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SID
SOCIETY FOR INFORMATION DISPLAY

IDW ’18

THE 25TH INTERNATIONAL DISPLAY WORKSHOPS

Special Topics of Interest on

- Oxide-Semiconductor TFT
- Quantum Dot Technologies
- AR/VR and Hyper Reality
- Automotive Displays
- Wide Color Gamut and Color Reproduction
- Haptics Technologies

Topical Session on

- User Experience and Cognitive Engineering (UXC)

Workshops on

- LC Science and Technologies (LCT)
- Active Matrix Displays (AMD)
- FPD Manufacturing, Materials and Components (FMC)
- Inorganic Emissive Display and Phosphors (PH)
- OLED Displays and Related Technologies (OLED)
- 3D/Hyper-Realistic Displays and Systems (3D)
- Applied Vision and Human Factors (VHF)
- Projection and Large-Area Displays and Their Components (PRJ)
- Electronic Paper (EP)
- MEMS and Emerging Technologies for Future Displays and Devices (MEET)
- Display Electronic Systems (DES)
- Flexible Electronics (FLX)
- Touch Panels and Input Technologies (INP)

Final Program

Nagoya Congress Center
Nagoya, Japan
December 12 – 14, 2018

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Workshop on Display Electronic Systems

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Innovative Demonstration Session

PROGRAM HIGHLIGHTS

The 25th International Display Workshops will be held as IDW ’18 for encouraging aggressive research and development of display technologies throughout the world and especially in the Asian region. IDW ’18 focuses on the following 6 special topics and 1 topical session, which are extremely timely, as well as 13 active workshops.

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The three-day conference will feature 472 papers, including 3 keynote addresses, 124 invited presentations, 147 oral presentations, and 198 poster presentations. Following the plenary session of keynote addresses on 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 ’18 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)

Oxide semiconductor TFTs have already occupied an important position in the industry field of flat panel displays. Constituent materials, fabrication processes, characteristic enhancement technology, life-time prolonging techniques, etc. have become mature technologies. On the other hand, there is great room to improve the characteristics. All the authors will present novel oxide semiconductor materials, new device structures, solution processes, post-deposition processes, etc. Moreover, they will also propose emerging applications beyond the conventional ones. Don't miss them!!

Special Topics of Interest on Quantum Dot Technologies (QDT)

This topic will cover all aspects of the science and technologies of Quantum Dot (QD) and Quantum Rod (QR), ranging from materials research, device structure and properties, device applications for lighting and display, manufacturing and high color gamut of display using QD. This topic will specialize in QD Technologies (QDT) for the purpose of

establishing a venue for revitalization in each field.
A highlight for IDW'18 will be the development of GaN nanocolumn LED for monolithic micro-LED displays, and the narrow band-edge emission from chalcopyrite semiconductor quantum dots, ligand materials to enhance luminous efficiency and stability of perovskite quantum dots, and recent progress of QD materials (PH-WS), applications of quantum dot materials, high brightness nano/micro LED, energy-saving displays and lighting devices (MEET-WS), perovskite QD technologies, light-emitting transistors with QD and the evaluation of carrier transport properties by impedance spectroscopy method (OLED-WS) .

Special Topics of Interest on AR/VR and Hyper Reality (AR&VR)
Augmented reality (AR) and virtual reality (VR) applications employing high-performance display devices such as sensors, cameras with tracking capabilities, and computer graphics technologies have shown significant progress in the past few years.
This year we have organized six oral and three poster sessions ranging from hardware to software systems. The IDW '18 is a venue to access the versatile state-of-the-art in AR and VR.

Special Topics of Interest on Automotive Displays (AUTO)
One of the applications of display systems is in transportation systems including automobiles. From 2016, Automotive Displays (AUTO) was initiated as the new Special Topic of Interest (STI) where a lot of presentations concerning automobile displays were given. In 2018, WSs such as VHF, DES, INP, UXC, 3D, and PRJ will organize the AUTO. In "these sessions", you can hear new technological presentations, for examples, the Head-Up Display (HUD) that can give a stable display regardless of ambient light changes, and the gesture touch display in which users do not have to directly touch the surface of the display. Furthermore, flight deck display development will be reviewed. This AUTO will surely interest audiences such as users and designers of automobiles.

Special Topics of Interest on Wide Color Gamut and Color Reproduction (WCG)
Thanks to rods and three color cones in our retinas, we can enjoy the high dynamic range and wide color gamut (WCG). We need to understand our rods, cones, and nerve systems, and then to develop suitable materials, components, displays, and systems with color-gamut-expansion and color-reproduction technologies based on color/color vision research and WCG-related standardization.
Now in its second year as a Special Topics of Interest (STI), WCG STI is attracting more attention and the sessions have subsequently been expanded. One oral session in LCT-WS, one poster session in FMC-WS, and two oral and one poster sessions in VHF-WS await audiences composed not only of color enthusiasts but also those who just wish to listen in. The color-related materials and displays in LCT and FMC, color perception in VHF are not to be missed. With novel achievements in color vision and color conversion, you are sure to find yourself drawn into a whole new world of color.

Special Topics of Interest on Haptics Technologies (HAP)
Haptic technologies have been attracting attention in various fields as a next-generation technology to provide new user experiences. As a forum for discussing the integration of display technologies and haptic technologies, we have planned the special topic of interest on haptics display technologies, following on from the last IDW. The many invited talks will be given by leading Japanese researchers on topics such as human haptic perception and measurement, presentation, and modulation of haptic information, including pseudo-haptic display technologies for shape and human-centric flexible shape haptics technologies. In the demonstration session, participants can actually

"experience" the technologies related to the talks.

Topical Session on User Experience and Cognitive Engineering (UXC)
UXC gives four sessions this year. UXC1 (Visual Experience) gives studies on the visualization of sensor data and eye tracking analysis. UXC2 (Tangible Interface and Education) shows haptic technologies and the use of digital tools in education. EP4/UXC3 (Ideal Replacement of Paper) considers ideal digital tools to replace paper through the evaluation of e-book readers. DES2/UXC4 (AI Applied to Display) explores new directions of display technologies through AI technologies.

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 11 invited presentations related to (i) enhancement of color gamut by using quantum dots or specifically designed film, (ii) FLC technology and HUD technology for 3D displays, and (iii) LC lenses and several types of LC phase shifters including LC antennas. Moreover, several emerging technologies related to Flexible LCDs, transparent LCDs, reflective LCDs, holographic displays, high image quality technology by polymer stabilized technique, photoalignment technology, in-cell technology, and analysis of display unevenness and its remedies are presented.

Workshop on Active Matrix Displays (AMD)
The AMD workshop covers oxide TFT, Si-TFT, organic/carbon TFT, micro-LED, OLED, sensors, and other devices. Recent paper presentations tend to focus on oxide TFT, which is highly expected to play a role in applications for higher resolution LC and OLED displays. We highlight the oxide TFT as a special topic of interest (STI) OXT, with three dedicated sessions covering a wide area from materials, physics, devices, and processes to applications. Furthermore, we have prepared two sessions for organic/carbon devices and 8K and micro-LED displays. We look forward to your participation!

Workshop on FPD Manufacturing, Materials and Components (FMC)
The FMC workshop (WS) 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 FMC includes five sessions with three joint sessions, and six invited talks on recent topics. The oral sessions are made up of 20 papers, and the poster session contains 26 papers over 7 poster sessions. In the FMC sessions, recent developments and manufacturing issues of MicroLED display will be presented. In addition, papers on display optics, their concepts, metrologies, and augmented reality (AR) as well as head-mount display (HMD) using waveguides will be presented. In a materials and components session, papers on light polarization technologies will be highlighted. Furthermore, the performance properties of optical films and their materials such as cyclo-olefin, high-k insulator, MoTi wiring, and gate metal Al/Mo, will be presented.

Workshop on Inorganic Emissive Display and Phosphors (PH)
This workshop presents the latest achievements in devices and phosphors for emissive displays, lighting, and imaging. Invited talks will present emerging technologies such as GaN nanocolumn LED for micro-LED display, narrow band-edge emission from chalcopyrite semiconductor quantum dots, and self-healing phosphor for high-power LED.

