficiency Perovskite Light-Emitting Diodes**

S. J. Kim[,**], C. Y. Moon[*], T. W. Jeon[*], S. O. Kim[*], S. G. Lee[**], Y. M. Ha[**]*

[*]KAIST, Korea
[**]LG Display, Korea

We established a uniform $CH_3NH_3PbBr_3$ ($MAPbBr_3$) perovskite thin film as an emitting layer by using nano-grain engineering with non-solvent treatment. High efficiency perovskite LEDs are successfully demonstrated with solution-processed electron transport material, BCP, due to superior electron transport and hole blocking property.

OLEDp1 - 6 **Rb_2CO_3 as an n-Type Dopant in Enhancing the Electron Injection of Organic Light-Emitting Devices**

Y.-H. Liu, M.-C. Li, H.-W. Lu, C.-T. Tsai, S.-Y. Chu

Nat. Cheng Kung Univ., Taiwan

A new electron injection layer (EIL) of doping rubidium carbonate (Rb_2CO_3) in organic light-emitting diodes (OLEDs) has been investigated. The maximum luminance and current efficiency compared to the standard device are increased by 71.8% and 30.7%, respectively.

OLEDp1 - 7 **High Efficiency Blue Phosphorescent Organic Light-Emitting Diodes with Double Emitting Layers**

T. L. Chiu, Y.-H. Hung, J.-J. Huang[*], M.-K. Leung[*], J.-H. Lee[*], H.-C. Ho[**]

Yuan Ze Univ., Taiwan
[*]Nat. Taiwan Univ., Taiwan
[**]ITRI, Taiwan

A blue phosphorescent organic light-emitting diode (OLED) with double emitting layer design exhibits an enhanced efficiency performance (56 cd/A, 50 lm/W, 25%EQE). The double emitting layers were constructed by our new materials such as a bipolar 9-(2-(4,5-diphenyl-4H-1,2,4-triazol-3-yl)phenyl)-9H-carbazole (CbzTAZ) host and an electron-transporting 2,2'-bis(1-phenyl-1H-benzo[d]imidazole-2-yl)biphenyl (BImBP) doping with blue emitter, bis[2-(4,6-difluorophenyl)pyridinato-C2,N](picolinato)iridium(III) (FIrpic).

OLEDp1 - 8 Withdrawn

OLEDp1 - 9 Withdrawn

OLEDp1 - 10 High Efficiency Deep Blue Organic Light-Emitting Diodes Using Thermally Activated Delayed Fluorescence Emitter

H. I. Yang, G. W. Kim, J. B. Im, G. H. Kim, J. H. Kwon

Kyung Hee Univ., Korea

We report a highly efficient deep-blue TADF emitter, KHU-TB. The KHU-TB structure was designed by introducing rigid acceptor moiety. The rigid molecular structure improved not only PLQY also reduced exciton lifetime, which lead to high EQE of 24.5%, deep-blue color coordinates of (0.15, 0.15) and reduced efficiency roll-off.

OLEDp1 - 11 Organic Thin Film Transistors by Using an Insulator/ Protein Overlayer and Their Applications

I. Bae, H. G. Jeon, W. S. Lee, J. N. Huh, Y. Aggarwal, B. Park

Kwangwoon Univ., Korea

We present our study of the effect of an insulator/protein overlayer deposited onto active layers in organic thin film transistors (OTFTs). The improved performance of OTFTs was found to stem from the formation of a second current channel in the active layer via the negatively charged protein overlayer. .

OLEDp1 - 12 Withdrawn

OLEDp1 - 13 Enhanced Performance of Light-Emitting Diodes Based on Quantum Dot-Semiconducting Polymer by Engineering Emission Layer Morphology

Y. Lee[*], A. Fokina[**], J. H. Chang[,***], M. Park[*], Y. Sung[*], W. K. Bae[***], K. Char[*], C. Lee[*], R. Zentel[**]*

[*]Seoul Nat. Univ., Korea
[**]Johannes Gutenberg Univ., Germany
[***]KIST, Korea

Red quantum dot light emitting diode based on chemically grafted $CdSe/Zn_{1-x}Cd_xS$ core-shell-structure quantum-dot newly-synthesized semiconducting polymer hybrids, which exhibit improved device performances in terms of external quantum efficiency, current density and luminescence was studied.

OLEDp1 - 14L Withdrawn

OLEDp1 - 15L Diameter Controllable Nano Lens Array Fabrication for Highly Efficient and Color Stable OLEDs Using a Maskless Deposition

Y.-S. Park, D.-H. Cho, K.-H. Han, J. Lee, Y. Han*, N.S. Cho, B. Yu, J.-J. Kim*, J.-I. Lee*

ETRI, Korea
**Seoul Nat. Univ., Korea*

A nano lens array (NLA) solves the current issues of light extraction technologies of AMOLED displays. A lens diameter is tuned to be applied to OLEDs by controlling process parameters. The NLA increases the light extraction efficiency by 1.6 times, shows excellent spatial uniformity, and does not induce image blurring.

OLEDp1 - 16L Suppression of Color Shift of Organic Light Emitting Diodes by Introduction of Circular Polarizer with Nanoporous Film

W. Y. Lee, N. S. Kim, M. C. Suh

Kyung Hee Univ., Korea

To improve poor viewing angle characteristics of top emission organic light emitting diodes, we applied nanoporous film (NPF) formed on the circular polarizer (CP). We got the improved viewing angle characteristics ($\Delta u'v'$ in CIE 1976 with viewing angle, from 0.096 to 0.051).

OLEDp1 - 17L Role of Electron Transport Materials on the Efficiency of Solution-Processed Red Phosphorescent OLEDs with Thermally Evaporated Blue Common Structure

D. H. Shin, M. C. Suh

Kyung Hee Univ., Korea

We prepared highly efficient solution processed red phosphorescent OLEDs with blue common layer structure. We found that the efficiency is dependent upon the type of electron transport materials utilized for this architecture. New electron transport material with fluoranthene and benzoquinoline groups resulted in higher current efficiency than the conventional ETL.

OLEDp1 - 18L Investigating the Role of Co-host EML Architecture on Emission Efficiency in PHOLEDs

U. Lee, W. Park, Y. Kang, H. Lim, D. Yune, T.-K. Lee, S. S. Kim

Sungkyunkwan Univ., Korea

CBP:TPBi co-host layer is introduced to control carrier accumulation and exciplex formations at emission layer of PHOLEDs. When ratio of TPBi in co-host layer is increased, hole accumulation and exciplex formation at co-host are increased. In this device, hole accumulation effect is dominant factor to emission than exciplex formation.

OLEDp1 - 19L Organic Multi-function Diodes Based on Rubrene/ PTCDI-C13 Stack

M. Yamada, S. Naka, H. Okada

Univ. of Toyama, Japan

We have demonstrate an organic multi-function diode based on rubrene as an emitter/donor and perylene derivative PTCDI-C13 as an electron transporter/ accepter. The device shows electroluminescent properties with a maximum luminance 970 cd/m^2, photodiode with high on/off ratio of 5×10^4, and photovoltaic properties with a power conversion efficiency 0.15%.

OLEDp1 - 20L Analysis of Interface Mixing Effects of Solution Processed Organic Lighting Emitting Diodes by Impedance Spectroscopy

D. A. Ahn, D. H. Shin, M. C. Suh

Kyung Hee Univ., Korea

We fabricated green phosphorescent OLEDs using solution process and analyzed the device characteristics using impedance spectroscopy. Charge carriers inject more easily into EML with non-rinsing process in solution processed OLEDs. Thus, we found that partially interface mixing could improve performance of OLEDs

OLEDp1 - 21L UV-Ozone-Treated Ultra-Thin Al_2O_3-Doped ZnO Film as Anode Buffer Layer on Organic Light Emitting Diodes

H.-W. Lu, P.-C. Kao[*]*, S.-Y. Chu*

Nat. Cheng Kung Univ., Taiwan
[*]*Nat. Chiayi Univ., Taiwan*

The UV-ozone treated 2 wt% Al_2O_3-doped ZnO layers for 1 nm as anode buffer layer were prepared by thermal evaporation. The current density enhanced from 235 to 355 mA/cm^2, luminance enhanced from 7588 to 13470 cd/m^2, and efficiency enhanced from 3.2 to 3.8 cd/A.

OLEDp1 - 22L Effects of Ultra-Thin Cerium Fluoride as Anode Buffer Layer of Organic Light Emitting Diodes with Thermal Activated Delayed Fluorescence

H.-H. Su, H.-W. Lu, P.-C. Kao[*]*, S.-Y. Chu*

Nat. Cheng Kung Univ., Taiwan
[*]*Nat. Chiayi Univ., Taiwan*

The external quantum efficiency was enhanced by UV-ozone treated 0.5 nm CeF_3 film as anode buffer layer from 14 to 17%. The current density enhanced from 170 to 312 mA/cm^2, luminance enhanced from 14780 to 24326 cd/m^2, and efficiency enhanced from 24.4 to 29.2 cd/A.

OLEDp1 - 23L **Analysis of Degradation Mechanism in PHOLED with Multi-Layer Using Impedance Spectroscopy**

S. G. Lee, H. D. Lee, K. S. Kim, H. C. Choi, B. C. Ahn, I. B. Kang

LG Display, Korea

In this study, two different multi-layer EMLs were analyzed using the impedance spectroscopy. They were deposited by scanning method with linear source system. We found a big difference in the lifetimes by the device structures. Also, we can understand degradation mechanism.

10:30 - 13:00 **Multipurpose Hall**

***Poster* OLEDp2: OLED/LIT Poster**
Special Topics of Interest on Lighting and Quantum Dot Technologies

OLEDp2 - 1 **Efficiency Enhancement of Blue Organic Light-Emitting Diodes Using a Corrugated Structure**

M. Hwang, H. Lee, S. M. Cho

Sungkyunkwan Univ., Korea

Silver-nanowire embedded flexible transparent electrode was fabricated via fully roll-to-roll process. Silver-nanowire was coated with mayer rod and embedded with NOA63. Sheet resistance of fabricated electrode was below 8 ohm/sq and transmittance was over 85%. The RMS value of surface roughness was below 10 nm.

OLEDp2 - 2 **Quantum Dot Light-Emitting Diode with Ligand-Controlled $CuInS_2$/ZnS Quantum Dot**

M. Hishinuma, J. Maki, T. Fukuda, N. Kamata, Z. Honda

Saitama Univ., Japan

The organic ligand of the semiconductor quantum dot prevents the reduced current efficiency of the quantum dot light-emitting diode. In this research, we investigated the inverted structure with the $CuInS_2$/ZnS quantum dots, and achieved the reduced threshold voltage by the decompression annealing to remove the organic ligand.

OLEDp2 - 3 **Reduced Exciton Lifetime in TADF Materials for Blue OLEDs**

Y. C. Kim, G. H. Kim, G. W. Kim, J. B. Im, J. H. Kwon

Kyung Hee Univ., Korea

We report newly designed and synthesized TADF molecule, KHU-TB-1. The KHU-TB-1 demonstrated a short exciton lifetime of 7.2 μs compared to the reference TADF emitter molecule (TCzTRz:9.5 μs). The fabricated blue OLED with KHU-TB-1 emitter exhibits maximum EQE and luminance of 22.0% and 13,630 cd/m^2. It also demonstrated an improved roll-off characteristic and color-quality.

OLEDp2 - 4L **Integration of Patterned Quantum Dot Film with Blue OLED for the Realization of Rec. 2020 Color Gamut**

H.-J. Kim, M.-H. Shin, S.-E. Kim, S.-J. Park, Y.-J. Kim

Yonsei Univ., Korea

We applied patterned red and green quantum dot (QD) to blue organic light emitting diode (OLED) as light converting component and found optimized characteristics of patterned QD for wide color gamut by simulation and realized 97% of Rec. 2020 standard that is NTSC 130% in CIE 1931 by experiments.

10:30 - 13:00 **Multipurpose Hall**

***Poster* OLEDp3: OLED/PE Poster**

Special Topics of Interest on Printed Electronics

OLEDp3 - 1 **Investigation on Poly(3-Hexylthiophene) Nano-Fiber Transistors with Hybrid Nano Compositor**

M.-H. Chih, C.-E. Tsai, Y.-T. Chen, Y.-J. Li, Y.-W. Wang

Nat. Changhua Univ. of Education, Taiwan

We investigated Poly(3-hexylthiophene)(P3HT) transistors characteristics with different nano material compositors. Moderate doping would enhance P3HT device properties and their resist to water/oxygen, even increase the ordering of molecule structure. In this article, we choose water absorbent/resist polymers, well-order liquid crystal, and metal oxide nanoparticles to modulate P3HT transistors' properties.

OLEDp3 - 2 **Investigation of Solution Process Rubrene Transistors under Different Annealing Conditions**

Y.-H. Cheng, P.-C. Lai, P.-Y. Tsai, K.-C. Fan, Y.-W. Wang

Nat. Changhua Univ. of Education, Taiwan

We investigated the characteristics transition of solution processed Rubrene transistors under various annealing temperature and concentrations. Rubrene has been proven as a high potential organic semiconductor. Solution process promises its application in large area coating and cost down. The fabricated device achieved a mobility ~10^{-4} cm^2/Vs and on/off ratio ~10^3.

OLEDp3 - 3 **Multiple Horizontal-Dip-Coating of Small Molecular Emission Layers for Solution-Processable Organic Light-Emitting Devices**

H. G. Jeon, W. S. Lee, J. N. Huh, Y. Aggarwal, B. Park

Kwangwoon Univ., Korea

We report an investigation of small molecular organic light-emitting diodes, consisted of solution-processable light-emitting layers (EMLs) using a horizontal-dip coating method with multiple coating cycles. It was shown that the formation of nano-pinhole defects in the EMLs was found to decrease with an increase in the number of coating cycles.

OLEDp3 - 4L Low Cost Process for Integrated Substrates of Flexible OLEDs using Printing and Plating

D.-H. Cho, O. E. Kwon, Y.-S. Park, B. G. Yu, J. Lee, J. Moon, H. Cho, H. Lee, N.-S. Cho

ETRI, Korea

We have developed cost-effective process for a flexible integrated substrate of OLEDs with a screen printing, an electroless copper plating, and a deboding process. A photolithographic method and expensive materials such as polyimide and silver did not used. The OLED devices with the integrated substrates were successfully fabricated.

----- Lunch -----

16:50 - 18:10 **501**

OLED5: OLED Materials II

Chair: H. Kuma, Idemitsu Kosan, Japan
Co-Chair: K. Monzen, Nissan Chem. Ind., Japan

OLED5 - 1: *Invited* 16:50 Molecular and Device Architecture Design for Highly Efficient and Durable OLEDs Based on TADF

D. P.-K. Tsang[*], T. Matsushima[,**], C. Adachi[*,**,***]*

[*]Kyushu Univ., Japan
[**]JST, Japan
[***]Int. Inst. for Carbon Neutral Energy Res., Japan

We report a way to greatly improve the stability of OLEDs having a green emitter exhibiting thermally activated delayed fluorescence (TADF), by introducing ultrathin (1 to 3 nm) interlayers of 8-hydroxyquinolinato lithium (Liq) between hole-blocking layer and its surrounding emissive and electron-transport layers.

OLED5 - 2: *Invited* 17:10 Design of Emitters and Charge Transporters for Highly Efficient Organic LEDs

H. Kaji, Y. Wada, K. Shizu, S. Kubo, K. Suzuki, T. Fukushima, C. Adachi[,**]*

Kyoto Univ., Japan
[*]Kyushu Univ., Japan
[**]JST, Japan

We show a simple high throughput screening method for developing thermally activated delayed fluorescence (TADF) materials. Using this method, we identified a number of molecules with favourable TADF characteristics. Here, we present some example TADF molecules and their applications to organic light emitting diodes, including solution-processed and host-free devices.

OLED5 - 3 **High Efficiency and Long Lifetime Fluorescent Blue**
17:30 **Devices**

H.-L. Huang, P.-W. Hsu, C.-J. Lin
eRay Optoelect. Tech., Taiwan

A new deep-blue dopant BD with EL spectrum of 448 and 475 nm was designed and developed. The blue device exhibited blue color with CIEy of 0.141, EQE of 8.31%, and LT70 lifetime of 11,960 hrs. The stacked WOLED device using BD shows 28.16% EQE and lifetime is around 100,000 hrs.

OLED5 - 4 **Highly Efficient and Low Efficiency Roll-Off Green**
17:50 **Thermally Activated Delayed Fluorescence**

J. B. Im, G. H. Kim, J. S. Moon, K. J. Kim, J. Y. Lee, J. H. Kwon
Kyung Hee Univ., Korea

We reports highly efficient green thermally activated delayed fluorescence emitters (KHU-TG1, KHU-TG2) with small energy gap between the singlet-triplet states (0.08 eV) and short delayed fluorescence lifetime (τ_d) (2.68, 1.36 μs). Fabricated devices performed maximum external quantum efficiency (EQE) of 28.8, 23.2% with improved roll-off characteristic.

Author Interviews
18:10 – 18:50, Multipurpose Hall

Supporting Organizations:
The Japanese Society of Printing Science and Technology

Panel Discussion on Display Technologies for Sports in Japanese

Organized by International Display Workshops
General Incorporated Association
Tuesday, Dec. 6, 2016

16:45-18:00

Room 501 (5F)

Fukuoka International Congress Center
Detailed information will be announced at
http://sport.idw.or.jp/

Workshop on 3D/Hyper-Realistic Displays and Systems

Wednesday, December 7

13:00 - 13:10 **Main Hall**

Opening

Opening Remarks
13:00

N. Inoue, Program Chair, 3DSA
M. Tsuchida, 3D-WS Chair, IDW

13:10 - 14:30 **Main Hall**

3DSA1/3D1: Holography

Chair: N. Hur, ETRI, Korea
Co-Chair: T. Kakue, Chiba Univ., Japan

3DSA1/ 3D1 - 1: 13:10 ***Invited*** **Digital Holographic Display for 360° Viewable 3D Color Image Rendering and Performance Evaluation**

J. Kim, K. Hong, Y. Lim, J. Kim, H.-G. Choo
ETRI, Korea

We present our novel approach on the implementation of digital holographic display, which is capable of rendering 360° viewable holographic image floating over a table-type display. 1,024 holograms for different perspective views are time multiplexed by a fast-operating DMD device to cover 360° of viewing zone around the image.

3DSA1/ 3D1 - 2 13:30 **Projection-Type Holographic Three-Dimensional Display**

K. Wakunami, R. Oi, T. Senoh, Y. Ichihashi, M. Okui, K. Yamamoto
NICT, Japan

To increase both display size and the visual angle at the same time, here we show a novel projection-type holographic 3D display in which a digitally designed holographic optical element (DDHOE) fabricated by the wavefront printing technique and digital holographic projection technique was combined for the first time.

3DSA1/ 3D1 - 3 13:50 **Generation of Color Three-Dimensional Images by Viewing-Zone Scanning Holographic Display**

Y. Matsumoto, Y. Takaki

Tokyo Univ. of A&T, Japan

The viewing-zone scanning holographic display can enlarge both the viewing zone and screen size. In this study, the color image generation technique is developed. The time-multiplexing technique is utilized; R, G, and B lasers sequentially illuminate a MEMS-SLM operating at a high framerate and is scanned by a horizontal scanner.

3DSA1/ 3D1 - 4 14:10 **Development of Run-Length-Based Fourier Transform**

T. Akamatsu, T. Shimobaba, T. Kakue, T. Ito

Chiba Univ., Japan

High-speed image processing is required in various technologies. The calculation time of image processing depends on the number of pixels. On the other hand, data compression can reduce the number of pixels. In this paper, we have developed Fourier transform algorithm on run-length compressed data.

----- Break -----

14:40 - 16:00 **Main Hall**

3D2/3DSA2: Visualization and AR
Special Topics of Interest on AR/VR and Hyper Reality

Chair: J.-W. Kim, ETRI, Korea
Co-Chair: H. Kakeya, Univ. of Tsukuba, Japan

3D2/ 3DSA2 - 1: 14:40 ***Invited*** **Progress on Head-Worn Display Technology for Augmented Reality**

Y. Wang, D. Cheng, C. Xu

Beijing Inst. of Tech., China

Several problems with significant impact on the development of head-worn displays for augmented reality are discussed, including the size and weight, the contradiction between large field-of-view and high resolution, and accommodation and convergence disparity. Methods proposed by Beijing Institute of Technology to solve or alleviate these problems are presented.

3D2/ 3DSA2 - 2 15:00 **Efficiency Balance for a See-Through Head-Mounted Display with Microstructures**

X.-C. Wang, K.-W. Zhao, Y.-D. Lu, C.-Y. Chuang, M.-C. Chan, J.-W. Pan

Nat. Chiao Tung Univ., Taiwan

The efficiency balance phenomenon for see-through head-mounted displays with different microstructure conditions can be found both theoretically and using optical simulation software. The simulation is based on factors taken from previous research studies. It's found that the balance value of the optical efficiency remains almost constant under different microstructure conditions.

3D2/ 3DSA2 - 3 15:20 **Changing Perceived Leg Length and Motion on Virtual Walking Generator**

T. Hamada, K. Yoshiho, R. Kondo, Y. Ikei[*], K. Hirota[**], T. Amemiya[***], M. Kitazaki

Toyohashi Univ. of Tech., Japan
[*]Tokyo Metropolitan Univ., Japan
[**]Univ. of Electro-Commun., Japan
[***]NTT, Japan

Disabled people cannot freely walk around. To overcome it, we developed a virtual walking generator that users can feel realistic walking sensations based on their body shape, and found that perceived leg length and walking motion were changed by altering timings of foot vibrations as a temporal factor of footsteps.

3D2/ 3DSA2 - 4 15:40 **Sparse Registration for Small Amount of Overlap between Point Clouds**

L. Sun, Y. Manabe, N. Yata

Chiba Univ., Japan

This paper proposes a framework for point clouds registration of small amount of overlap. This proposed method resamples point clouds into a large number of small point cloud groups, then matches the group between point clouds by Plane Distance histogram (PAD) of each groups based on sparse representation.

----- Break -----

16:20 - 17:40 **Main Hall**

3DSA3/3D3: Autostereoscopic Display

Chair: Y.-P. Huang, Nat. Chiao Tung Univ., Taiwan
Co-Chair: Y. Ichihashi, NICT, Japan

3DSA3/ 3D3 - 1 **Withdrawn**

3DSA3/ 3D3 - 5L 16:20 **Implementation of Volumetric 3D Display with Liquid Crystal Based Fast Switching Active Optical Shutter and Polarization Controller**

K.-I. Joo, H. Park, M.-K. Park, H.-D. Jeong, S.-W.Min[*]*, H.-R. Kim*

Kyungpook Nat. Univ., Korea
[*]*Kyung Hee Univ., Korea*

We develop the volumetric 3D display by using liquid crystal based fast switching active optical shutter and polarization controller. Our proposed volumetric 3D display can project the clear depth image without image blurring at each active optical shutter to enhance the depth perception of 3D volume image.

3DSA3/ 3D3 - 2 16:40 **Parallax Barrier Based Autostereoscopic Display with a Deep Viewing Zone**

H. Kakeya, H. Takahashi, K. Okada

Univ. of Tsukuba, Japan

A full HD autostereoscopic display with a deep viewing zone is attained based on time-division multiplexing parallax barrier. Viewing zone is expanded by changing the width of the barrier in accordance with the viewer's position. Fine tuning of the barrier width is realized by utilizing subpixel structure of LCD panels.

Also presented in Innovative Demonstration Session (see p. 264)

3DSA3/ 3D3 - 3 17:00 **Time-Multiplexing Multi-View Three-Dimensional Display Using Virtually Moving Microlens Array**

M.-K. Park, B. Kim, K.-I. Joo, H. Park, Y.-S. Kim[*]*, G. Lee*[*]*, H.-R. Kim*

Kyungpook Nat. Univ., Korea
[*]*ETRI, Korea*

We propose time-multiplexing auto-stereoscopic 3D display system using the virtually moving microlens array operated electrically to enhance the angular resolution without the decrease of the lateral resolution. To prove the proposed concept experimentally, we fabricated 5.5-in. 20-view auto-stereoscopic 3D mobile display.

3DSA3/ 3D3 - 4 17:20 **Design of Portable LF Display for High-Quality 3D View Generation**

G. Lee, H. Eum, E. Lee, H. Lee, W.-S. Cheong, N. Hur, B. Kim[*]*, J. J. Kwon*[*]

ETRI, Korea
[*]*Samsung Display, Korea*

This paper introduces an implementation of portable light field (LF) display to reconstruct full-parallax LF images. Specifically, this paper proposes an algorithm that can generate elemental image from full-parallax multi-view images in the consideration of depth range at LF display.

Author Interviews
17:40 – 18:20, Multipurpose Hall

Thursday, December 8

10:30 - 13:00 **Multipurpose Hall**

***Poster* 3Dp1/3DSAp1: 3D and Hyper-Realistic Systems and Applications 1**

Special Topics of Interest on AR/VR and Hyper Reality

3Dp1/ 3DSAp1 - 1 **Research on Binocular Parallax 3D Display Device with Liquid Crystal Barrier**

X. Liu, G. Yin, M. Peng, J. Shao, Y. Zhang, K. Chao

BOE Tech. Group, China

A theoretical model for 3D display's crosstalk simulation was constructed. The major parameters that influence view distance are shrink ratio, aperture ratio and barrier position. The curved 3D display device is also discussed, which shows an intresting character that the crosstalk-free zone distorts like a curvature.

3Dp1/ 3DSAp1 - 2 **Does Eye Strain Decrease after Observing 3D Imaging on the Light Field Display?**

M. Shoda, T. Iwane, R. Niimi[*]

Nikon, Japan
[*]*Niigata Univ., Japan*

We examined whether observing light field display decreases eye strain than lenticular display. Light field display did not alter eye strain, though it enhanced accommodation at far location. We concluded that light field display enhanced stereognostic sense without heavier eye strain.

3Dp1/ 3DSAp1 - 3 **Developing a Photometric Device for Generating Quality Texture and Normal Map**

Y.-C. Chen, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

We develop a 3D image capturing device for estimating the surface normals and capturing the texture from target object simultaneously. Several experiments are carried out. In addition, we not only analyse different arrangements of illuminants may cause distinguishing result, but also discuss how to refine by the proposed approach.

3Dp1/ 3DSAp1 - 4 **Optical Approach for the Correlation of Micro Lens from 3D Display System by Measurement System**

J. Seo, Y. M. Jeon, Y. J. Ahn, S. J. Huh, J. J. Kwon, Y. J. Park, W. K. Choe, T. W. Kang, H. Y. Chu

Samsung Display, Korea

In this study on analyze optical method for the surface profile of a micro-lens using a interferometer. This Optical system could measure to the shape and the refractive index profile of the lens. Simulated for effects on the illuminance area by the fill factor.

3Dp1/ 3DSAp1 - 5 **CNN-Based Pedestrian and Vehicle Detection Using Stereo Camera**

G.-C. Lee, J. Yoo

Kwangwoon Univ., Korea

In this paper, we propose a pedestrian and vehicle detection algorithm based on CNN using a stereo camera. In the proposed algorithm, object candidates are first obtained by using the disparity from the stereo camera. Then, the objects are recognized by the CNN which has a similar architecture of AlexNet.

3Dp1/ 3DSAp1 - 6 **GPU Acceleration of Hologram Generation Based on Ray-Sampling Plane**

H. Sato[,**], T. Kakue[*], K. Wakunami[**], Y. Ichihashi[**], R. Oi[**], K. Yamamoto[**], T. Shimobaba[*], T. Ito[*]*

[*]Chiba Univ., Japan
[**]NICT, Japan

We accelerated hologram generation based on ray-sampling plane by GPU. The computational time by CPU was 20.0s, and the computational time by GPU was 0.112s. We achieved to generate a 2048×2048-pixels hologram by GPU approximately 200 times faster than generating it by CPU.

3Dp1/ 3DSAp1 - 7 **Mobile-Type Color Binocular Holographic Display System**

K.-J. Oh, M. S. Yoon, H.-G. Choo, J. Kim

ETRI, Korea

In this paper, we present a mobile-type color binocular holographic display system. The proposed binocular holographic display system is designed based on 5.5-in. transmissive liquid crystal display (LCD) panel and adopts viewing window based approach.

3Dp1/ 3DSAp1 - 8 **Waveguide Holograms Attached on LCD Panel for a Hybrid Display System**

W.-K. Lin[,**], B.-S. Lin[*], W.-C. Su[**]*

[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Changhua Univ. of Education, Taiwan

In this paper, a hybrid display system is presented. The display system offers 2D information via a liquid crystal display and simultaneously offers 3D information via a waveguide hologram. The waveguide hologram system has a small thickness and is compatible with LCD panel.

3Dp1/ 3DSAp1 - 9 **Holographic Device for Generating Collimated Beam by Using a LED**

Y.-J. You[*], W.-K. Lin[,**], Q.-Y. Chen[*], B.-S. Lin[**], W.-C. Su[*]*

[*]Nat. Changhua Univ. of Education, Taiwan
[**]Nat. Chiao Tung Univ., Taiwan

In this study, we design a small size device to produce a collimated beam by using a LED. The generated collimated beam from the device can be used to reconstruct holograms. The collimated light device consist of a green LED, a converging lens and a hologram.

3Dp1/ 3DSAp1 - 10 **Study on Compact Holographic Head-Mounted Display for Augmented Reality**

E. Murakami, Y. Oguro, Y. Sakamoto

Hokkaido Univ., Japan

This paper proposes a compact holographic HMD system for AR. The holographic HMD system can reconstruct the images at a free depth with lightweight and compact structure. The experimental result shows that an AR scene is correctly displayed by the holographic HMD system.

Also presented in Innovative Demonstration Session (see p. 262)

3Dp1/ 3DSAp1 - 11 **Mixed Display Method for Real Objects and CG Texts in Electronic Holography**

R. Oi, Y. Ichihashi, T. Senoh, M. Okui, K. Wakunami, K. Yamamoto

NICT, Japan

We present an electronic holography display, which provide CG texts in front of the real scene objects. Two types of displaying methods were studied. One is transparency text display and the other is solid text display. An experimental result shows that the solid text provide better view for the observers.

3Dp1/ 3DSAp1 - 12 **Improvement of Color Reproducibility of Full-Color 3D Display Using Binary Phase Distribution**

S. Harada, K. Nitta, O. Matoba

Kobe Univ., Japan

Color reproducibility of the reconstructed full-color image is improved by using the optimized binary phase distribution and the speckle averaging. The dummy area is introduced to control the power. Numerical and experimental results are presented.

3Dp1/ 3DSAp1 - 13 **Improvement of Full-Color Image Quality Using 1D Phase Modulation SLM by Iterative Fresnel Method with Dummy Area**

R. Toritani, K. Nitta, O. Matoba

Kobe Univ., Japan

A full-color 3D display using a 1D phase-modulation spatial light modulator is presented. We presented a method to improve the reconstructed image quality by the optimized phase distribution by Fresnel iterative method with dummy area. Numerical results are presented.

3Dp1/ 3DSAp1 - 14 Speeding Up of Image Quality Improvement Using Amplitude Inverse Filter Method in Random Phase-Free Hologram

Y. Nagahama, T. Shimobaba, T. Kakue, T. Ito

Chiba Univ., Japan

The combination of the random phase-free method and Gerchberg-Saxton (GS) algorithm succeeded in improving the image quality of holograms. However, the GS algorithm takes a long computation time. In this research, we propose faster methods for the image quality improvement of the random phase-free hologram.

3Dp1/ 3DSAp1 - 15 Surface Quality Inspection of Micromechanical Parts Based on Phase-Shifting Methods

T.-Y. Hsiao, Y.-L. Liu, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

Phase-shifting method, which is an optical measurement method and able to detect the surface profiles of the object, has many capabilities including high speed, high resolution and real-time. In this paper, we propose a practical method which is based on phase-shifting method to inspecting the surface quality of micromechanical parts.

3Dp1/ 3DSAp1 - 16 Grey Relational Analysis of Subjective and Non-Subjective Evaluations during Watching 3D Films

C.-Y. Chen, Y.-H. Su, P.-J. Wu[*], Y.-K. Chen[**], B.-S. Lin[*]

Nat. Taiwan Univ. of S&T, Taiwan
[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Taichung Univ. of S&T, Taiwan

This study proposes an evaluation of the subjective and non-subjective assessments by using Grey Relational Analysis while users watching a 3D video. The proposed method can indicate a reliable relation between subjective and non-subjective evaluations to reduce the possibility of inconsistent results when evaluating the human factors of 3D displays.

3Dp1/ 3DSAp1 - 17 Evaluation of Perceived 3D Structure of Multi-View 3D Medical Image Based on Transparent Visualization: A Psychophysical Study

Y. Sakano[,**], Y. Kitaura[***], K. Hasegawa[***], R. Lopez-Gulliver[***], H. Ando[*,**], S. Tanaka[***]*

[*]NICT, Japan
[**]Osaka Univ., Japan
[***]Ritsumeikan Univ., Japan

As an efficient transparent-rendering method, a stochastic point-based rendering method was proposed recently. In the present study, we found that by applying luminance gradient inherent in this method in addition to the traditional Phong shading to a medical data, perceived 3D structure gets closer to the ground truth.

3Dp1/ 3DSAp1 - 18 **Accommodation Measurement in VR Device of Google Cardboard Type**

H. Kang, H. Hong

Seoul Nat. Univ. of S&T, Korea

Virtual image by VR device was shown only to left eye of the user and the white uniform background was shown to right eye. The accommodation of right eye was measured to change in accord with the position of virtual image seen by left eye.