Workshop on OLED Displays and Related Technologies (OLED)
The OLED workshop covers all aspects of the science and technologies of OLED, QLED and other organic devices, ranging from material science, basic device physics for OLED device and display technologies, and other applications. The oral and poster sessions will cover OLED display and device technologies, materials and process technologies for soluble OLED and advanced technologies concerning OLED/QLED devices and materials. Recent progress such as micro-OLED display, perovskite QD technologies, and automotive applications etc. will be reported on. We will also focus in special on Quantum Dot technologies (QDT) as a special topic of interest (STI) at IDW '18.

Workshop on 3D/Hyper-Realistic Displays and Systems (3D)
The 3D/hyper-realistic displays and systems workshop will consist of many papers on 3D systems and devices for holography, autostereoscopic display, integral photography, and emerging applications for AR. There will be some invited talks related to interactive displays, a novel AR display based on multiple viewpoint images, and emerging displays for VR etc. 3D poster sessions include demonstrations, which will help participants to experience the brand-new sensations of 3D images.

Workshop on Applied Vision and Human Factors (VHF)
The VHF workshop covers all ergonomic factors on human interfaces, such as visual aspects, environmental related aspects, and measurements. We have eight oral sessions and seven poster sessions, including special topic sessions on color, automotive applications, and virtual reality, in addition to HDR and physiological factors. We also have a joint session on 3D. Eight invited talks will be given in the oral sessions, concerning color gamut metrics, 8K HDR with 10,000 cd/m^2 of peak luminance, automotive ergonomics, AR/VR ergonomics, brain neuroimaging, and autonomic nervous system applications.

Workshop on Projection and Large-Area Displays and Their Components (PRJ)
The PRJ workshop covers the latest projection mapping, wearable applications, vehicle display and lighting technologies, solid-state light sources, lighting, holograms, short throw optics, etc., Augmented Reality / Virtual Reality, 3D measurement, standardization of wearable/new light sources and all the projection related technologies. This year's session will focus on wearable-related technologies, automotive displays and sensors, laser light sources, projection devices, solid state light source projectors, projection mapping and standardization.

Workshop on Electronic Paper (EP)
The EP workshop focuses on emerging topics in electronic paper including new applications and user interface studies. Application fields for e-paper are now expanding to books, documents, notes, shelf labels, signage, smart devices and more. Challenging presentations will be given in the following five sessions: 1) Expansion of electrophoretic displays, 2) Emerging e-Paper technologies, 3) Advance of electrochromic displays, 4) Approaches to ideal replacement of paper media, 5) Various challenges for e-paper.

Workshop on MEMS and Emerging Technologies for Future Displays and Devices (MEET)
The MEET workshop is unique in covering all aspects of MEMS, micro-LED, Quantum Dot, nanotechnologies and emerging technologies concerning future displays, imaging devices, and emerging electron devices. The MEET workshop has established the sessions of micro-LEDs and Quantum Dot/Quantum Dot light-emitting diodes for the first time in the world academic society and 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, Nanotechnologies and

display conferences in the world, this is the only opportunity for MEMS, Nanotechnologies 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 will come from CEA-LETI, Ecole Polytechnique, Columbia University, Brunel University, Seoul National University, Kyung Hee University, Fuzhou University, Southern University of Science and Technology, Luminit, Veeco, QMAT, Nanosys, DIC, TCL, and ULVAC. 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 32 papers including 10 invited talks and 9 poster presentations. This year, we will organize five oral sessions which include a session on 8K technologies and two AUTO STI (Special Topics of Interest) sessions that feature AI and display technologies. Furthermore, sessions on micro-LED and OLED, and unconventional/ unique displays will be organized.

Workshop on Flexible Electronics (FLX)

The FLX workshop focuses on advanced technologies for flexible electronics including foldable 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 most topical flexible devices and material technologies including new TFT fabrication technologies, flexible sensors, and innovative Roll-to-Roll processes.

Workshop on Touch Panels and Input Technologies (INP)

Interface technologies such as touch panels and interactive technologies which have already extended to automotive HMIs are the stars of the session. Following to last meeting, this year, advances in haptic sensors, AR/VR systems, sensing devices for 3D/depth cameras, finger/face authentication devices, in-cell force touch panels, and interactive displays for automotive HMIs are topics that will be focused on. INP papers will open a new window in displays and interactive technologies, not only for devices but also for systems, making them essential viewing.

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 ’18. The award winners will be announced on the IDW website and given a plaque after the conference.

IDW 25th Ceremony for Certificate of Appreciation

This year will mark the 25th anniversary of International Display Workshops (IDW '18). In commemoration of the anniversary, we will give a certificate of appreciation to the first Committee Chairs, Prof. Kobayashi, Prof. Uchiike and Prof. Mikoshiba. In addition, we will make a new prize which bears the names of the chairs, “Kobayashi-Uchiike-Mikoshiba Prize” that will be granted from next year in IDW '19.

I-DEMO (Innovative Demonstration Session)

I-DEMO will be held on December 13 at Event Hall (1F, Bldg.1). 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 ’18 Exhibition, which will be held from December 12 through December 14, 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 (Event Hall, 1F, Bldg.1).

December 12 (Wed.) 12:40 – 18:00
December 13 (Thu.) 10:00 – 18:00
December 14 (Fri.) 10:00 – 14:00

IDW ’18 Tutorial in Japanese

Organized by SID Japan Chapter
Tuesday, Dec. 11, 2018
13:00 – 18:00
International Conference Rooms
(3F, Building 3)
Nagoya Congress Center

Detailed information will be announced at
http://www.sid-japan.org/

Evening Get-Together with Wine

Tuesday, Dec. 11, 2018
18:00 – 20:00
Cafeteria Cascade (B1F, Building 3)
Nagoya Congress Center

Sponsored by Merck Performance Materials Ltd.
See page 14 for details

GENERAL INFORMATION

SPONSORSHIP
IDW ’18 is sponsored by the Institute of Image Information and Television Engineers (ITE) and the Society for Information Display (SID).

CONFERENCE SITE
Nagoya Congress Center
1-1 Atsuta-nishimachi, Atsuta-ku, Nagoya 456-0036, Japan
URL: http://www.nagoya-congress-center.jp/en/
Phone: +81-52-683-7711
Fax: +81-52-683-7777

ON-SITE SECRETARIAT
Telephone for IDW ’18 will be temporarily set up in the secretariat room (Room 437) at Nagoya Congress Center (December 11-14).
Phone: +81-52-682-2023

RECEPTION
A buffet style reception will be held on the evening of December 12 from 19:00-21:00 at the 1F, North Building in Atsutajingu Kaikan, 1-1-1 Jingu, Atsuta-ku, Nagoya. Atsutajingu Kaikan is located in Atsuta Shrine 2.3km away from the Nagoya Congress Center, approx. 10min. by car. 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 11 from 18:00 to 20:00 at Cafeteria Cascade (B1F) in Nagoya Congress Center. Wine (sponsored by Merck Performance Materials Ltd.) and snacks will be served to participants in a relaxed atmosphere for networking. Admission is free with your name tag.

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 ’18 includes admission to the conference and a USB flash drive of the proceedings. Detailed information will be announced on the website.

	Until Nov. 2	On and After Nov. 3
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” 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 ’18 committee.
***Full-time student, photocopy of student ID is required.
****Photocopy of your membership card is required.

Please note that the payment of reduced registration fee is accepted until Nov. 2. The full fee will be charged for payments made on and after Nov. 3. Also note that the number of reception tickets to register on site is limited.

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
Two 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 30, 2018.

(2) On-site Registration
Conference registration desk will open:
December 11 (Tue.) 17:00 – 20:00
December 12 (Wed.) 8:00 – 18:00
December 13 (Thu.) 8:00 – 18:00
December 14 (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 **Nov. 2**, cancellation is accepted by writing to IDW '18 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 Nov. 3
- No-shows
- Cancellations by presenters
- Cancellations by visa invitation letter applicants who have already received a visa invitation letter.

However, after IDW '18 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 '18 due to the outbreak of infectious diseases and other unavoidable factors, we will substitute the IDW with the mail delivery of the IDW '18 proceedings at a later date to all those who have registered and completed payment.