3Dp1/ 3DSAp1 - 19 **Head Tracking Based Immersive Sound Reproduction for Virtual Reality Display**

C. J. Chun, K. M. Jeon, J. M. Moon, H. K. Kim, J. Yoo[*]

Gwangju Inst. of S&T, Korea
[*]Kwangwoon Univ., Korea

This paper proposes a head tracking-based sound reproduction method to improve auditory realism in a virtual reality environment. To this end, a 4-channel omnidirectional microphone array is used for capturing ambient sounds. Then, a delay-and-sum beamformer is applied to the sounds for estimating the direction of the source.

3Dp1/ 3DSAp1 - 20 **Audio-Haptic Display for a Sense of Walking: Influence of Arm-Swing Interaction and User's Posture on Reproduced Walking in Real Space**

Y. Okuya, Y. Ikei[*], Y. Kamishohara[*], K. Hirota[**], T. Amemiya[***], M. Kitazaki[****]

Univ. Paris-Sud, France
[*]Tokyo Metropolitan Univ., Japan
[**]Univ. of Electro-Commun., Japan
[***]NTT, Japan
[****]Toyohashi Univ. of Tech., Japan

We present techniques to enhance a sense of walking without user's leg motion in 3D soundscape environment. Sound of footsteps and vibratory stimulus at the sole are simulated with physical models, responding to virtual walking steps. A sense of walking was investigated with user's reproduced walk in a real space.

3Dp1/ 3DSAp1 - 21 **Experimental Assessment on Viewer's Impressions of 4K Ultra-High Definition and Multi-View 3D Images**

M. Okui, M. Makino, S. Yoshida, S. Iwasawa, K. Yamamoto

NICT, Japan

We conducted an experimental subjective assessment wherein we compared viewers' impressions of depth sensation on a multiprojector HD-resolution 3D display with those on a 4K ultra-high definition LC display both with and without an interactive viewpoint operation.

3Dp1/ 3DSAp1 - 22 Bodily Reliving Experience Based on Multisensory Passive Stimulation

R. Koide, S. Imao, K. Yamada, N. Saka, K. Tashiro, M. Kurosawa, Y. Ikei, K. Hirota[*], T. Amemiya[**], M. Kitazaki[***]

Tokyo Metropolitan Univ., Japan
[*]Univ. of Electro-Commun., Japan
[**]NTT, Japan
[***]Toyohashi Univ. of Tech., Japan

This paper describes characteristics of a passive stimulation method using a vestibular and proprioceptive device for presentation of body motion sensation while the real body of the user is sitting. The motion of a seat and pedals/sliders was controlled to produce the sensation of a real walking motion.

3Dp1/ 3DSAp1 - 23L Symmetricity in Perceptual Limit of Doubled Image Induced by Linearly Blended Images

M. Date, K. Takeuchi, K. Okami, H. Fujii, H. Kimata, R. Kimura[*], K. Iwata[*], T. Kojima[*], M. Miyao[*]

NTT, Japan
[*]Nagoya Univ., Japan

Linear blending is a useful technique to produce an interpolated image from multiple camera images, especially in real time applications using smooth motion parallax. In this paper we evaluated the symmetricity of perceptual limit in a doubled image induced by linear blending and confirmed the suitability of symmetrical camera alignment.

3Dp1/ 3DSAp1 - 24L Study on Rendering Ultra High-Resolution Image for 3D Models

C.-C. Lee, Y.-L. Liu, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

With the innovation of emerging technologies, museums can reinterpret artifacts. Therefore, it's important to efficiently render high resolution images. We propose a practical solution to render an ultra high resolution image, which has almost no limitation in image size, for 3D digital heritage model based on OpenGL.

3Dp1/ 3DSAp1 - 25L New Directional Backlight of Arc 3D Display for Stereoscopic Display with All Surrounding Viewpoints

R. Ozaki, H. Yamamoto[*], H. Mizushina, S. Suyama

Tokushima Univ., Japan
[*]Utsunomiya Univ., Japan

In order to realize stereoscopic display with all surrounding viewpoints, a new circularly symmetric configuration with a radial parallax barrier has been proposed. All surrounding viewpoints can be successfully achieved by suppressing undesired images by using arc 3D display as a new directional backlight.

3Dp1/ 3DSAp1 - 26L **Developing a Foot Scanner Based on Multiple Laser Triangulation Scanners and One Linear Stage**

W. Huang, T.-H. Lin, Y.-L. Liu

Nat. Taiwan Univ. of S&T, Taiwan

This paper presents a self-developed foot scanner by using three laser scanner modules, a linear stage, and a software algorithm to obtain 3D foot models. The algorithm in this prototype utilizes several reference images for system calibration. Thus, different scanner modules are preciously integrated for reconstructing 3D foot models.

3Dp1/ 3DSAp1 - 27L **A Two-In-One System of Structured Light Scanner and Light Cured Printer**

Y.-L. Liu, H.-T. Yau[*]*, R.-S. Lin*[*]*, Y.-J. Chen*[**]*, T.-H. Lin, J.-Y. Jeng*

Nat. Taiwan Univ. of S&T, Taiwan
[*]*Nat. Chung Cheng Univ., Taiwan*
[**]*Nat. Taiwan Univ., Taiwan*

Additive manufacturing is regarded as the third wave of industrial revolution. The dental industry is also the critical business opportunities. Therefore, most of the dental design and production are transformed into digital solutions. In this paper, we present a two-in-one system of 3D scanner and printer for orthodontics

3Dp1/ 3DSAp1 - 28L **Volumetric 3D Display System Using Rotating Spiral Screen - Evaluation of Image Visibility at a Bright Room -**

S. Suzuki, C. Fujikawa, M. Omodani

Tokai Univ., Japan

We had proposed a novel method of volumetric 3D display, in which multi layers of section images are projected on a rotating spiral screen. In this study, we evaluated dependence of 3D image visibility and screen invisibility to room illuminance when varying illuminance on a screen by image projection.

Also presented in Innovative Demonstration Session (see p. 262)

3Dp1/ 3DSAp1 - 29L **Withdrawn**

14:10 - 16:40 **Multipurpose Hall**

***Poster* 3DSAp2/3Dp2: 3D and Hyper-Realistic Systems and Applications 2**

Special Topics of Interest on AR/VR and Hyper Reality

Special Topics of Interest on Automotive Displays

3DSAp2/ 3Dp2 - 1 **Gradation Expression by Overlap of Voxels in Volumetric Display Composed of Photochromic Materials**

F. Kawashima, R. Hirayama, A. Shiraki, H. Nakayama[*]*, T. Kakue, T. Shimobaba, T. Ito*

Chiba Univ., Japan

[*]*Nat. Astronomical Observatory of Japan, Japan*

We proposed a volumetric display composed of photochromic materials. It can be controlled in a non-contact from the outside. We made a volumetric display that can display different multiple pictures depending on the surface to observe. The gradation expression is realized by overlapping the colored voxels.

3DSAp2/ 3Dp2 - 2 **Viewing Zone Expansion by Blurring Edge Parts in Edge-Based DFD Display**

T. Yamamoto, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We propose the method for enlarging viewing zone in Edge-based DFD display by blurring edge parts. In conventional DFD display, viewing zone is restricted between the overlapped region of front and rear images, that is, within interocular distance. On the other hand, the viewing zone can be widely enlarged over interocular distance by blurring edge parts in Edge-based DFD display.

3DSAp2/ 3Dp2 - 3 **Depth Perception Difference by Only Two Light Sources with Various Distances in Non-Overlapped DFD Display**

R. Takano, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We have proposed Non-overlapped DFD (Depth-Fused 3D) display only by two light sources and clarify those distance limitation for image depth fusion. When the vertical distance between two light sources increases, two light sources become difficult to fuse to one depth and have separated and scattered perceived depths.

3DSAp2/ 3Dp2 - 4 **Large and Deep Edge-Based DFD Display by Blurring Edge Parts**

Y. Nagao, H. Mizushina, S. Suyama

Tokushima Univ., Japan

Large and deep Edge-based DFD display can be achieved by blurring edge parts and increasing observation distance and screen size. Conventional DFD image is separated to front, rear and midpoint regions over 5 arcmin. Front and rear images can be fused to depth even at the image depth of around 17.9 arcmin.

3DSAp2/ 3Dp2 - 5 **Resolution Enhanced 3D Light Field Microscope with Liquid Crystal Wedge**

H.-H. Lee, P.-Y. Hsieh, W.-C. Chu, G. Saavedra[*]*, M. Martinez-Corral*[*]*, Y.-P. Huang*

Nat. Chiao Tung Univ., Taiwan
[*]Univ. de Valéncia, Spain

In this paper, a resolution enhanced light field microscope system with LC devices was proposed. With a LC wedge placed in the light field system, the resolution of light field microscope can be improved by combining light field images with displacement.

3DSAp2/ 3Dp2 - 6 **Implementation of Artifacts Reduced Multi-View Display with High Quality 3D Images**

E. D. Lee, G. Lee, W.-S. Cheong, N. Hur

ETRI, Korea

In this paper, we propose a 16-view display with 4K flat panel display and lenticular lens arrays, which has low inter-view crosstalk about 14%, unnoticeable moiré effect and wide viewing width about 7 times of binocular distance.

3DSAp2/ 3Dp2 - 7 **Floating 3D Interactive Device Using Special Pattern of Spatial-Multiplexed Barrier**

S.-W. Hsu, C.-W. Shih, J.-Y. Wu, C.-H. Ting, Y.-P. Huang

Nat. Chiao Tung Univ., Taiwan

The proposed auto-stereoscopic floating 3D interactive system use multiplexed barrier with special pattern to achieve floating 3D image and have interactive system in the device. The special pattern of sptial-multiplexed can let the observer have the comfortable 3D perceive feeling.

Also presented in Innovative Demonstration Session (see p. 264)

3DSAp2/ 3Dp2 - 8 **Super Multiview Stereoscopic Display Using Time-Division Parallax Barrier**

K. Okada, H. Kakeya

Univ. of Tsukuba, Japan

We attain a high resolution super multiview stereoscopic display based on time-division multiplexing parallax barrier method. By enlarging the distance between the barrier and the image display panels, the interval between the viewpoints is narrowed so that multiple rays enter the pupil, which enables induction of focal accommodation of the viewer.

3DSAp2/ 3Dp2 - 9 **Depth Enhancement of Light Field Microscopy with Fast-Response Hexagonal Liquid Crystal Micro-Lens Array**

H.-A. Lin, C.-Y. Chu, P.-Y. Hsieh, Y.-P. Huang, C.-H. Kuo

Nat. Chiao Tung Univ., Taiwan

In this paper, we proposed a fast response hexagonal liquid crystal micro-lens array for 3D light field microscopy. The property of liquid crystal lens is that it can change the focal length electrically. With this property, the working range in light field microscopy was extended from 0.27 mm to 0.8 mm.

3DSAp2/ 3Dp2 - 10 **Increasing Luminance of Aerial Image Perpendicular to the Table Top**

T. Kobori, H. Yamamoto

Utsunomiya Univ., Japan

This paper proposes a method to increase luminance of an aerial image that is formed perpendicularly to the table top. Our method utilizes a prism sheet to deflect principal rays from an ordinary display. Deflection angle and efficiency have been analyzed and confirmed experimentally with a prototype aerial display.

3DSAp2/ 3Dp2 - 11 **Luminance Improvement of Aerial Double-Layered Display with Polarized AIRR**

S. Ito, H. Yamamoto

Utsunomiya Univ., Japan

We propose novel design of aerial double-layered display with polarized AIRR (aerial imaging by retro-reflection). Four types of structures have been proposed and compared experimentally. We have successfully improved luminance of aerial images of a polarization-processing display without surface polarizer. Aerial double-layered images have been formed with our polarized AIRR.

3DSAp2/ 3Dp2 - 12 **Wide-Screen Head-Up Display with a Projection Lens Array**

T.-S. Yeh, W.-C. Su

Nat. Changhua Univ. of Education, Taiwan

The optical design for a virtual image system in a vehicle is presented. We use a lens array to implement a wide-screen virtual image projection display system. In this system, the virtual image location is in front of the eyebox with a distance of 1500 mm.

3DSAp2/ 3Dp2 - 13 **Formation of Aerial Image with Motion Parallax Generated by Scattered Light on Arcs**

K. Kawai, H. Yamamoto

Utsunomiya Univ., Japan

This paper proposes methods to form aerial image with motion parallax that is generated by scattered light on arcs. Aerial image of an arc 3D display is formed with aerial imaging by retro-reflection (AIRR). Furthermore, our proposed method enables us to stack aerial images by illuminating stacked arc 3D boards.

3DSAp2/ 3Dp2 - 14 **Aerial Imaging with Transparent Acrylic Cubes and Applications for Steganography**

S. Morita, S. Onose, T. Okamoto, H. Yamamoto

Utsunomiya Univ., Japan

This paper proposes aerial imaging by use of transparent acrylic cubes. Arrangements of cubes have been investigated and results shows freedom in arrangements. Furthermore, we have demonstrated a new steganography, which embed a secret LED sign and the secret is decodable by placing a screen at the limited position.

3DSAp2/ 3Dp2 - 15 **Colorizing 3D Objects in Free-Viewpoint Through a Transparent LCD**

Y.-P. Pi, P.-L. Sun, H.-P. Chien, H.-C. Li, Y.-C. Su

Nat. Taiwan Univ. of S&T, Taiwan

A method to colorize 3D objects through a transparent LCD in free-viewpoint is proposed. It uses a video camera to detect eye-sight of a viewer in real-time, and then displays the geometric corrected shadow-less color projection of the 3D objects (achromatic 3D prints or plaster models) onto the transparent LCD.

3DSAp2/ 3Dp2 - 16 **Digital Cosmetic Coloring System for 3D Facial Images**

M.-H. Lin, Y.-P. Pi, H.-S. Chen, P.-L. Sun, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

This study presents a cosmetic simulation system to create a 3D makeup facial image. We use a 3D scanner to capture a model's face, and produce a 3D makeup effect. By introducing skin colors of a reference image into the 3D-scanning image, a pleasing 3D facial image can be created.

3DSAp2/ 3Dp2 - 17 **New Method for Luminance Addition/Subtraction System by Using Polarization Operation in Layered TN-LCDs**

Z. Fan, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We propose a new method to add/subtract luminance in layered TN-LCDs (Twisted nematic liquid crystal displays) by using polarization operation. Our method can successfully achieve the complete control of whole luminance even when one LCD has any luminance.

3DSAp2/ 3Dp2 - 18 **Effect of a Cell Gap with a Bi-Focal LC Lens on 3D Properties in Two-Way Multi-View 2D/3D Display Combining the Bi-Focal LC Lens and HV×DP Panel**

Y. Ibata, J. Matsushima, K. Masumura, T. Asai, T. Sato, K. Shigemura

NLT Techs., Japan

We can narrow down which LC lens cell gap conditions can improve 3D properties achieve a good balance in a two-way multi-view 2D/3D display combining a bi-focal LC lens and HV × DP panel by simulation. Validity of the simulation is verified by experimental results.

3DSAp2/ 3Dp2 - 19 **LCD Panel Design for HMD Based on Retinal Projection Display**

S.-K. Zhou[*], W.-K. Lin[,**], W.-H. Lin[*], B.-S. Lin[**], W.-C. Su[*]*

[*]Nat. Changhua Univ. of Education, Taiwan
[**]Nat. Chiao Tung Univ., Taiwan

A HMD based on retinal projection technology has been successfully demonstrated by using a HOE, an LCD panel and a waveguide. The HMD shows the information from the LCD panel. The requirement arrangement of the LCD panel in this system was discussed.

3DSAp2/ 3Dp2 - 20 **Based on Three Dimensional Gesture and Finger of Mid-Air Interaction Interface with OCR Handwriting**

M.-Y. Lee, S.-C. Yang, S.-C. Wang, Y.-C. Fan

Nat. Taipei Univ. of Tech., Taiwan

Accompany with interactive media increasingly vigorous development. The application of embodied interactive system has received frequent usage. This system has become popular whatever in company, activities, exhibition hall, museum, or game device. The most nature and easy way to write character is achieved through our hand.

3DSAp2/ 3Dp2 - 21 **Layered Multi-View DFD Display for Improving Perceived Depth and Image Shift Smoothness even at Small Number of Multi-View**

T. Eguchi, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We propose a new 3D display, “Layered multi-view DFD (Depth-fused 3D) display” with mixed various kinds of parallax components, resulting in good monocular depth perception and smooth image shift, even at small number of multi-view. These are improved when the gap between front and rear displays is large and appropriate.

3DSAp2/ 3Dp2 - 22 **Perception of Many Transparent Layered Images in the Depth-Fused 3D Display**

K. Sakamaki, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We have proposed how to make many transparent layered images in Depth-fused 3D display. Three transparent layered images can be displayed by using four layered LCDs. In this paper, we evaluated the perceived depth dependences in three layered transparent images by using four image planes.

3DSAp2/ 3Dp2 - 23L **Coding Performance for Moving Picture of Integral Three-Dimensional Image Using 3D-HEVC**

K. Hara, M. Kawakita, T. Mishina, H. Kikuchi

NHK, Japan

To develop coding techniques for integral image, we investigated the performance of 3D-HEVC for the moving elemental images. We coded multi-view images converted from the elemental images, and carried out the objective and subjective assessments. The results show that 3D-HEVC has the advantages of high coding performance for integral images.

3DSAp2/ 3Dp2 - 24L **Evaluation of Depth Perception of Integral Photography**

G. Taniguchi, M. Suzuki[*], S. Yano, M.-C. Park[**]

Shimane Univ., Japan
[*]Meiwa e-Tech, Japan
[**]KIST, Korea

We evaluated the depth perception of integral photography (IP) and real objects (RO) using the eye movement and subjective methods. The depth perception of IP had the same tendency regardless of the evaluation method. The depth perception of IP and RO evaluated by the eye movement method was different.

3DSAp2/ 3Dp2 - 25L **Projection-Type Integral 3D Display with Highly Accurate Method for Auto-Compensating Elemental Image**

H. Watanabe, M. Kawakita, N. Okaichi, H. Sasaki, M. Kano, J. Arai, T. Mishina

NHK, Japan

We developed a highly accurate method for auto-compensating an elemental image for an integral three-dimensional (3D) display. An elemental image is geometrically corrected from the detection results of the position errors between the elemental image and lens array using 3D markers. We experimentally confirmed improvement in the 3D image quality.

3DSAp2/ 3Dp2 - 26L **Imaging Performance via Liquid Crystal Lens Arrays with Disclination Line Considerations in Integral Imaging System**

Y.-J. Chang, W.-Y. Lu, C.-R. Sheu

Nat. Cheng Kung Univ., Taiwan

Recently, liquid crystal lens arrays have been paid attention on researches for autostereoscopic applications. In this paper, we demonstrate and compare imaging performance of integral imaging system via liquid crystal lens arrays, which disclination issues are significantly affect elementary images and image reconstruction.

3DSAp2/ 3Dp2 - 27L **Holographic Images Analysis Considering Phase Distribution in Small Liquid Crystal Pixels**

Y. Isomae, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

We proposed the simulation method of reconstructed images in considering influence of phase distribution in the pixels and clarified zero-order diffraction appeared on the reconstructed images. This result is useful for designing fine liquid crystal on silicon for realizing wide-viewing-angle holographic display.

3DSAp2/ 3Dp2 - 28L **High Definition Spatiotemporal Division Multiplexing Electroholography Using DMD**

M. Fujiwara, N. Takada, C. W. Ooi, Y. Maeda, H. Nakayama[*], T. Kakue[**], T. Shimobaba[**], T. Ito[**]

Kochi Univ., Japan
[*]Nat. Astronomical Observatory of Japan, Japan
[**]Chiba Univ., Japan

We propose high-speed computer-generated hologram reproduction using digital mirror device for high-definition spatiotemporal division multiplexing electroholography. Finally, we succeeded to play high-definition 3D movie of 3D object comprised about 900,000 points at 60 fps when each frame was divided into twelve.

3DSAp2/ 3Dp2 - 29L **Holographic Collimator Based on Waveguide Holograms**

W.-K.Lin[,**], W.-H.Lin[**], S.-K.Zhou[**], B.-S.Lin[*], W.-C.Su[**]*

[*]Nat. Chiao Tung Univ., Taiwan

[**]Nat. Changhua Univ. of Education, Taiwan

A Collimated beam device was presented based on PMMA waveguide by using holographic technique. The dimension of the device is only 15 cm × 8 cm × 0.8 cm, and the diameter of the generated collimation beam is around 5.9 cm. The device can be used as a backlight for hologram displaying.

----- Break -----

16:50 - 18:10 **Main Hall**

3D4/3DSA5: Image Processing

Chair: H. Saito, Keio Univ., Japan
Co-Chair: K. Takahashi, Nagoya Univ., Japan

3D4/ 3DSA5 - 1 16:50 **Face Tracking Method Using Depth Information**

J.-H. Lee, J. Yoo

Kwangwoon Univ., Korea

This paper first discusses the disadvantages of the existing CamShift Algorithm, and then proposes a new Camshift Algorithm that performs better than the existing algorithm. The experimental results prove that the proposed algorithm is superior in tracking performance to that of existing TLD tracking algorithm, and offers faster processing speed.

3D4/ 3DSA5 - 2 17:10 **3D Interactive System Based on Neural Network Training of Dual Cameras**

T.-Y. Lu, X. Li, C.-H. Chen, Y.-P. Huang

Nat. Chiao Tung Univ., Taiwan

A bare-finger 3D interactive technology for portable devices was developed. Using dual cameras with a reformed the field of viewing, a blind working range close to the camera is eliminated. Moreover, the algorithm of neural network, different from stereo vision, was presented to determine the positions of fingertips.

3D4/ 3DSA5 - 3 17:30 **Synthesis of Top View Image and Detection of Obstacles Using Multiple Cameras for Monitoring Around a Truck**

K. Uehara, H. Saito, K. Yamamoto[*], H. Sato[*]

Keio Univ., Japan

[*]Mitsubishi Fuso Truck & Bus, Japan

We propose a system that supports truck drivers. It can be used to prevent collisions between trucks and obstacles. This is accomplished by using a top view image and a function for the detection of obstacles around a truck based on their height. Our system requires only color cameras.

3D4/ 3DSA5 - 4 17:50 **Study on Band-Efficient System Design and Video Coding for Fixed & Mobile Hybrid UHD 3DTV System Using Scalable HEVC**

*S.-H. Kim, K. H. Yong, K.-H. Jung**

ETRI, Korea
**Kookmin Univ., Korea*

This paper presents a band-efficient stereoscopic 3D system design and video coding technologies for Fixed & Mobile hybrid UHD 3DTV using scalable HEVC. The proposed system can support layered 4K-UHDTV, Mobile HD & UHD 3DTV services at the same time within RF 6 MHz bandwidth using Scalable HEVC video codec.

Author Interviews
18:10 – 18:50, Multipurpose Hall

Friday, December 9

9:00 - 10:20 **Main Hall**

3DSA6/3D5: Volume Display and Display Analysis

Chair: T. Fujii, Nagoya Univ.,Japan
Co-Chair: D. Miyazaki, Osaka City Univ., Japan

3DSA6/ 3D5 - 1: 9:00 ***Invited*** **TSTF Up-Conversion Crystal as an Image Space of Electro-Holography**

J.-Y. Son, H. Lee, C.-K. Sung, B.-R. Lee, H. Chu**

Konyang Univ., Korea
**ETRI, Korea*

The problems in current electro-holography based on a digital display chip are addressed. The characteristics of a ZBLAN glass used for the image space of a 360° viewable holographic display and of the reconstructed image in the space are described. Improving the image characteristics are discussed.

3DSA6/ 3D5 - 2 9:20 **Aerial Projection of Three-Dimensional Color Motion Pictures Based on Electro-Holography with Parabolic Mirrors**

T. Kakue, A. Uemura, T. Nishitsuji, T. Shimobaba, T. Ito

Chiba Univ., Japan

We report an aerial projection system based on color electro-holography with two parabolic mirrors. Our system can realize real-time reconstruction of floating three-dimensional color images. We successfully demonstrated the proposed system with a single spatial-light modulator and a color LED by the time division method.

3DSA6/ 3D5 - 3 9:40 **Viewing Zones Analysis of Convex Multi-View Autostereoscopic 3D Display with Barrier**

J.-Y. Lai, W.-C. Lin, H. Y. Lin

Nat. Taiwan Univ., Taiwan

The viewing zones of a convex multi-view autostereoscopic display is investigated. While a convex display broadens the viewing angle, the view number is limited by screen curvature instead. Therefore, we propose the viable barrier parameters and maximum view numbers for the AS3D display under different curvatures.

3DSA6/ 3D5 - 4 10:00 **Period of Color Moiré Fringes in Contact-Type 3D Displays**

H. Lee, J. Kim, J.-Y. Son

Univ. of Konyang, Korea

A formula to predict color moiré fringes appearing in the contact-type Multiview 3D images is presented. It works not even for the displays but also typical moirés from two superposed regular pattern plate, especially for plates with large period differences. The formula is easily transformed for the slanted moirés

----- Break -----

10:40 - 12:00 **Main Hall**

3D6/3DSA7: Aerial Display

Chair: J.-Y. Son, Konyang Univ., Korea
Co-Chair: H. Mizushina, Tokushima Univ., Japan

3D6/ 3DSA7 - 1 10:40 **Aerial Volumetric Image Display Based on Retroreflective Imaging and Optical Scanning with a Slanted Rotating Mirror**

D. Miyazaki, R. Tamaki, T. Mukai

Osaka City Univ., Japan

Imaging based on retroreflection can provide aerial image formation with a wide view angle and low-distortion in spite of high numerical aperture. A floating volumetric display technology based on retroreflection with a dihedral corner reflector array and optical scanning with a slanted rotating mirror are described.

3D6/ 3DSA7 - 2 11:00 **3D Volume Image Reconstruction in Space, Using Combined System of Light-Field Display and Aerial Imaging Device**

*T. Iwane, M. Nakajima, H. Yamamoto**

Nikon, Japan

**Utsunomiya Univ., Japan*

Combined light-field display and aerial imaging device, 3D aerial display system has been realized. Circular polarization control, using cholesteric liquid-crystal polymer layer, improves light-use efficiency and enables a cost-effective large-size 3D aerial display system.

3D6/ 3DSA7 - 3 11:20 **Horizontal Parallax Table-Top Floating Image System with Toroidal-Lens Structure**

P.-Y. Chou, C.-H. Tai, S.-H. Huang, Y.-P. Huang

Nat. Chiao Tung Univ., Taiwan

A new horizontal parallax table-top floating image system with toroidal-lens optical film was proposed. By this system, light field of each projector could be controlled as fan ray and properties could be evaluated by simulation. According to imaging principle and inverse light tracking, displaying 3D floating images could be achieved.

3D6/ 3DSA7 - 4 11:40 **Visual and Thermal Floating Display with AIRR and WARM**

T. Okamoto, S. Ito, K. Onuki, S. Onose, T. Itoigawa, H. Yamamoto

Utsunomiya Univ., Japan

We have developed a visual and thermal floating display. Our developed display forms aerial visual images over a table top and locally heats a part of aerial images. Aerial images are formed with aerial imaging by retro-reflection (AIRR). Aerial heating is realized with double-layered arrays of rectangular mirror (WARM).

Also presented in Innovative Demonstration Session (see p. 262)

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 14:50 **Main Hall**

3D7/3DSA8: Technologies for 3D Imaging

Chair: Y. Takaki, Tokyo Univ. of A&T, Japan
Co-Chair: J. Arai, NHK, Japan

3D7/ 3DSA8 - 1 13:30 **Synthesis of Wide FOV RGB-D Images by Registration and Upsampling of 3D Lidar with Omnidirectional RGB Camera**

H. Usami, S. Miyata, H. Saito

Keio Univ., Japan

We present a method for synthesizing wide-field-of-view (FOV) RGB-D images by combining three-dimensional (3D) Lidar and an omnidirectional RGB camera. In this system, 3D point clouds captured by the Lidar are upsampled and colored by registration with the omnidirectional RGB image. We show free-viewpoint images generated via this method.

3D7/ 3DSA8 - 2 13:50 **DIBR Digital Image Watermarking Based on Depth Image and DWT**

Y.-S. Lee, Y.-H. Seo, D.-W. Kim
Kwangwoon Univ., Korea

This paper proposes a digital watermarking scheme to get higher robustness for a DIBR image. This scheme includes a method to find the least distortable regions by using the depth image. For blind watermark, the depth image only in embedding procedure, while in extraction only the original watermark is used.

3D7/ 3DSA8 - 3 14:10 **Spectral Color Reproduction of Multiband 3D Projector Using Evolution Strategy**

M. Tomizawa, N. Yata, Y. Manabe
Chiba Univ., Japan

Stereoscopic video technology is developing. In previous study, we have proposed a stereoscopic display system which has an expanded color gamut. This paper proposes an accurate color and spectral reproduction method of a three-dimensional image display system with expanded color gamut using covariance matrix adaptation evolution strategy (CMA-ES).

3D7/ 3DSA8 - 4 14:30 **Liquid Crystal Lens for Polarized 2D/3D Endoscopic Imaging**

A. Hassanfiroozi, Y.-P. Huang, H.-P. D. Shieh
Nat. Chiao Tung Univ., Taiwan

Analysis of the polarization properties of light reflected by an artificial tissue from a polarized incident light using an LC lens have been investigated to enhance endoscopic imaging system. Polarizer dependency of LC lens could benefit us to have a sharper image with higher contract.

----- Break -----

15:15 - 16:45 **Main Hall**

DES4/3D8: 3D Display and Sensor
Special Topics of Interest on AR/VR and Hyper Reality

Chair: Y. Oyamada, Tottori Univ., Japan
Co-Chair: H. Yamamoto, Utsunomiya Univ., Japan

DES4/ 3D8 - 1: 15:15 ***Invited*** **Displaying Real World Light Fields Using Stacked LCDs**

K. Takahashi, Y. Kobayashi, T. Fujii
Nagoya Univ., Japan

We have developed a prototype of a layered light-field (3D) display, where three liquid crystal display (LCD) panels are stacked in front of a backlight. We have also created an end-to-end system where a real 3D scene captured by a multi-view camera is reproduced in 3D on this prototype display.

Also presented in Innovative Demonstration Session (see p. 263)

DES4/ 3D8 - 2: 15:40 ***Invited*** **Lock-in-Detection Based Time-of-Flight CMOS Image Sensors**

K. Yasutomi, S. Kawahito

Shizuoka Univ., Japan

This paper reviews recent time-of-flight (TOF) range imagers particularly for indirect TOF measurement by using lock-in pixels. Lateral Electric Field charge Modulators (LEFM) in the lock-in pixel is a key component to achieve higher range resolution. In this paper, different implementations of TOF range imagers for various applications are described.

DES4/ 3D8 - 3 16:05 **Holographic Augmented Reality Head-Up Display with Eye Tracking and Steering Light Source**

Y.-T. Kim, J. Seo, W. Seo, G. Sung, Y. Kim, H. Song, J. An, C.-S. Choi, S. Kim, H. Kim, Y. Kim, Y. Kim, H.-S. Lee

Samsung Elect., Korea

We realized a holographic head-up display using a steering light source with eye position tracking. It can represent a real augmented reality which perfectly matches virtual graphic images to the real world. Further, for the determination of the position of the light source, 3D calibration method is proposed.

DES4/ 3D8 - 4 16:25 **Flat Autostereoscopic 3D Display with Enhanced Resolution Using a Wavelength Selective Filter Barrier**

S. Jurk, M. Kuhlmey, R. Bartmann, B. Duckstein, R. de la Barré

Fraunhofer HHI, Germany

A spatially multiplexed autostereoscopic 3D display design with lamellar parallax barrier consisting of wavelength-selective color filters is presented. In comparison to conventional similar parallax barriers the resolution, brightness and crosstalk are enhanced. The filtering of single colors enhances a separation of stereo images.

Author Interviews
16:45 – 17:10, Multipurpose Hall

Workshop on Applied Vision and Human Factors

Wednesday, December 7

13:00 - 13:05 **502**

Opening

Opening Remarks
13:00

Y. Shimodaira, Shizuoka Univ., Japan

13:05 - 14:20 **502**

VHF1: Ergonomics for Automotive Applications
Special Topics of Interest on Automotive Displays

Chair: Y. Shimodaira, Shizuoka Univ., Japan
Co-Chair: K. Sakamoto, Panasonic, Japan

VHF1 - 1
13:05

Influence of Image Position and Visual Target on Depth Perception When Using Automotive 3D Head-Up Display

R. Noguchi, T. Daimon, T. Mori[*]*, K. Kasazumi*[*]

Keio Univ., Japan
[*]*Panasonic, Japan*

We previously proposed a three-dimensional (3D) head-up display (HUD) that places virtual images in the appropriate 3D position based on virtual image focal depth and image plane angle. Here, we compare the 3D-HUD with a conventional augmented reality HUD and investigate how image position and visual target influence depth perception.

VHF1 - 2
13:25

Traffic Signal with PWM Coding for Visible Light Communication

C.-J. Ou, M.-Y. Cheng, Z.-W. Huang, C.-H. Ou[*]*, H.-E Lu*

Hsiuping Univ. of S&T, Taiwan
[*]*Dongshan High School, Taiwan*

LED with PWM control can improve the broadcasting information. Simulation through the dynamic routing program, results suggest that through this device, a 40% traffic jam situation can be amended, which manifest the ability of the information display system to improve not just the information qualities, but besides the existing parts.

VHF1 - 3 13:45 **Key Perceptual Factors for Smart Garnish Light/ Display**

J. K. Ko, S. Y. Choi, M. S. Noh, S. S. Kim[*], G. H. Kim[*], W. K. Song[*], K.-G. Seok[**]

Korea Inst. of Lighting & Tech., Korea
[*]Seoyon Elect., Korea
[**]Dilussion, Korea

The important perceptual factors are investigated for a smart garnish considering that a conventional garnish can be replaced by lights or displays. The color and pattern stimuli determined to satisfy key emotional requirements can be utilized to deliver various visual messages as well as interior lighting mood options for automobile.

VHF1 - 4L 14:05 **Effective Evaluation of Moving Image Quality of Display Using Morphing Wavelet with Layered Range of Resolution**

I. Kawahara, H. Tabata

KEISOKU GIKEN, Japan

Visual assessment of moving image quality is drastically improved by optimizing shape and presenting scheme of test pattern. Morphing wavelet, or transforming burst while scrolling across the screen were analyzed, and proved to have high discrimination and stability, with significantly reduced overall measurement time and physical strain on observers.

Also presented in Innovative Demonstration Session (see p. 263)

----- Break -----

14:40 - 16:00 **503**

UXC2/VHF2: Human Factors

Chair: H. Shibata, Fuji Xerox, Japan
Co-Chair: N. Hiruma, NHK-ES, Japan

UXC2/ VHF2 - 1: 14:40 ***Invited*** **Development of Japanese Electronic Text Readers Based on Perceptual Mechanisms of Reading**

J. Kobayashi[,**], E. Shinbori[*], T. Kawashima[**]*

[*]Dai Nippon Printing, Japan
[**]Future Univ. Hakodate, Japan

We have proposed stepped-line and vibration text layouts to improve eye movement efficiency. The reading speeds obtained with the proposed layouts are faster compared to a conventional Japanese layout. This is primarily achieved by a reduction in the number of eye fixations.

UXC2/ VHF2 - 2 **Withdrawn**

UXC2/ VHF2 - 3 15:20 **Experiment of Psychological Impact of LED Display**

*T. Matsui, T. Fukuda, S. Nagamachi**

Osaka Univ., Japan
**LEM Design Studio, Japan*

LED display replace paper advertising as digital signage and create new light-scape in urban system. However, LED has impact on human mind and it should be researched to establish comfortable urban landscape. This paper shows results of psychological experiment investigated the relationship between luminance level and glaring and uncomfortable emotion.

UXC2/ VHF2 - 4 15:40 **Effects of Different Comfortable Binocular Disparities on the DP3 Signal-an Event-Related Potential Study Using an Oddball Task**

P. Ye, X. Wu, D. Gao, S. Deng, N. Xu, J. She, J. Chen

Sun Yat-Sen Univ., China

Displaying the stereoscopic 3D contents within the comfort zone could reduce the induced visual fatigue. We studied the EEG signal of DP3 (differential P3) elicited by the 3D contents possessing different disparities within the comfort zone. The proposed approach could facilitate accurately improving the definition of the comfort zone.

----- Break -----

Reception

Wednesday, Dec. 7, 2016
19:00 – 21:00
Crowne Grand Ball Room (2F)
ANA Crowne Plaza Fukuoka
See page 14 for details

16:20 - 17:40 **503**

VHF3: Display Measurement and Simulation

Chair: J. Bergquist, Semiconductor Energy Lab., Japan
Co-Chair: S. Uehara, Asahi Glass, Japan

VHF3 - 1
16:20

Mura Image Quality Evaluation Based on Fourier Spectrum Analysis

K. Ishiguro, T. Asano, T. Kondoh, W. Liu**

Hiroshima Inst. of Tech., Japan
**Fast, Japan*

A novel image quality inspection method that evaluates low contrast mura (non-uniform regions) by analyzing the Fourier power spectrum is presented. The power spectrum is filtered using CSF (Contrast Sensitivity Function). The spatial frequency and direction angle histograms of the power spectrum showed good correlations with mura image qualities.

VHF3 - 2
16:40

Optical Properties of a Transparent LCD

P. Boher, T. Leroux, T. Bignon, V. Collomb-Patton

ELDIM, France

Optical properties of a transparent LCD are measured using two multispectral systems. Spectral of W, K, R, G and B states is obtained with a Fourier optics system and used to compute the angular behavior of the display. High spatial imaging measurements at the sub-pixel level are also performed.

VHF3 - 3
17:00

Preferred Background Lighting and Tone Reproduction Curves of See-Through Displays

H.-P. Chien, P.-L. Sun

Nat. Taiwan Univ. of S&T, Taiwan

Five psychophysical experiments were performed to investigate preferred tone curves and background lighting geometries of a transparent LCD (T-LCD) and a see-through head-mounted LCD (HM-LCD) under different viewing conditions. To enhance image quality of a dim-backlight T-LCD or a bright surround HM-LCD, both brightness and contrast should be heightened accordingly.

VHF3 - 4
17:20

1-D Simulation on Sparkle Perception

X. Zhong, D. Liu, J. Liu, Y. Yang, H. Cui, D. Lee, P.-H. Lung

Wuhan China Star Optoelect. Tech., China

We tried to build a 1D model to simulate perceived sparkle by inviting "local parallel approximation". It simplifies some conditions to make the model easy to carry out. Several factors such as view angle, arc depth, arc width, sub-pixel size which may affect the sparkle level are simulated.

Author Interviews
17:40 – 18:10, Multipurpose Hall

Thursday, December 8

9:00 - 10:20 **Main Hall**

3DSA4/VHF4: Human Vision
Special Topics of Interest on AR/VR and Hyper Reality

Chair: S. Yano, Shimane Univ., Japan
Co-Chair: S. Uehara, Asahi Glass, Japan

3DSA4/ VHF4 - 1: 9:00 ***Invited*** **Brain Function Analysis of Visual and Cross-Modal Information**

H. Ando[,**]*

[*]NICT, Japan
[**]Osaka Univ., Japan

To clarify how visual information is processed in the human visual system and how visual information interacts with other sensory modalities, we have investigated human brain functions using functional Magnetic Resonance Imaging (fMRI) techniques. Recent results of our fMRI experiments are described in this paper.

3DSA4/ VHF4 - 2: 9:20 ***Invited*** **Human Vision Response in AR & VR**

Y.-S. Chen, Y.-P. Huang[*], C.-Y. Chen[**]

Cathay General Hospital, Taiwan
[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Taiwan Univ. of S&T, Taiwan

The human vision response in AR & VR is definitely different from stereoptic images created by human macula of the real world. The index of physiological measurement for visual response should be developed and standardized in order to improve the AR & VR display in the future.

3DSA4/ VHF4 - 3 9:40 **Attentive Tracking of Moving Objects in Stereoscopic Viewing**

A. U. Rehman, Y. Nosaki[*], K. Kihara[*], S. Ohtsuka[*]

Kagoshima Nat. College of Tech., Japan
[*]Kagoshima Univ., Japan

This experiment examines the attentive tracking of moving objects in stereoscopic viewing. Participants could successfully track moving objects in an attentive task by ignoring the distractors' plane. In addition, they were able to divide attention equally among a range of depth planes.

3DSA4/ VHF4 - 4 10:00 **Subjective Experiment Study on Binocular Overlap Effect of Different Colors for the Augmented Reality Near-Eye Display**

H. Zhang, Y. Tang, Y. Zheng, Y. Xie[*]*, B. Wang*

Southeast Univ., China
[*]*S&T on Electro-optic Control Lab., China*

The binocular overlap effect of different colors for the augmented reality near-eye display was studied. This experiment included 10 participants to observe and grade on the influence of the different colors on the binocular overlap effect. The results indicate that different colors have an impact on the binocular overlap effect.

Author Interviews
10:30 – 11:10, Room 201

10:30 - 13:00 **Multipurpose Hall**

***Poster* VHFp1: Applied Vision and Human Factors - Automotive applications**
Special Topics of Interest on Automotive Displays

VHFp1 - 1 **Evaluation of Specular Reflectance for Automotive Display**

K. Mo, B. Choi

LG Display, Korea

Reflection is one of the most important factors for the automotive display. Therefore, a measuring method of reflection must be defined properly for correct reflectance data. We suggest a new method of specular reflectance only void of diffuse components. It shows a correlation between measured data and human eye.

EXHIBITION

12:40 – 18:00 Wednesday, Dec. 7
10:00 – 18:00 Thursday, Dec. 8
10:00 – 14:00 Friday, Dec. 9
Lobby (2F, 4F)
Fukuoka International Congress Center
Free admission with your IDW/AD '16 registration name tag

10:30 - 13:00 **Multipurpose Hall**

***Poster* VHFp2: Applied Vision and Human Factors - Lighting technologies**

Special Topics of Interest on Lighting and Quantum Dot Technologies

VHFp2 - 1 **Quantification of LCD's Light Leakage of Each Corner Using 2D FFT and 2D CSF**

S. W. Jung, J. Y. Kim

LG Display, Korea

The light leakage has been known as one of the chronic LCD's defects. The display manufactures are continuously developing a new method for the improvement of light leakage. Therefore the needs of quantitative evaluation between the human's perception and the measurement system which can be practical in the field have been emphasized.

10:30 - 13:00 **Multipurpose Hall**

***Poster* VHFp3: Applied Vision and Human Factors**

VHFp3 - 1 **Visual-Chromatic Spatial and Temporal Frequency Responses of Color-Blind People**

H. Isono

Tokyo Denki Univ., Japan

This paper describes measurements of visual-chromatic spatial and temporal frequency responses of color blind subjects and those of subjects with normal color vision. The results clearly indicated that there was significant differences in color contrast sensitivity for a red-green stimulus between color-blind subjects and subjects with normal color vision.

VHFp3 - 2 **Withdrawn**

VHFp3 - 3 **Comparison of Watermarking for 3D Models under Different Lighting Conditions**

H.-L. Liu, Y.-L. Liu, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

This paper proposes a method by adjusting the original texture color of 3D model to generate an invisible color difference as watermarking. After the watermark is added, we can apply an illuminant condition to render the 3D model, which will be enlarged to be noticed.

VHFp3 - 4 **Circular Polarizing Light Panel for Reducing Visual Fatigue**

D. Liu, H. Sun, Y. Tang, Z. Yang, D.-J. Li, H. Cui, P.-H. Lung

Wuhan China Star Optoelect. Tech., China

It is linearly polarized light that emitted from liquid crystal display (LCD). The picture will be invisible when wearing the sunglasses, and prolonged viewing may cause visual fatigue. This paper presents a circular polarizing light panel (CPLP), which can relieve the visual fatigue and give a better visual enjoyment.

VHFp3 - 5 **Image Quality Perception Model Based on Retinal Structures for Evaluation of Wearable Visual Devices**

C.-J. Ou, H. Y. Sun, D. P. C. Lin*, C.-H. Lin, S. L Young, Z.-W. Huang, C.-R. Ho*

Hsiuping Univ. of S&T, Taiwan
**Chung Shan Medical Univ., Taiwan*

For the past few years, there is still a lack of the details and unified modelling that combined both the human eye and the refined retina model in the literatures. New methods to estimate the vision qualities of the display information and illumination condition are provided.

Friday, December 9

9:00 - 10:30 **503**

VHF5: Human Factors and Applications

Chair: Y. Hisatake, Japan Display, Japan
Co-Chair: S. Uehara, Asahi Glass, Japan

VHF5 - 1: 9:00 ***Invited*** **Visual Effects of Concave Curved Displays in Large and Wide-Angle Environment: Immersion and Aftereffect**

S. Ohtsuka

Kagoshima Univ., Japan

Visibility of simulated flat and curved displays is compared. Experiments show that (1) curved displays are preferred over flat ones, however, (2) curved displays induce strong curved-surface-aftereffect (CS-AE) in some individuals. Subjects with a rigid perception of CS-AE are able to well integrate visual and gravity sensory systems.

VHF5 - 2 9:30 **Image Quality Evaluation Method for Online Camera Module Inspection Based on Human Vision**

P.-J. Weng, Q. Zong, W.-C. Chao, Y.-P. Huang, H.-P. D. Shieh

Nat. Chiao Tung Univ., Taiwan

MTF and contrast sensitivity function are combined to calculate TV line value of camera modules. Standard deviation of the error between TV line values judged by testees and that calculated by proposed method is only 22 for 720P camera modules. This method helps reduce human resources for online camera module inspection.

VHF5 - 3 9:50 **Novel Optical Compensation Algorithm for AMOLED Mura Cancellation**

Y. Deng, Y. Jin, S. Syu, M. Jou

Shenzhen China Star Optoelect. Tech., China

We present a novel algorithm for the optical compensation of OLED displays, which optimize the target luminance distribution at high-brightness grayscale to minimize brightness loss during the compensating process, and enable fast and accurate searches for the compensation gray value that corresponds to the target luminance.

VHF5 - 4L: 10:10 ***Invited*** **Evaluation of Historical Learning in an Elementary School Using 3D Educational Materials**

T. Shibata, K. Sato[,**], R. Ikejiri[***]*

Tokyo Univ. of Social Welfare, Japan
[*]Takaido-Higashi Elementary School, Japan
[**]Tohoku Univ., Japan
[***]Univ. of Tokyo, Japan

An experimental class in an elementary school was undertaken to examine how the advantages of stereoscopic 3D images could be utilized in education. The results from the worksheets completed by students revealed that 3D educational content could assist students in creating novel questions.

----- Break -----

10:40 - 12:10 **503**

VHF6: Visual Comfort and Motion Sickness

Chair: T. Shibata, Tokyo Univ. of Social Welfare, Japan
Co-Chair: Y. Endo, Asahi Glass, Japan

VHF6 - 1: 10:40 ***Invited*** **What Kind of Motion Is the Primary Cause of Visually Induced Motion Sickness?**

H. Ujike, H. Watanabe

AIST, Japan

Reducing incidence of VIMS is essential for supporting recent innovative moving image technology. For the effective factors of visual motion, we focus on types of motion and its velocity, and on total dose of visual motion. The knowledge can be the bases of ergonomic guideline for reducing incidence of VIMS.

VHF6 - 2
11:10

Visual Comfort of Head Mounted Displays

Y. Kim, J. Park, Y. Jun*, H. Kim**, Y.-J. Seo**, Y. K. Park**

Ewha Color Design Inst., Korea
**Ewha Womans Univ., Korea*
***Samsung Display, Korea*

Motion sickness, well-known side effect of HMD, was measured in various viewing postures of HMD. Only few responded misery symptoms after watching HMD with free vision and head movement. The viewing posture is important for motion sickness while viewing HMD and it can overcome the side-effect for conventional stereoscopic displays.

VHF6 - 3
11:30

The Reduction of Harmful Blue Light Radiation of LCD for Prevention of Photo-Damage to Human Eyes

Y. Yang, H. Cui, X. Zhong, D. Li, Y. San, J. Liu

Wuhan China Star Optoelect. Tech., China

We reviewed the influence of blue light of LCDs to fatigue and diseases of human eyes. By red-shifting the blue peak of LEDs used in the LCD back light, we reduced the most influential blue light of wave length from 415 nm to 455 nm significantly.

VHF6 - 4L:
11:50

Invited **Visually Induced Motion Sickness in VR: What Representation of Sensory Information Conflict?**

H. Watanabe, H. Ujike

AIST, Japan

Research on visually induced motion sickness (VIMS) has traditionally focused on velocity and frequency as the components of optokinetic stimulation that define this phenomenon. This study investigates how forward and rotational acceleration components in virtual reality content are related to the perceived sense of acceleration, discomfort and head motion.

Author Interviews
12:10 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 14:55 **503**

VHF7: Color Vision and Illumination

Chair: H. Ujike, AIST, Japan
Co-Chair: Y. Imai, Mitsubishi Elec., Japan

VHF7 - 1: 13:30 ***Invited*** **Electronic Color Target for Evaluation of Color Reproduction of Wide Gamut Image Devices**

Y. Shimodaira, H. Urabe, H. Suzuki[*], M. Katoh[**]

Shizuoka Univ., Japan
[*]Nobuo Elec., Japan
[**]Papalab, Japan

An electronic color target system was developed for testing color reproduction of video cameras and digital still cameras. It was approved as ISO/TS 17321-4. The system is expected to use for evaluation of color reproduction of wide gamut image devices and can reproduce spectral distribution of any object color.

VHF7 - 2 14:00 **Analysis of Color Saturation at Low Gray Levels**

Y. J. Chen, P. C. Yeh, H. C. Huang, C. S. Cheng, W. M. Huang

AU Optronics Tech. Ctr., Taiwan

We used pure color samples to discover the main factor “contrast ratio” (CR) that affects color gamut for the low gray levels. A model was developed to demonstrate the phenomenon that the color gamut decreases as the gray level decay. We adjusted gamma to improve the color gamut at low gray levels and maintain CR.

VHF7 - 3 14:20 **Optimal White LED Spectrum for Pattern Recognition under Mesopic Condition**

H.-C. Li, P. L. Sun, R. Luo[*]

Nat. Taiwan Univ. of S&T, Taiwan
[*]Univ. of Leeds, UK

The spectrum of white LED was optimized based on its 3D color gamut under mesopic luminance levels, and a psychophysical experiment was conducted to test the speed and accuracy of pattern recognition under low luminance conditions.

VHF7 - 4L 14:40 **The Design of the 3D Visual Target for Vision Screening**

C.-Y. Chen, P.-J. Wu[*], C.-H. Chuang[**], Y.-H. Siao[***], H.-C. Lin[***], T.-H. Cho[****], C.-H. Lin[***]

Nat. Taiwan Univ. of S&T., Taiwan
[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Taiwan Univ., Taiwan
[***]Nat. Yunlin Univ. of S&T, Taiwan
[****]Shu Zen Junior College of Medicine & Management, Taiwan

A 3D visual target optometry system different from traditional systems with 2D visual targets is proposed in this study. In addition to examining single-eye Snellen acuity, it could also measure binocular Snellen acuity and acquire the visual acuity of nearsighted people when viewing the real world.

----- Break -----

15:10 - 16:10 **503**

VHF8/UXC4: High Dynamic Range and Virtual Reality

Chair: Y. Hisatake, Japan Display, Japan
Co-Chair: H. Shibata, Fuji Xerox, Japan

VHF8/ UXC4 - 1L 15:10 **Effect of Variable System Gamma for Hybrid Log-Gamma HDR Video Production**

Y. Ikeda, Y. Kusakabe, K. Masaoka, Y. Nishida

NHK, Japan

We conducted an experiment of Hybrid Log-Gamma (HLG) high dynamic range (HDR) video production at different display peak luminance levels. The experiment confirmed that the HLG HDR video production with a variable system gamma yields more consistent video level management results regardless of the peak luminance of a master monitor than that with a fixed system gamma.

VHF8/ UXC4 - 2L 15:25 **Global Dimming Strategies for Improving Subjective Visual Quality of HDR Video on Liquid Crystal Displays**

M. Choi, D. Hoffman

Samsung Display, USA

We examined five strategies of global dimming backlight control with video sequences and emulated their LCD contrast on an OLED panel. We performed a subjective study to rank preferences with cinematic content. Dynamic global dimming with temporal smoothing was preferred over static and frame-by-frame approaches.

VHF8/ UXC4 - 3L 15:40 **Subjective Evaluation of See-Through Head Mounted Display**

R. Kimura, T. Totani[*]*, T. Miyao*[*]*, T. Kojima, M. Miyao*
Nagoya Univ., Japan
[*]*Seiko Epson, Japan*

We conducted an experiment easy work with 119 participants. Easy work is that participants assembled the LEGOs according to assembly layout with a see-through head mounted display (HMD). We tested the subjective evaluation of see-through HMD and working efficiency.

VHF8/ UXC4 - 4L 15:55 **Comparison of the Readability of a Tablet Device and See-Through Smart Glasses**

K. Iwata, T. Totani[*]*, T. Miyao*[*]*, P.R. Lege, T. Kojima, M. Miyao*
Nagoya Univ., Japan
[*]*Seiko Epson, Japan*

We carried out experiments to evaluate the readability of two devices, a tablet device (iPad) and smart glasses (BT-300). In the experiments, participants were asked to make subjective evaluations and their reading time was measured. We also calculated their percentage of correct answers, and compared the readability of each device.

Author Interviews
16:30 – 17:10, Multipurpose Hall

Supporting Organizations:
Technical Committee on Electronic Information Displays, Electronics Society, IEICE
Technical Group on Information Display, ITE

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by Oral and Poster Presenters
Thursday, Dec. 8, 2016
10:30-16:40
Multipurpose Hall (2F)
Fukuoka International Congress Center

Workshop on Projection and Large-Area Displays and Their Components

Thursday, December 8

9:00 - 9:05 **412**

Opening

Opening Remarks
9:00

S. Ouchi, Hitachi, Japan

9:05 - 10:25 **412**

PRJ1: Standardization and Characterization

Chair: S. Ouchi, Hitachi, Japan
Co-Chair: T. Yagi, Mitsubishi Elec., Japan

PRJ1 - 1: 9:05 ***Invited*** **Performance Characterization and Measurement Methods for Eyewear Display**

K. Oshima[,**], K. Naruse[*,***], K. Tsurutani[*,***], J. Iwai[****], S. Uehara[*,*****], S. Ouchi[*,******], Y. Shibahara[*,*******], H. Wakemoto[*,********], M. Kurashige[*,*********]*

[*]JEITA, Japan
[**]Otsuka Elect., Japan
[***]Konica Minolta, Japan
[****]Telepathy Japan, Japan
[*****]Toshiba, Japan
[******]Hitachi, Japan
[*******]FUJIFILM, Japan
[********]Japan Display, Japan
[*********]Dai Nippon Printing, Japan

Eyewear display evaluation is based on light rays directed from the display to the viewer and the entrance pupil of measuring equipment. The results show that the pupil size should be smaller than the width of light rays, for correct evaluating characteristics such as luminance and its uniformity.

PRJ1 - 2
9:25
Overview of Standardization Activities for Head Mounted Displays

K. Hyodo, S. Uehara[*], H. Ujike[**], S. Ouchi[***], K. Oshima[****], H. Watanabe[**]

Konica Minolta, Japan
[*]Toshiba, Japan
[**]AIST, Japan
[***]Hitachi, Japan
[****]Otsuka Elect., Japan

Recently, thanks to technologies' evolution, Head Mounted Displays (hereafter HMDs) are getting popular. Since HMDs are quite different from ordinary displays, i.e. LCD or OLED (Organic Light Emitted Displays), it is not proper to apply existing standards. This paper exposes the overview of standardization activities for HMDs.

PRJ1 - 3
9:45
Standardization Activities for Electronic Display Devices in IEC TC 110

M. Kurashige

Dai Nippon Printing, Japan

IEC TC 110 expanded its scope from "flat-panel display devices" to "electronics display devices" in 2012, the standardization works in this field were actively developed so far. Working groups are not only limited in conventional FPDs, but have included flexible, laser, and eyewear display device.

PRJ1 - 4
10:05
High Color Rendering Index Using BGYR Four-Color Laser Illuminants

J. Kinoshita, H. Aizawa, A. Takamori, K. Yamamoto

Osaka Univ., Japan

Average color rendering index of illuminants using BGYR four-color laser diodes with a very narrow spectral linewidth is theoretically demonstrated to achieve as high as 90, and is experimentally verified to achieve 82 in the wide range of color-correlated temperature.

10:25 - 10:37 **412**

Short Presentation PRJp: Projection Displays

All authors of poster papers for the PRJp1 session will give a brief 3-minute oral presentations with no discussion time in advance.

Author Interviews
10:40 – 11:10, Room 201

10:30 - 13:00 **Multipurpose Hall**

***Poster* PRJp1: Projection Displays**
Special Topics of Interest on AR/VR and Hyper Reality

PRJp1 - 1 **Lens Design for HUD in Vehicles with Smart Phone**

Q.-Y. Chen, T.-S. Yeh, Y.-J. You, W.-C. Su

Nat. Changhua Univ. of Education, Taiwan

The lens design for head-up display (HUD) in vehicles with smart phone is presented. In this study, smart phone is used as the display source of the HUD. A 196 mm x 111 mm virtual image in front of Observer with a distance of 1300 mm is successfully demonstrated.

PRJp1 - 2 **Interactive Editing and Automatic Projection of Motion Impression on Real-World Objects**

T. Fukiage, T. Kawabe, S. Nishida

NTT, Japan

We present a ready-to-use application for a projection mapping technique that can add motion impressions to real objects. The application automatically finds projection targets and projects motion-inducer patterns in alignment with images or textures on the targets' surfaces. The application also supports interactive editing of animation contents.

PRJp1 - 3 **Single Lens Complex Modulation by Iterative Spatial Cross Modulation Method**

*Y. Qi, J. Xia, C. Chang**

Southeast Univ., China
**Nanjing Normal Univ., China*

An iterative algorithm in the calculation of CGH to realize accurate complex modulation based on spatial cross modulation method (SCMM) is presented. It enables us to generate high spatial resolution and diffraction efficiency images without sacrificing the size of the images. The feasibility is verified by numerical and optical experiments.

PRJp1 - 4L **See-Through Near-Eye Displays for Visual Impairment**

L. Zhou, C. P. Chen, Y. Wu, K. Wang, Z. Zhang

Shanghai Jiao Tong Univ., China

We propose a see-through near-eye display, which is dedicated to the users who are visually impaired. Our design is characterized by a pair of corrective lenses coated with holographic volume gratings. Its key optical performance include FOV of 14°, MTF above 0.4 at 5 cycles/mm, and distortion less than 5%.

----- Lunch -----

Friday, December 9

9:00 - 10:20 **201**

PRJ2: Wearable Display
Special Topics of Interest on AR/VR and Hyper Reality

Chair: D. Cuypers, imec, Belgium
Co-Chair: T. Suzuki, JVC KENWOOD, Japan

PRJ2 - 1
9:00

Wearable See-Through Retinal Projector Using Optical Simulation Design

H. A. Chen, W. S. Sun, Y. C. Chiang*, Z. P. Yang, J. W. Pan*

Nat. Chiao Tung Univ., Taiwan
**Nat. Central Univ., Taiwan*

This study proposes a new simulation design for a wearable see-through retinal projector combined with a compact camera. The see-through retinal projector is composed of an illumination system and eyepiece system. In this eyeglass-mounted design, all the information is projected directly into the user's eyes using a see-through retinal projector.

PRJ2 - 2
9:20

Optical Design of Wide Viewing Eyeglass-Type Wearable Device Using Multiple Reflection Element

S. Sawada, A. Moriya, T. Sasaki, J. Yamaguchi, M. Baba

Toshiba, Japan

We propose an optical design of an eyeglass-type wearable device using a multiple reflection element (MRE) composed of multiple reflectors arranged in parallel. It gives the wearer a digital image with wide viewing angles while maintaining the size by reflecting an image projected from a projector at a MRE.

PRJ2 - 3
9:40

Optimization and Verification of Viewing Angle for Wearable Display Device for Outdoor Use

J. Iwai, H. Kimura

Telepathy Japan, Japan

We have studied optimized way of increasing a viewing angle of optics for our wearable display device. As a result, we have maintained the eye box of the optical unit with bigger viewing angle by adjusting the best viewing angle of exit light of the optical unit.

Also presented in Innovative Demonstration Session (see p. 263)

PRJ2 - 4
10:00

Common Platform for Maintenance System with Wearable Device

T. Fujiwara, R. Kabata, Y. Narita*, K. Kikuchi*, K. Oonishi**

Hitachi, Japan
**Hitachi Syss., Japan*

The purpose of our research is that we develop a common platform with various OS. In this study, we developed the abstraction layer between HTML5 and OS native functions. Our method can adapt four times OS than previous research method. Generally, communication between them is difficult.

----- Lunch -----

10:40 - 12:00 **201**

PRJ3: Projection Components and Devices
Special Topics of Interest on Lighting and Quantum Dot Technologies

Chair: S. Shikama, Setsunan Univ., Japan
Co-Chair: J. W. Pan, Nat. Chiao Tung Univ.,Taiwan

PRJ3 - 1: 10:40 ***Invited*** **Experimental Characterization of Oxide Semiconductors-Based SLM for Practical Use**

S. Nakashima, W. Nomura, N. Tate

Kyushu Univ., Japan

We have been studying the implementation of a zinc-oxide spatial light modulator (ZnO-SLM) using a light-assisted annealing method. It reveals novel performance as an optical switch based on surface current-induced magneto-optical effect. As a step toward practical use, we experimentally verified possible integration densities and wavelength characteristics.

PRJ3 - 2 11:00 **Improvement of Output Power Dependence on Temperature in 638-nm BA-LD**

T. Yagi, K. Kuramoto, S. Abe, M. Kusunoki, M. Miyashita

Mitsubishi Elec., Japan

Epitaxial growth technology for 638-nm LDs was improved. It was revealed that the technology suppressed carrier overflow from an active layer of the LD. By using the technology, the newly designed BA-LD for CW operation emitted 1.74 W under 55°C, CW with wall plug efficiency of 20.0%.

PRJ3 - 3 11:20 **Liquid Crystal Based Beam Deflectors**

D. Cuypers, X. Shang, H. De Smet

imec, Belgium

Devices consisting of micro grating structures combined with liquid crystals offer interesting applications as electrically tunable photonic devices for beam steering. Both linear and circular types are constructed using soft lithography and evaluated.

PRJ3 - 4 11:40 **Very Compact Waveguide-Type RGB Coupler with Multimode Converter**

J. Sakamoto, S. Katayose, K. Watanabe, M. Itoh, T. Hashimoto

NTT, Japan

We developed an optical-waveguide-type red-green-blue (RGB) multiplexer that uses additional waveguides for mode conversion to reduce circuit length and enhance isolation among colors. The coupler circuit is about 2.5-mm long and 1-mm thick, and the loss, excluding that of input/output routing circuits, is less than 1.2 dB for each color.

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 15:05 **201**

PRJ4/DES3: 3D and Near Eye Displays
Special Topics of Interest on AR/VR and Hyper Reality

Chair: J. Reitterer, TriLite Techs., Austria
Co-Chair: T. Hayashi, Okamoto Glass, Japan

PRJ4/DES3 - 1: 13:30 ***Invited*** **Projection Mapping Technologies for AR**

D. Iwai
Osaka Univ., Japan

This invited talk will present recent projection mapping technologies for augmented reality. First, fundamental technologies are briefly explained, which have been proposed to overcome the technical limitations of ordinary projectors. Second, augmented reality (AR) applications using projection mapping technologies are introduced.

PRJ4/DES3 - 2: 13:50 ***Invited*** **Animating Static Objects by Illusion-Based Projection Mapping**

S. Nishida, T. Kawabe, T. Fukiage, M. Sawayama
NTT, Japan

In this presentation, we will explain a light projection technique that we recently developed. Based on the scientific knowledge about human visual processing, this technique, called Deformation Lamps (HenGenTou), is able to add a variety of illusory, yet realistic, distortions to a wide range of static projection targets.
Also presented in Innovative Demonstration Session (see p. 263)

PRJ4/DES3 - 3: 14:10 ***Invited*** **3D Billboards without Glasses**

J. Reitterer, F. Fidler, G. Schmid, C. Hambeck, F. S. Julien-Wallsee, W. Leeb[*], U. Schmid[*]
TriLite Techs., Austria
[*]Tech. Univ. Wien, Austria

We have developed a technology enabling autostereoscopic billboards which provide outdoor-compatible luminance and are scalable to practically any desired display size. Each display element consists of a MEMS laser scanner that deflects the emitted light beams to the left and right eyes of multiple viewers in a time-multiplexed manner.

PRJ4/DES3 - 4 14:30 **Smart Contact Lens Platform with a Deformed Active Artificial Iris**

A. V. Quintero[,**], S. Delcour[*,**], R. Verplancke[*,**], J. Vanfleteren[*,**], H. De Smet[*,**]*
[*]Ghent Univ., Belgium
[**]imec, Belgium

This paper explores the challenges regarding the thermoforming of a deformable guest-host liquid crystal display within a smart contact lens. Focus was given to the finite element modelling of its fabrication, to find respective design rules. Such displays are thought to be used in vision correction applications (i.e. artificial iris).

PRJ4/ DES3 - 5L 14:50 **Compact Optical Engine with Speckle Reduction Element for Laser Pico-Projector**

J.-Y. Lee, B. Yim, T.-H. Kim**, J.-U. Bu**, Y.-J. Kim*

Yonsei Univ., Korea
**Wikioptics, Korea*
***SenPlus, Korea*

Compact optical engine has been designed and fabricated with speckle reduction element for laser pico-projector. Various optical components are fabricated and assembled in small size of optical engine under 5 cc volume. It was confirmed that speckle contrast was reduced 38.02% for the green light from the experimental result.

15:30 - 16:30 **201**

PRJ5: Automotive Displays
Special Topics of Interest on Automotive Displays

Chair: V. R. Bhakta, Texas Instrs., USA
Co-Chair: K. Ohara, Texas Instrs., Japan

PRJ5 - 1: 15:30 ***Invited*** **Adaptive High Resolution Headlight Using Texas Instruments DLP Technology**

V. R. Bhakta, B. Ballard

Texas Instrs., USA

Glare-free high beam solutions on the road support resolutions up to 100 pixels. To improve throughput and functionality, we propose a high resolution (> 100k pixels) glare-free high beam using Texas Instruments DLP chipsets. We will present an optical design of an LED illuminated headlight and share performance measurements.