Reception

Wednesday evening
Dec. 12, 2018
19:00 – 21:00

Atsutajingu Kaikan, Atsuta Shrine
(1F, North Building)

Atsutajingu Kaikan is located 2.3km away from Nagoya Congress Center, approx. 10min. by car.
See page 14 for details

INQUIRIES

IDW '18 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

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
- Human Interface Society
- Information Processing Society of Japan
- The Institute of Electrical Engineers of Japan
- The Institute of Electronics, Information and Communication Engineers
- 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 Japanese Society for Artificial Intelligence
- The Optical Society of Japan
- The Society of Automotive Engineers of Japan
- The Society of Instrument and Control Engineers
- The Society of Polymer Science, Japan
- The Virtual Reality Society of Japan
- Vision Society of Japan

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TOKYO ELECTRON LIMITED
ULVAC, Inc.
Zeon Corporation

FUNDS

- Nagoya Convention & Visitors Bureau

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

TRAVEL INFORMATION

ACCOMMODATIONS
JTB NAGOYA Branch will handle arrangements for your hotel reservations.

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

Hotel list and the rates are available on the Pullout of this Advance Program.

JTB NAGOYA Branch
Office Hours: 9:30-17:30 (Weekdays only)
E-mail: cub_mice@jbn.jtb.jp

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

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

JAPAN RAIL PASS
Japan Railway (JR) provides the following economical passes. They should be purchased before you leave your country. Please contact your travel agency. Visit the following sites for the details.

The JAPAN RAIL PASS is the most economical way to travel throughout Japan by rail and JR buses.

Japan Rail Pass: http://www.japanrailpass.net/en/

CLIMATE
The average temperature in Nagoya during the period is around 11.4°C in the daytime and 2.6°C at night.

NAGOYA

The city of Nagoya is located in the center of Honshu, the main island of Japan, and has good access to Tokyo, Kyoto, Osaka and all other areas. Central Japan International Airport (Centrair) is the gateway of Central Japan to the sky, and is only about 30 min. away from Nagoya station by railway. Nagoya is famous for the birthplace of three notable feudal lords, Oda Nobunaga, Toyotomi Hideyoshi and Tokugawa Ieyasu. They were active persons in the 16th century. There are many heritages such as Nagoya castle, Atsuta Shrine, Tokugawaen, and so on. In Nagoya, traditional industries like ceramics and textiles, and today's key industries like automobiles, aviation, and machine tools have been developed. The local "Nagoya-meshi" such as Hitsumabushi, Misokatsu, Kishimen-Noodle, Misonikomi etc. differ from those of Tokyo and Osaka foods and are the great variety and unmatched originality. The Nagoya Congress Center, with a design motif of a swan poised for flight, is located about 6 km from Nagoya station and is accessible from Nagoya station about 20 minutes by subway and a further 5-minute walk.

PLACES OF INTEREST

Nagoya Castle

This is a castle built in 1612 for the Owari Tokugawa Family. The current donjon was reconstructed in 1959. The 3rd floor through the 5th floor were remodeled in 1997 and were used to exhibit artifacts depicting the lives of the feudal lords and ordinary citizens of Nagoya in those days, as well as telling the story behind the golden Shachihoko. Access: a 5-minute walk from the "Shiyakusho" subway station.

Atsuta Shrine

The Atsuta Shrine is the 2nd largest shrine after the Ise Shrine and about 6.5 million people visit there annually. Shogun Nobunaga prayed for the victory of the war here and the "Nobunaga-bei walls" were made by him in 1560. In the Atsuta Jingu Museum, about 4,000 articles have been collected which were donated by people ranging widely in class from the Imperial Family and Shogun to common persons. Access: a 5-minute walk from Meijo-Line "Jingu-Nishi" station or Meitetsu Nagoya-Line "Jingu-Mae" station.

The Tokugawa Art Museum

The Tokugawa Art Museum is known for its collection of "Daimyo Dogu," the precious treasure of the Owari Tokugawa feudal lords. The collection includes over 10,000 items such as armors and swords belonging to Hideyoshi, Ieyasu and successive feudal lords of the Owari Tokugawa clan. Access: a 10-minute walk from the JR Ozone station.

Toyota Commemorative Museum of Industry and Technology

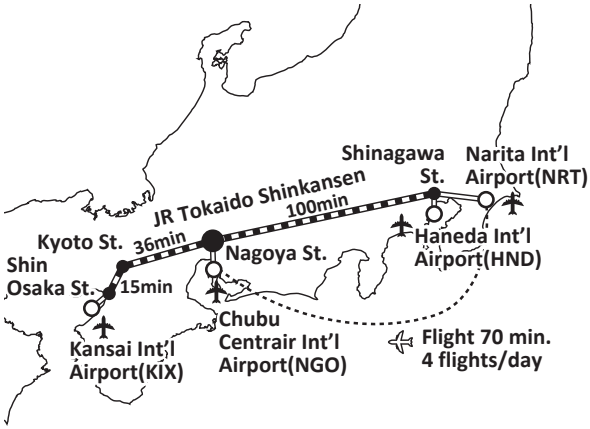
The Toyota Group established this museum to help people understand the importance and wonder of "making things" and the "originality and research" behind it, which have become harder to see as the high technology of industries has evolved in recent years. Access: a 3-minute walk from "Sako" station on the Meitetsu Nagoya-Line.

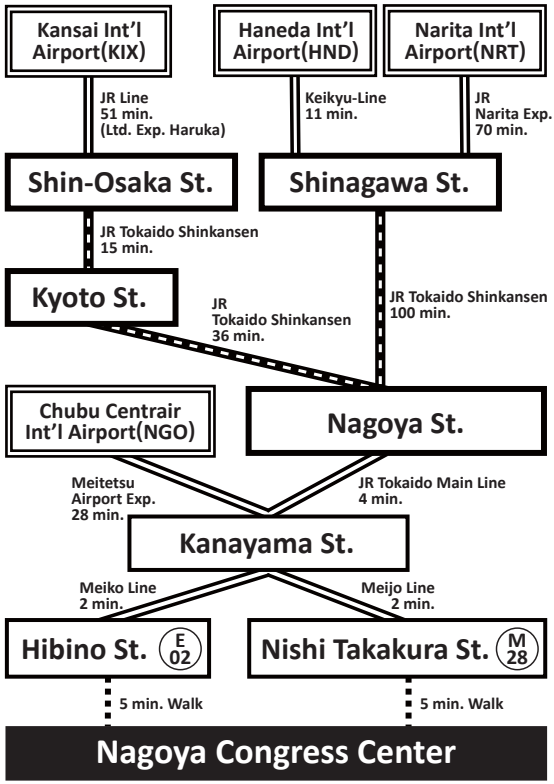
Please see the following websites for more information.

http://www.nagoya-info.jp/en/

http://www.nagoya-congress-center.jp/en/

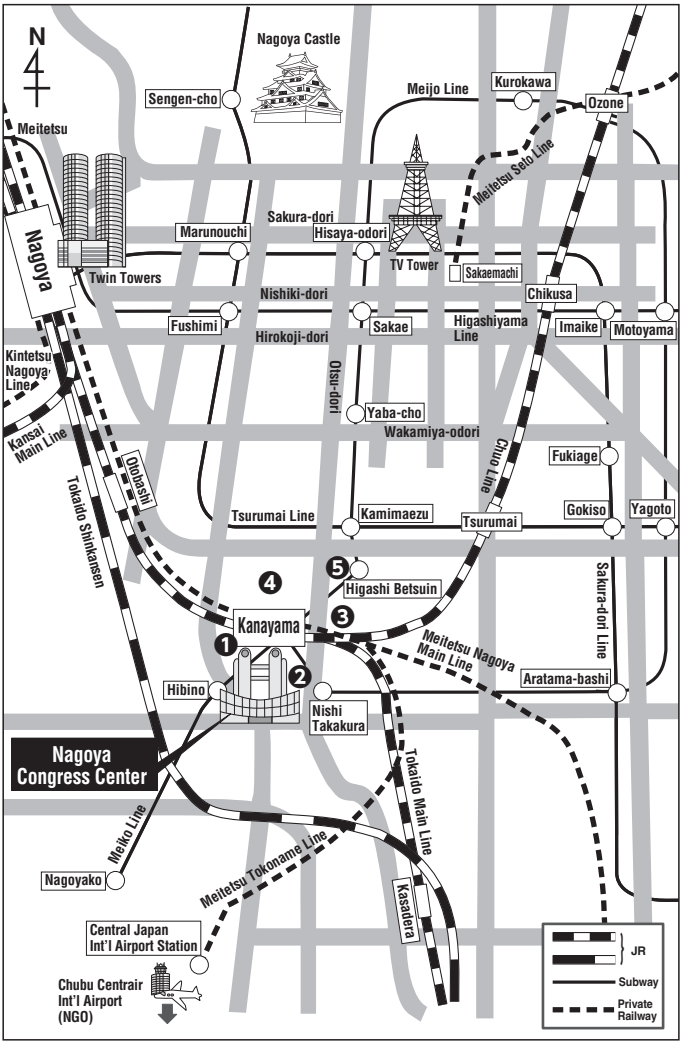
Access to Conference Site





Transportation information on this program may be changed. Please confirm the details with each airline and railway company. (as of November 8, 2018)

Hotel Map



❶	ANA Crowne Plaza Hotel Grand Court Nagoya	Phone: +81-52-683-4111
❷	Cypress Garden Hotel	Phone: +81-52-679-1661
❸	Nagoya Kanayama Hotel	Phone: +81-52-322-1111
❹	Meitetsu Inn Nagoya Kanayama	Phone: +81-52-324-3434
❺	Hotel Route-Inn Nagoya Higashi Betsuin	Phone: +81-52-339-1101

Plenary Sessions

Wednesday, December 12

9:30 - 9:50 **Shirotori Hall**

Opening

Master of Ceremony: Y. Hisatake, Executive Chair, IDW '18

Opening Remarks
9:30

A. Mikami, General Chair, IDW '18
H. Seetzen, President, SID
K. Kawazoe, President, ITE
H. Kumomi, Program Chair, IDW '18

9:50 - 9:55 **Shirotori Hall**

IDW 25th Ceremony for Certificate of Appreciation

Master of Ceremony: H. Okumura, Director, IDW Inc. Assn.

9:55 - 11:55 **Shirotori Hall**

Keynote Addresses

Chair: H. Kumomi, Program Chair, IDW '18
Co-Chair: A. Mikami, General Chair, IDW '18

Keynote Address - 1
9:55

Human Visual Processing in Driving

K. Okajima

Yokohama Nat. Univ., Japan

Vision science is a constantly advancing field, thus the amount of basic knowledge is rapidly increasing. In driving, the human visual processing and the environmental conditions to be considered are quite complicated. I introduce how to apply vision science for structing the engineering using human visual processing when driving.

Keynote Address - 2
10:35

OLED, Change Your Lifestyle

S. Y. Yoon

LG Display, Korea

Nowadays, we can communicate through display by connecting people to people, people to things, things to things. In the future, Display will be used widely for various applications and displays will be around us in everyday life. There are many kinds of displays in the market, LCD, OLED, projector, and so on. Specially, we think and believe OLED is the most optimal display for the future. So, OLED display status will be reviewed with market and evolutionary trend. Future OLED with various design freedom will be discussed such as flexible and rollable TV.

Keynote Address - 3
11:15

Touching with Feeling: Integrating Haptics with Touch Display

E. Colgate

Northwestern Univ., USA

“Surface Haptic” devices provide tactile feedback on touch screens and trackpads. An important class of surface haptic technologies is based on friction modulation, which allows a finger to feel textures, vibrations, edges, and clicks while sliding over a touchscreen. Here, I describe TanvasTouch, a friction modulation technology based on electroadhesion.

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters
Thursday, Dec. 13, 2018
11:40 – 15:50
Event Hall (1F, Building 1)
Nagoya Congress Center

Special Topics of Interest on Oxide-Semiconductor TFT

Thursday, December 13

10:40 - 13:10 **Event Hall**

***Poster* AMDp1: Oxide TFTs**

AMDp1 - 1 **Organic Passivation Layer in Back-Channel-Etch Amorphous InGaZnO Thin Film Transistor with Color Filter on Array Structure for Large Size High Resolution Display Application**

G. T. Li[,**], W. Wu[**], F. Zhu[**], J. J. Liu[**], Y. H. Meng[**], S. Li[**], H. Zhou[*]*

[*]Peking Univ., China
[**]Shenzhen China Star Optoelect. Tech., China

We improved the NBTS stability of BCE a-IGZO TFT with COA structure by using organic PV2 layer, which is attributed to less residual H_2O molecule in the device resulting from high vapor penetration of organic PV2. We also optimized PV1 deposition condition to achieve good PBTS stability and uniformity.

AMDp1 - 2 **Detecting Thickness of Accumulation Layer in a-IGZO Thin Film Transistors by Kelvin Probe Force Microscopy**

X. Shi[,**], C. Lu[*], D. Geng[*], N. Lu[*], J. Wang[*], L. Li[*], M. Liu[*]*

[*]Chinese Ac. of Sci., China
[**]Univ. of Chinese Ac. of Sci., China

The thickness of accumulated charges in a-IGZO thin film transistors was firstly directly measured by Kelvin Probe Force Microscopy. From morphology and surface potential information, it is demonstrated that: I) in subthreshold region, the accumulation layer almost keeps constant regardless of change of gate voltages, II) when the gate voltage exceed threshold, the thickness of accumulation layer firstly increases precipitously and finally reaches a situation value almost 20 nm.

AMDp1 - 3 **Highly Stable Self-Aligned Coplanar Bulk Accumulation a-IGZO TFTs Under High Temperature Bias Stress**

H. Kim, S. Lee, J. Lee, J. Jang

Kyung Hee Univ., Korea

In our study, we fabricate top-gate self-align (SA) bulk-accumulation (BA) coplanar amorphous indium-gallium-zinc oxide (a-IGZO) thin film transistors (TFTs), and evaluate the high temperature and bias stabilities. The performance of BA TFTs with SA structure shows excellent stability under the gate bias at 120°C.

AMDp1 - 4 In-O-N Thin-film Transistors with Superior Stability

H.-D. Kim, H.-S. Kim

Chungnam Nat. Univ., Korea

In this work, a relatively new type of semiconductor, indium oxynitride (InON) is studied by experimental evaluation of thin films and TFT devices. It is demonstrated that InON films has superior air stability compared to ZnON films.

AMDp1 - 5 Comparator for Integrated Readout Circuits with a-IGZO TFTs

Y. Gong[,**], D. Geng[*], Y. Su[*], X. Shi[*], C. Lu[*], N. Lu[*], L. Li[*], M. Liu[*]*

[*]Chinese Ac. of Sci., China
[**]Shandong Univ., China

We propose an integrated comparator design based on a-IGZO TFTs. The comparator contains two amplification stages that can compare 500 mV difference between the reference and the input signal. Simulation shows that the circuit can work under a clock frequency of 100 kHz and power consumption is around 1.036 mW.

AMDp1 - 6 A Study on Degradation Mechanism of Flexible a-InGaZnO Thin Film Transistor Under Repetitive Bending Stress Using Simulation

K.-L. Han, H.-J. Jeong, B.-S. Kim, S. Oh, J.-S. Park

Hanyang Univ., Korea

We examined the degradation mechanism of the oxide TFT under repetitive bending stress. As the bending cycle accumulated, the transfer characteristics of the TFTs are degraded. We tried to interpret the cause of degradation by mapping the stress distribution under bending situation using simulation program.

AMDp1 - 7 a-IGZO TFT Gate Driver Circuit for Suppressing Ripple Voltage without Pull-Down Unit

C.Y. Park, Y.-S. Kim

Sungkyunkwan Univ., Korea

This paper proposes the gate driver circuit which is able to overcome the degradation of TFTs using additional circuit configuration instead of the pull-down unit. In addition, proposed circuit only uses two clock bus lines to realize bezel-less display and it can be applied to FHD graphics display panel.

AMDp1 - 8 **High Performance In-Ga-Zn-O Thin-Film Transistors via Microwave and Electron-Beam Radiation at Room Temperature**

S.-C. Jang, H.-D. Kim, H.-S. Kim

Chungnam Nat. Univ., Korea

In this work, to fabricate low temperature processed high performance amorphous InGaZnO thin film transistors (a-IGZO TFTs), microwave and electron beam annealing process were investigated. It is shown that both annealing process are suitable to replace high temperature (>300°C) annealing.