PRJ5 - 2 **Withdrawn**

PRJ5 - 3 15:50 **Integrated RGB Laser Light Module for Augmented and Virtual Reality Applications**

J. Reitterer, F. Fidler, G. Schmid, C. Hambeck, F. S. Julien-Wallsee, W. Leeb, U. Schmid**

TriLite Techs., Austria
**Tech. Univ. Wien, Austria*

We have developed an integrated, hermetically sealed RGB laser light module comprising three bare die semiconductor laser diodes (one each for red, green, and blue) with associated monitor photodiodes and a common microlens.

PRJ5 - 4
16:10

Development of Head-Up Display for Railway Vehicle

A. Michimori, J. Kondo, S. Nakahara, A. Heishi, T. Yamamura, S. Ohashi, H. Yokoyama[*]*, H. Horiuchi*[*]

Mitsubishi Elec., Japan
[*]*East Japan Railway, Japan*

We have developed a head-up display (HUD) for railway vehicles. We conducted stationary tests and running tests of the head-up display using actual vehicles and confirmed its good visibility and effectiveness in railway vehicles.

Author Interviews
16:30 – 17:10, Multipurpose Hall

Supporting Organizations:
Laser Display and Lighting Conference
Laser Display Technology Research Group, Optical Society of Japan
Technical Group on Information Display, ITE

Workshop on Electronic Paper

Wednesday, December 7

14:40 - 14:45 **502**

Opening

Opening Remarks
14:40

K. Hashimoto, E Ink Japan, Japan

14:45 - 16:10 **502**

EP1: Color e-Paper Technologies

Chair: M. Omodani, Tokai Univ., Japan
Co-Chair: G. Zhou, South China Normal Univ., China

EP1 - 1: ***Invited*** **Full-Color Electrophoretic Displays**
14:45

S. J. Telfer, M. D. McCreary
E Ink, USA

Full color electrophoretic displays utilizing colored particles, no color filter array, and a single TFT array backplane have been demonstrated for the first time. A full color gamut has been achieved with a single layer of electrophoretic fluid addressed with commercially demonstrated TFT backplanes using both Microcup and microcapsule structures.

EP1 - 2 **Novel Organic Electrochromic Device toward Multi-Color Representation**
15:10

M. Yukikawa, K. Nakamura, N. Kobayashi
Chiba Univ., Japan

Electrochromism is reversible color change by electrochemical reaction. In this paper, we designed novel organic electrochromic device based on bispyridinepyrrole derivatives and phenothiazine molecule. The EC properties of the devices were analyzed and discussed for the possibility to multi-color representation.

EP1 - 3: ***Invited*** **Three-Particle Electrophoretic Display**
15:30

M. Wang, Y. Li, C. Lin, H. Du, H. Zang
E Ink California, USA

Three-particle EPD technology has elevated the impact of ePaper by adding vivid highlight color to black/white optical states. The E Ink Spectra product line offers red/black/white and yellow/black/white image films for Electronic Shelf Label (ESL) applications. In this paper, we review the technology and show the advancements.

EP1 - 4L 15:55 **Multicolor Twisting-Ball Display without CFA**

Y. Komazaki, T. Torii

Univ. of Tokyo, Japan

We proposed a new concept of multicolor e-paper without color filter array (CFA) based on twisting ball display and proved the feasibility of the concept by performing a RG (red and green) display. Developed display has a simple structure which is suitable for large-sized panel like conventional twisting-ball display.

----- Break -----

Author Interviews
17:40 – 18:20, Multipurpose Hall

Thursday, December 8

9:00 - 10:10 **502**

EP2: Flexible e-Paper and IoT Application of e-Paper

Chair: N. Kobayashi, Chiba Univ., Japan
Co-Chair: Y. Toko, Stanley Elec., Japan

EP2 - 1: 9:00 ***Invited*** **High Durable Electrochromic Devices with Plastic Substrates**

H. Yaginuma, S. Yamamoto, D. Gotoh, K. Yutani, T. Fukuda, F. Kaneko, M. Inoue, H. Takahashi, Y. Okada, K. Takauji, T. Yashiro

Ricoh, Japan

We have developed oxidation and reduction (redox) electrochromic materials that had lower redox potential. By using these materials in both electrodes and controlling the driving voltage, we have developed an EC device that could repeatedly change its color over 100,000 cycles with plastic substrates.

EP2 - 2: 9:25 ***Invited*** **Advances in Flexible Electrophoretic Displays**

C. C. Tsai

E Ink Holdings, Taiwan

Plastic electrophoretic display (EPD) has been developed using both a-Si TFT and OTFT backplanes. Combined with features of daylight readability, light weight, shatterproof and extremely low power consumption, flexible EPD opened up a wide range of applications including smart cards, luggage tags, digital paper, IoT products, signages, architectures, etc.

EP2 - 3 9:50 **E-Paper as Key Display Technology for Internet of Things (IoT)**

K. Blankenbach, A. Marsal, T. Fegert

Pforzheim Univ., Germany

We compared e-paper displays with reflective LCDs and LEDs for "Internet of Things" (IoT) applications. Criteria were low power consumption, bistability, ambient light performance and content (HMI) to be visualized. We found out that low resolution graphic e-paper displays are the most appropriate approach for professional IoT systems.

10:10 - 10:40 **502**

Short Presentation EPp1: Electronic Paper

All authors of poster papers for the EPp1 session will give a brief 3-minute oral presentations with no discussion time in advance.

Author Interviews
10:40 – 11:10, Room 201

----- Lunch -----

14:10 - 16:40 **Multipurpose Hall**

***Poster* EPp1: Electronic Paper**

EPp1 - 1 **Discussion on Novel e-Paper Driving Mechanism and Possible Ways to Realize Full-Color Electronic Paper**

L. Wang, Y.-C. Wang, G.-S. Liu, H.-P. Shieh[*]*, S.-Z. Deng, B.-R. Yang*

Sun Yat-Sen Univ., China
[*]*Nat. Chiao Tung Univ., Taiwan*

Due to the low power consumption and bistability of electrophoretic display (EPD), using triboelectric-generator to power an EPD becomes possible. Moreover, feasible methods were proposed to arrange the color microcapsules in a certain position as subpixels, thus achieving the full-color EPD without color filter.

EPp1 - 2 **All-Printed Flexible Electrochromic Paper Based on Electrolyte Matrix**

S.-Y. Peng, Y.-C. Liao

Nat. Taiwan Univ., Taiwan

In this study, we present a state-of-the-art electrochromic paper (ECP) as rewritable device. After applying a DC voltage with a stylus, the ECP can switch between red and transparent colors without additional inks.

EPp1 - 3L **Fast-Moving Ball Actuator for Larger Sized-Low Cost Electronic Paper Display**

M. Hong, H. W. Yoon, K. H. Yang, S. Han[*], B. Bae[*], J. Lee[*], S.-W. Lee[**], M. Kim[**], J.-K. Song[***], D.-K. Lee[***], S.-K. Hong[****], M. Fahad[****]

Korea Univ., Korea
[*]Hoseo Univ., Korea
[**]Kyung Hee Univ., Korea
[***]Sungkyunkwan Univ., Korea
[****]Dongguk Univ., Korea

Fast-moving ball actuator for a novel electronic paper display has been developing. It is consisted of active light shutter and smart color reflector. It shows fast response time, full color without TFT arrays, which are major factors leading to innovation in large sized electronic paper display for outdoor public applications.

EPp1 - 4L **Experiment of Conductive Particle Actuation Using Capacitive Force : A New Method to Measure Adhesion Force Between Conductive Particles and Micro-Electrodes**

K. H. Yang, H. W. Yoon, M. Hong

Korea Univ., Korea

Our study, a number of conductive micro particles of the movement, is a new way to measure the adhesive force. The method obtains a surface roughness of a group rather than a single particle. Unlike the destructive measuring method using a Focused Ion Beam (FIB) it can be measured without physical damage to the particles

EPp1 - 5L **Rewritable Paper Utilizing Kapok Fibers Containing Pressure Sensitive Material**

S. Kiyama, K. Noda, R. Wada, S. Yoshinari, S. Maeda

Tokai Univ., Japan

We have succeeded in making Kapok fibers containing pressure sensitive material. Kapok fiber is natural half-transparent hollow tube. We think that the Kapok fibers containing pressure sensitive material have potential to apply to the field of anti-counterfeit and rewritable paper.

EPp1 - 6L **Hansen Solubility Parameter Value of the Inner Wall of Kapok Fibers Containing Functional Materials**

S. Yoshinari, S. Kiyama, K. Noda, R. Wada, S. Maeda

Tokai Univ., Japan

Most important thing to obtain successful Kapok fibers containing functional materials is to understand the nature of the inner wall of Kapok fiber. Therefore, in this present work, we have determined the HSP value of the inner wall of Kapok fiber.

EPp1 - 7L **SnO_2 Electrodes Prepared by Mist Deposition Processes for Ag Deposition-Based Three-Way EC Device**

H. Suzuki, S. Sato, K. Yamashiro, T. Shida, Y. Seki, T. Sasaki, K. Pak, S. Seki, T. Suenaga, K. Kumagai, T. Satoh, T. Uchida[*]

Nat. Inst. of Tech., Sendai College, Japan
[*]Tokyo Polytechnic Univ., Japan

Tin oxide (SnO_2) electrodes were prepared with a unique mist CVD apparatus. The electrode surface was modified with SnO_2 particles prepared by the spray-mist deposition process. By using these electrodes, we have fabricated the Ag deposition-based three-way electrochemical device which transform into three optical states - transparent, mirror and black.

EPp1 - 8L **Titanium Plate as Rewritable Imaging Media**

M. Tsuzuki, I. Komatsu, K. Matsunaka, S. Maeda

Tokai Univ., Japan

The method for preparing digital images on titanium plate by anodic oxidization and photo lithography was studied. First making a photoresist mask. And then we decomposed by an electric voltage to make Image. And we found that 1% HF solution could erase the image in a few minutes.

EPp1 - 9L **Fabrication of Plastic Cholesteric LCDs for Color e-Paper Applications Using Simplified Processes**

D.-S. Yoon[*,**], *S.-J. Lee*[*], *H.-S. Yang*[*], *G.-H. Kim*[*], *H.-J. Hong*[*,**], *Z. Hong*[**], *B.-Y. Lee*[**], *S.-G. Hyeon*[***], *S.-B. Kwon*[*,**]

[*]*Hoseo Univ., Korea*
[**]*NDIS, Korea*
[***]*JNC KOREA, Korea*

Using simplified fabrication process, LC layer formation through dispensing and lamination at room temperature and atmosphere pressure, we developed plastic cholesteric LCDs that show bright color with good color saturation, which are suitable for various color e-papers such as e-pop, poster, billboard and so on.

Also presented in Innovative Demonstration Session (see p. 263)

EPp1 - 10L **Evaluation of e-Paper as a Substitution of Paper in Office - Comparison with Paper and PC in a Proofing Task -**

N. Ota, M. Omodani

Tokai Univ., Japan

We compared working efficiency, preference, and fatigue of paper, e-Paper, and PC for a job to find mistakes on a typical office documents. e-Paper showed similarly superior efficiency and preference as those shown by paper. These results indicate ability of e-Paper as a substitution of paper for seeking paperless office.

----- Break -----

16:50 - 18:15 **502**

EP3: Novel Materials for e-Paper

Chair: S. Maeda, Tokai Univ., Japan
Co-Chair: M. Higuchi, NIMS, Japan

EP3 - 1: 16:50 ***Invited*** **A Bistable Electrochromic Display for a Low Energy-Consuming Persistent Imaging**

Y. Kim, H. Shin, E. Kim
Yonsei Univ., Korea

Electrochromic (EC) devices based on conjugated polymers showed large a vivid color contrast along with a long memory effect. In view of their bistability at voltage off state, the polymeric thin film EC device showed a possible application to a persistent imaging device having a low energy-consumption.

EP3 - 2 17:15 **Electrochemically Triggered Fluorescence and Coloration in Single Fluoran Molecule**

K. Nakamura, K. Kanazawa, N. Kobayashi
Chiba Univ., Japan

Multifunctional electroswitching of both emission and coloration were demonstrated by using fluoran derivatives in an electrolytic solution. The mechanism for this electroswitching was attributed to the reversible electrochemically induced closing and opening of the lactone ring in the fluoran molecule.

EP3 - 3 **Withdrawn**

EP3 - 5L 17:35 **Response Characteristics of Low-Temperature Sintered Indium Tin Oxide Porous Electrode for Fast-Response Electrochromic Display**

Y. Watanabe, K. Suemori, T. Kamata
NAIST, Japan

We investigated the response characteristics of a low-temperature-sintered indium tin oxide (ITO) porous electrode as an electrochromic dye-modified transparent electrode for fast-response electrochromic display (ECD). From the process temperature, resistivity, dye adsorption capability, and optical transmittance, the ITO porous electrode is a promising display electrode for flexible fast-response ECD applications.

EP3 - 4
17:55

Achievement of Long-Term Stability of AC-Driven Electrochemiluminescence from Ruthenium(II) Complex by Adding TiO_2 Nanoparticles

S. Tsuneyasu, K. Ichihara, K. Nakamura, N. Kobayashi
Chiba Univ., Japan

Electrochromism (EC) and electrochemiluminescence (ECL) are known as electrochemical reaction leading to coloration and light emission, respectively. Reflective-emissive dual-mode display device can be achieved by combining both EC and ECL mechanism. In this study, we introduced TiO_2 nanoparticles into the ECL device in order to improve AC-driven ECL properties.

Author Interviews
18:15 – 18:50, Multipurpose Hall

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by Oral and Poster Presenters
Thursday, Dec. 8, 2016
10:30-16:40
Multipurpose Hall (2F)
Fukuoka International Congress Center

EP

IDW/AD '16 Tutorial in Japanese

Organized by SID Japan Chapter
Tuesday, Dec. 6, 2016
12:20-16:30
Room 501
Fukuoka International Congress Center
Detailed information will be announced at
http://www.sid-japan.org/

Workshop on MEMS and Emerging Technologies for Future Displays and Devices

Thursday, December 8

9:00 - 9:05 **409**

Opening

Opening Remarks
9:00

M. Nakamoto, Shizuoka Univ., Japan

9:05 - 10:25 **409**

MEET1: Nanotechnologies for Display Applications

Chair: P. Kathirgamanathan, Brunel Univ. London, UK
Co-Chair: K. C. Park, Kyung Hee Univ., Korea

MEET1 - 1: ***Invited*** **Graphene for Field Emission Applications**
9:05

W. I. Milne[,**], T. Hallam[***], G. Duesberg[***], C. Li[****], W. Lei[****], B. P. Wang[****], M. T. Cole[*]*

[*]Univ. of Cambridge, UK
[**]Tokyo Tech, Japan
[***]Trinity College Dublin, Ireland
[****]Southeast Univ., China

Herein we present graphene as a possible candidate for a variety of field emission applications. The atomically thin, ordered structure of graphene has exceptionally high attainable aspect ratios - potentially higher even than that of CNTs - whilst defective edge terminations render it superior to metallic nanowires for such applications.

MEET1 - 2: ***Invited*** **New Approach for Fabricating High-Brightness GaN LED Microdisplays with High Resolution and Very Small Pixel-Pitch**
9:25

F. Templier, L. Benaïssa, I. Degirmencioglu, M. Charles, S. Tirano, A. Daami

CEA-LETI & 3-5 Lab, France

A new approach for fabricating high-brightness GaN microdisplays is proposed. The demonstration of feasibility is achieved with the production of 3 µm pixel pitch microLED arrays on silicon. Such LEDs have interesting electrical characteristics. This technology is therefore very promising for fabricating high brightness, ultra-high-resolution microdisplays needed for augmented reality.

MEET1 - 3: 9:45 ***Invited*** **Novel Approach to the Manufacture of MicroLED Colour Conversion Structures**

J. Silver, P. G. Harris, G. R. Fern, J. Bonar, G. Valentine*, S. Gorton**

Brunel Univ. London, UK
**mLED, UK*

This report discusses a novel approach for manufacturing colour conversion layers for micro-LED arrays. Colour conversion layers with discrete 20 µm pixels have been made using photolithography to define well structures which are then filled with either conventional phosphors or quantum dots.

MEET1 - 4: 10:05 ***Invited*** **Transfer Printing of Passive Matrix Displays Using Inorganic Micro-LEDs**

A. J. Trindade, E. Radauscher, S. Bonafede*, D. Gomez*, T. Moore*, C. Prevatte*, B. Raymond*, B. Fisher*, K. Ghosal*, A. Fecioru, D. Kneeburg*, M. Meitl*, C. Bower**

X-Celeprint, Ireland
**X-Celeprint, USA*

Displays that emit light from microscale inorganic light emitting diodes (iLEDs) have the potential to be bright, robust and power efficient. High-throughput assembly technologies are key enablers for creating full-color and large-format iLED displays. This paper presents a variety of passive matrix display (PMiLED) designs fabricated using transfer-printed microscale iLEDs.

----- Break -----

Author Interviews
10:30 – 11:10, Room 201

----- Lunch -----

14:10 - 16:40 **Multipurpose Hall**

Poster **MEETp1: Quantum Dots and Nanotechnologies**
Special Topics of Interest on Lighting and Quantum Dot Technologies

MEETp1 - 1 **$CsPbBr_3$ Based Perovskite Nanocrystals for Light-Emitting Diodes**

S.-Y. Cho, H.-M. Kim, E. Moyen, J. Jang

Kyung Hee Univ., Korea

We have synthetized $CsPbBr_3$ based perovskite nanocrystals (NCs) for light-emitting diodes. The $CsPbBr_3$ NCs solution shows a photo-luminescence (PL) peak at 517 nm under UV illumination with a narrow full-width half maximum (FWHM) of less than 24 nm. The highest PL intensity can be obtained at a 1:1 molar ratio of $PbBr_2$: CsBr.

MEETp1 - 2 **All Solution Processed Charge Generation Junction for Quantum-Dot Light Emitting Diodes**

E. Hwang, H.-M. Kim, J. Kim, J. Jang

Kyung Hee Univ., Korea

In this study, all-solution processed inverted yellow-emitting tandem quantum-dot light emitting diodes (QLEDs) are suggested. The solution processed p-n junctions are used to generate charges between bottom and top cells of tandem QLEDs. The tandem QLEDs with triple charge generation junctions by solution processing is fabricated for low-cost QLED manufacturing.

14:10 - 16:40 **Multipurpose Hall**

Poster **MEETp2: Novel Materials and Components**

MEETp2 - 1 **Fabrication of Nano-Gap in Thin Metal (Ag, Au, Cu) Film Using Water-Soluble Inorganic Film for Surface-Enhanced Raman Spectroscopy**

K. Min, W. J. Jeon, H. K. Yu

Ajou Univ., Korea

Thin metal film coated above water soluble ceramic film tends to form island film with nano sized particle and gap as time goes on. Properly cracked Ag film will be a high performance SERS substrate. We show SERS peaks with Ag film thickness using Rhodamine 6G.

MEETp2 - 2 **Doping Effect on Performance of Solution-Processed Metal Oxide P-N Heterojunction Diodes**

J. Shin, J. Kim, H.-M. Kim, J. Jang

Kyung Hee Univ., Korea

Doping effect of solution-processed metal oxide p-n heterojunction diodes has been investigated. The p-n diode quality factor decreases from 2.0 to 1.5 and on/off current ratio increases from 880 to 5860 by doping. The p-n diode manufactured by simple sol–gel solution process can be used for low-cost large-area oxide diodes.

MEETp2 - 3 **Application of Projector Display Technology for Inspection of Hydrogen Production Rate with Designed TiO_2 Electrodes**

C.-J. Ou, R.-Y. Lan, C.-R. Ho, Y.-S. Hong, Z.-F. Chen, C.-J. Huang

Hsiuping Univ. of S&T, Taiwan

TiO_2 is well known as the electrode for display technology. To defeat the possible shortage for the energy supply, a novel inspection system that founded on the information display technology is proven. Through this system, the generate rate of the Hydrogen is being inspected and measured.

MEETp2 - 4 Update Review on the Application of Information Display Technology for Optogenetics and Cell Illuminating Device

C.-J. Ou, M. Y. Cheng, C.-R. Ho, Y.-J. Hsu, C.-J. Huang

Hsiuping Univ. of S&T, Taiwan

To develop cost-effective optogenetic experimental setup for investigating synaptic gating (neuron connectivities) through the display technology is reviewed. Comments on various kinds of display technology what related with the optogenetic and the disease detection, and the adaptive optical component with variable focusing capabilities may be implemented for this attractive field.

MEETp2 - 5L Morphological and Electrical Properties of Nanocrystalline Zinc Oxide Thin Films

K. H. Kim, Z. Jin, Y. Yoshihara, Y. Abe, M. Kawamura, T. Kiba

Kitami Inst. of Tech., Japan

We investigated the morphological and electrical properties of zinc oxide (ZnO) thin films prepared via sol-gel method with various annealing temperatures and times. The nanocrystalline size and resistivity increased and decreased, respectively, with increasing annealing temperatures. However, those properties were less dependent on the time duration at a constant temperature.

MEETp2 - 6L Rotary-Linear Ultrasonic Motor of the Lead-Free NKN-based Ceramics for Camera Applications

C.-M. Weng, S.-Y. Chu, C.-C. Tsai[*], C.-S. Hong[**], J. Sheen[***]

Nat. Cheng Kung Univ., Taiwan
[*]Tung Fang Design Inst., Taiwan
[**]Nat. Kaohsiung Normal Univ., Taiwan
[***]Nat. Formosa Univ., Taiwan

Lead-free CuF_2-doped and CuO-doped $Na_{0.5}K_{0.5}NbO_3$ ($NKNCO_x$ and $NKNCF_x$, x = 0 - 1.5 mol%) piezoelectric ceramics were synthesized and the influence of additives on microstructure, electrical properties and mechanical properties of the proposed samples were investigated. Furthermore, the proposed rotary-linear ultrasonic motors have been developed for camera applications.

MEETp2 - 7L Application of Display Projector as Solar Panel Inspection

C.-J. Ou, Z.-Y. Shih, K.-S. Hsu, C.-J. Huang

Hsiuping Univ. of S&T, Taiwan

In this report, we demonstrate the feasibilities that using the commercialized projector as inspection modules for solar cell that along with various spectrum flexibilities. This inspection system, give a satisfied result and excellent credit, which indicates a new application of the display technology to the green energy industry.

Friday, December 9

9:00 - 10:20 **413**

MEET2: Novel Materials and Components

Chair: J. Silver, Brunel Univ. London, UK
Co-Chair: C. Lee, Seoul Nat. Univ., Korea

MEET2 - 1 **Withdrawn**

MEET2 - 5L: 9:00 ***Invited*** **Quantum Rod Film (QRF) Optical Properties and Stability**

J.S.Niehaus[*], K.Poulsen[*], S.Becker[*], T.M.Jochum[*], H.Weller[,**]*

[*]Ctr. for Appl. NanoTech., Germany
[**]Univ. of Hamburg, Germany

Hereby we present high quality CdSe/CdS nanorods emitting in red and green and their embedding into a polymer matrix suitable for optoelectronic devices. The high quantum yields of the produced particles can be maintained in the polymer matrix. Stability tests using these polymer compounds will also be shown.

MEET2 - 2: 9:20 ***Invited*** **Fabrication of High Performance Electron Beam with Carbon Nanotube Cold Cathode and Its Applications**

J. S. Kang, K. C. Park

Kyung Hee Univ., Korea

We developed novel electron beams with CNTs cold cathodes. The electron beam shows more than 90% electron transmission ratio through gate electrode, resulting higher anode current and lower thermal damage on gate electrode. The electron beam shows anode current more than 10 mA with DC driving at less than 1 cm^2 area.

MEET2 - 3 9:40 **Graphene Protected Ag Nanowires: Blocking of Surface Migration for Thermally Stable and Wide-Range-Wavelength Transparent Flexible Electrodes**

A. Lee, J. Lee, H. K. Yu

Ajou Univ., Korea

Graphene layers were transferred on both side of Ag nanowires for used in transparent flexible electrodes. The graphene-protected Ag nanowires have shown stable sheet resistivity at high temperature (~170°C) during several hundred hours. Moreover, the graphene blocked surface plasmonic absorption of Ag nanowires, resulting in uniform transparency at wide-range-wavelength.

MEET2 - 4: 10:00 ***Invited*** **Progress in Electro-Fluidic Displays at South China Normal University**

B. Tang[*], Y. Deng[,**], R. A. Hayes[*,**,***], G. F. Zhou[*,**,***]*

[*]South China Normal Univ., China
[**]Shenzhen Guohua Optoelect. Tech, China
[***]Ac. of Shenzhen Guohua Optoelect., China

Electro-fluidic display (EFD) or electro-wetting technology is one of the most promising reflective displays for its full color and video speed. Here we give a short update on the recent progress of EFD at South China Normal University, including new materials and process, driving scheme and dynamic modeling work.

Also presented in Innovative Demonstration Session (see p. 263)

----- Break -----

10:40 - 12:00 **413**

MEET3: Fundamental Components and Process Technologies

Chair: F. Templier, CEA-LETI, France
Co-Chair: K. C. Park, Kyung Hee Univ., Korea

MEET3 - 1: 10:40 ***Invited*** **Plastic Packaging Recycling Using Intelligent Separation Technologies for Materials**

J. Silver, P. G. Harris, G. R. Fern, E. Kosier[*], M. Kay[*], J. Mitchell[*]

Brunel Univ. London, UK
[*]Nextek, UK

The sorting of plastic articles is currently achieved using near infrared spectroscopy but this cannot identify all material types. The objective of this work is to develop luminescent codes that can be printed onto plastic articles that identify both the material and also end-use in high speed sorting equipment.

MEET3 - 2: 11:00 ***Invited*** **Efficient SPICE Model of TFT with Gaussian Density of States**

Y. Bonnassieux, S. Jung, G. Horowitz

Ecole Polytechnique, France

Efficient SPICE Model of OTFT must take into account the specificity of charge transportation in organic material. One of the most important property is the Gaussian density of states coupled with the gate bias dependency of the mobility.

MEET3 - 3: 11:20 ***Invited*** **Nanostructured Polymer Particles for Display Applications and Others Prepared by Self-Organization Processes**

H. Yabu

Tohoku Univ., Japan

We have discovered a simple and versatile particle preparation method termed "Self-ORganized Precipitation (SORP)." One of the advantages of the SORP method is that mixtures of polymers and other functional materials including nanoparticles and pigments can be transformed into nanoparticles. Morphological control and application of polymer particles will be discussed.

MEET3 - 4 11:40 **Plasma Nano Texturing Photo Resistor for Pixel ITO Forming in 3-Mask TFT Process**

M. Lu, J. Yao, S. Qin, X. Liu, G. Huang, X. Cai, Z. Li

Shenzhen China Star Optoelect. Tech., China

We demonstrated a high-efficient ITO lift off process which made it easy to fabricate 3Mask TFT, with low cost and high yield. In this process, we used nano texturing photo resister to form nano pillar forest in the surface of photo resister to enhance ITO lift off.

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 14:50 **413**

MEET4: EL Quantum Dots Technologies
Special Topics of Interest on Lighting and Quantum Dot Technologies

Chair: K. C. Park, Kyung Hee Univ., Korea
Co-Chair: X. W. Sun, Southern Univ. of S&T, China

MEET4 - 1: 13:30 ***Invited*** **Tandem QLED with Oxide Charge Generation Junction**

J. Jang, H.-M. Kim, E. Hwang

Kyung Hee Univ., Korea

This paper reviews the solution-processed charge generation junctions (CGJs) which can be used for single and tandem quantum-dot light emitting diodes (QLEDs) and organic light emitting diodes (OLEDs). Organic charge-generation layer by thermal evaporation, solution processed charge-generation junction and tandem QLED with oxide-oxide CGJ is introduced.

MEET4 - 2: *Invited* Full-Color Patterning of Quantum Dot Displays Based on Transfer Printing and Inkjet Printing
13:50

J. Han, D. Ko, J. Roh, H. Jung, Y. Lee, J. Sohn, W. K. Bae[*]*, C. Lee*

Seoul Nat. Univ., Korea
[*]KIST, Korea

To realize the full-color QLED display, the QD emissive layer should be patterned to red, green, and blue subpixels. Here, we resent two full-color patterning methods such as transfer printing and inkjet printing and discuss key issues that must be solved for realizing practical QLED displays.

MEET4 - 3: *Invited* Solution-Processable Hybrid Light-Emitting Devices Based on Organic/Inorganic Nanocomposites
14:10

Y. Liu, F. Li, J. Lin, H. Hu, T. Guo

Fuzhou Univ., China

By combining the unique advantages of organic and inorganic materials, hybrid light-emitting devices could exhibit superior device performances based on low cost solution processes. In this speak, we present our recent works regarding the design, fabrication and performance optimization of hybrid light-emitting devices based on semiconductor quantum dots, etc.

MEET4 - 4: *Invited* Quantum Dot Electroluminescence
14:30

P. Kathirgamanathan, M. Kumaraverl, N. Bramananthan, S. Ravichandran, L. M. Bushby, S. Surendrakumar

Brunel Univ. London, UK

Colloidal quantum dots have the potential to offer saturated colours satisfying the new REC 2020 (ITU-R-BT 2020) standard. By using suitable device architecture and quantum dot size, we achieved a very high efficiency of 4 cd/A for CIE (x, y) of (0.708, 0.292) meeting the REC 2020 specification. A world record efficiency of 16 cd/A and 11 lm/W for (0.704, 0.296) has been achieved by employing a novel hole transporter.

----- Break -----

15:10 - 16:30 **413**

MEET5: Emerging Quantum Dots and Nanotechnologies
Special Topics of Interest on Lighting and Quantum Dot Technologies

Chair: J. Jang, Kyung Hee Univ., Korea
Co-Chair: Y. Bonnassieux, Ecole Polytechnique, France

MEET5 - 1: ***Invited*** **What's Next for Quantum Dots? Delivering the Ultimate Visual Experience to the Mainstream**
15:10

H. Kim

Nanosys, USA

Display engineers strived for decades to produce displays that deliver immersive, life-like visual experiences – so-called Ultimate Visual Experience (UVE). Quantum Dot Enhancement Film (QDEF) makes UVE possible and affordable. This paper covers the latest Quantum Dot technology and supply chain developments for delivering UVE-capable LCD products to mainstream consumers.

MEET5 - 2: ***Invited*** **Heavy Metal-Free Quantum Dots for Consumer Applications**
15:30

N. L. Pickett, N. C. Gresty, I. Naasani

Nanoco Techs., UK

In recent years, display products containing quantum dots have begun to appear on the consumer market. However, many products still contain toxic cadmium. Herein, we report on the synthesis and development of heavy metal-free quantum dots, with a particular focus on displays, lighting and biological imaging applications.

MEET5 - 3: ***Invited*** **Luminescent Nanocrystals and Devices for Energy-Saving Quality Displays and Lighting**
15:50

K. Wang, X. W. Sun

Southern Univ. of S&T, China

We introduce a new kind of quantum dot composites as luminescent microspheres featuring high efficiency, narrow FWHM and excellent long-term operation stability for PL application. Moreover, very bright and efficient hybrid perovskite QLEDs based on $FA_{0.8}Cs_{0.2}PbBr_3$ perovskite nanocrystals with organic-inorganic mixed cations were also demonstrated.

MEET5 - 4: 16:10 ***Invited*** **Optical Characteristics of Quantum Rod Color Pixel Converter Combined with Twisted Nematic LCD**

M. Hasegawa, Y. Hirayama

Merck, Japan

We fabricated quantum rod-based color conversion subpixels by ink jet printing. We stacked these subpixels on a twisted nematic liquid crystal (TN-LC) panel, and evaluated their optical properties, including color gamut, contrast ratio, and viewing angle. The panel covers 80% of the BT.2020 standard color gamut. The TN LC panel with collimated blue LED showed the effects of polarizers and the alignment of LC. However, combination with the QR emission layer eliminated the effects of polarizer and LC, and led to a very wide viewing angle even in a grey level.

Author Interviews
16:30 – 17:10, Multipurpose Hall

3DSA 2016

The 8th International Conference on 3D Systems and Applications
Held in conjunction with IDW/AD '16

Fukuoka International Congress Center
December 7-9, 2016
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IDW Best Paper Award

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These awards will go to the most outstanding papers selected from those presented at IDW/AD '16.
The 2016 award winners will be announced on the IDW website: http://www.idw.or.jp/award.html

Workshop on Display Electronic Systems

Thursday, December 8

14:10 - 16:40 **Multipurpose Hall**

Poster **DESp1: Display Electronic Systems**

DESp1 - 1 **Development of 98-in. 8K HDR LCD and the Related Technologies**

C. Jung, Y. Bi, G. Sun, C. Zhou, Q. Yang, S. Li, Y. Im, L. Zhang, J. Jun

BOE Tech. Group, China

In order to overcome the gap with real images and images on display, a number of technologies and products for HDR (High Dynamic Range) came out. The current papers suggest some driving skills and algorithms improving image quality, which is essential to realize the 8K HDR technology.