AMDp1 - 9 **Low-Temperature Processed IGTO Thin-Film Transistors with High Mobility by Reducing Deposition Pressure**

H.-A. Kim, J. O. Kim, J. S. Hur, J. K. Jeong

Hanyang Univ., Korea

We focused on the chamber-pressure (P_C) dependence on the structural and chemical properties of IGTO thin film: as the P_C decreased, the surface morphology and film density were improved, which translated to the remarkable enhancement in terms of the μ_{FE} and SS of IGTO TFTs at the low annealing temperature.

AMDp1 - 10 **IGZO TFT Gate Driver Circuit Capable of Compensating Threshold Voltage Shift for Pull-Down Unit**

J. Oh, J.-H. Kim, K.-H. Lee[*], E. S. Ha[*], K. C. Park[**], J.-H. Jeon[***], Y.-S. Kim

Sungkyunkwan Univ., Korea
[*]Gyeonggi Sci. High School, Korea
[**]Konkuk Univ., Korea
[***]Korea Aerospace Univ., Korea

This paper proposes the gate driver circuit which is able to compensate V_{TH} shift for pull-down unit. Using 4T1C circuit configuration, we can improve the reliability of pull-down unit for continuous bias stress. In addition, a simplified circuit is obtained since Q and V_{OUT} node share the same circuit configuration.

AMDp1 - 11 **Double-Layered Indium-Zinc-Oxide Thin Film Transistors with an Addition of Hydrogen Peroxide**

W. Jeon, B. Choi

Sungkyunkwan Univ., Korea

Hydrogen peroxide (H_2O_2) incorporated double-stacked indium-zinc-oxide thin-film-transistors (IZO TFTs) were fabricated and evaluated. Devices showed the enhanced electrical properties of on-off ratio, threshold voltage shift, and subthreshold swing with an incorporation of the H_2O_2 into the channel layer. Finally, superior electrical properties were achieved with the H_2O_2 incorporated double-stacked TFTs.

AMDp1 - 12 **Withdrawn**

AMDp1 - 13L a-IGZO TFT Fabrication Using Advanced Imprint Lithography

H. Chae, S. Kim, J. Cho, S. Cho*

Sungkyunkwan Univ., Korea
**Samsung Inst. of Tech., Korea*

The imprint lithography has advantage of decreased process step. This study aims to fabricate a-IGZO TFT of bottom gate-type using the advanced imprint lithography. Before the imprinting, layers were deposited on the substrate. The surface was coated with resin to make pattern. Multi-layers were dry etched using the process gas.

AMDp1 - 14L Solution-processed Metal Oxide Semiconductors Fabricated with Oxygen Radical Assisting Perchlorate Precursors through a New Reaction Route

P. Gao, L. Lan

South China Univ. of Tech., China

An innovative and simple chemical route for fabricating MO semiconducting films at relatively low temperature is demonstrated. The precursor, which consisted of perchlorate and nitrate, is easily converted into In_2O_3 at an annealing temperature of 250°C due to oxygen radical assisting decomposition and large amount of heat generation.

AMDp1 - 15L Dynamic Bipolar Pulsed DC Sputtered IGZO for Mura-Free AMOLED Backplanes

Y.-C. P. Tsai, H.-W. Chang, J. Grillmayer, A. S. Bhoolokam, J. B. Kim**, D. K. Yim**, M. Bender**

Applied Materials Taiwan, Taiwan
**Applied Materials, Germany*
***Applied Materials, USA*

Applied Materials' dynamic PVD system (New Aristo) has been developed to provide high throughput, excellent target utilization and uniform thin film performance by combining a novel rotary target technology with a continuous coating architecture. It has been optimized for stable and uniform, mura-free IGZO for large-area AMOLED backplanes.

AMDp1 - 16L Development of Rare Metal Free Al/Ga-Sn-O/Al Cell Structure Switching Resistance Memory

S. Sugisaki, A. Kurasaki, R. Tanaka, T. Matsuda, M. Kimura

Ryukoku Univ., Japan

We are developing an amorphous Ga-Sn-O (GTO) thin film for a switching resistance memory (SRM). The a-GTO SRM device was fabricated by physical vapor deposition at low temperature (150°C). The a-GTO SRM showed a bipolar switching characteristic of ON/OFF ratio (~10) with endurance (~100).

AMDp1 - 17L Withdrawn

14:20 - 16:50

Poster FMCp7: Manufacturing and Materials of Oxide TFTs

FMCp7 - 1L **Deposition of Insulator Film by Inductively Coupled Plasma CVD System with Low Impedance Antennas**

T. Sakai, M. Fujiwara, D. Azuma, S. Nakata, Y. Setoguchi, Y. Andoh

Nissin Elec., Japan

Thin-film transistor (TFT) for flat panel display (FPD) is expected to be applied to the next-generation large and high-definition. For this reason, we developed the inductively coupled plasma (ICP) CVD system with low impedance antennas applicable to the Gen. 6 and larger substrates.

FMCp7 - 2L **Deposition of Crystalline InGaZnO Film at Low Temperature Process by Inductively Coupled Plasma Sputtering System**

D. Matsuo, R. Miyanaga[*]*, T. Ikeda, S. Kisida, Y. Setoguchi, Y. Andoh, M. Fujii*[*]*, Y. Uraoka*[*]

Nissin Elec., Japan
[*]*NAIST, Japan*

We report the correlation between the crystallinity of the IGZO film and the ICP-sputtering conditions. When an IGZO film is formed by ICP-sputtering, crystallization of the IGZO film was confirmed regardless of the presence of heating. Crystallinity was increased remarkably as the oxygen ratio in the sputtering gas increased.

FMCp7 - 3L **ZnO:Ga Thin Film with Hydrogen and Nitrogen Post Annealing and Applications in Transparent RRAM**

L. W. Wang, C.-C Lin, S.-Y. Chu

Nat. Cheng Kung Univ., Taiwan

In this article is talking about Ga:ZnO (GZO) which is kind of transparent conductive oxide with non-toxic and stability. In order to reduce the resistance and improve the device performance, uses the nitrogen and hydrogen mixture furnace annealing as post treatment. Discuss about the GZO electrode with hydrogen post treatment.

Friday, December 14

10:40 - 11:50 **Reception Hall 1**

AMD6: Oxide TFT: Device

Chair: J. Kim, Tokyo Tech, Japan
Co-Chair: K. Takatori, Huawei Techs. Japan, Japan

AMD6 - 1 ***Invited*** **Spreading Currents in Oxide TFTs**
10:40

S. Lee, T.-W. Kim, J. Jang*
Kyung Hee Univ., Korea
**Samsung Display, Korea*

We report the spreading currents in a-IGZO and its application to TFT and TFT circuit designs. It is confirmed that the drain currents are same with and without stripe patterns. This can reduce the overlap capacitance between gate and source/drain electrodes without degrading the drain currents.

AMD6 - 2 ***Invited*** **Top-Gate Oxide TFT Technologies**
11:05 **for Advanced LCDs**

I. Suzumura, Y. Yamaguchi, H. Kawanago
Japan Display, Japan

We have developed an oxide thin-film-transistor (TFT) technology for advanced liquid crystal displays (LCDs). To realize plastic-film LCDs, top-gate oxide TFTs with channel lengths L = 2 and 3 μm were fabricated at approximately <300°C using Generation 4.5 mother glass. Sufficient TFT performance and reliability were simultaneously obtained.

AMD6 - 3 **Oxide Semiconductor Based Vertical TFT**
11:30 **for Ultra High-resolution Backplane Technology**

K.-H. Lee, S. Lee, H.-I. Yeom, J.-B. Ko, C.-S. Hwang, S.-H. K. Park*
KAIST, Korea
**ETRI, Korea*

Recently, ultra high-resolution and super-brightness for HDR are critical issues for display. To realize them, 'Vertical TFT' can be an appropriate candidate. Because of its vertical channel structure & short channel length, smaller footprint and powerful current-driving capability are available. Now, we are conducting study on fabricating array structure.

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:35 **Reception Hall 1**

AMD7: Oxide TFT: Stability and Fundamental (1)

Chair: I. Suzumura, Japan Display, Japan
Co-Chair: H. Kumomi, Tokyo Tech, Japan

AMD7 - 1
13:10 ***Invited*** **Electronic Structure and Defects in Amorphous Oxide Semiconductor: A Comprehensive Review**

T. Kamiya, H. Kumomi, H. Hosono

Tokyo Tech, Japan

This paper will summarize the knowledge about carrier transport mechanisms, electronic structures, defect structures of amorphous oxide semiconductor (AOS) including controversial models and proposals.

AMD7 - 2
13:35 **Enhancing Reliability of Amorphous In-Ga-Zn-O Thin Film Transistors by Nitrogen Doping**

T. Sung, K. Park, J. H. Kim[*], H.-W. Park[**], P. Yun[***], J. Noh[***], S. W. Lee[***], K.-S. Park[***], S. Y. Yoon[***], I. B. Kang[***], K.-B. Chung[**], H.-S. Kim[*], J.-Y. Kwon

Yonsei Univ., Korea
[*]Chungnam Nat. Univ., Korea
[**]Dongguk Univ., Korea
[***]LG Display, Korea

Device stability and electrical properties of the a-IGZO Thin-film Transistors (TFTs) were analyzed in relation to the amount of nitrogen incorporated in the a-IGZO channel. The stability of the a-IGZO TFTs was enhanced owing to the incorporated nitrogen, and the corresponding mechanism was studied by simulation and experiment.

AMD7 - 3
13:55 **Simulation Study of Self-Heating Effects on Amorphous Oxide Semiconductor TFTs: Channel-Length Dependence**

K. Abe, M. Fujinaga, T. Kuwagaki

Silvaco Japan, Japan

A new device model to study self-heating effects of amorphous oxide semiconductor TFTs for a device simulator is proposed. Simulation results with the model including the self-heating effects can reproduce ON-properties of the TFTs with channel-length between 4 and 40 μm. The self-heating under the ON-operation.

AMD7 - 4
14:15

A 31-in. 4K2K AMOLED Display Using High Mobility and Reliability Top-Gate Self-Aligned IGZO TFTs with Cu Electrode

Z.-S. Liu, **, Y.-J. Hsu*, **, S.-N. Zhao*, **, J.-S. Im*, **, Y.-C. Wu*, **, P.-Y. Lu*, ***

**Nat. Eng. Lab. For AMOLED Process Tech., China*
***Shenzhen China Star Optoelect. Semiconductor Display Tech., China*

A top-gate self-aligned oxide TFT with Cu electrode for AMOLED display was developed. The oxidation of Cu electrode in SiOX deposition process was studied and solved. The performance and reliability of TFTs with different structure were studied. Finally, high-mobility and high-reliability top-gate self-aligned IGZO TFTs with Cu electrode was obtained.

----- Break -----

14:50 - 16:10 **Reception Hall 1**

AMD8: Oxide TFT: Stability and Fundamental (2)

Chair: T. Kamiya, Tokyo Tech, Japan
Co-Chair: S. Horita, JAIST, Japan

AMD8 - 1
14:50

Invited Highly Stable High Mobility Oxide TFT for High Resolution AMOLED

J. B. Ko, S.-H. Lee, K.W. Park , J.-R. Lee, W.-W. Park*, S.-H. K. Park*

KAIST, Korea
**AVACO, Korea*

We report the methodologies of the way to the highly stable high mobility top gate Al:ITZO TFT. We introduced ECR high density plasma sputtering method and proper plasma treatment, followed by the proper H supply to the active layer for negligible charge trapping characteristics to yield high stability.

AMD8 - 2
15:15

Improvement of the Stability Under High Voltage and High Temperature Stress by Using Nitrogen Doped IGZO TFTs

I.-T. Cho, J. Noh, P. Yun, J. Jang, D. Lee, J.-H. Baeck, S.-W. Lee, K.-S. Park, S. Y. Yoon, J.-Y. Kwon, I. Kang*

LG Display, Korea
**Yonsei Univ., Korea*

The stability under high temperature and voltage stress is the most important property for the commercial display and automobile display. We report the improvement results about the abnormal behavior of V_{th}(-) shift under high temperature PBTS and hump degradation of subthreshold slope under high voltage stress by using IGZO:N TFTs.

AMD8 - 3
15:35

Development of Tunneling Contact a-IGZO TFT with Graphene Interlayer

L. Wang, L. Zhang, X. Zhang*, Z. Zhu, H. Zhu*
Visionox Tech., China
**Shenzhen Univ., China*

Tunneling contact (TC) a-IGZO TFT is demonstrated. The TC TFT shows much lower saturation voltage as compared with conventional a-IGZO TFT, owing to the graphene interlayer between active and source/drain metal. Performance enhancement of the TC a-IGZO TFT is discussed and performed.

AMD8 - 4L
15:55

High Stress Stability Imparted by Sn Addition Effect in High Mobility Amorphous IGZTO TFTs

M. Ochi, K. Nishiyama, Y. Teramae, H. Goto, T. Kugimiya
Kobe Steel, Japan

The electrical characteristics of TFTs based on a-IGZO with Sn dopant (a-IGZTO) realized not only enhancement of saturation mobility (μ_{sat}) but also drastic improvement in stability under negative bias thermal illumination stress (NBTIS). The electronic states on back-channel side of the a-IGZTO were clearly correlated to improve the stress stability.

Author Interviews
16:20 – 16:50

Special Topics of Interest on Quantum Dot Technologies

Thursday, December 13

10:40 - 13:10 **Event Hall**

Poster **PHp1: QD Phosphors and Devices**

PHp1 - 1 **Withdrawn**

PHp1 - 2 **Thermal Stability of $CsPbBr_3$ Quantum Dots and Their Application to Light-Emitting Diodes**

H. Sasaki, N. Kamata, Z. Honda

Saitama Univ., Japan

We investigated the thermal stability of $CsPbBr_3$ QDs with different ligands, and fabricated inverted-type $CsPbBr_3$ QD light-emitting diodes. $CsPbBr_3$ QDs with DDAB ligands showed higher thermal stability compared with those with OLA and OA ligands, and furthermore we improved luminance up to 1057 cd/m^2 from 79 cd/m^2.

PHp1 - 3 **Withdrawn**

PHp1 - 4 **Withdrawn**

10:40 - 13:10 **Event Hall**

Poster **OLEDp2: OLED/QDT Poster**

OLEDp2 - 1 **Efficiency Improvement of Quantum Dot Light Emitting Diode by Using DMSO Treated PEDOT: PSS**

T. J. Bae, S. H. Song, S. J. Park, S. S. Kim, J. K. Song

Sungkyunkwan Univ., Korea

We suggest dimethyl sulfoxide (DMSO) doped poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) as hole injection layer for quantum dot light emitting diode(QLED). Due to an elimination of PSS-PEDOT bonding in PEDOT:PSS, the performance of device increased. The result showed improvement in luminance, power efficiency, external quantum efficiency and current efficiency up to 31.87%.

OLEDp2 - 2 Organic Electron Transport Layer for High Performance Green Inverted Quantum Dot Light Emitting Diodes

C. Y. Lee, H. W. Bae, K. J. Eun, N. N. Mude, J. H. Kwon

Kyung Hee Univ., Korea

We report a new organic electron transport layer(ETL) for high performance of green inverted quantum dot light emitting diodes(QLED). We anticipate that this organic ETL not only delay electron flow to match charge balance but also reduce exciton quenching between inorganic zinc oxide(ZnO) layer and quantum dot(QD) layer.

OLEDp2 - 3L A Charge Injection Model for QLEDs Based on Dynamic Equilibrium Conditions

S.-K. Kim, Y.-S. Kim

Hongik Univ., Korea

Charge injection phenomenon into layers of QLED was analyzed under a dynamic equilibrium condition. Assuming traps are distributed exponentially in forbidden energy band, effects of major parameters on the injection behavior were investigated to elucidate their effects on the current-voltage relationship in QLEDs.

OLEDp2 - 4L Metal Oxide Nanoparticles in an Electron Transport Layer for Efficient Charge Balance in Inverted Quantum Dot Light-Emitting Diodes

H. Kim, W. Lee, H. K. Chung, H. Chae

Sungkyunkwan Univ., Korea

In this work, a facile method is proposed to improve the charge balance of quantum dot light-emitting diodes (QLEDs) by controlling concentration ratio of two metal oxide nanoparticles (MON, ZnO) with different electron mobility. Charge balance in QLED improved with 0.063 wt% MON mixed with ZnO by lowering electron injection.