DESp1 - 2 **65-in. 8K4K Curved LCD**

L.-W. Chu, L. Sun, W.-C. Peng, J.-J. Xie, W.-Q. Zhao, A.-L. Hu, Y.-H. Fu, P.-S. Kuo, B. Zhao, Y.-Y. Chen

Shenzhen China Star Optoelect. Tech., China

A 65-in. super hi-vision curved LCD was successfully developed. Two 4K2K TCONs are adopted to control the left panel and the right panel. The intra panel interface is high speed point-to-point. The FPGA board with total 80 lane V-by-One inputs and outputs includes several CSOT developed algorithms.

DESp1 - 3 **Novel a-Si:H Gate Driver Circuit for In-Cell Touch TFT-LCDs**

W.-L. Wu, P.-C. Lai, M.-H. Cheng, C.-L. Lin

Nat. Cheng Kung Univ., Taiwan

This work proposes a novel gate driver circuit based on hydrogenated amorphous silicon (a-Si:H) technology for thin-film transistor liquid crystal displays (TFT-LCDs) with the in-cell touch sensing structure. Simulation results demonstrate that the variations of the rising and falling time are below 2% after the touch sensing operation.

DESp1 - 4 **Novel Structure with Time Division Driving Method for a-Si:H TFT LCDs**

P.-C. Lai, C.-E. Wu, F.-H. Chen, C.-L. Lin

Nat. Cheng Kung Univ., Taiwan

Novel gate driver circuit turns off the driving TFT during the touch sensing period to ameliorate the degradation of the driving TFT for in-cell touch panels. Based on the RPI a-Si:H TFT model of the HSPICE simulator, uniform and stable gate signals are produced by the proposed gate driver circuit.

DESp1 - 5 **Peak Luminance Increase Method in RGBW AMOLED Display**

Z.-Y. Lin, C.-M. Hsu, M.-T. Lee

AU Optronics, Taiwan

RGBW display has longer lifetime and wider dynamic range than RGB display. This paper use RGBW display of high dynamic range to improve the display range of high brightness pixels. Make the RGBW display shows closer to the dynamic range of the human eye.

DESp1 - 6 **Most Power Saving WRGB Algorithm without Saturation Reduction**

J. J. Wu, K. Hsiao, W. W. Zheng, J. Fan

Shenzhen China Star Optoelect. Tech., China

WRGB algorithm is essential to display right color in WRGB LCD.We introduce a new algorithm:a turning point W_T is determined,if W is larger than W_T, the saturation is inevitably reduced, otherwise the tansmittance is reduced. So the algorithm ensures the highest transmittance which means the most power saving yet without saturation reduction.

DESp1 - 7 **Implant Scan Strategy for Ultra-High Gray Level Flat Panel Display**

C. Wang, L. Man, Y. Ji, F. Ran, M. Xu

Shanghai Univ., China

We present a full digital implant scan strategy for the flat panel display. The mathematical model of the implant scan strategy is built. The experiment results show that the gray levels reach above 2000 when the clock frequency is only 143.9 MHz with the implant scan strategy.

DESp1 - 8 **Challenges and Methods for Local Dimming of Long-Edge LCD TVs**

M. Grüning, M. Schmidt, D, Schäfer, C. Xu

Saarland Univ., Germany

The major challenges for local dimming of long-edge LCD TVs are the predominant horizontal structure in most natural images and vertically collimated light profile, so that horizontal non-uniformity and Halo artifacts may appear. Our local dimming algorithm is amended by new adaptive filters. This way, the issues can be eliminated.

DESp1 - 9 **Photographing Steganography by Use of Spatio-Temporal Coding on a High-Frame-Rate LED Display**

M. Takahashi, H. Yamamoto

Utsunomiya Univ., Japan

This paper proposes a novel steganography technique for digital signage by use of spatio-temporal coding. Observers perceive an original image because coded images are changed too rapidly for them to distinguish the changes. However, a photographed portion of the frames shows an image that is different from the apparent image.

DESp1 - 10 **Image Super-Resolution Based on Multiple Linear Mappings**

H. Sun, R. Wang, W. Lu, L. He, X. Gao, M. J. Jou[*]*, S. S. Syu*[*]*, J. S. Li*[*]

Xidian Univ., China
[*]*Shenzhen China Star Optoelect. Tech., China*

We propose an efficient image Super-Resolution method that learns multiple linear mappings to directly transform Low-Resolution (LR) feature subspaces into High-Resolution (HR) subspaces. This method learns a compact LR-HR subdictionary pair regarding to each subspace, then the shared representation coefficients are obtained to infer the mapping relationship utilizing the global regression.

DESp1 - 11L **A 10-Bit Area-Efficient DAC with Voltage-Average Technique for LCD Column Driver Applications**

C.-W. Lu, C.-M. Hsiao

Nat. Tsing Hua Univ., Taiwan

This paper proposes a 10-bit area-efficient DAC with a voltage-average technique, comprising a 6-bit RDAC, a voltage-average circuit, and a new 4-bit DAC-embedded op-amp. The maximum DNL and INL were measured as 0.58 LSB and 0.88 LSB, respectively. The proposed 10-bit DAC occupies only 75% that of conventional 8-bit RDACs.

----- Break -----

16:50 - 16:55 **413**

Opening

Opening Remarks
16:50

H. Okumura, Toshiba, Japan

16:55 - 18:20 **413**

DES1: DES 10th Anniversary

Chair: K. Morita, NTSEL, Japan
Co-Chair: T. Kishigami, Mitsubishi Elec., Japan

DES1 - 1: 16:55 ***Invited*** **10th Anniversary: Display Innovation - Past and Future of the DES-WS -**

H. Okumura

Toshiba, Japan

The challenging history of the DES workshop and innovative DES related topics including Overdrive technology is reviewed and the future trend of the Display electronics and system technologies are introduced, as 10th anniversary of the DES-WS.

DES1 - 2: 17:10 ***Invited*** **Display Electronic Systems: Augmented Reality in the Next Decade**

Y. Oyamada

Tottori Univ., Japan

Augmented Reality is regarded as one of the technology closest to users in Display Electronic Systems. This paper discusses future prospects of Augmented Reality from a software perspective, especially display electronic systems. We first remind the readers the definition and review the literature and then mention its future prospects.

DES1 - 3: 17:30 ***Invited*** **Development of a New Head-Up Display System Using 2D Local Dimming with RGBW Technology**

K. Sako, N. Takasaki, S. Aoki, T. Yata, T. Harada

Japan Display, Japan

We have developed a prototype of Head-Up Display system using new 2D local dimming method, which is considered luminance distribution of each backlight. Our system has taken high contrast ratio, low power consumption, high luminance, and invisible the post card effect phenomenon that is slightly illuminated the entire projection area.

DES1 - 4: 17:55 ***Invited*** **Three-Dimensional Head-Up Display for Automobiles Using Super Multi-View Display**

Y. Takaki

Tokyo Univ. of A&T, Japan

A super multi-view display, which is free from the visual fatigue and has smooth motion parallax, is used to construct three-dimensional (3D) head-up displays for automobiles. Smooth motion parallax is important for displaying 3D images at near to far distances and superimposing driving information precisely on real scenes.

Author Interviews
18:20 – 18:50, Multipurpose Hall

Friday, December 9

10:40 - 12:05 **502**

DES2: High Image Quality Technology

Chair: T. Yamamoto, NHK, Japan
Co-Chair: A. Sakaigawa, Huawei, Japan

DES2 - 1: 10:40 ***Invited*** **Verification of Visually Lossless Image Quality for Display Stream Compression in Consumer Devices**

W. Wang, D. Hoffman, D. Stolitzka, W. Xiong
Samsung Display America R&D Lab., USA

Display stream compression (DSC) must have excellent stability such that it produces no scintillation artifacts with motion sequences that force a constant re-encoding of the data. We evaluated different image motion testing paradigms, including panning imagery, to explore DSC visual quality on demanding HDR imagery.

DES2 - 2 11:05 **Development of OLED Display Using Adaptive Temporal Aperture Control Driving Methods with Transition Area Insertion**

T. Usui, Y. Takano, T. Yamamoto
NHK, Japan

For a longer lifetime and better motion image quality of OLED displays, we previously proposed an adaptive temporal aperture control method. To realize an actual OLED display applying this method, we developed a signal processing unit and scan drivers. We confirmed effectiveness of our proposed method by the developed display.

DES2 - 3 11:25 **Introduction of "Panel Display Enhance" Technology and Its Application on High ppi Display Device**

Z. Zhang, L. Fang, X. Zhan, C. He, M. Huang, H. Kusanagi, H. Ikeno, L. Wu, X. Zhou, P. Shen, J. Li, C. Tseng
XiaMen Tianma Microelect., China

We've developed the PDE (Panel Display Enhance) technology from the arrangement and algorithm parts. How to achieve high ppi display effect of PDE technology is analyzed in theory. Based on the arrangement of "WAVE", we have designed and produced a 847 ppi LCD screen, the display is prominent.

DES2 - 4 11:45 **8K Ultra-High-Definition Medical Display System**

L. Geng, C. Leng, R. Duan, C. Wei
BOE Tech. Group, China

This paper introduces the architecture of BOE 8K (resolution is 7680 × 4320) Ultra-High-Definition (UHD) medical display system, and demonstrates the key technology of Ultra-High-Definition medical image processing, including DICOM (Digital Imaging and Communications in Medicine) calibration, resolution up-scaling and highly parallel processing.

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 15:05 **201**

PRJ4/DES3: 3D and Near Eye Displays
Special Topics of Interest on AR/VR and Hyper Reality

Chair: J. Reitterer, TriLite Techs., Austria
Co-Chair: T. Hayashi, Okamoto Glass, Japan

PRJ4/DES3 - 1: 13:30 ***Invited*** **Projection Mapping Technologies for AR**

D. Iwai

Osaka Univ., Japan

This invited talk will present recent projection mapping technologies for augmented reality. First, fundamental technologies are briefly explained, which have been proposed to overcome the technical limitations of ordinary projectors. Second, augmented reality (AR) applications using projection mapping technologies are introduced.

PRJ4/DES3 - 2: 13:50 ***Invited*** **Animating Static Objects by Illusion-Based Projection Mapping**

S. Nishida, T. Kawabe, T. Fukiage, M. Sawayama

NTT, Japan

In this presentation, we will explain a light projection technique that we recently developed. Based on the scientific knowledge about human visual processing, this technique, called Deformation Lamps (HenGenTou), is able to add a variety of illusory, yet realistic, distortions to a wide range of static projection targets.
Also presented in Innovative Demonstration Session (see p. 263)

PRJ4/DES3 - 3: 14:10 ***Invited*** **3D Billboards without Glasses**

J. Reitterer, F. Fidler, G. Schmid, C. Hambeck, F. S. Julien-Wallsee, W. Leeb[*]*, U. Schmid*[*]

TriLite Techs., Austria
[*]*Tech. Univ. Wien, Austria*

We have developed a technology enabling autostereoscopic billboards which provide outdoor-compatible luminance and are scalable to practically any desired display size. Each display element consists of a MEMS laser scanner that deflects the emitted light beams to the left and right eyes of multiple viewers in a time-multiplexed manner.

PRJ4/ DES3 - 4 14:30 **Smart Contact Lens Platform with a Deformed Active Artificial Iris**

A. V. Quintero[,**], S. Delcour[*,**], R. Verplancke[*,**], J. Vanfleteren[*,**], H. De Smet[*,**]*

[*]Ghent Univ., Belgium
[**]imec, Belgium

This paper explores the challenges regarding the thermoforming of a deformable guest-host liquid crystal display within a smart contact lens. Focus was given to the finite element modelling of its fabrication, to find respective design rules. Such displays are thought to be used in vision correction applications (i.e. artificial iris).

PRJ4/ DES3 - 5L 14:50 **Compact Optical Engine with Speckle Reduction Element for Laser Pico-Projector**

J.-Y. Lee, B. Yim[*], T.-H. Kim[**], J.-U. Bu[**], Y.-J. Kim

Yonsei Univ., Korea
[*]Wikioptics, Korea
[**]SenPlus, Korea

Compact optical engine has been designed and fabricated with speckle reduction element for laser pico-projector. Various optical components are fabricated and assembled in small size of optical engine under 5 cc volume. It was confirmed that speckle contrast was reduced 38.02% for the green light from the experimental result.

----- Break -----

15:15 - 16:45 **Main Hall**

DES4/3D8: 3D Display and Sensor
Special Topics of Interest on AR/VR and Hyper Reality

Chair: Y. Oyamada, Tottori Univ., Japan
Co-Chair: H. Yamamoto, Utsunomiya Univ., Japan

DES4/ 3D8 - 1: 15:15 ***Invited*** **Displaying Real World Light Fields Using Stacked LCDs**

K. Takahashi, Y. Kobayashi, T. Fujii

Nagoya Univ., Japan

We have developed a prototype of a layered light-field (3D) display, where three LCD panels are stacked in front of a backlight. We have also created an end-to-end system where a real 3D scene captured by a multi-view camera is reproduced in 3D on this prototype display.
Also presented in Innovative Demonstration Session (see p. 263)

DES4/ 3D8 - 2: 15:40 ***Invited*** **Lock-in-Detection Based Time-of-Flight CMOS Image Sensors**

K. Yasutomi, S. Kawahito

Shizuoka Univ., Japan

This paper reviews recent time-of-flight (TOF) range imagers particularly for indirect TOF measurement by using lock-in pixels. Lateral Electric Field charge Modulators (LEFM) in the lock-in pixel is a key component to achieve higher range resolution. In this paper, different implementations of TOF range imagers for various applications are described.

DES4/ 3D8 - 3 16:05 **Holographic Augmented Reality Head-Up Display with Eye Tracking and Steering Light Source**

Y.-T. Kim, J. Seo, W. Seo, G. Sung, Y. Kim, H. Song, J. An, C.-S. Choi, S. Kim, H. Kim, Y. Kim, Y. Kim, H.-S. Lee

Samsung Elect., Korea

We realized a holographic head-up display using a steering light source with eye position tracking. It can represent a real augmented reality which perfectly matches virtual graphic images to the real world. Further, for the determination of the position of the light source, 3D calibration method is proposed.

DES4/ 3D8 - 4 16:25 **Flat Autostereoscopic 3D Display with Enhanced Resolution Using a Wavelength Selective Filter Barrier**

S. Jurk, M. Kuhlmey, R. Bartmann, B. Duckstein, R. de la Barré

Fraunhofer HHI, Germany

A spatially multiplexed autostereoscopic 3D display design with lamellar parallax barrier consisting of wavelength-selective color filters is presented. In comparison to conventional similar parallax barriers the resolution, brightness and crosstalk are enhanced. The filtering of single colors enhances a separation of stereo images.

Author Interviews
16:45 – 17:10, Multipurpose Hall

Supporting Organizations:
Fukuoka Section, IEEE
The Society of Automotive Engineers of Japan (JSAE)
Special Interest Group on Mixed Reality (SIG-MR), The Virtual Reality Society of Japan
Technical Committee on Electronic Information Displays, Electronics Society, IEICE
Technical Committee on Image Engineering (IE), Information and Systems Society, IEICE
Technical Group on Information Display, ITE

Workshop on Flexible Electronics

Wednesday, December 7

16:20 - 17:45 **412**

LCT3/FLX1: Flexible LCDs

Chair: S. Oka, Japan Display, Japan
Co-Chair: M. Kimura, Nagaoka Univ. of Tech., Japan

LCT3/FLX1 - 1: 16:20 ***Invited*** **Roll Plastic TFT-LCD with 20R Curvature Using Soft Backlight Unit**

N. Sugiura, P.-H. Chiu, W.-Y. Li, Z.-H. Chen, W.-J. Chiu, C.-R. Chang, T.-H. Huang, Y.-H. Lai, J.-K. Lu, Y.-C. Lin

AU Optronics, Taiwan

We have developed a roll plastic TFT-LCD with 20R curvature using an advanced hyper-viewing-angle mode, optically compensated colorless polyimide substrates, and a soft backlight unit with an optimized micro-surface-structure. This technology enables both high optical performance and high reliability of roll plastic TFT-LCDs.

LCT3/FLX1 - 2: 16:45 ***Invited*** **Substrate and Polymer-Wall Technologies for Future Foldable LCD Applications**

T. Ishinabe, Y. Obonai, S. Honda, Y. Shibata, H. Fujikake

Tohoku Univ., Japan

Highly reliable foldable display has been crucial technology for future LCD applications such as large digital signages and automotive displays. We have developed foldable LCD using ultra-thin polyimide substrates with polymer walls structure by the coat-debond fabrication method and successfully achieved small curvature radius less than 2 mm.

LCT3/FLX1 - 3 17:10 **Flexible LC Light Shutter with Polymer Wall Structure**

S.-M. Ji, J.-W. Huh, J.-H. Kim, Y.-G. Choi, B.-H. Yu, T.-H. Yoon

Pusan Nat. Univ., Korea

We fabricated an initially-transparent flexible LC light shutter with the wall structure. It uses light scattering and absorption at the same time so that it can hide objects behind it and provide black color. We expect that the light shutter can provide high visibility to a flexible see-through display.

LCT3/ FLX1 - 4L 17:30 **Solution-Processed Graphene/PEDOT:PSS Film as Alternative to ITO**

T. Hu, H. Wang, X. Zhang, G. Liu, H. Chen, Y. Lee

Shenzhen China Star Optoelect. Tech., China

An ITO alternative film was obtained from high conductivity graphene nanosheet combining with the PEDOT:PSS, and the film with 123 nm film thickness exhibited a sheet resistance of 185 Ω/□ and 95% light transmittance at 550 nm. Moreover, the film has good adhesive due to the addition of graphene.

Author Interviews
17:45 – 18:20, Multipurpose Hall

Thursday, December 8

10:30 - 13:00 **Multipurpose Hall**

Poster **FLXp1: Flexible Electronics**

FLXp1 - 1 10:30 **High Gas Barrier Thin Film Deposition by PECVD on Plastic Substrates Using a Novel and Highly Volatile Precursor, TG-41, for OLED Applications**

H. Chiba, K. Iwanaga, K. Tokuhisa

TOSOH, Japan

Flat, colorless, and transparent high gas barrier layer was deposited by PECVD using a novel and highly volatile organosilane precursor, TG-41, on polyethylene naphthalate substrate. WVTR of the 800 nm thick gas barrier layer deposited from TG-41 was 2.0×10^{-4} g/m^2/day or lower under 40°C, 90%RH condition.

FLXp1 - 2 **Withdrawn**

FLXp1 - 3 **Flexible OLEDs Fabricated on Transparent Chitin Nanofiber Paper**

D. Lee, H.-G. Im, Y. C. Han, E. G. Jeong, M. Rolandi[*], Y. H. Kim, K. C. Choi, J. Jin[**], B.-S. Bae

KAIST, Korea
[*]Univ. of California, Santa Cruz, USA
[**]Univ. of Ulsan, Korea

In this study, we report a fabrication of flexible organic light-emitting diodes (OLEDs) on transparent paper made of self-assembled chitin nanofiber (ChNF) without any planarization steps. The transparent ChNF paper is produced by a centrifugal casting, which fabricates a large 20 mm-thick uniform transparent ChNF paper.

FLXp1 - 4 **Development of Organic Face Sealing Layer with Hygroscopic Particles for Encapsulation of OLEDs**

C.-J. Lee, Y. S. Park, S. P. Hwang*, M.-G. Kwak*

KETI, Korea
**DUKSAN Neolux, Korea*

We developed the structure with organic face sealing layer included hygroscopic particles, and metal foil to flexible OLED. Organic face sealing layer, silicone:ZrO_x was coated on OLED and then Al foil was laminated on organic layer. This encapsulation shows similar lifetime property to compare glass cap and improve initial drop.

FLXp1 - 5 **Roll-to-Roll Processing of Silver/ITO Continuous Deposition on Planarized Stainless Steel Foil**

Y. Hagiwara, H. Itoh, T. Furukawa**, H. Kobayashi**, S. Yamaguchi, N. Yamada, J. Nakatsuka***, M. Koden**, H. Nakada***

Nippon Steel & Sumitomo Metal, Japan
**Teijin, Japan*
***Yamagata Univ., Japan*
****Nippon Steel & Sumikin Materials, Japan*

Planarized stainless steel foil fabricated by 'Roll-to-Roll' process has been developed as a flexible substrate. In this study, continuous deposition of silver alloy and ITO layers on planarized stainless steel foil was carried out using 'Roll-to-Roll' deposition equipment.

FLXp1 - 6 **Withdrawn**

FLXp1 - 7 **Roll-to-Roll Fabrication Process of Silver Nanowire Embedded Flexible Transparent Electrode for OLEDs**

C. Kim, E. Jung, Y. E. Sul, S. M. Cho

Sungkyunkwan Univ., Korea

Silver nanowire embedded flexible transparent electrode was fabricated via fully roll-to-roll process. Silver nanowire was coated with a Meyer rod and embedded in UV-curable resin(NOA63). Sheet resistance of fabricated electrode was below 8 ohm/sq and transmittance was over 85%. The RMS value of surface roughness was below 3 nm.

FLXp1 - 8 **Flexible OLEDs Fabricated by Completely Roll-to-Roll Process**

H. Lee, E. Jung, C. Kim, S. M. Cho

Sungkyunkwan Univ., Korea

We fabricate flexible OLEDs by completely roll-to-roll process. Roll-to-roll ALD/PECVD process was used for thin film encapsulation of substrate and devices. Ag-NW imbedded film was used as an anode of devices. The device was fabricated by roll-to-roll thermal evaporation process and encapsulate with multi-layer moisture barrier film.

FLXp1 - 9 **Electroplated Metal Grid/Surface-Embedded Silver Nanowire Hybrid Structure: A Robust and Flexible Transparent Conducting Electrode Platform**

J. Jang, H.-G. Im, J. Jin, J. Lee, J.-Y. Lee, B.-S. Bae*

KAIST, Korea
**Univ. of Ulsan, Korea*

We report flexible transparent conducting electrode film using a metal grid/silver nanowire (AgNW) hybrid structure (MG/NW-GFRHybrimer). The MG/NW-GFRHybrimer consists of an AgNW-embedded glass-fabric reinforced plastic film (AgNW-GFRHybrimer) as a seed layer, and an electroplated metal grid. The MG/NW-GFRHybrimer exhibits excellent opto-electrical properties, superior thermal stability, and outstanding mechanical flexibility.

FLXp1 - 10 **Improvement of Optical Properties of Transparent Polyimide Films for High-Temperature Curing**

J.-J. Lee, S.-J. Kim, S. Kim, H. Choe, S.-H. Paek

Kyung Hee Univ., Korea

We have investigated how the optical and thermal properties of polyimide (PI) films are affected by the thermal curing conditions and then improved the optical properties of transparent PI films, with little change in the thermal properties, by adopting the curing system and process designed for the higher-temperature treatment.

FLXp1 - 11 **Effect of Surface Treatment on the Optical and Electrical Properties of AgNW Films**

C. Wei, Y.-J. Lin

Tatung Univ., Taiwan

The sheet resistance and optical transparency of AgNW films were sensitive to substrate property. Such effect was investigated by changing the wettability of glass substrate via oxygen plasma. The results show for more hydrophilic surface, the sheet resistance is worse and the transparency exhibits scattering pattern.

FLXp1 - 12 **To Improve Flexibility of Flexible LTPS-TFTs by Using Stress Absorbing Structure**

W.-H. Chen, M.-C. Hsieh, T.-C. Chang, B.-Y. Su, M.-J. Yang, Y.-H. Chung, T.-J. Wang, K.-J. Chen

ITRI, Taiwan

This study demonstrates low temperature polycrystalline silicon (LTPS) thin film transistor (TFT) with stress-absorbing (SA) structure on polyimide substrates for reducing mechanical strain at bending states. SA-LTPS-TFTs show $\Delta V_{th} \sim 0.1$ V after 100,000 times repetitive bending (r = 3 mm) and no significant performance degradation with 85°C/85% R.H. environment tests.

FLXp1 - 13L **Uniform Lying Helix of Cholesteric Liquid Crystal Aligned by Means of Slit Coat Technique with Electric Treatment**

T. Kouno, M. Kimura

Nagaoka Univ. of Tech., Japan

Slit coat technique was applied to fabricate a uniform lying helix (ULH) mode liquid crystal display. Optimum processing condition such as coating speed of cholesteric liquid crystal and applied voltage between slit-lip and substrate was investigated.

FLXp1 - 14L **Effects of LC-Confining Spacers on Cell Gap Uniformity of Flexible LCDs in Coat-Debond Process**

Y. Obonai, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

We discussed the effects of LC-confining spacers on the uniformity of cell gap of flexible LCDs using coat-debond polyimide substrates. We clarified that lattice-shaped polymer spacer is effective to stabilize the cell gap by suppressing the flow of LC during debonding process, even when the spacer distance is 1.0 mm.

FLXp1 - 15L **Optical Compensation of Curved Thin Polycarbonate Substrates for High Contrast Flexible LCDs**

S. Honda, T. Ishinabe, Y. Shibata, H. Fujikake

Tohoku Univ., Japan

We established optical compensation method of curved polycarbonate substrates and clarified that we can improve a contrast ratio by using the positive optical retardation films. These results indicated the feasibility of realizing high contrast ratio and wide viewing angle range of flexible LCDs.

FLXp1 - 16L **A New Solution-Processable Small-Molecule Organic Semiconductor, Having High Thermal Durability**

S. Inoue, S. Shinamura, Y. Sadamitsu, S. Arai[*], S. Horiuchi[**], T. Hasegawa[,**]*

Nippon Kayaku, Japan
[*]Univ. of Tokyo, Japan
[**]AIST, Japan

To realize practical solution-processable organic semiconductors for the use in “printed” thin-film transistors (TFTs), we have successfully developed a new extended p-electron skeleton that can compose small-molecule organic semiconductors (SM-OSCs) showing high field-effect mobility, sufficient solvent solubility, and high thermal durability, being of triplicate required in one material.

FLXp1 - 17L **Organic Floating-Gate Transistor Memory Based on Solution-Processed Organic Films**

F. Shiono, T. Nagase, T. Kobayashi, H. Naito[*],

Osaka Pref. Univ., Japan

Organic nonvolatile transistor memories based on solution-processed organic layers with top-gate configuration are presented. Soluble small-molecule semiconductors are employed as floating gates and dispersed in insulating polymers to form charge storage layers. Organic transistor memories exhibit reversible threshold voltage shifts by writing and erasing and retention characteristics over 10^5 s.

10:30 - 13:00 **Multipurpose Hall**

***Poster* FLXp2: Oxide TFT for Flexible Devices**
Special Topics of Interest on Oxide-Semiconductor TFT

FLXp2 - 1L **10:30** **Low-Temperature (150ºC) Processed Self-Aligned InGaZnO Hybrid Thin-film Transistor with an Organic Gate Insulator**

M. Furuta, Y. Krieg[*], G. Tatsuoka, S. G. M. Aman, Y. Hirota, N. Frühauf[*]

Kochi Univ. of Tech., Japan
[*]Univ. of Stuttgart, Germany

High performance, top-gated, and self-aligned In-Ga-Zn-O thin-film transistor was demonstrated at 150°C using an organic gate insulator. Fabricated hybrid TFT exhibited excellent electrical properties with the field effect mobility of 10.2 cm^2/Vs, subthreshold swing of 0.19 V/dec. The hybrid TFT is one good candidates for flexible and/or printed electronics.

FLXp2 - 2L **Multi-Functional Indium Tin Oxide Thin Films for Flexible Device**

S. H. Kim, J. N. Jang, S. Yi, M. P. Hong

Korea Univ., Korea

We introduce magnetic field shielded sputtering to block negative oxygen ion bombardments. The ITO thin films formed by MFSS at RT, a nanocrystalline phase is formed which leads to superior electro-optical characteristics. The ITO films also possessed low water permeability therefore, they are suitable for flexible devices.

----- Lunch -----

16:50 - 18:10 **412**

FMC5/FLX2: Manufacturing and Equipment

Chair: A. Fujita, JNC, Japan
Co-Chair: M. Ito, Toppan Printing, Japan

FMC5/FLX2 - 1: 16:50 ***Invited*** **Development of the Flexible Surface Light Source Using Luminous Array Film Technology**

K. Awamoto, H. Hirakawa, J. Takahashi, T. Hidaka*, T. Shinoda*

Shinoda Plasma, Japan
**Shikoh Tech LLC, Japan*

We developed a new technology of a Luminous Array Film (LAFi) as a large screen, bendable, film-like, emissive display and we produced the 150-in. diagonal curved display. We applied the LAFi to a flexible light source and we developed the Hg-free high luminance deep-UV surface light source.

FMC5/FLX2 - 2 17:10 **Fabrication of Thin-Film Coatings on Large Size Ultra-Thin Glass for Flexible Devices**

M. Junghaehnel, T. Preussner, J. Westphalen, S. Mogck

Fraunhofer Inst., Germany

Ultra-thin flexible glass is an emerging flexible substrate material for flexible displays, devices or lighting. 100 µm thick flexible glasses with a maximum dimension of 600 × 600 mm² were deposited with inorganic and organic thin-films in sheet-to-sheet and roll-to-roll processes.

FMC5/FLX2 - 3 17:30 **Cutting Method for Electronic Device Made Using Ultra-Thin Glass**

N. Inayama, S. Miwa, T. Fujii

Nippon Elec. Glass, Japan

The simultaneous laser thermal stress cutting method (SLTSC) has been newly developed as cutting methods for an electronic device made using ultrathin glass. Compared with other methods, the novel cutting method is one path cutting of the display to achieve high bending strength due to high quality edge.

FMC5/FLX2 - 4 17:50 **Direct Imaging Exposure Equipment with High Overlay Accuracy for Flexible Substrate in Roll-to-Roll Method**

Y. Kito, M. Hori, Y. Hayashida, T. Suzuki, H. Komiyama, T. Watanabe, T. Kurashige, M. Kato, K. Nara

Nikon, Japan

To fabricate TFTs on a flexible substrate, it is required to make overlay patterns with high alignment accuracy. We developed roll-to-roll exposure equipment with high overlay accuracy for flexible substrate. By a prototype, we succeeded to make patterns on a PET film directly, achieving overlay accuracy less than +/- 5mm.

Author Interviews
18:10 – 18:50, Multipurpose Hall

Friday, December 9

9:00 - 10:20 **501**

FLX3: Flexible Device Technologies 1

Chair: M. Nakata, NHK, Japan
Co-Chair: T. Kamata, AIST, Japan

FLX3 - 1: 9:00 ***Invited*** **Substrates and Non-ITO Electrodes for Flexible OLEDs**

M. Koden, T. Furukawa, T. Yuki, H. Kobayashi, H. Nakada

Yamagata Univ., Japan

We have developed flexible substrates and non-ITO electrodes for flexible OLED devices in "Yamagata University Organic Thin Film Device Consortium," to which 21 companies participated. The developed technologies on ultra-thin glass, stainless steel foil, barrier film and non-ITO transparent electrodes are reviewed.

FLX3 - 2 9:25 **High Performance LTPS-TFT Fabricated on Polyimide Substrate for Advanced Flexible Mobile Applications**

J. Kim, H. Kim, M. Baek, J. Lee, M. Park, C. Kim, Y. Hwang, J. Park

Samsung Display, Korea

For the first time, we report turn-over Vt behaviors of LTPS TFT fabricated on polyimide (PI) substrate under negative bias temperature stress, in comparison to the glass substrate. It is found that Vt shifts depend on the barrier layer process optimization to reduce interfacial traps between the barrier and PI.

FLX3 - 3 9:45 **All-Printed Non-ITO Transparent Electrodes on Ultra-Thin Glass for OLED Lighting**

T. Furukawa, M. Sakakibara[*]*, N. Kawamura, M. Koden*

Yamagata Univ., Japan
[*]*Dai Nippon Printing, Japan*

We have developed all-printed non-ITO transparent electrodes on ultra-thin glass, using the transparence conductive polymer and the assistant Ag electrode instead of ITO. The developed all-printed non-ITO transparent electrodes on ultra-thin glass were applied to OLED lighting devices, obtaining uniform emission.

FLX3 - 4L 10:05 **Ultrathin Graphene Oxide/Polyelectrolyte Nano-Composite Barrier for Flexible OLED Displays**

S.-Y. Yang, C.-S. Kim, S.-K. Kim, Y.-S. Kim

Hongik Univ., Korea

Ultrathin flexible barrier film consisted of graphene oxide/polyelectrolyte multilayer were prepared using Layer-by-Layer process. Effects of hydrophilic ligands, interplanar spacing between graphene oxide layers and defects in graphene oxide basal plane on the barrier characteristics were evaluated.

----- Break -----

10:40 - 11:50 **501**

FLX4: Flexible Device Technologies 2

Chair: T. Eguchi, Sumitomo Bakelite, Japan
Co-Chair: Y. Uraoka, NAIST, Japan

FLX4 - 1: 10:40 ***Invited*** **Edge Sealing Technologies for Foldable AMOLED Display**

G. Chen, F. Su, K.-T. Chen, J.-C. Ho, C.-C. Lee, J. Chen

ITRI, Taiwan

An edge sealing technology was proposed for foldable AMOLED display. The process and adhesion of side wall barrier architecture were discussed in this paper. A 3 mm bending radius foldable on-cell touch AMOLED is successfully demonstrated for new smart handheld device applications.

FLX4 - 2: 11:05 ***Invited*** **Advances in Intense Pulse Light Solutions for Display Manufacturing**

S. Ahmed

Xenon, USA

The use of Intense Pulsed Light in the manufacture of Displays includes UV Curing of adhesive layers and sintering of printed contacts and conductive layers is presented. For Layer bonding, high intensity UV sources allow for faster, deeper cures useable in low temperature substrate application in a Roll-to-Roll process.

FLX4 - 3 11:30 **3D Finite Element Analysis of Stress Distribution and Transfer Characteristics of Flexible IGZO TFT under Mechanical Bending**

Y.-F. Niu, S.-F. Liu, J.-Y. Chiou, C.-Y. Huang, Y.-W. Chiu, M.-H. Lai, Y.-W. Liu

Chunghwa Picture Tubes, Taiwan

We report influences of bending on electrical and mechanical reliability of flexible IGZO TFT. Results include different bending radius and repeated bending test. Tensile stress would cause negative Vth shift. We use FEA software to analyze 3D stress distribution and point out stress concentration region in our TFT structure.

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 14:45 **501**

FLX5: Flexible Printed Electronics 1
Special Topics of Interest on Printed Electronics

Chair: H. Maeda, Dai Nippon Printing, Japan
Co-Chair: H. Endo, NEC, Japan

FLX5 - 1: 13:30 ***Invited*** **Organic Complementary Circuits Based on Solution-Processed Organic Transistors: Toward Flexible Electronics**

M. Uno

Tech. Res. Inst. of Osaka Pref., Japan

We present our recent progress on organic complementary logic circuits based on solution-processed high-mobility organic transistors. Flexible temperature sensors and their read-out circuits of analog-to-digital converters are developed on plastic films, demonstrating the extreme high yield of organic transistors.

FLX5 - 2: 13:55 ***Invited*** **High Mobility and Operational Stability of Top-Gate Organic Transistors Based on Solution-Processable Organic Semiconductors**

T. Nagase, K. Takagi, R. Nakamichi, T. Kobayashi, H. Naito

Osaka Pref. Univ., Japan

We report that the use of top-gate configuration for OTFTs based on solution-processable organic semiconductors allows enhancing field-effect mobility as well as operational stability. The roles of the surface of solution-processed organic semiconductor thin films and their interfaces with polymer gate insulators for enhanced performances in top-gate OTFTs are discussed.

FLX5 - 3: 14:20 ***Invited*** **Flexible/Stretchable Electronics Based on Carbon Nanotube Thin Films**

Y. Ohno

Nagoya Univ., Japan

Among various kinds of semiconductor thin films, carbon nanotube (CNT) thin film provide high-performance devices on flexible polymer films at low cost process such as printing technologies. Here, recent progresses CNT-based flexible devices, including high-mobility thin-film formation, wafer-scale device fabrication and characterization, and electrical and mechanical characteristics, are reported.

----- Break -----

15:10 - 16:15 **501**

FLX6: Flexible Printed Electronics 2
Special Topics of Interest on Printed Electronics

Chair: T. Furukawa, Yamagata Univ., Japan
Co-Chair: T. Shiro, Teijin, Japan

FLX6 - 1: 15:10 ***Invited*** **Printing Ultrafine Conductive Pattern Through Ligand Conversion of Metal Nanoparticles on Photoactivated Surface**

T. Yamada

AIST, Japan

We have succeeded in manufacturing ultrafine conductive pattern through reactive sintering of metal nanoparticles on photoactivated surface at almost room temperature. VUV light can produce photoactivated patterned surface on perfluorinated polymer with carboxylate group, and subsequent coating of alkylamine-encapsulated silver nanocolloids, which triggers to form self-fused solid silver layer.

FLX6 - 2 15:35 **New Alignment Technology for Printed Electronics over Large Flexible Substrates**

Y. Mishima, M. Akiyama, T. Noudou, K. Hashimoto, N. Watanabe, T. Kamata

Japan Advanced Printed Elect. Tech. Res. Assn., Japan

Using newly developed high precision alignment technology, we have realized printed wiring patterns with a high accuracy of less than 2 μm on a G1-size deformed plastic film without fixing on the supporting substrate. 5 μm gate-overlapped TFTs array with a cut-off frequency of 1.1 MHz is confirmed.

FLX6 - 3 15:55 **Inkjet Printing Equipment for Multiple Layered Electronics Devices on Roll-to-Roll Flexible Substrates**

S. Tomoeda, Y. Goto[*]*, D. Kumaki*[*]*, S. Tokito*[*]*, H. Hirata, T. Hatakeyama*

Toray Eng., Japan
[*]*Yamagata Univ., Japan*

Distortions of flexible substrates make it difficult for the conventional means, e.g. photolithography using masks, to be applied to the manufacturing of patterned layers. Utilizing inkjet technology, Toray Engineering has developed the equipment which overcomes the problems of the substrate distortion.

Author Interviews
16:30 – 17:10, Multipurpose Hall

Supporting Organizations:
Technical Committee on Electronic Information Displays, Electronics Society, IEICE
Technical Group on Information Display, ITE

Workshop on Touch Panels and Input Technologies

Wednesday, December 7

13:00 - 13:05 **201**

Opening

Opening Remarks
13:00

N. Hashimoto, Citizen Holdings, Japan

13:05 - 14:20 **201**

INP1: AR and Interactive Systems
Special Topics of Interest on AR/VR and Hyper Reality

Chair: M. Sato, Tokyo Tech, Japan
Co-Chair: N. Hashimoto, Citizen Holdings, Japan

INP1 - 1: ***Invited*** **Somatic Interfaces to Interact with Image**
13:05 **Information**

*Y. Kume, T. Mizuno**

Tokyo Polytechnic Univ., Japan
**Univ. of Electro-Commun., Japan*

Multimodal interfaces for portable/wearable image displays are required to enhance realities and interactivities. We are currently developing several somatic interfaces for this purpose. These include handheld display to provide visual–tactile–force sensations, force-like sensations by mechanical vibration, and wearable system measuring nasal skin temperature to estimate mental workload.
Also presented in Innovative Demonstration Session (see p. 263)

INP1 - 2: ***Invited*** **Retinal Imaging Laser Eyewear with Focus-**
13:30 **Free and Augmented Reality**

M. Sugawara, M. Suzuki, H. Miyauchi

QD Laser, Japan

Retinal Imaging Laser Eyewear has a miniature laser projector inside the frame which provides the wearer with digital image information through the pupil using the retina as a screen. This compact universal-design eyewear features focus-free and augmented-reality image independent of the wearers' visual acuity and point of focus.
Also presented in Innovative Demonstration Session (see p. 263)

INP1 - 3: 13:55 ***Invited*** **String-Based Haptic Interface for Mobile Devices**

K. Honda, S. Ma[*]*, Y. Qian*[*]*, M. Sato*[*]

Tokyo Univ. of Marine S&T, Japan
[*]*Tokyo Tech, Japan*

In this research, a haptic device, which is able to be attached to mobile devices, has been proposed. The proposed device provides one degree of freedom force feedback. It is considered that the proposed device may be able to be adapted as a handy tool for creating multi-modal experiences.

Also presented in Innovative Demonstration Session (see p. 263)

----- Break -----

14:40 - 16:05 **201**

INP2: Automotive HMI
Special Topics of Interest on Automotive Displays

Chair: N. Haneda, DENSO, Japan
Co-Chair: H. Haga, NLT Techs., Japan

INP2 - 1: 14:40 ***Invited*** **Communication System Using Lights for Automobile**

N. Haneda

DENSO, Japan

This research is about three optical systems for communicating between people and automobiles. A Head-Up Display that directly projects images within a human's eye; an optical camouflage display that makes physical obstacles to the driver's vision and an external vehicle communication system to facilitate communication between passengers and road users.

INP2 - 2 15:05 **Automotive Grade Haptic Feedback System Based on Automotive Grade Embedded Operating System**

F.-H. Tsao, C.-L. Li, W.-F. Chang, H.-H. Chen, H.-M. Su, W.-T. Tseng

Chunghwa Picture Tubes, Taiwan

Based on automotive grade embedded operating system "Automotive Grade Linux" (AGL) and CPT's automotive grade liquid crystal display (LCD) panel with piezo vibrator, we have developed a automotive haptic feedback system successfully. In this paper, we applied different vibration patterns and vibration strength corresponding to function separately.

INP2 - 3
15:25

Smart Steering Wheel with Swept Frequency Capacitive Sensing

Y. Ono, Y. Morimoto, R. Hattori, M. Watanabe, N. Michida*, K. Nishikawa**

Kyushu Univ., Japan
**Mazda Motor, Japan*

We present a smart steering wheel that detects the gripping position and area, and the distance to the approaching driver's hands by measuring the resonant frequency and its resistance value in an LCR circuit composed of the floating capacitance of the gripping hand and the body resistance.

Also presented in Innovative Demonstration Session (see p. 264)

INP2 - 4
15:45

Electrostatic Tactile Display for Interaction with Multiple-Unique Sensations

D. Sugimoto, H. Haga, K. Shigemura

NLT Techs., Japan

An electrostatic tactile display that presents multiple, unique sensations concurrently on a touch surface has been demonstrated. A beat frequency created by a pair of driving frequencies supplied to adjacent electrodes, which is the origin of the tactile sensation, is modulated using a frequency-variable voltage source.

Also presented in Innovative Demonstration Session (see p. 264)

----- Break -----

16:20 - 17:30 **201**

INP3: Touch Panel

Chair: K. Yamazaki, Corning Japan, Japan
Co-Chair: Y. Teranishi, Japan Display, Japan

INP3 - 1:
16:20

Invited High-Definition In-Cell Touch Panel with Parallel Scanning Method

K. Tada, K. Kida, S. Yamagishi, T. Maruyama, J. Mugiraneza, Y. Sugita, H. Kawamori, T. Saitoh, H. Shioe

Sharp, Japan

We describe a high-definition in-cell (HDI) touch panel technology that uses a parallel scanning method. We have developed a 5.7-in. WQHD LTPS HDI LCD. We have also developed a 5.7-in. FHD LTPS HDI LCD which is specialized for passive stylus usage and shows 46.6 dB SNR with the stylus.

INP3 - 2: 16:45 ***Invited*** **New In-Cell Capacitive Touch Panel Technology with Low Resistance Material Sensor and New Driving Method for Narrow Dead Band Display**

Y. Teranishi, K. Noguchi, H. Mizuhashi, K. Ishizaki, H. Kurasawa, Y. Nakajima

Japan Display, Japan

The new in-cell touch panel technology which has low resistance receiver sensor and some unique driving methods has been developed for high resolution, narrow dead band display. This paper shows not only new features but also new LTPS TFT circuit technologies. We also review a newly developed 5.5-in. WQHD prototype.

Also presented in Innovative Demonstration Session (see p. 264)

INP3 - 3 17:10 **Dynamic Tuning Fading Factor for Improving Position Tracking on Capacitive Touch Panels**

T.-C. Chu, Y.-M. Chang, C.-E. Wu, C.-Y. Chuang, C.-L. Lin

Nat. Cheng Kung Univ., Taiwan

This paper presents a method by utilizing the fading factor to enhance the ability of tracking position and shorten the trajectory delay in the Kalman filter. Experimental results show that the comparison of RMSE and standard deviation between Kalman filter and propose method for capacitive touch panels system.

Author Interviews
17:40 – 18:20, Multipurpose Hall

Thursday, December 8

14:10 - 16:40 **Multipurpose Hall**

Poster **INPp1: Interactive Technologies**
Special Topics of Interest on AR/VR and Hyper Reality

INPp1 - 1 **Single Pixel Imaging with a High-Frame-Rate LED Digital Signage**

S. Onose[*], M. Takahashi[*], H. Yamamoto[,**], Y. Mizutani[**,***], T. Yasui[**,****]*

[*]Utsunomiya Univ., Japan
[**]JST, Japan
[***]Osaka Univ., Japan
[****]Tokushima Univ., Japan

This paper proposes a single-pixel imaging by use of a high-frame-rate LED display. Ghost imaging algorithm is applied to reconstruct an image under randomly modulated illuminations with a point detector. We have constructed spatio-temporal codes to embed random-dot patterns in an apparent image and conducted numerical experiments on single-pixel imaging.

INPp1 - 2 **Advanced High Integration Touch In-Cell Display Module**

D.-W. Kuo, C.-Y. Hsu, H.-H. Chen, H.-M. Su, W.-T. Tseng
Chunghwa Picture Tubes, Taiwan

We using amorphous process to make in-cell touch panel with high resolution. The 5.5-in. in-cell touch panel with FHD resolution has also be realized successfully. When the resolution is upgraded, it not only increases the difficult of process, but also increases challenge to implement in-cell touch.

INPp1 - 3 **Gesture Recognition Using RGB-D Camera for 3D Virtual Reality and Interaction System**

Y.-Y. Hsu, L.-J. Zheng, H.-I Ning, Y.-C. Fan
Taipei Univ. of Tech., Taiwan

Virtual Reality technology becomes very important recently. We proposed the gesture recognition using RGB-D camera for 3D virtual reality and interaction system. The computer graphics establishes the 3D objects and the RGB-D camera performs accurate gesture recognition. Finally, we integrate and generate functions by different depth distance in 3D environment.

INPp1 - 4 **Research on Touch Electrode Visibility of Touch Panel in Single Layer On-Cell Technology**

H. Fan, C. Wu, W. He, X. Yu, S. Yi
Chengdu BOE Optoelect. Tech., China

ITO pattern visible of single layer on-cell panel has been studied. Both horizontal and vertical stripes were investigated. Several countermeasures have been proposed for improving the two types of stripe, an excellent solution has been obtained, which does have perfect performance with low process difficulty and no other side effect.

INPp1 - 5L **A-Si:H Gate Driver Circuit for In-Cell Touch Panels Driven by Multi-V Blanking Method**

M.-H. Cheng, C.-H. Tseng, C.-E. Lee, C.-L. Lin
Nat. Cheng Kung Univ., Taiwan

A gate driver circuit for in-cell touch panels to avoid the thin-film transistor stress problem is presented. An 85°C TFT model is developed and HSPICE verifies the functionality of the circuit. Simulation shows the maximum deviation of transition times is only 0.65%.

INPp1 - 6L **A Novel Capacitive Touch Sensing Circuit for Low Power Application**

K.-H. Seol, S.-J. Song, J. Seo, H. Nam
Kyung Hee Univ., Korea

This paper presents a novel touch sensing circuit that can distinguish three cases such as touch on the current line, touch on the other line, and no touch. The proposed circuit shows different output voltage of 1.08 V, 0.76 V, and 0.44 V for three cases.

----- Break -----

16:50 - 18:00 **201**

INP4: Touch Panel and Force Interaction

Chair: Y. Tajitsu, Kansai Univ., Japan
Co-Chair: T. Nakabayashi, Sharp, Japan

INP4 - 1: 16:50 ***Invited*** **Smart Piezoelectric Fabric and Its Application**

Y. Tajitsu

Kansai Univ., Japan

The potential of a system that enables the monitoring of complex human movements via new smart fabrics based on a piezoelectric poly-L-lactic acid (PLLA) fabric with the function of sensing complex human motion is described.

INP4 - 2: 17:15 ***Invited*** **Pressure-Sensible Capacitive Touch Systems**

T. Nakabayashi, H. Tanaka, M. Miyamoto

Sharp, Japan

A precise pressure-sensing technique for capacitive touch systems is presented. Natural writing experiences with the force touch sensing revolutionize remarkably, whose input method is such as styli and brushes as well as fingers. The technique here can be applied to a wide range of applications from smartphones to digital signage.
Also presented in Innovative Demonstration Session (see p. 264)

INP4 - 3 17:40 **Full In-Cell Force Touch Solution with LTPS Technology**

C. Pan, C. Zhong, Q. He, X. Zhou, B. Shen, J. Y. Li, Z. Zeng

XiaMen Tianma Microelect., China

In this paper, we introduce a 3D touch technology, it means the capacitive touch screen can not only achieve traditional touch function, but also achieve the detection of touching pressure, which integrated display, touch, force 3 functions in a LCD module.
Also presented in Innovative Demonstration Session (see p. 264)

Author Interviews
18:10 – 18:50, Multipurpose Hall

Supporting Organizations:
The Forum for Advancement of Stereoscopic Three Dimensional Image Technology and Arts
Holographic Display Artists and Engineers Club (HODIC), The Optical Society of Japan
Human Interface Society
Technical Group on Information Sensing Technologies, ITE

Workshop on The 8th International Conference on 3D Systems and Applications

Wednesday, December 7

13:00 - 13:10 **Main Hall**

Opening

Opening Remarks
13:00

N. Inoue, Program Chair, 3DSA
M. Tsuchida, 3D-WS Chair, IDW

13:10 - 14:30 **Main Hall**

3DSA1/3D1: Holography

Chair: N. Hur, ETRI, Korea
Co-Chair: T. Kakue, Chiba Univ., Japan

3DSA1/ 3D1 - 1: 13:10 ***Invited*** **Digital Holographic Display for 360° Viewable 3D Color Image Rendering and Performance Evaluation**

J. Kim, K. Hong, Y. Lim, J. Kim, H.-G. Choo
ETRI, Korea

We present our novel approach on the implementation of digital holographic display, which is capable of rendering 360° viewable holographic image floating over a table-type display. 1,024 holograms for different perspective views are time multiplexed by a fast-operating DMD device to cover 360° of viewing zone around the image.

3DSA1/ 3D1 - 2 13:30 **Projection-Type Holographic Three-Dimensional Display**

K. Wakunami, R. Oi, T. Senoh, Y. Ichihashi, M. Okui, K. Yamamoto
NICT, Japan

To increase both display size and the visual angle at the same time, here we show a novel projection-type holographic 3D display in which a digitally designed holographic optical element (DDHOE) fabricated by the wavefront printing technique and digital holographic projection technique was combined for the first time.

3DSA1/ 3D1 - 3 13:50 **Generation of Color Three-Dimensional Images by Viewing-Zone Scanning Holographic Display**

Y. Matsumoto, Y. Takaki

Tokyo Univ. of A&T, Japan

The viewing-zone scanning holographic display can enlarge both the viewing zone and screen size. In this study, the color image generation technique is developed. The time-multiplexing technique is utilized; R, G, and B lasers sequentially illuminate a MEMS-SLM operating at a high framerate and is scanned by a horizontal scanner.

3DSA1/ 3D1 - 4 14:10 **Development of Run-Length-Based Fourier Transform**

T. Akamatsu, T. Shimobaba, T. Kakue, T. Ito

Chiba Univ., Japan

High-speed image processing is required in various technologies. The calculation time of image processing depends on the number of pixels. On the other hand, data compression can reduce the number of pixels. In this paper, we have developed Fourier transform algorithm on run-length compressed data.

----- Break -----

14:40 - 16:00 **Main Hall**

3D2/3DSA2: Visualization and AR

Special Topics of Interest on AR/VR and Hyper Reality

Chair: J.-W. Kim, ETRI, Korea
Co-Chair: H. Kakeya, Univ. of Tsukuba, Japan

3D2/ 3DSA2 - 1: 14:40 ***Invited*** **Progress on Head-Worn Display Technology for Augmented Reality**

Y. Wang, D. Cheng, C. Xu

Beijing Inst. of Tech., China

Several problems with significant impact on the development of head-worn displays for augmented reality are discussed, including the size and weight, the contradiction between large field-of-view and high resolution, and accommodation and convergence disparity. Methods proposed by Beijing Institute of Technology to solve or alleviate these problems are presented.

3D2/ 3DSA2 - 2 15:00 **Efficiency Balance for a See-Through Head-Mounted Display with Microstructures**

X.-C. Wang, K.-W. Zhao, Y.-D. Lu, C.-Y. Chuang, M.-C. Chan, J.-W. Pan

Nat. Chiao Tung Univ., Taiwan

The efficiency balance phenomenon for see-through head-mounted displays with different microstructure conditions can be found both theoretically and using optical simulation software. The simulation is based on factors taken from previous research studies. It's found that the balance value of the optical efficiency remains almost constant under different microstructure conditions.

3D2/ 3DSA2 - 3 15:20 **Changing Perceived Leg Length and Motion on Virtual Walking Generator**

T. Hamada, K. Yoshiho, R. Kondo, Y. Ikei[*], K. Hirota[**], T. Amemiya[***], M. Kitazaki

Toyohashi Univ. of Tech., Japan
[*]Tokyo Metropolitan Univ., Japan
[**]Univ. of Electro-Commun., Japan
[***]NTT, Japan

Disabled people cannot freely walk around. To overcome it, we developed a virtual walking generator that users can feel realistic walking sensations based on their body shape, and found that perceived leg length and walking motion were changed by altering timings of foot vibrations as a temporal factor of footsteps.

3D2/ 3DSA2 - 4 15:40 **Sparse Registration for Small Amount of Overlap between Point Clouds**

L. Sun, Y. Manabe, N. Yata

Chiba Univ., Japan

This paper proposes a framework for point clouds registration of small amount of overlap. This proposed method resamples point clouds into a large number of small point cloud groups, then matches the group between point clouds by Plane Distance histogram (PAD) of each groups based on sparse representation.

----- Break -----

16:20 - 17:40 **Main Hall**

3DSA3/3D3: Autostereoscopic Display

Chair: Y.-P. Huang, Nat. Chiao Tung Univ., Taiwan
Co-Chair: Y. Ichihashi, NICT, Japan

3DSA3/ 3D3 - 1 **Withdrawn**

3DSA3/ 3D3 - 5L 16:20 **Implementation of Volumetric 3D Display with Liquid Crystal Based Fast Switching Active Optical Shutter and Polarization Controller**

K.-I. Joo, H. Park, M.-K. Park, H.-D. Jeong, S.-W.Min, H.-R. Kim*

Kyungpook Nat. Univ., Korea
**Kyung Hee Univ., Korea*

We develop the volumetric 3D display by using liquid crystal based fast switching active optical shutter and polarization controller. Our proposed volumetric 3D display can project the clear depth image without image blurring at each active optical shutter to enhance the depth perception of 3D volume image.

3DSA3/ 3D3 - 2 16:40 **Parallax Barrier Based Autostereoscopic Display with a Deep Viewing Zone**

H. Kakeya, H.Takahashi, K. Okada

Univ. of Tsukuba, Japan

A full HD autostereoscopic display with a deep viewing zone is attained based on time-division multiplexing parallax barrier. Viewing zone is expanded by changing the width of the barrier in accordance with the viewer's position. Fine tuning of the barrier width is realized by utilizing subpixel structure of LCD panels.

Also presented in Innovative Demonstration Session (see p. 264)

3DSA3/ 3D3 - 3 17:00 **Time-Multiplexing Multi-View Three-Dimensional Display Using Virtually Moving Microlens Array**

M.-K. Park, B. Kim, K.-I. Joo, H. Park, Y.-S. Kim, G. Lee*, H.-R. Kim*

Kyungpook Nat. Univ., Korea
**ETRI, Korea*

We propose time-multiplexing auto-stereoscopic 3D display system using the virtually moving microlens array operated electrically to enhance the angular resolution without the decrease of the lateral resolution. To prove the proposed concept experimentally, we fabricated 5.5-in. 20-view auto-stereoscopic 3D mobile display.

3DSA3/ 3D3 - 4 17:20 **Design of Portable LF Display for High-Quality 3D View Generation**

G. Lee, H. Eum, E. Lee, H. Lee, W.-S. Cheong, N. Hur, B. Kim, J. J. Kwon**

ETRI, Korea
**Samsung Display, Korea*

This paper introduces an implementation of portable light field (LF) display to reconstruct full-parallax LF images. Specifically, this paper proposes an algorithm that can generate elemental image from full-parallax multi-view images in the consideration of depth range at LF display.

Author Interviews
17:40 – 18:20, Multipurpose Hall

Thursday, December 8

9:00 - 10:20 **Main Hall**

3DSA4/VHF4: Human Vision
Special Topics of Interest on AR/VR and Hyper Reality

Chair: S. Yano, Shimane Univ., Japan
Co-Chair: S. Uehara, Asahi Glass, Japan

3DSA4/VHF4 - 1: 9:00 ***Invited*** **Brain Function Analysis of Visual and Cross-Modal Information**

H. Ando[,**]*

[*]NICT, Japan
[**]Osaka Univ., Japan

To clarify how visual information is processed in the human visual system and how visual information interacts with other sensory modalities, we have investigated human brain functions using functional Magnetic Resonance Imaging (fMRI) techniques. Recent results of our fMRI experiments are described in this paper.

3DSA4/VHF4 - 2: 9:20 ***Invited*** **Human Vision Response in AR & VR**

Y.-S. Chen, Y.-P. Huang[*], C.-Y. Chen[**]

Cathay General Hospital, Taiwan
[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Taiwan Univ. of S&T, Taiwan

The human vision response in AR & VR is definitely different from stereoptic images created by human macula of the real world. The index of physiological measurement for visual response should be developed and standardized in order to improve the AR & VR display in the future.

3DSA4/VHF4 - 3 9:40 **Attentive Tracking of Moving Objects in Stereoscopic Viewing**

A. U. Rehman, Y. Nosaki[*], K. Kihara[*], S. Ohtsuka[*]

Kagoshima Nat. College of Tech., Japan
[*]Kagoshima Univ., Japan

This experiment examines the attentive tracking of moving objects in stereoscopic viewing. Participants could successfully track moving objects in an attentive task by ignoring the distractors' plane. In addition, they were able to divide attention equally among a range of depth planes.

3DSA4/ VHF4 - 4 10:00 **Subjective Experiment Study on Binocular Overlap Effect of Different Colors for the Augmented Reality Near-Eye Display**

H. Zhang, Y. Tang, Y. Zheng, Y. Xie[*]*, B. Wang*

Southeast Univ., China
[*]*S&T on Electro-optic Control Lab., China*

The binocular overlap effect of different colors for the augmented reality near-eye display was studied. This experiment included 10 participants to observe and grade on the influence of the different colors on the binocular overlap effect. The results indicate that different colors have an impact on the binocular overlap effect.

----- Break -----

Author Interviews
10:30 – 11:10, Room 201

10:30 - 13:00 **Multipurpose Hall**

***Poster* 3Dp1/3DSAp1: 3D and Hyper-Realistic Systems and Applications 1**
Special Topics of Interest on AR/VR and Hyper Reality

3Dp1/ 3DSAp1 - 1 **Research on Binocular Parallax 3D Display Device with Liquid Crystal Barrier**

X. Liu, G. Yin, M. Peng, J. Shao, Y. Zhang, K. Chao

BOE Tech. Group, China

A theoretical model for 3D display's crosstalk simulation was constructed. The major parameters that influence view distance are shrink ratio, aperture ratio and barrier position. The curved 3D display device is also discussed, which shows an interesting character that the crosstalk-free zone distorts like a curvature.

3Dp1/ 3DSAp1 - 2 **Does Eye Strain Decrease after Observing 3D Imaging on the Light Field Display?**

M. Shoda, T. Iwane, R. Niimi[*]

Nikon, Japan
[*]*Niigata Univ., Japan*

We examined whether observing light field display decreases eye strain than lenticular display. Light field display did not alter eye strain, though it enhanced accommodation at far location. We concluded that light field display enhanced stereognostic sense without heavier eye strain.

3Dp1/ 3DSAp1 - 3 **Developing a Photometric Device for Generating Quality Texture and Normal Map**

Y.-C. Chen, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

We develop a 3D image capturing device for estimating the surface normals and capturing the texture from target object simultaneously. Several experiments are carried out. In addition, we not only analyse different arrangements of illuminants may cause distinguishing result, but also discuss how to refine by the proposed approach.

3Dp1/ 3DSAp1 - 4 **Optical Approach for the Correlation of Micro Lens from 3D Display System by Measurement System**

J. Seo, Y. M. Jeon, Y. J. Ahn, S. J. Huh, J. J. Kwon, Y. J. Park, W. K. Choe, T. W. Kang, H. Y. Chu

Samsung Display, Korea

In this study on analyze optical method for the surface profile of a micro-lens using a interferometer. This Optical system could measure to the shape and the refractive index profile of the lens. Simulated for effects on the illuminance area by the fill factor.

3Dp1/ 3DSAp1 - 5 **CNN-Based Pedestrian and Vehicle Detection Using Stereo Camera**

G.-C. Lee, J. Yoo

Kwangwoon Univ., Korea

In this paper, we propose a pedestrian and vehicle detection algorithm based on CNN using a stereo camera. In the proposed algorithm, object candidates are first obtained by using the disparity from the stereo camera. Then, the objects are recognized by the CNN which has a similar architecture of AlexNet.

3Dp1/ 3DSAp1 - 6 **GPU Acceleration of Hologram Generation Based on Ray-Sampling Plane**

H. Sato[,**], T. Kakue[*], K. Wakunami[**], Y. Ichihashi[**], R. Oi[**], K. Yamamoto[**], T. Shimobaba[*], T. Ito[*]*

[*]Chiba Univ., Japan
[**]NICT, Japan

We accelerated hologram generation based on ray-sampling plane by GPU. The computational time by CPU was 20.0s, and the computational time by GPU was 0.112s. We achieved to generate a 2048×2048-pixels hologram by GPU approximately 200 times faster than generating it by CPU.

3Dp1/ 3DSAp1 - 7 **Mobile-Type Color Binocular Holographic Display System**

K.-J. Oh, M. S. Yoon, H.-G. Choo, J. Kim

ETRI, Korea

In this paper, we present a mobile-type color binocular holographic display system. The proposed binocular holographic display system is designed based on 5.5-in. transmissive liquid crystal display (LCD) panel and adopts viewing window based approach.

3Dp1/ 3DSAp1 - 8 **Waveguide Holograms Attached on LCD Panel for a Hybrid Display System**

W.-K. Lin[,**], B.-S. Lin[*], W.-C. Su[**]*

[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Changhua Univ. of Education, Taiwan

In this paper, a hybrid display system is presented. The display system offers 2D information via a liquid crystal display and simultaneously offers 3D information via a waveguide hologram. The waveguide hologram system has a small thickness and is compatible with LCD panel.

3Dp1/ 3DSAp1 - 9 **Holographic Device for Generating Collimated Beam by Using a LED**

Y.-J. You[*], W.-K. Lin[,**], Q.-Y. Chen[*], B.-S. Lin[**], W.-C. Su[*]*

[*]Nat. Changhua Univ. of Education, Taiwan
[**]Nat. Chiao Tung Univ., Taiwan

In this study, we design a small size device to produce a collimated beam by using a LED. The generated collimated beam from the device can be used to reconstruct holograms. The collimated light device consist of a green LED, a converging lens and a hologram.

3Dp1/ 3DSAp1 - 10 **Study on Compact Holographic Head-Mounted Display for Augmented Reality**

E. Murakami, Y. Oguro, Y. Sakamoto

Hokkaido Univ., Japan

This paper proposes a compact holographic HMD system for AR. The holographic HMD system can reconstruct the images at a free depth with lightweight and compact structure. The experimental result shows that an AR scene is correctly displayed by the holographic HMD system.

Also presented in Innovative Demonstration Session (see p. 262)

3Dp1/ 3DSAp1 - 11 **Mixed Display Method for Real Objects and CG Texts in Electronic Holography**

R. Oi, Y. Ichihashi, T. Senoh, M. Okui, K. Wakunami, K. Yamamoto

NICT, Japan

We present an electronic holography display, which provides CG texts in front of the real scene objects. Two types of displaying methods were studied. One is transparency text display and the other is solid text display. An experimental result shows that the solid text provide better view for the observers.

3Dp1/ 3DSAp1 - 12 **Improvement of Color Reproducibility of Full-Color 3D Display Using Binary Phase Distribution**

S. Harada, K. Nitta, O. Matoba

Kobe Univ., Japan

Color reproducibility of the reconstructed full-color image is improved by using the optimized binary phase distribution and the speckle averaging. The dummy area is introduced to control the power. Numerical and experimental results are presented.

3Dp1/ 3DSAp1 - 13 **Improvement of Full-Color Image Quality Using 1D Phase Modulation SLM by Iterative Fresnel Method with Dummy Area**

R. Toritani, K. Nitta, O. Matoba

Kobe Univ., Japan

A full-color 3D display using a 1D phase-modulation spatial light modulator is presented. We presented a method to improve the reconstructed image quality by the optimized phase distribution by Fresnel iterative method with dummy area. Numerical results are presented.

3Dp1/ 3DSAp1 - 14 **Speeding Up of Image Quality Improvement Using Amplitude Inverse Filter Method in Random Phase-Free Hologram**

Y. Nagahama, T. Shimobaba, T. Kakue, T. Ito

Chiba Univ., Japan

The combination of the random phase-free method and Gerchberg-Saxton (GS) algorithm succeeded in improving the image quality of holograms. However, the GS algorithm takes a long computation time. In this research, we propose faster methods for the image quality improvement of the random phase-free hologram.

3Dp1/ 3DSAp1 - 15 **Surface Quality Inspection of Micromechanical Parts Based on Phase-Shifting Methods**

T.-Y. Hsiao, Y.-L. Liu, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

Phase-shifting method, which is an optical measurement method and able to detect the surface profiles of the object, has many capabilities including high speed, high resolution and real-time. In this paper, we propose a practical method which is based on phase-shifting method to inspecting the surface quality of micromechanical parts.

3Dp1/ 3DSAp1 - 16 **Grey Relational Analysis of Subjective and Non-Subjective Evaluations during Watching 3D Films**

C.-Y. Chen, Y.-H. Su, P.-J. Wu[*], Y.-K. Chen[**], B.-S. Lin[*]

Nat. Taiwan Univ. of S&T, Taiwan
[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Taichung Univ. of S&T, Taiwan

This study proposes an evaluation of the subjective and non-subjective assessments by using Grey Relational Analysis while users watching a 3D video. The proposed method can indicate a reliable relation between subjective and non-subjective evaluations to reduce the possibility of inconsistent results when evaluating the human factors of 3D displays.