OLEDp2 - 5L High Brightness and Low Roll-Off Quantum-Dot Light Emitting Diodes Using Doped Metal Oxide Electron Transport Layer

Y. Lee, H.-M. Kim, J. Kim, J. Jang

Kyung Hee Univ., Korea

We report a doped metal oxide electron transport layer (ETL) for inverted green QLEDs (G-QLEDs). The G-QLED with doped metal oxide ETL exhibited low efficiency roll-off characteristic compared to that with pristine ETL. The efficiency roll-off of the G-QLED was improved from 57% to 3% at 10,000 cd/m^2.

10:40 - 13:10 **Event Hall**

Poster **MEETp1: Quantum Dots and Nanotechnologies**

MEETp1 - 1 **Enhancement of Optical Emission from Quantum Dots by Photonic Crystal Cavities Fabricated on SOI Substrates**

T. Matsutomi, T. Hayashi, Y. Takamatsu, K. Tanaka, K. Yasui

Nagaoka Univ. of Tech., Japan

To enhance optical emission from quantum dots, photonic crystal cavities were fabricated in a silicon-on-insulator (SOI) substrate using electron beam lithography and dry etching. Quantum dots trapped in these cavities, having various air hole diameters, exhibited increased emission.

MEETp1 - 2 **High Efficiency Green Cd-Free Quantum Dot Light-Emitting Diodes with Cross-Linked Hole Transport Layer**

K. J. Eun, M. N. Naik, C. Y. Lee, J. H. Kwon

Kyung Hee Univ., Korea

We report highly efficient green Cd-free quantum dot light-emitting diodes (QLEDs) with cross linked hole transport layer (HTL). Our HTL has deep HOMO level with prevention of interlayer intermixing between QD and HTL layer. Fabricated Cd-free QLEDs device with our cross-linked HTL shows maximum external quantum efficiency (EQE) of 4.75%.

14:20 - 16:50

Poster **FMCp6: Quantum Dot Technologies in FPD Components**

FMCp6 - 1L **Stability Improvement of Quantum Dot Color Conversion Films by Direct Bonding Between Designed Ligands and Polymer Matrix**

E. Nam, C. Lee, H. K. Chung, H. Chae

Sungkyunkwan Univ., Korea

New preparing method of the reactive ligand substituted quantum dot (QD) was presented. The designed QD formed direct bond with siloxanes matrix via hydrosilylation. The prepared QD-matrix was studied stability for application on-chip packaging as a color converter on blue light-emitting diodes (LEDs).

Friday, December 14

9:00 - 10:20 **Room 432**

OLED5: OLED Device Technology

Chair: T. Wakimoto, Merck PM, Japan
Co-Chair: T. Shimizu, NHK, Japan

OLED5 - 1 ***Invited*** **Monochromatic LEDs Based on Perovskite Quantum Dots: Opportunities and Challenges**
9:00

C.-J. Shih, S. Kumar, J. Jagielski
ETH Zurich, Switzerland

Perovskite quantum dots (QDs) are emerging as one of the most promising candidates for the monochromatic light-emitting diodes (LEDs) approaching the Rec. 2020 color gamut due to their extremely narrow emission bandwidth. Here we briefly summarize the opportunities and challenges in both fundamental and technological aspects, based on our recent work in this field.

OLED5 - 2 **Negative Capacitance as a Diagnostic Tool for Recombination in Purple Quantum Dot LEDs**
9:20

C. Blauth[,**], T. Hirai[**], P. Mulvaney[*]*
[*]Univ. of Melbourne, Australia
[**]CSIRO Manufacturing, Australia

Impedance spectroscopy (IS) and the study of the capacitance are strong and non-destructive approaches to determining the recombination properties in quantum dot light emitting diodes (QLEDs). We report here for the first time unique capacitance behaviour in wide band gap QLEDs due to the ligands present around the nanocrystals.

OLED5 - 3 **Withdrawn**

OLED5 - 5L **Controllable Variations for High Performance Perovskite Light Emitting Diodes Device Fabrication in Solution Process**
9:40

D.Y. Kim, D. H. Kwak, M. C. Suh
Kyung Hee Univ., Korea

We report 3 important factors for efficient Perovskite LED. We have inserted interlayer between hole transport layer and emitting layer to obtain an appropriate perovskite morphology. We also varied the perovskite precursor concentration and the solvent for additive-nanocrystal pinning(A-NCP). Consequently, we could obtain moderately high performance from our PeLED.

OLED5 - 4
10:00 **High-Performance, Solution-Processed Quantum Dots Hybrid Light-Emitting Field-Effect Transistors**

P. He, L. Lan, J. Peng

South China Univ. of Tech., China

The high-performance quantum-dots hybrid light-emitting field-effect transistors (QDs-HLEFETs) were demonstrated, which combined high luminous-efficiency quantum dots (QDs) and solution-processed scandium-incorporated indium oxide (Sc:In_2O_3) semiconductor as light-emitting layer and electron transport layer, respectively.

----- Break -----

10:40 - 12:10 **Room 432**

PH2/OLED6: QD Phosphors and Devices

Chair: R.-J. Xie, Xiamen Univ., China
Co-Chair: Y. Sakai, Mitsubishi Chem., Japan

PH2/
OLED6 - 1
10:40 ***Invited*** **Narrow Band-Edge Emission from $AgInS_2$ Semiconductor Quantum Dots by the Formation of Amorphous III-VI Semiconductor Shells**

T. Uematsu

Osaka Univ., Japan

A spectrally narrow band-edge photoluminescence was achieved for the first time by coating silver indium sulfide ($AgInS_2$) colloidal semiconductor quantum dots with indium sulfide (InS_x) or gallium sulfide (GaS_x) shells. Photoluminescence quantum yield as high as 56% was achieved by the surface modification of shells with phosphine compounds.

PH2/
OLED6 - 2
11:00 **Novel Ligand Materials to Enhance Luminous Efficiency and Stability of Perovskite Quantum Dot**

S.-Y. Cheng, C.-T. Chiu, J.-T. Lian, B.-K. Hsu[*]*, T.-Y. Lin*[*]

Chunghwa Picture Tubes, Taiwan
[*]*Nat. Taiwan Ocean Univ., Taiwan*

Perovskite quantum dots (PeQDs) have attracted much attention in recent years. However, because of the poor stability against temperatures, polar solvents, and UV light, the application of PeQDs is limited. We have succeeded in synthesizing a wavelength tunable(420~670 nm) PeQDs with high-stable, high photoluminescence quantum yields and narrow FWHM.

PH2/ OLED6 - 3 11:20

Improved Stability of $CsPbBr_3$ Perovskite Quantum Dots by Suppressing the Interligand Proton Transfer and Applying the Polystyrene Coating

Y. Cai, Y. Li, R.-J. Xie

Xiamen Univ., China

We first adopted hexadecyl trimethyl ammonium bromide to synthesize $CsPbBr_3$ QDs. The interligand proton transfer was thus suppressed and the obtained $CsPbBr_3$ QDs showed enhanced stability against acetone. Then, a polymer of carboxyl-functional polystyrene (cPS) was used to coat $CsPbBr_3$ QDs and the composite shows improved thermal and moisture stability.

PH2/ OLED6 - 4

Withdrawn

PH2/ OLED6 - 5L 11:40

Perovskite Quantum Dots with Enhanced Thermal Stability for Display Application

L. Sinatra, M. Lutfullin, M. Mahmud, J. Pan[*]*, O. Bakr*[*]

Quantum Solutions , Saudi Arabia
[*]*King Abdullah Univ. of S&T, Saudi Arabia*

We report here Zero-Dimensional perovskite (Cs_4PbBr_6) that has similar optical properties as Perovskite $CsPbBr_3$ QDs with FHWM <20 nm and PLQY >80-90%. However, the former material has incredibly higher thermal baking stability (180°C for 3 hours in air) and also higher photodegradation resistivity (300 hours at 85°C).

PH2/ OLED6 - 6L 11:55

Enhancement of Optical Intensity and Color Gamut in White OLED Display Using Photoresist Dispersed Quantum Dot/TiO_2 Mixed Film

H.-J. Kim, H.-B. Yang, W. R. Kim[*]*, Y. H. Kim*[*]*, M. S. Kwak*[*]*, Y.-J. Kim*

Yonsei Univ., Korea
[*]*LG Display, Korea*

We applied patterned QD/TiO_2 mixed film to white OLED display to enhance both optical intensity and color gamut. In experimental data, optical intensity of red and green light was increased by 49.3% and 14.5%, respectively with the enhanced color gamut after adding photoresist film dispersed with QD/TiO_2 mixture.