3Dp1/ 3DSAp1 - 17 **Evaluation of Perceived 3D Structure of Multi-View 3D Medical Image Based on Transparent Visualization: A Psychophysical Study**

Y. Sakano[,**], Y. Kitaura[**], K. Hasegawa[***], R. Lopez-Gulliver[***], H. Ando[*,**], S. Tanaka[***]*

[*]NICT, Japan
[**]Osaka Univ., Japan
[**]Ritsumeikan Univ., Japan

As an efficient transparent-rendering method, a stochastic point-based rendering method was proposed recently. In the present study, we found that by applying luminance gradient inherent in this method in addition to the traditional Phong shading to a medical data, perceived 3D structure gets closer to the ground truth.

3Dp1/ 3DSAp1 - 18 **Accommodation Measurement in VR Device of Google Cardboard Type**

H. Kang, H. Hong

Seoul Nat. Univ. of S&T, Korea

Virtual image by VR device was shown only to left eye of the user and the white uniform background was shown to right eye. The accommodation of right eye was measured to change in accord with the position of virtual image seen by left eye.

3Dp1/ 3DSAp1 - 19 **Head Tracking Based Immersive Sound Reproduction for Virtual Reality Display**

C. J. Chun, K. M. Jeon, J. M. Moon, H. K. Kim, J. Yoo[*]

Gwangju Inst. of S&T, Korea
[*]Kwangwoon Univ., Korea

This paper proposes a head tracking-based sound reproduction method to improve auditory realism in a virtual reality environment. To this end, a 4-channel omnidirectional microphone array is used for capturing ambient sounds. Then, a delay-and-sum beamformer is applied to the sounds for estimating the direction of the source.

3Dp1/ 3DSAp1 - 20 **Audio-Haptic Display for a Sense of Walking: Influence of Arm-Swing Interaction and User's Posture on Reproduced Walking in Real Space**

Y. Okuya, Y. Ikei[*], Y. Kamishohara[*], K. Hirota[**], T. Amemiya[***], M. Kitazaki[****]

Univ. Paris-Sud, France
[*]Tokyo Metropolitan Univ., Japan
[**]Univ. of Electro-Commun., Japan
[***]NTT, Japan
[****]Toyohashi Univ. of Tech., Japan

We present techniques to enhance a sense of walking without user's leg motion in 3D soundscape environment. Sound of footsteps and vibratory stimulus at the sole are simulated with physical models, responding to virtual walking steps. A sense of walking was investigated with user's reproduced walk in a real space.

3Dp1/ 3DSAp1 - 21 Experimental Assessment on Viewer's Impressions of 4K Ultra-High Definition and Multi-View 3D Images

M. Okui, M. Makino, S. Yoshida, S. Iwasawa, K. Yamamoto

NICT, Japan

We conducted an experimental subjective assessment wherein we compared viewers' impressions of depth sensation on a multiprojector HD-resolution 3D display with those on a 4K ultra-high definition LC display both with and without an interactive viewpoint operation.

3Dp1/ 3DSAp1 - 22 Bodily Reliving Experience Based on Multisensory Passive Stimulation

R. Koide, S. Imao, K. Yamada, N. Saka, K. Tashiro, M. Kurosawa, Y. Ikei, K. Hirota[*], T. Amemiya[**], M. Kitazaki[***]

Tokyo Metropolitan Univ., Japan
[*]Univ. of Electro-Commun., Japan
[**]NTT, Japan
[***]Toyohashi Univ. of Tech., Japan

This paper describes characteristics of a passive stimulation method using a vestibular and proprioceptive device for presentation of body motion sensation while the real body of the user is sitting. The motion of a seat and pedals/sliders was controlled to produce the sensation of a real walking motion.

3Dp1/ 3DSAp1 - 23L Symmetricity in Perceptual Limit of Doubled Image Induced by Linearly Blended Images

M. Date, K. Takeuchi, K. Okami, H. Fujii, H. Kimata, R. Kimura[*], K. Iwata[*], T. Kojima[*], M. Miyao[*]

NTT, Japan
[*]Nagoya Univ., Japan

Linear blending is a useful technique to produce an interpolated image from multiple camera images, especially in real time applications using smooth motion parallax. In this paper we evaluated the symmetricity of perceptual limit in a doubled image induced by linear blending and confirmed the suitability of symmetrical camera alignment.

3Dp1/ 3DSAp1 - 24L Study on Rendering Ultra High-Resolution Image for 3D Models

C.-C. Lee, Y.-L. Liu, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

With the innovation of emerging technologies, museums can reinterpret artifacts. Therefore, it's important to efficiently render high resolution images. We propose a practical solution to render an ultra high resolution image, which has almost no limitation in image size, for 3D digital heritage model based on OpenGL.

3Dp1/ 3DSAp1 - 25L **New Directional Backlight of Arc 3D Display for Stereoscopic Display with All Surrounding Viewpoints**

R. Ozaki, H. Yamamoto, H. Mizushina, S. Suyama*

Tokushima Univ., Japan
**Utsunomiya Univ., Japan*

In order to realize stereoscopic display with all surrounding viewpoints, a new circularly symmetric configuration with a radial parallax barrier has been proposed. All surrounding viewpoints can be successfully achieved by suppressing undesired images by using arc 3D display as a new directional backlight.

3Dp1/ 3DSAp1 - 26L **Developing a Foot Scanner Based on Multiple Laser Triangulation Scanners and One Linear Stage**

W. Huang, T.-H. Lin, Y.-L. Liu

Nat. Taiwan Univ. of S&T, Taiwan

This paper presents a self-developed foot scanner by using three laser scanner modules, a linear stage, and a software algorithm to obtain 3D foot models. The algorithm in this prototype utilizes several reference images for system calibration. Thus, different scanner modules are preciously integrated for reconstructing 3D foot models.

3Dp1/ 3DSAp1 - 27L **A Two-In-One System of Structured Light Scanner and Light Cured Printer**

Y.-L. Liu, H.-T. Yau, R.-S. Lin*, Y.-J. Chen**, T.-H. Lin, J.-Y. Jeng*

Nat. Taiwan Univ. of S&T, Taiwan
**Nat. Chung Cheng Univ., Taiwan*
***Nat. Taiwan Univ., Taiwan*

Additive manufacturing is regarded as the third wave of industrial revolution. The dental industry is also the critical business opportunities. Therefore, most of the dental design and production are transformed into digital solutions. In this paper, we present a two-in-one system of 3D scanner and printer for orthodontics

3Dp1/ 3DSAp1 - 28L **Volumetric 3D Display System Using Rotating Spiral Screen - Evaluation of Image Visibility at a Bright Room -**

S. Suzuki, C. Fujikawa, M. Omodani

Tokai Univ., Japan

We had proposed a novel method of volumetric 3D display, in which multi layers of section images are projected on a rotating spiral screen. In this study, we evaluated dependence of 3D image visibility and screen invisibility to room illuminance when varying illuminance on a screen by image projection.

Also presented in Innovative Demonstration Session (see p. 262)

3Dp1/ 3DSAp1 - 29L **Withdrawn**

----- Lunch -----

14:10 - 16:40 **Multipurpose Hall**

***Poster* 3DSAp2/3Dp2: 3D and Hyper-Realistic Systems and Applications 2**

Special Topics of Interest on AR/VR and Hyper Reality

Special Topics of Interest on Automotive Displays

3DSAp2/ 3Dp2 - 1 **Gradation Expression by Overlap of Voxels in Volumetric Display Composed of Photochromic Materials**

F. Kawashima, R. Hirayama, A. Shiraki, H. Nakayama[*]*, T. Kakue, T. Shimobaba, T. Ito*

Chiba Univ., Japan
[*]*Nat. Astronomical Observatory of Japan, Japan*

We proposed a volumetric display composed of photochromic materials. It can be controlled in a non-contact from the outside. We made a volumetric display that can display different multiple pictures depending on the surface to observe. The gradation expression is realized by overlapping the colored voxels.

3DSAp2/ 3Dp2 - 2 **Viewing Zone Expansion by Blurring Edge Parts in Edge-Based DFD Display**

T. Yamamoto, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We propose the method for enlarging viewing zone in Edge-based DFD display by blurring edge parts. In conventional DFD display, viewing zone is restricted between the overlapped region of front and rear images, that is, within interocular distance. On the other hand, the viewing zone can be widely enlarged over interocular distance by blurring Edge parts in Edge-based DFD display.

3DSAp2/ 3Dp2 - 3 **Depth Perception Difference by Only Two Light Sources with Various Distances in Non-Overlapped DFD Display**

R. Takano, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We have proposed Non-overlapped DFD (Depth-Fused 3D) display only by two light sources and clarify those distance limitation for image depth fusion. When the vertical distance between two light sources increases, two light sources become difficult to fuse to one depth and have separated and scattered perceived depths.

3DSAp2/ 3Dp2 - 4 **Large and Deep Edge-Based DFD Display by Blurring Edge Parts**

Y. Nagao, H. Mizushina, S. Suyama

Tokushima Univ., Japan

Large and deep Edge-based DFD display can be achieved by blurring edge parts and increasing observation distance and screen size. Conventional DFD image is separated to front, rear and midpoint regions over 5 arcmin. Front and rear images can be fused to depth even at the image depth of around 17.9 arcmin.

3DSAp2/ 3Dp2 - 5 **Resolution Enhanced 3D Light Field Microscope with Liquid Crystal Wedge**

H.-H. Lee, P.-Y. Hsieh, W.-C. Chu, G. Saavedra[*]*, M. Martinez-Corral*[*]*, Y.-P. Huang*

Nat. Chiao Tung Univ., Taiwan
[*]Univ. de Valéncia, Spain

In this paper, a resolution enhanced light field microscope system with LC devices was proposed. With a LC wedge placed in the light field system, the resolution of light field microscope can be improved by combining light field images with displacement.

3DSAp2/ 3Dp2 - 6 **Implementation of Artifacts Reduced Multi-View Display with High Quality 3D Images**

E. D. Lee, G. Lee, W.-S. Cheong, N. Hur

ETRI, Korea

In this paper, we propose a 16-view display with 4K flat panel display and lenticular lens arrays, which has low inter-view crosstalk about 14%, unnoticeable moiré effect and wide viewing width about 7 times of binocular distance.

3DSAp2/ 3Dp2 - 7 **Floating 3D Interactive Device Using Special Pattern of Spatial-Multiplexed Barrier**

S.-W. Hsu, C.-W. Shih, J.-Y. Wu, C.-H. Ting, Y.-P. Huang

Nat. Chiao Tung Univ., Taiwan

The proposed auto-stereoscopic floating 3D interactive system use multiplexed barrier with special pattern to achieve floating 3D image and have interactive system in the device. The special pattern of sptial-multiplexed can let the observer have the comfortable 3D perceive feeling.

Also presented in Innovative Demonstration Session (see p. 264)

3DSAp2/ 3Dp2 - 8 **Super Multiview Stereoscopic Display Using Time-Division Parallax Barrier**

K. Okada, H. Kakeya

Univ. of Tsukuba, Japan

We attain a high resolution super multiview stereoscopic display based on time-division multiplexing parallax barrier method. By enlarging the distance between the barrier and the image display panels, the interval between the viewpoints is narrowed so that multiple rays enter the pupil, which enables induction of focal accommodation of the viewer.

3DSAp2/ 3Dp2 - 9 **Depth Enhancement of Light Field Microscopy with Fast-Response Hexagonal Liquid Crystal Micro-Lens Array**

H.-A. Lin, C.-Y. Chu, P.-Y. Hsieh, Y.-P. Huang, C.-H. Kuo

Nat. Chiao Tung Univ., Taiwan

In this paper, we proposed a fast response hexagonal liquid crystal micro-lens array for 3D light field microscopy. The property of liquid crystal lens is that it can change the focal length electrically. With this property, the working range in light field microscopy was extended from 0.27 mm to 0.8 mm.

3DSAp2/ 3Dp2 - 10 **Increasing Luminance of Aerial Image Perpendicular to the Table Top**

T. Kobori, H. Yamamoto

Utsunomiya Univ., Japan

This paper proposes a method to increase luminance of an aerial image that is formed perpendicularly to the table top. Our method utilizes a prism sheet to deflect principal rays from an ordinary display. Deflection angle and efficiency have been analyzed and confirmed experimentally with a prototype aerial display.

3DSAp2/ 3Dp2 - 11 **Luminance Improvement of Aerial Double-Layered Display with Polarized AIRR**

S. Ito, H. Yamamoto

Utsunomiya Univ., Japan

We propose novel design of aerial double-layered display with polarized AIRR (aerial imaging by retro-reflection). Four types of structures have been proposed and compared experimentally. We have successfully improved luminance of aerial images of a polarization-processing display without surface polarizer. Aerial double-layered images have been formed with our polarized AIRR.

3DSAp2/ 3Dp2 - 12 **Wide-Screen Head-Up Display with a Projection Lens Array**

T.-S. Yeh, W.-C. Su

Nat. Changhua Univ. of Education, Taiwan

The optical design for a virtual image system in a vehicle is presented. We use a lens array to implement a wide-screen virtual image projection display system. In this system, the virtual image location is in front of the eyebox with a distance of 1500 mm.

3DSAp2/ 3Dp2 - 13 **Formation of Aerial Image with Motion Parallax Generated by Scattered Light on Arcs**

K. Kawai, H. Yamamoto

Utsunomiya Univ., Japan

This paper proposes methods to form aerial image with motion parallax that is generated by scattered light on arcs. Aerial image of an arc 3D display is formed with aerial imaging by retro-reflection (AIRR). Furthermore, our proposed method enables us to stack aerial images by illuminating stacked arc 3D boards.

3DSAp2/ 3Dp2 - 14 **Aerial Imaging with Transparent Acrylic Cubes and Applications for Steganography**

S. Morita, S. Onose, T. Okamoto, H. Yamamoto

Utsunomiya Univ., Japan

This paper proposes aerial imaging by use of transparent acrylic cubes. Arrangements of cubes have been investigated and results shows freedom in arrangements. Furthermore, we have demonstrated a new steganography, which embed a secret LED sign and the secret is decodable by placing a screen at the limited position.

3DSAp2/ 3Dp2 - 15 **Colorizing 3D Objects in Free-Viewpoint Through a Transparent LCD**

Y.-P. Pi, P.-L. Sun, H.-P. Chien, H.-C. Li, Y.-C. Su

Nat. Taiwan Univ. of S&T, Taiwan

A method to colorize 3D objects through a transparent LCD in free-viewpoint is proposed. It uses a video camera to detect eye-sight of a viewer in real-time, and then displays the geometric corrected shadow-less color projection of the 3D objects (achromatic 3D prints or plaster models) onto the transparent LCD.

3DSAp2/ 3Dp2 - 16 **Digital Cosmetic Coloring System for 3D Facial Images**

M.-H. Lin, Y.-P. Pi, H.-S. Chen, P.-L. Sun, T.-H. Lin

Nat. Taiwan Univ. of S&T, Taiwan

This study presents a cosmetic simulation system to create a 3D makeup facial image. We use a 3D scanner to capture a model's face, and produce a 3D makeup effect. By introducing skin colors of a reference image into the 3D-scanning image, a pleasing 3D facial image can be created.

3DSAp2/ 3Dp2 - 17 **New Method for Luminance Addition/Subtraction System by Using Polarization Operation in Layered TN-LCDs**

Z. Fan, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We propose a new method to add/subtract luminance in layered TN-LCDs (Twisted nematic liquid crystal displays) by using polarization operation. Our method can successfully achieve the complete control of whole luminance even when one LCD has any luminance.

3DSAp2/ 3Dp2 - 18 **Effect of a Cell Gap with a Bi-Focal LC Lens on 3D Properties in Two-Way Multi-View 2D/3D Display Combining the Bi-Focal LC Lens and HV×DP Panel**

Y. Ibata, J. Matsushima, K. Masumura, T. Asai, T. Sato, K. Shigemura

NLT Techs., Japan

We can narrow down which LC lens cell gap conditions can improve 3D properties achieve a good balance in a two-way multi-view 2D/3D display combining a bi-focal LC lens and HV×DP panel by simulation. Validity of the simulation is verified by experimental results.

3DSAp2/ 3Dp2 - 19 **LCD Panel Design for HMD Based on Retinal Projection Display**

S.-K. Zhou[*], W.-K. Lin[,**], W.-H. Lin[*], B.-S. Lin[**], W.-C. Su[*]*

[*]Nat. Changhua Univ. of Education, Taiwan
[**]Nat. Chiao Tung Univ., Taiwan

A HMD based on retinal projection technology has been successfully demonstrated by using a HOE, an LCD panel and a waveguide. The HMD shows the information from the LCD panel. The requirement arrangement of the LCD panel in this system was discussed.

3DSAp2/ 3Dp2 - 20 **Based on Three Dimensional Gesture and Finger of Mid-Air Interaction Interface with OCR Handwriting**

M.-Y. Lee, S.-C. Yang, S.-C. Wang, Y.-C. Fan

Nat. Taipei Univ. of Tech., Taiwan

Accompany with interactive media increasingly vigorous development. The application of embodied interactive system has received frequent usage. This system has become popular whatever in company, activities, exhibition hall, museum, or game device. The most nature and easy way to write character is achieved through our hand.

3DSAp2/ 3Dp2 - 21 **Layered Multi-View DFD Display for Improving Perceived Depth and Image Shift Smoothness even at Small Number of Multi-View**

T. Eguchi, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We propose a new 3D display, “Layered multi-view DFD (Depth-fused 3D) display” with mixed various kinds of parallax components, resulting in good monocular depth perception and smooth image shift, even at small number of multi-view. These are improved when the gap between front and rear displays is large and appropriate.

3DSAp2/ 3Dp2 - 22 **Perception of Many Transparent Layered Images in the Depth-Fused 3D Display**

K. Sakamaki, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We have proposed how to make many transparent layered images in Depth-fused 3D display. Three transparent layered images can be displayed by using four layered LCDs. In this paper, we evaluated the perceived depth dependences in three layered transparent images by using four image planes.

3DSAp2/ 3Dp2 - 23L **Coding Performance for Moving Picture of Integral Three-Dimensional Image Using 3D-HEVC**

K. Hara, M. Kawakita, T. Mishina, H. Kikuchi

NHK, Japan

To develop coding techniques for integral image, we investigated the performance of 3D-HEVC for the moving elemental images. We coded multi-view images converted from the elemental images, and carried out the objective and subjective assessments. The results show that 3D-HEVC has the advantages of high coding performance for integral images.

3DSAp2/ 3Dp2 - 24L **Evaluation of Depth Perception of Integral Photography**

G. Taniguchi, M. Suzuki[*], S. Yano, M.-C. Park[**]

Shimane Univ., Japan
[*]Meiwa e-Tech, Japan
[**]KIST, Korea

We evaluated the depth perception of integral photography (IP) and real objects (RO) using the eye movement and subjective methods. The depth perception of IP had the same tendency regardless of the evaluation method. The depth perception of IP and RO evaluated by the eye movement method was different.

3DSAp2/ 3Dp2 - 25L **Projection-Type Integral 3D Display with Highly Accurate Method for Auto-Compensating Elemental Image**

H. Watanabe, M. Kawakita, N. Okaichi, H. Sasaki, M. Kano, J. Arai, T. Mishina

NHK, Japan

We developed a highly accurate method for auto-compensating an elemental image for an integral three-dimensional (3D) display. An elemental image is geometrically corrected from the detection results of the position errors between the elemental image and lens array using 3D markers. We experimentally confirmed improvement in the 3D image quality.

3DSAp2/ 3Dp2 - 26L **Imaging Performance via Liquid Crystal Lens Arrays with Disclination Line Considerations in Integral Imaging System**

Y.-J. Chang, W.-Y. Lu, C.-R. Sheu

Nat. Cheng Kung Univ., Taiwan

Recently, liquid crystal lens arrays have been paid attention on researches for autostereoscopic applications. In this paper, we demonstrate and compare imaging performance of integral imaging system via liquid crystal lens arrays, which disclination issues are significantly affect elementary images and image reconstruction.

3DSAp2/ 3Dp2 - 27L **Holographic Images Analysis Considering Phase Distribution in Small Liquid Crystal Pixels**

Y. Isomae, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

We proposed the simulation method of reconstructed images in considering influence of phase distribution in the pixels and clarified zero-order diffraction appeared on the reconstructed images. This result is useful for designing fine liquid crystal on silicon for realizing wide-viewing-angle holographic display.

3DSAp2/ 3Dp2 - 28L **High Definition Spatiotemporal Division Multiplexing Electroholography Using DMD**

M. Fujiwara, N. Takada, C. W. Ooi, Y. Maeda, H. Nakayama[*], T. Kakue[**], T. Shimobaba[**], T. Ito[**]

Kochi Univ., Japan
[*]Nat. Astronomical Observatory of Japan, Japan
[**]Chiba Univ., Japan

We propose high-speed computer-generated hologram reproduction using digital mirror device for high-definition spatiotemporal division multiplexing electroholography. Finally, we succeeded to play high-definition 3D movie of 3D object comprised about 900,000 points at 60 fps when each frame was divided into twelve.

3DSAp2/ 3Dp2 - 29L **Holographic Collimator Based on Waveguide Holograms**

W.-K.Lin[,**], W.-H.Lin[**], S.-K.Zhou[**], B.-S.Lin[*], W.-C.Su[**]*
[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Changhua Univ. of Education, Taiwan

A Collimated beam device was presented based on PMMA waveguide by using holographic technique. The dimension of the device is only 15 cm × 8 cm × 0.8 cm, and the diameter of the generated collimation beam is around 5.9 cm. The device can be used as a backlight for hologram displaying.

----- Break -----

16:50 - 18:10 **Main Hall**

3D4/3DSA5: Image Processing

Chair: H. Saito, Keio Univ., Japan
Co-Chair: K. Takahashi, Nagoya Univ., Japan

3D4/ 3DSA5 - 1 16:50 **Face Tracking Method Using Depth Information**

J.-H. Lee, J. Yoo
Kwangwoon Univ., Korea

This paper first discusses the disadvantages of the existing CamShift Algorithm, and then proposes a new Camshift Algorithm that performs better than the existing algorithm. The experimental results prove that the proposed algorithm is superior in tracking performance to that of existing TLD tracking algorithm, and offers faster processing speed.

3D4/ 3DSA5 - 2 17:10 **3D Interactive System Based on Neural Network Training of Dual Cameras**

T.-Y. Lu, X. Li, C.-H. Chen, Y.-P. Huang
Nat. Chiao Tung Univ., Taiwan

A bare-finger 3D interactive technology for portable devices was developed. Using dual cameras with a reformed the field of viewing, a blind working range close to the camera is eliminated. Moreover, the algorithm of neural network, different from stereo vision, was presented to determine the positions of fingertips.

3D4/ 3DSA5 - 3 17:30 **Synthesis of Top View Image and Detection of Obstacles Using Multiple Cameras for Monitoring Around a Truck**

K. Uehara, H. Saito, K. Yamamoto[*]*, H. Sato*[*]

Keio Univ., Japan
[*]*Mitsubishi Fuso Truck & Bus, Japan*

We propose a system that supports truck drivers. It can be used to prevent collisions between trucks and obstacles. This is accomplished by using a top view image and a function for the detection of obstacles around a truck based on their height. Our system requires only color cameras.

3D4/ 3DSA5 - 4 17:50 **Study on Band-Efficient System Design and Video Coding for Fixed & Mobile Hybrid UHD 3DTV System Using Scalable HEVC**

S.-H. Kim, K. H. Yong, K.-H. Jung[*]

ETRI, Korea
[*]*Kookmin Univ., Korea*

This paper presents a band-efficient stereoscopic 3D system design and video coding technologies for Fixed & Mobile hybrid UHD 3DTV using scalable HEVC. The proposed system can support layered 4K-UHDTV, Mobile HD & UHD 3DTV services at the same time within RF 6 MHz bandwidth using Scalable HEVC video codec.

Author Interviews
18:10 – 18:50, Multipurpose Hall

Friday, December 9

9:00 - 10:20 **Main Hall**

3DSA6/3D5: Volume Display and Display Analysis

Chair: T. Fujii, Nagoya Univ., Japan
Co-Chair: D. Miyazaki, Osaka City Univ., Japan

3DSA6/3D5 - 1: 9:00 ***Invited*** **TSTF Up-Conversion Crystal as an Image Space of Electro-Holography**

J.-Y. Son, H. Lee, C.-K. Sung, B.-R. Lee[*]*, H. Chu*[*]

Konyang Univ., Korea
[*]*ETRI, Korea*

The problems in current electro-holography based on a digital display chip are addressed. The characteristics of a ZBLAN glass used for the image space of a 360° viewable holographic display and of the reconstructed image in the space are described. Improving the image characteristics are discussed.

3DSA6/3D5 - 2 9:20 **Aerial Projection of Three-Dimensional Color Motion Pictures Based on Electro-Holography with Parabolic Mirrors**

T. Kakue, A. Uemura, T. Nishitsuji, T. Shimobaba, T. Ito

Chiba Univ., Japan

We report an aerial projection system based on color electro-holography with two parabolic mirrors. Our system can realize real-time reconstruction of floating three-dimensional color images. We successfully demonstrated the proposed system with a single spatial-light modulator and a color LED by the time division method.

3DSA6/3D5 - 3 9:40 **Viewing Zones Analysis of Convex Multi-View Autostereoscopic 3D Display with Barrier**

J.-Y. Lai, W.-C. Lin, H. Y. Lin

Nat. Taiwan Univ., Taiwan

The viewing zones of a convex multi-view autostereoscopic display is investigated. While a convex display broadens the viewing angle, the view number is limited by screen curvature instead. Therefore, we propose the viable barrier parameters and maximum view numbers for the AS3D display under different curvatures.

3DSA6/3D5 - 4 10:00 **Period of Color Moiré Fringes in Contact-Type 3D Displays**

H. Lee, J. Kim, J.-Y. Son

Univ. of Konyang, Korea

A formula to predict color moiré fringes appearing in the contact-type Multiview 3D images is presented. It works not even for the displays but also typical moirés from two superposed regular pattern plate, especially for plates with large period differences. The formula is easily transformed for the slanted moirés

----- Break -----

10:40 - 12:00 **Main Hall**

3D6/3DSA7: Aerial Display

Chair: J.-Y. Son, Konyang Univ., Korea
Co-Chair: H. Mizushina, Tokushima Univ., Japan

3D6/ 3DSA7 - 1 10:40 **Aerial Volumetric Image Display Based on Retroreflective Imaging and Optical Scanning with a Slanted Rotating Mirror**

D. Miyazaki, R. Tamaki, T. Mukai

Osaka City Univ., Japan

Imaging based on retroreflection can provide aerial image formation with a wide view angle and low-distortion in spite of high numerical aperture. A floating volumetric display technology based on retroreflection with a dihedral corner reflector array and optical scanning with a slanted rotating mirror are described.

3D6/ 3DSA7 - 2 11:00 **3D Volume Image Reconstruction in Space, Using Combined System of Light-Field Display and Aerial Imaging Device**

*T. Iwane, M. Nakajima, H. Yamamoto**

Nikon, Japan
**Utsunomiya Univ., Japan*

Combined light-field display and aerial imaging device, 3D aerial display system has been realized. Circular polarization control, using cholesteric liquid-crystal polymer layer, improves light-use efficiency and enables a cost-effective large-size 3D aerial display system.

3D6/ 3DSA7 - 3 11:20 **Horizontal Parallax Table-Top Floating Image System with Toroidal-Lens Structure**

P.-Y. Chou, C.-H. Tai, S.-H. Huang, Y.-P. Huang

Nat. Chiao Tung Univ., Taiwan

A new horizontal parallax table-top floating image system with toroidal-lens optical film was proposed. By this system, light field of each projector could be controlled as fan ray and properties could be evaluated by simulation. According to imaging principle and inverse light tracking, displaying 3D floating images could be achieved.

3D6/ 3DSA7 - 4 11:40 **Visual and Thermal Floating Display with AIRR and WARM**

T. Okamoto, S. Ito, K. Onuki, S. Onose, T. Itoigawa, H. Yamamoto

Utsunomiya Univ., Japan

We have developed a visual and thermal floating display. Our developed display forms aerial visual images over a table top and locally heats a part of aerial images. Aerial images are formed with aerial imaging by retro-reflection (AIRR). Aerial heating is realized with double-layered arrays of rectangular mirror (WARM).

Also presented in Innovative Demonstration Session (see p. 262)

Author Interviews
12:00 – 12:40, Multipurpose Hall

----- Lunch -----

13:30 - 14:50 **Main Hall**

3D7/3DSA8: Technologies for 3D Imaging

Chair: Y. Takaki, Tokyo Univ. of A&T, Japan
Co-Chair: J. Arai, NHK, Japan

3D7/ 3DSA8 - 1 13:30 **Synthesis of Wide FOV RGB-D Images by Registration and Upsampling of 3D Lidar with Omnidirectional RGB Camera**

H. Usami, S. Miyata, H. Saito
Keio Univ., Japan

We present a method for synthesizing wide-field-of-view (FOV) RGB-D images by combining three-dimensional (3D) Lidar and an omnidirectional RGB camera. In this system, 3D point clouds captured by the Lidar are upsampled and colored by registration with the omnidirectional RGB image. We show free-viewpoint images generated via this method.

3D7/ 3DSA8 - 2 13:50 **DIBR Digital Image Watermarking Based on Depth Image and DWT**

Y.-S. Lee, Y.-H. Seo, D.-W. Kim
Kwangwoon Univ., Korea

This paper proposes a digital watermarking scheme to get higher robustness for a DIBR image. This scheme includes a method to find the least distortable regions by using the depth image. For blind watermark, the depth image only in embedding procedure, while in extraction only the original watermark is used.

3D7/ 3DSA8 - 3 14:10 **Spectral Color Reproduction of Multiband 3D Projector Using Evolution Strategy**

M. Tomizawa, N. Yata, Y. Manabe
Chiba Univ., Japan

Stereoscopic video technology is developing. In previous study, we have proposed a stereoscopic display system which has an expanded color gamut. This paper proposes an accurate color and spectral reproduction method of a three-dimensional image display system with expanded color gamut using covariance matrix adaptation evolution strategy (CMA-ES).

3D7/ 3DSA8 - 4 14:30 **Liquid Crystal Lens for Polarized 2D/3D Endoscopic Imaging**

A. Hassanfiroozi, Y.-P. Huang, H.-P. D. Shieh
Nat. Chiao Tung Univ., Taiwan

Analysis of the polarization properties of light reflected by an artificial tissue from a polarized incident light using an LC lens have been investigated to enhance endoscopic imaging system. Polarizer dependency of LC lens could benefit us to have a sharper image with higher contract.

----- Break -----

Author Interviews
16:30 – 17:10, Multipurpose Hall

Supporting Organizations:
The Virtual Reality Society of Japan
Society for Information Display (SID) Taipei Chapter

Panel Discussion on Display Technologies for Sports in Japanese

Organized by International Display Workshops
General Incorporated Association
Tuesday, Dec. 6, 2016

16:45-18:00

Room 501 (5F)

Fukuoka International Congress Center
Detailed information will be announced at
http://sport.idw.or.jp/

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December 7-9, 2016
See page 133 for details
Free admission with your IDW/AD '16 registration name tag
http://www.3dsa.org/

Innovative Demonstration Session

Thursday, December 8

10:30 - 16:40 **Multipurpose Hall**

Innovative Demonstration Session

AMD3 - 2 **LCD with Ultra High Resolution and Super Fast Response Giving Super Reality to VR Application**

N. Ueda, K. Okada, S. Uchida, K. Yamamoto, K. Yamamoto, H. Yoshida

Sharp, Japan

AMD4/ LCT4 - 2 **Development of 27-in. 8K4K LCD Prototype Using an IGZO TFT Backplane**

S. Yamada, F. Shimoshikiryoh, Y. Itoh, A. Ban

Sharp, Japan

FMC2 - 2 **Preventing Surface Reflected Light on Retro-Reflector in AIRR**

R. Kujime[,**], H. Yamamoto[**]*

[*]Tokushima Univ., Japan

[**]Utsunomiya Univ., Japan

3D6/ 3DSA7 - 4 **Visual and Thermal Floating Display with AIRR and WARM**

T. Okamoto, S. Ito, K. Onuki, S. Ohose, T. Itoigawa, H. Yamamoto

Utsunomiya Univ., Japan

3Dp1/ 3DSAp1 - 10 **Study on Compact Holographic Head-Mounted Display for Augmented Reality**

E. Murakami, Y. Oguro, Y. Sakamoto

Hokkaido Univ., Japan

3Dp1/ 3DSAp1 - 28L **Volumetric 3D Display System Using Rotating Spiral Screen -Evaluation of Image Visibility at a Bright Room -**

S. Suzuki, C. Fujikawa, M. Omodani

Tokai Univ., Japan

VHF1 - 4L **Effective Evaluation of Moving Image Quality of Display Using Morphing Wavelet with Layered Range of Resolution**

I. Kawahara, H. Tabata

KEISOKU GIKEN, Japan

PRJ2 - 3 **Optimization and Verification of Viewing Angle for Wearable Display Device for Outdoor Use**

J. Iwai, H. Kimura

Telepathy Japan, Japan

PRJ4/ DES3 - 2 **Animating Static Objects by Illusion-Based Projection Mapping**

S. Nishida, T. Kawabe, T. Fukiage, M. Sawayama

NTT, Japan

EPp1 - 9L **Fabrication of Plastic Cholesteric LCDs for Color e-Paper Applications Using Simplified Processes**

D.-S. Yoon[,**], S.-J. Lee[*], H.-S. Yang[*], G.-H. Kim[*], H.-J. Hong[*,**], Z. Hong[**], B.-Y. Lee[**], S.-G. Hyeon[***], S.-B. Kwon[*,**]*

[*]Hoseo Univ., Korea
[**]NDIS, Korea
[***]JNC KOREA, Korea

MEET2 - 4 **Progress in Electro-Fluidic Displays at South China Normal University**

B. Tang[*], Y. Deng[,**], R. A. Hayes[*,**,***], G. F. Zhou[*,**,***]*

[*]South China Normal Univ., China
[**]Shenzhen Guohua Optoelect. Tech, China
[***]Ac. of Shenzhen Guohua Optoelect., China

DES4/ 3D8 - 1 **Displaying Real World Light Fields Using Stacked LCDs**

K. Takahashi, Y. Kobayashi, T. Fujii

Nagoya Univ., Japan

INP1 - 1 **Somatic Interfaces to Interact with Image Information**

Y. Kume, T. Mizuno[*]

Tokyo Polytechnic Univ., Japan
[*]Univ. of Electro-Commun., Japan

INP1 - 2 **Retinal Imaging Laser Eyewear with Focus-Free and Augmented Reality**

M. Sugawara, M. Suzuki, H. Miyauchi

QD Laser, Japan

INP1 - 3 **String-Based Haptic Interface for Mobile Devices**

K. Honda, S. Ma[*], Y. Qian[*], M. Sato[*]

Tokyo Univ. of Marine S&T, Japan
[*]Tokyo Tech, Japan

INP2 - 3 **Smart Steering Wheel with Swept Frequency Capacitive Sensing**

Y. Ono, Y. Morimoto, R. Hattori, M. Watanabe[*]*, N. Michida*[*]*, K. Nishikawa*[*]

Kyushu Univ., Japan

[*]Mazda Motor, Japan

INP2 - 4 **Electrostatic Tactile Display for Interaction with Multiple-Unique Sensations**

D. Sugimoto, H. Haga, K. Shigemura

NLT Techs., Japan

INP3 - 2 **New In-Cell Capacitive Touch Panel Technology with Low Resistance Material Sensor and New Driving Method for Narrow Dead Band Display**

Y. Teranishi, K. Noguchi, H. Mizuhashi, K. Ishizaki, H. Kurasawa, Y. Nakajima

Japan Display, Japan

INP4 - 2 **Pressure-Sensitivity and Capacitive Touch Sensing Systems**

T. Nakabayashi, H. Tanaka, M. Miyamoto

Sharp, Japan

INP4 - 3 **Full In-Cell Force Touch Solution with LTPS Technology**

C. Pan, C. Zhong, Q. He, X. Zhou, B. Shen, J. Y. Li, Z. Zeng

XiaMen Tianma Microelect., China

3DSA3/ 3D3 - 2 **Parallax Barrier Based Autostereoscopic Display with a Deep Viewing Zone**

H. Kakeya, H. Takahashi, K. Okada

Univ. of Tsukuba, Japan

3DSAp2/ 3Dp2 - 7 **Floating 3D Interactive Device Using Special Pattern of Spatial-Multiplexed Barrier**

S.-W. Hsu, C.-W. Shih, J.-Y. Wu, C.-H. Ting, Y.-P. Huang

Nat. Chiao Tung Univ., Taiwan

UXC3 - 2 **Proposal of a Paper Book Type Input Device for Page Navigation for Digital Documents**

S. Masunaga, X. Xu, H. Terabe, K. Shibuta, H. Shibata

Fuji Xerox, Japan

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	J.-Y. Son	Konyang Univ.
	C.-H. Tsai	ITRI
	M. Tsuboi	NTT DOCOMO
	H. Yamamoto	Utsunomiya Univ.
	S. Yano	Shimane Univ.

Workshop on Applied Vision and Human Factors

Workshop Chair:	Y. Hisatake	Japan Display
Workshop Vice-Chair, Vice-General Secretary:	S. Uehara	Asahi Glass
Program Chair:	K. Masaoka	NHK
Program Vice-Chair:	T. Nakatsue	Sony
General Secretary:	A. Yoshida	Sharp
Program Committee:	J. Bergquist	Semiconductor Energy Lab.
	Y. Endo	Asahi Glass
	N. Hiruma	NHK-ES
	H. Isono	
	T. Kurita	NHK-Media Tech.
	Y. Nakamura	Mitsubishi Elec.
	G. Ohashi	Shizuoka Univ.
	K. Sakamoto	Panasonic
	T. Shibata	Tokyo Univ. of Social Welfare
	Y. Shimodaira	Shizuoka Univ.
	H. Ujike	AIST
	Y. Imai	Mitsubishi Elec.

Workshop on Projection and Large-Area Display and Their Components

Workshop Chair:	S. Ouchi	Hitachi
Program Chair:	K. Ohara	Texas Instr. Japan
Program Vice-Chair:	S. Shikama	Setsunan Univ.
General Secretary:	T. Suzuki	JVC KENWOOD
Vice-Secretary:	O. Akimoto	Sony Semiconductor Solutions
	M. Takaso	Telepathy Japan
Program Committee:	Y. Asakura	Nittoh Kogaku
	T. Fujiwara	Hitachi
	T. Fukui	Yamanashi Univ.
	T. Hashizume	Seiko Epson
	H. Hatanaka	Ushio
	T. Hayashi	Okamoto Glass
	H. Kanayama	Panasonic
	T. Kawazoe	Univ. of Tokyo
	H. Kikuchi	NHK
	H. Nakano	Barco
	H. Sugiura	Mitsubishi Elec.
	M. Takayama	Honda
	N. Tate	Kyushu Univ.

Workshop on Electronic Paper

Workshop Chair:	K. Hashimoto	E Ink Japan
Program Chair:	T. Fujisawa	DIC
Program Vice-Chair:	N. Kobayashi	Chiba Univ.
General Secretary:	Y. Toko	Stanley Elec.
Program Committee:	H. Arisawa	Fuji Xerox
	M. Higuchi	NIMS
	Y. Hotta	Ricoh
	S. Maeda	Tokai Univ.
	M. Omodani	Tokai Univ.
	N.-S. Roh	Samsung Display
	A. Suzuki	Chiba Univ.
	G. Zhou	South China Normal Univ.

Workshop on MEMS and Emerging Technologies for Future Displays and Devices

Workshop Chair:	M. Nakamoto	Shizuoka Univ.
Program Chair:	Y. Nakai	Toshiba
	J. Moon	Shizuoka Univ.
General Secretary:	T. Ichihara	Panasonic
Vice-Secretary:	T. Komoda	Yamagata Univ.
Program Committee:	T. Akinwande	MIT
	Z. Y. Alpaslan	Ostendo Techs.
	G. Barbastathis	MIT
	Y. Bonnassieux	Ecole Polytechnique
	V. Bulovic	MIT
	S. Coe-Sullivan	QD Vision
	M. Esashi	Tohoku Univ.
	G. Fern	Brunel Univ.
	A. Flewitt	Univ. of Cambridge
	H. Fujita	Univ. of Tokyo
	P. H. Holloway	Univ. of Florida
	J. Jang	Kyung Hee Univ.
	P. Kathirgamanathan	Brunel Univ.
	H. Kikuchi	NHK
	J. M. Kim	Univ. of Oxford
	I. Kymissis	Columbia Univ.
	V. Lee	Lumiode

	J. Manders	NanoPhotonica
	W. Milne	Univ. of Cambridge
	K. C. Park	Kyung Hee Univ.
	D. Pribat	Ecole Polytechnique
	J. Silver	Brunel Univ.
	S. Tanaka	Tohoku Univ.
	F. Templier	CEA-LETI
	H. Tuller	MIT
	S. Uchikoga	Toshiba
	J. Van Derlofske	3M
	Q. Yan	Sichuan COC Display Devices

Workshop on Display Electronic System

Workshop Chair:	H. Okumura	Toshiba
Workshop Vice-Chair:	T. Yamamoto	NHK
Program Chair:	Y. Oyamada	Tottori Univ.
General Secretary:	T. Mitasaki	NTT
Program Committee:	T. Fujine	Sharp
	R. Hattori	Kyushu Univ.
	K. Käläntär	Global Optical Solutions
	L. Kerofsky	InterDigital Communs.
	H.-S. Koo	Minghsin Univ. of S&T
	O.-K. Kwon	Hanyang Univ.
	K. Makita	Canon
	K. Morita	Nat. Traffic Safety & Environment Lab.
	A. Nagase	Mitsubishi Elec.
	H. Nam	Kyung Hee Univ.
	H. Nitta	Japan Display
	S. Ono	Apple
	A. Sakaigawa	Huawei Techs. Japan
	K. Sekiya	Kanagawa Inst. of Tech
	S. Takamura	NTT
	T. Kishigami	Mitsubishi Elec.

Workshop on Flexible Electronics

Workshop Chair:	M. Kimura	Nagaoka Univ. of Tech.
Program Chair:	T. Eguchi	Sumitomo Bakelite
General Secretary:	Y. Mishima	JAPERA
Program Committee:	K. Akamatsu	FUJIFILM
	H. Endo	NEC
	H. Fujikake	Tohoku Univ.
	M. Funahashi	Kagawa Univ.
	T. Furukawa	Yamagata Univ.
	H. Hirata	Toray Eng.
	M. Ito	Toppan Printing
	T. Kamata	AIST
	H. Maeda	DNP
	A. Miyamoto	Univ. of Tokyo
	T. Nagase	Osaka Pref. Univ.
	M. Nakata	NHK
	A. Nakazawa	Asahi Glass
	T. Sekitani	Osaka Univ.
	T. Shiro	Teijin
	T. Tomono	Toppan Printing
	K. Uemura	Nippon Steel & Sumitomo Metal
	Y. Uraoka	NAIST

Workshop on Touch Panels and Input Technologies

Workshop Chair:	N. Hashimoto	Citizen Holdings

Program Chair:	M. Sato	Tokyo Tech
Program Vice-Chair:	Y. Sugita	Sharp
General Secretary:	H. Haga	NLT Techs.
Program Committee:	K. Imoto	Toshiba
	M. Inoue	Huawei Techs. Japan
	H. Katoh	Sharp
	H.-S. Koo	Minghsin Univ. of S&T
	H. Mizuhashi	Japan Display
	K. Nakatani	Touchpanel Labs.
	J. Ohta	NAIST
	H. Okumura	Toshiba
	T. Ono	Mitsubishi Elec.
	Y. Sasaki	Mitsubishi Elec.
	J. Watanabe	NTT
	K. Yamazaki	Corning Japan

Workshop on the 8th International Conference on 3D System and Applications

Workshop Chair:	K. Enami	Tokyo Tech
Workshop Vice-Chair:	J. Kim	ETRI
	Y.-P. Huang	Nat. Chiao Tung Univ.
Program Chair:	N. Inoue	Ultra-Realistic Commun. Forum
Program Vice-Chair:	N. Hur	ETRI
	C.-Y. Chen	Nat. Taiwan Univ. of S&T
General Secretary:	K. Yamamoto	NICT
Vice Secretary:	M. Ohashi	Fukuoka Univ.
Program Committee:	A. Ando	Univ. of Toyama
	H. Ando	NICT
	K.-S. Chang	Delta Elect.
	C.-H. Chen	Nat. Chiao Tung Univ.
	F.-H. Cheng	Chung Hua Univ.
	W.-S. Cheong	ETRI
	B. C. Cho	Dong-ah Inst. of Media and Arts
	B. Choi	Korea Elect. Tech. Inst.
	H.-G. Choo	ETRI
	F. Chuang	Coretronic
	R. Dong	AU Optronics
	T. Endo	Nagaoka Univ. of Tech.
	Y.-C. Fan	Nat. Taipei Univ. of Tech.
	T. Fujii	Nagoya Univ.
	J. Hahn	Kyungpook Nat. Univ.
	F.-L. Hsiao	Nat. Changhua Univ. of Edu.
	C.-L. Hung	Innolux
	Y.-P. Hung	Nat. Taiwan Univ. of S&T
	I. Hwang	Samsung Display
	I. Hwang	ETRI
	Y. Ikei	Tokyo Metropolitan Univ.
	T. Ito	Chiba Univ.
	H. Kakeya	Univ. of Tsukuba
	T. Kawai	Waseda Univ.
	C. Kim	KAIST
	D. Kim	Samsung Elect.
	D.-W. Kim	Kwangwoon Univ.
	H.-L. Kim	Kyungpook Nat. Univ.
	H. K. Kim	Gwangju Inst. of S&T
	J.-P. Kim	LG Elect.
	M. Kim	Kangwon Nat. Univ.
	M. Kim	KAIST
	S.-K. Kim	KIST

	T. Kim	Sejong Univ.
	Y.-T. Kim	Korea Radio Promotion Assn.
	S.-H. Lai	Nat. Tsing Hua Univ.
	B. Lee	Seoul Nat. Univ.
	G. Lee	ETRI
	J. Y. Lee	ETRI
	H.-Y. Lin	Nat. Taiwan Univ.
	D. Miyazaki	Osaka City Univ.
	H. Mizushina	Tokushima Univ.
	Y.-L. Moon	Chosun Univ.
	J.-I. Park	Hanyang Univ.
	M.-C. Park	KIST
	H. Saitoh	Keio Univ.
	T. Senoh	NICT
	Y. Seo	Sogang Univ.
	Y.-H. Seo	Kwangwoon Univ.
	W.-C. Su	Nat. Changhua Univ. of Education
	Y. Takaki	Tokyo Univ. of A&T
	C.-H. Tsai	DOE
	C.-L. Wang	Wiston
	G.-Z. Wang	PixArt Imaging
	H. Yamamoto	Utsunomiya Univ.
	J.-F. Yang	Nat. Cheng-Kung Univ.
	S. Yea	LG Elect.
	J. Yoo	Kwangwoon Univ.
	H. Yoshikawa	Nihon Univ.

Topical Session on User Experience and Cognitive Engineering

Workshop Chair:	H. Shibata	Fuji Xerox
Program Chair:	J. Ichino	Kagawa Univ.
General Secretary:	H. Terabe	Fuji Xerox

Special Topics of Interest on Oxide-Semiconductor TFT

Facilitator:	M. Kimura	Ryukoku Univ.
Program Committee:		
AMD	H. Kumomi	Tokyo Tech
FMC	R. Yamaguchi	Akita Univ.
FLX	M. Nakata	NHK

Special Topics of Interest on AR/VR and Hyper Reality

Facilitator:	Y. Oyamada	Tottori Univ.
Program Committee:		
FMC	K. Käläntär	Global Optical Solutions
FMC	M. Shinohara	Omron
3D	M. Tsuchida	NTT
VHF	S. Uehara	Asahi Glass
PRJ	K. Ohara	Texas Instr. Japan
DES	Y. Oyamada	Tottori Univ.
INP	N. Hashimoto	Citizen Holdings

Special Topics of Interest on Lighting and Quantum Dot Technologies

Facilitator:	Y. Kijima	Huawei Techs. Japan
Program Committee:		
FMC	K. Käläntär	Global Optical Solutions
PH	K. Hara	Shizuoka Univ.
OLED	H. Kuma	Idemitsu Kosan
MEET	Y. Nakai	Toshiba
FLX	A. Miyamoto	Univ. of Tokyo

Special Topics of Interest on Printed Electronics

Facilitator:	M. Nakata	NHK

Program Committee:

LCT	T. Ishinabe	Tohoku Univ.
AMD	H. Minemawari	AIST
FMC	T. Tomono	Toppan Printing
OLED	T. Komatsu	JOLED
FLX	M. Nakata	NHK

Special Topics of Interest on Automotive Displays

Facilitator:	K. Morita	Nat. Traffic Safety & Environment Lab.
Program Committee:		
OLED	T. Ikuta	JNC Petrochem.
3D	M. Tsuchida	NTT
VHF	S. Uehara	Asahi Glass
PRJ	K. Ohara	Texas Instr. Japan
DES	K. Morita	Nat. Traffic Safety & Environment Lab.
FLX	Y. Uraoka	NAIST

FINANCIAL SUPPORTING ORGANIZATIONS (as of November 2, 2016)

Applied Materials, Inc.
ASAHI GLASS Co., Ltd.
Japan Display Inc.
Nichia Corporation
SHARP CORPORATION

SUPPORTING MEMBERS (as of November 2, 2016)

EIZO Corporation
JAPAN BROADCASTING CORPORATION
JNC Corporation
Merck Ltd.
NLT Technologies, Ltd.
TOKYO ELECTRON LIMITED
Toshiba Corporation
ULVAC, Inc.

EXHIBITORS: COMPANIES (as of November 2, 2016)

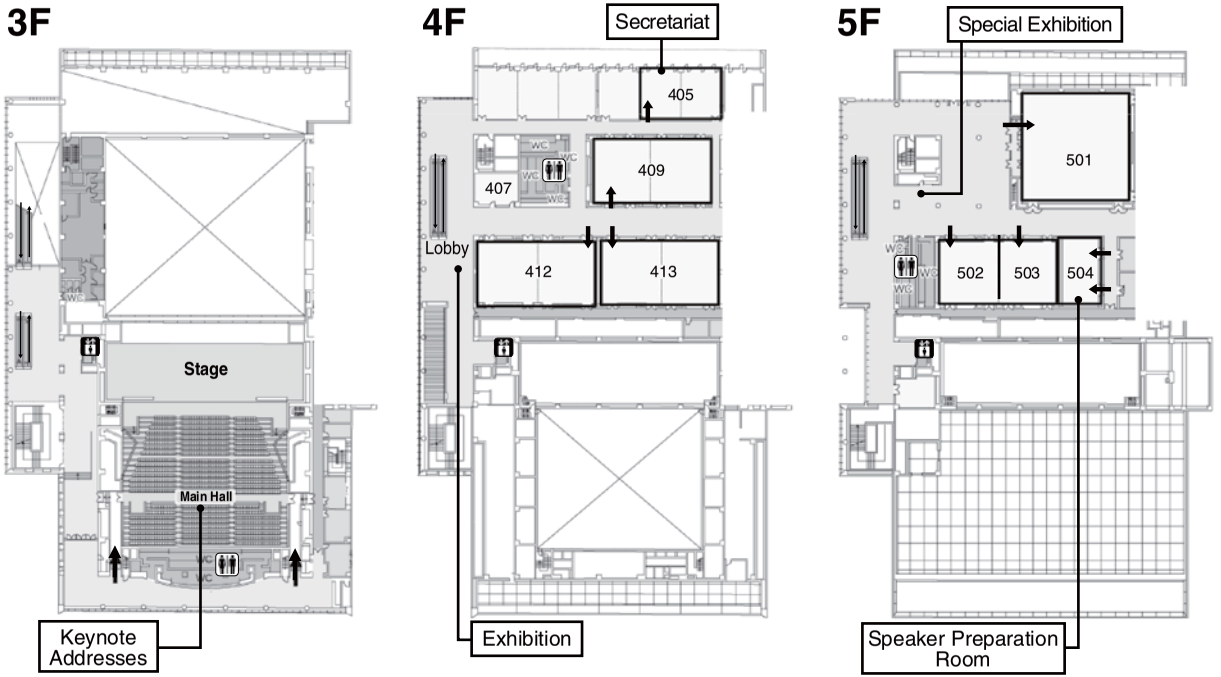
Current powered by GE
Fraunhofer Institute Organic Electronics, Electron Beam and Plasma Technology FEP
KONICA MINOLTA JAPAN, INC.
NAGASE & CO., LTD.
OXIDE Corporation
SHIGIYA MACHINERY WORKS LTD.
SHINTECH, INC.
Silvaco Japan Co., Ltd.
Sumika Chemical Analysis Service, Ltd.
Toray Research Center, Inc.
Tosoh Corporation
TOYO Corporation
Ube Material Industries, Ltd.
YUASA SYSTEM Co., Ltd.
VITEC GLOBAL ELECTRONICS CO., LTD.

EXHIBITORS: UNIVERSITIES (as of November 2, 2016)

Electron Device Engineering Labs., Univ. of Toyama
Fujieda Lab., Ritsumeikan Univ.
Iimura Lab., Tokyo Univ. of A&T
Kimura Lab., Nagaoka Univ. of Tech.
Maeda Lab., Tokai Univ.
Mutsu Lab./Ryukoku Extension Center, Ryukoku Univ.
Noguchi Lab., Univ. of the Ryukyus
Suyama Lab., Tokushima Univ.
Yamamoto Lab., Utsunomiya Univ.

FLOOR PLAN

2F
Exhibition
WC
WC
Lobby
201
Multipurpose Hall
Main Hall
Posters
I-DEMO
Authors Interviews
1F
Restaurant
RACONTER
Evening
Get-Together
WC
WC
Registration Desk
Entrance
Cloak


3F
Stage
Main Hall
Keynote Addresses
4F
Secretariat
405
409
407
412
413
Lobby
Exhibition
5F
Special Exhibition
501
502
503
504
Speaker Preparation Room

IDW / AD '16 Workshop Timetable

	1F	2F		3F	4F			5F			
Date	1F Lobby	Multipurpose Hall	201	Main Hall	409	412	413	501	502	503	2F, 4F Lobby
Tue., Dec. 6	Registration 17:00 - 20:00	Evening Get-Together at RACOUNTER (1F) 18:00 - 20:00									
Wednesday, December 7	Registration 8:00 - 18:00			Opening, Keynote Addresses 9:30 - 11:50							Exhibition 12:40 - 18:00
		Lunch									
			INP1 13:00 - 14:20	3DSA1/3D1 13:00 - 14:30	AMD1 13:00 - 14:25	LCT1 13:00 - 14:20	FMC1 13:00 - 14:20	OLED1 13:00 - 14:20	VHF1 13:00 - 14:20	UXC1 13:00 - 14:25	
		Break									
			INP2 14:40 - 16:05	3D2/3DSA2 14:40 - 16:00	AMD2 14:40 - 16:15	LCT2 14:40 - 15:55	FMC2 14:40 - 16:00	OLED2 14:40 - 16:00	EP1 14:40 - 16:10	UXC2/VHF2 14:40 - 16:00	
		Break									
			INP3 16:20 - 17:30	3DSA3/3D3 16:20 - 17:40	AMD3 16:20 - 17:50	LCT3/FLX1 16:20 - 17:45	FMC3 16:20 - 17:40	OLED3 16:20 - 17:15	PH1 16:20 - 17:45	VHF3 16:20 - 17:40	
		Author Interviews 17:40-18:20									
		Break									
		Reception at ANA Crowne Plaza Fukuoka, Crowne Grand Ball Room (2F) 19:00 - 21:00									
Thursday, December 8	Registration 8:00 - 18:00			3DSA4/VHF4 9:00 - 10:20	MEET1 9:00 - 10:25	PRJ1† 9:00 - 10:37	FMC4 9:00 - 10:20	OLED4 9:00 - 10:15	EP2† 9:00 - 10:40	UXC3† 9:00 - 10:31	Exhibition 10:00 - 18:00
		Break									
		Poster LCTp1 - 2,FMCp,OLEDp, 3Dp1/3DSAp1,VHFp,PRJp,FLXp,UXCp 10:30 - 13:00	Innovative Demonstration Session 10:30 - 16:40	Author Interviews 10:30-11:10							
		Lunch		Lunch							
		Poster LCTp3,AMDp,PHp,3DSAp2/3Dp2, EPp,MEETp,DESp,INPp 14:10 - 16:40									
		Break									
			INP4 16:50 - 18:00	3D4/3DSA5 16:50 - 18:10	AMD4/LCT4 16:50 - 18:20	FMC5/FLX2 16:50 - 18:10	DES1 16:50 - 18:20	OLED5 16:50 - 18:10	EP3 16:50 - 18:15	PH2 16:50 - 18:10	
		Author Interviews 18:10 - 18:50									
Friday, December 9	Registration 8:00 - 13:00		PRJ2 9:00 - 10:20	3DSA6/3D5 9:00 - 10:20	AMD5 9:00 - 10:25	LCT5 9:00 - 10:20	MEET2 9:00 - 10:20	FLX3 9:00 - 10:20		VHF5 9:00 - 10:30	Exhibition 10:00 - 14:00
		Break									
			PRJ3 10:40 - 12:00	3D6/3DSA7 10:40 - 12:00	AMD6 10:40 - 12:00	LCT6 10:40 - 12:00	MEET3 10:40 - 12:00	FLX4 10:40 - 11:50	DES2 10:40 - 12:05	VHF6 10:40 - 12:10	
		Author Interviews 12:00 - 12:40									
		Lunch									
			PRJ4/DES3 13:30 - 15:05	3D7/3DSA8 13:30 - 14:50	AMD7 13:30 - 14:50	LCT7 13:30 - 14:50	MEET4 13:30 - 14:50	FLX5 13:30 - 14:45	FMC6 13:30 - 14:50	VHF7 13:30 - 14:55	
		Break									
			PRJ5 15:30 - 16:30	DES4/3D8 15:15 - 16:45	AMD8 15:10 - 16:30		MEET5 15:10 - 16:30	FLX6 15:10 - 16:15		VHF8/UXC4 15:10 - 16:10	
		Author Interviews 16:30 - 17:10									

† Including Short Presentations

IDW/AD '16 Special Topics of Interest Navigator

	Wed., Dec. 7 PM	Thu., Dec. 8 PM	Thu., Dec. 8 AM	Fri., Dec. 9 PM	Fri., Dec. 9 AM
Oxide-Semiconductor TFT — 409	AMD1: Oxide TFT: High-Stability TFTs 13:00 - 14:25 AMD2: Oxide TFT: High-Performance TFTs 14:40 - 16:15 AMD8: High-Resolution Display 16:20 - 17:50	AMD3/LCT4: Super-High-Resolution LCDs 16:50 - 18:20		AMD7: Oxide TFT: Solution-Processed TFTs 13:30 - 14:50 AMD9: Oxide TFT: Novel Processes & Applications 15:10 - 16:30	AMD6:Flexible Devices 10:40 - 12:00
Multipurpose Hall		AMD1: Oxide TFTs 14:10 - 16:40	FMCp2:FLXp2:Poster 10:30 - 13:00		
Lighting and Quantum Dot Technologies — 201					PRJ3: Projection Components & Devices 10:40 - 12:00
413				MEET4: EL, Quantum Dots Technologies 13:30 - 14:50	MEET5: Emerging Quantum Dot & Nanotechnologis 15:10 - 16:30
501	OLED2: OLED for Lighting Applications 14:40 - 16:00				
502	PH1: Phosphors for Lighting Application 16:20 - 17:45				
Multipurpose Hall		PHp1:MEETp1:Poster 14:10 - 16:40	OLEDp2:VHFp2:Poster 10:30 - 13:00		
AR/VR and Hyper Reality — Main Hall	3D2/3DSA2: Visualization & AR 14:40 - 16:00		3DSA4/VHF4: Human Vision 9:00 - 10:20		DES4/3D8: 3D Display & Sensor 15:15 - 16:45
201	INP1: AR & Interactive Systems 13:00 - 14:20			PRJ4/DES3: 3D Near Eye Display 13:30 - 15:05	PRJ2: Wearable Display 9:00 - 10:20
Multipurpose Hall		INPp1:3DSAp2,3Dp2: Poster 14:10 - 16:40	3Dp1/3DSAp1, PRJp1: Poster 10:30 - 13:00		
Printed Electronics — 413			FLXp:Standardization on Printed Electronics 9:00 - 10:20		
501				FLX5: Flexible Printed Electronics 1 13:30 - 14:45	FLX6: Flexible Printed Electronics 2 15:10 - 16:15
Multipurpose Hall			OLEDp3: Poster 10:30 - 13:00		
Automotive Displays — 201	INP2: Automotive HMI 14:40 - 16:05				PRJ5: Automotive Display 15:30 - 16:30
502	VHF1: Ergonomics for Automotive Applications 13:00 - 14:20				
Multipurpose Hall		3DSAp2/3Dp2:3D AR Hyper-Reality Systems & Applications 2 14:10 - 16:40	VHFp1: Poster 10:30 - 13:00		

IDW / AD '16 Session Navigator

	Wednesday, December 7				Thursday, December 8						Friday, December 9					
	PM				AM			PM			AM			PM		
User Experience & Cognitive Engineering	503			Multipurpose Hall	503	201	Multipurpose Hall								503	
	User Study	Human Factors*		A.I.	Interaction Design	A.I.	Posters								High Dynamic Rande & Virtual Reality *	
3D/Hyper-Realistic Displays	Main Hall			Multipurpose Hall	Main Hall	201	Multipurpose Hall	Multipurpose Hall	Main Hall	Multipurpose Hall	Main Hall		Multipurpose Hall	Main Hall		Multipurpose Hall
	Holography*	Visualization & AR*	Autostereoscopic Display*	A.I.	Human Vision*	A.I.	Posters	Posters	Image Processing*	A.I.	Volume Display & Display Analysis*	Aerial Display*	A.I.	Technologies for 3D Imaging*	3D Display & Sensor*	A.I.
Active-Matrix Displays	409							Multipurpose Hall	409	Multipurpose Hall	409		Multipurpose Hall	409		Multipurpose Hall
	Oxide TFT: High-Stability TFTs	Oxide TFT: High-Performance TFTs	High-Resolution Displays	A.I.				Posters	Super-High-Resolution LCDs*	A.I.	Organic TFTs	Flexible Devices	A.I.	Oxide TFT: Solution-Processed TFTs	Oxide TFT: Novel Processes & Applications	A.I.
Display Electronic Systems				Multipurpose Hall				Multipurpose Hall	413	Multipurpose Hall		502	Multipurpose Hall	201	Main Hall	Multipurpose Hall
								Posters	DES 10th Anniversary	A.I.		High Image Quality Technology	A.I.	3D & Near Eye Displays*	3D Display & Sensor*	A.I.
Emissive Technologies			502	Multipurpose Hall				Multipurpose Hall	503	Multipurpose Hall				413		Multipurpose Hall
			Phosphors for Lighting Application	A.I.				Posters	Phosphors for General	A.I.				EL Quantum Dots Technologies	Emerging Quantum Dots & Nanotechnologies	A.I.
Emerging Technologies & Novel Applications								Multipurpose Hall			413		Multipurpose Hall			
								Posters			Novel Materials & Components	Fundamental Components & Process Technologies	A.I.			
e-Paper		502		Multipurpose Hall	502	201		Multipurpose Hall	502	Multipurpose Hall						
		Color e-Paper Technologies		A.I.	Flexible e-Paper and IoT Application of e-Paper	A.I.		Posters	Novel Materials for e-Paper	A.I.						
Flexible Electronics			412				Multipurpose Hall		412	Multipurpose Hall	501		Multipurpose Hall	501		Multipurpose Hall
			Flexible LCDs				Posters		Manufacturing & Equipment*	A.I.	Flexible Device Technologies 1	Flexible Device Technologies 2	A.I.	Flexible Printed Electronics 1	Flexible Printed Electronics 2	A.I.
Interactive Technologies	201			Multipurpose Hall				Multipurpose Hall	201	Multipurpose Hall						
	AR & Interactive Systems	Automotive HMI	Touch Panel	A.I.				Posters	Touch Panel & Force Interaction	A.I.						
Human Factor	502	503		Multipurpose Hall	Main Hall	201	Multipurpose Hall				503		Multipurpose Hall	503		Multipurpose Hall
	Ergonomics for Automotive Applications	Human Factors*	Display Measurement & Simulation	A.I.	Human Vision*	A.I.	Posters				Human Factors & Applications	Visual Comfort & Motion Sickness	A.I.	Color Vision & Illumination	High Dynamic & Virtual Reality*	A.I.
Liquid-Crystal Technologies	412			Multipurpose Hall			Multipurpose Hall	Multipurpose Hall	409	Multipurpose Hall	412		Multipurpose Hall	412		Multipurpose Hall
	Photoalignment	Evaluations	Flexible LCDs*	A.I.			Posters	Posters	Super-High-Resolution LCDs*	A.I.	Novel LC Applications	Quality of LCDs	A.I.	High Performance LC Mode		A.I.
Manufacturing, Process & Equipment			413	Multipurpose Hall	413	201	Multipurpose Hall		412	Multipurpose Hall						
			Manufacturing Technologies	A.I.	Standardization on Printed Electronics	A.I.	Posters		Manufacturing & Equipment*	A.I.						
Materials & Components	413			Multipurpose Hall			Multipurpose Hall							502		Multipurpose Hall
	Film Technologies	Display Optics & Information Technologies		A.I.			Posters							Materials & Components		A.I.
MEMS					409	201		Multipurpose Hall								
					Nanotechnologies for Display Applications	A.I.		Posters								
Organic Light-Emitting Displays & Organic Devices	501			Multipurpose Hall	501	201	Multipurpose Hall		501	Multipurpose Hall						
	OLED Displays	OLED for Lighting Applications	OLED Devices	A.I.	OLED Materials I	A.I.	Posters		OLED Materials II	A.I.						
Projection & Large Area Displays					412	201	Multipurpose Hall				201		Multipurpose Hall	201		Multipurpose Hall
					Standardization & Characterization	A.I.	Posters				Wearable Display	Projection Components & Devices	A.I.	3D & Near Eye Displays*	Automotive Display	A.I.

A.I. Author Interviews
* Joint Session

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