Author Interviews
12:10 – 12:30

----- Lunch -----

13:10 - 14:30 **International Conference Room**

MEET4: EL Quantum Dots Technologies

Chair: F. Yan, Fuzhou Univ., China
Co-Chair: Z. Liu, Southern Univ. of S&T, China

MEET4 - 1 ***Invited*** **Solution Processed Charge Generation Junctions for Highly Efficient Quantum-Dot Light Emitting Diodes**
13:10

J. Jang, H.-M. Kim, J. Kim
Kyung Hee Univ., Korea

This paper reviews the solution processed charge generation junctions (CGJs) for highly efficient quantum-dot light-emitting diodes (QLEDs). Various CGJs with organic/organic semiconductors were proposed for tandem OLEDs, while metal-oxide/metal-oxide junctions were proposed for QLEDs. We developed a new p-type oxide, Cu_2SnS_3, and n-type oxide, Li doped ZnO, for OLED and QLEDs.

MEET4 - 2 ***Invited*** **Efficient Inverted Quantum Dot Light-Emitting Diodes Fabricated by Inkjet Printing Technique**
13:30

D. Ko, H. Roh, J. Kwak, C. Lee*
Seoul Nat. Univ., Korea
**Univ. of Seoul, Korea*

Inkjet printing is most promising method for full-color patterning of quantum dot-based light-emitting diodes displays because the QD ink can be deposited on demand in required subpixel area with little materials loss. We report efficient inkjet-printed QLEDs fabricated by controlling the QD ink formulation and inkjet printing conditions.

MEET4 - 3 ***Invited*** **The Color Revolution: Towards Ultra-Wide Color Gamut**
13:50

C. Zhang, Y. Yang, M. Marus, B. Xu, K. Wang, X. W. Sun
Southern Univ. of S&T, China

We will present a much narrower candidate for color revolution, namely quantum nanoplatelets (NPLs) having an emission linewidth of 9 nm, which significantly smaller than QD (~30 nm) and perovskite QDs (~20 nm). Color gamut, which significantly larger than Rec. 2020 by using green emission 4-layer NPLs, could be achieved.

MEET4 - 4 ***Invited*** **Highly Saturated Color Quantum-Dot LEDs**
14:10

P. Kathirgamanathan
Brunel Univ. London, UK

Room temperature intense pulsed light annealing transforms the sol-gel derived ZnO films highly conductive and hydrophobic with improved interface with colloidal quantum dots. Thermally aged devices comprising IPL/ZnO gave a maximum current efficiency of 23 cd/A and a power efficiency of 30 lm/W.

----- Break -----

14:50 - 15:50 **International Conference Room**

MEET5: Emerging Quantum Dots and Nanotechnologies

Chair: I. Kymissis , Columbia Univ., USA
Co-Chair: X. W. Sun, Southern Univ. of S&T, China

MEET5 - 1 ***Invited*** **Cadmium-Free Quantum Dot Inkjet Inks for**
14:50 **Color Conversion Devices**

A. Ishizuka, E. Otsuki, T. Kizaki, T. Miki, S. Yoshihara, I. Kiyoto, E. Lee, R. Tangirala*, C. Hotz*, H. Kim**

DIC, Japan
**Nanosys, USA*

Quantum dot color conversion layers have the potential to revolutionize displays by improving efficiency and color gamut. To achieve these changes, QDs have to be deposited at sub-pixel pitch. Here we report on the fabrication and characterization of QD inks, as well as films made from inkjet deposition of these materials.

MEET5 - 2 ***Invited*** **Tailoring Quantum Dot Structure for**
15:10 **Enhanced Device Lifetime of Quantum-Dot Light-Emitting Diodes (QLEDs)**

Y. Yang, W. Cao, C. Xiang, L. Wu, L. Qian, X. Yan

TCL Corporate Res., China

The stability issue of QLEDs remains challenging and the mismatch of energy levels within QLED is believed to be one of the primary reasons for efficiency decay. We tailored the structure of QDs, instead of transport layers in conventional strategy, and achieved enhanced device lifetime of QLEDs.

MEET5 - 3 ***Invited*** **Synthesis and Optical Properties of Colloidal**
15:30 **InN Quantum Dots**

J. Nagakubo, M. Hirakawa, T. Nishihashi, H. Murakami

ULVAC, Japan

To prove the effectiveness of rapid synthesis for Indium-Nitride (InN) quantum dots, we investigated their crystal structure, energy level diagrams and compared with that of InN bulk. The values could be explained from previous studies, which was similar to the calculated value from the effective mass approximation.

Author Interviews
16:20 – 16:50

Special Topics of Interest on AR/VR and Hyper Reality

Wednesday, December 12

15:00 - 16:20 **Room 222**

3D1: Display Systems for AR

Chair: S. Yano, Shimane Univ., Japan
Co-Chair: D. Mikami, NTT, Japan

3D1 - 1
15:00 ***Invited*** **The Optimization of a Light-Field Holographic Projection System**

*C.-Y. Chen, C.-H. Chuang**

Nat. Taiwan Univ. of S&T, Taiwan
**Nat. Taiwan Univ., Taiwan*

A prototype system of head-mounted holographic display is presented with multi-depth. The system adopts modified Gerchberg-Saxton algorithm to produce the phase-only function. Furthermore, the proposed system could achieve multi-depth by using human eyes focus and zoom mechanism. Finally, the quality of images in this study are also analyzed and evaluated.

3D1 - 2
15:20 **Large-Size and See-Through Color Light Field Display Using Projector and DDHOE**

B. J. Jackin, L. Jorissen, R. Oi, K. Wakunami, Y. Ichihashi, M. Okui, K. Yamamoto*

NICT, Japan
**Hasselt Univ., Belgium*

A Light field display system that uses projector and holographically fabricated micro-lens array is presented. The ability of the display system to reconstruct 3D scenes in full color and large size, is being reported for the first time. The system being simple without any bulky optics is the added advantage.

3D1 - 3
15:40 **Geometric Phase Doublet Lens for Augmented Reality**

C.-K. Lee, W. Seo, G. Sung, S. Kim, B. Shin, Y.-T. Kim, J. Seo, J.-S. Chung, J. An, H. Song, Y. Kim, H. Kim, C.-S. Choi, Y. Kim, K. Won, S.-H. Lee, M. Jeon, H.-S. Lee, D. Lee

Samsung Elect., Korea

Novel optical combiner for augmented/mixed (AR/MR) reality is proposed by implementing doublet of geometric phase lenses. Depending on the polarization state of light, the real world scene directly transmits the lens and the virtual images are generated by the function of positive power of the lens.

3D1 - 4
16:00

A Simulation Platform to Convert Viewing Geometry of a Transparent Display for AR Applications

Y.-M. Chen, P.-L. Sun, C.-J. Li[*], H.-Y. Chen[*]

Nat. Taiwan Univ. of S&T, Taiwan
[*]ITRI, Taiwan

A simulation platform for designing an optic see-through AR system with various viewing parameters of transparent display is proposed. It consider whole environment parameters. Platform can simulate AR system with different parameters and it also can optimize the design of the AR system with different transparent displays and camera settings.

Author Interviews
18:10 – 18:40

15:05 - 16:25 **Room 131**

PRJ1/FMC2: Waveguide for AR-Near Eye Display

Chair: D. Cuypers, CMST, Belgium
Co-Chair: K. Käläntär, Global Optical Solutions, Japan

PRJ1/FMC2 - 1
15:05

Invited **A Plastic Holographic Waveguide Combiner for Light-Weight and Highly-Transparent Augmented Reality Glasses**

T. Yoshida, K. Tokuyama, Y. Takai, D. Tsukuda, T. Kaneko, N. Suzuki, T. Anzai[*], A. Yoshikaie, K. Akutsu, A. Machida

Sony, Japan
[*]Sony Global Manufacturing & Operations, Japan

We have developed a unique production process of a full-color plastic holographic waveguide combiner with a light-weight and see-through capability. The novel plastic waveguide technology enables us to increase design flexibility in the eyewear and to expand the market for augmented reality (AR). This paper presents the approach to production.

PRJ1/FMC2 - 2
15:25

Waveguide-HOE-Based Camera That Captures a Frontal Image for Flat-Panel Display

H. Konno[*], S. Igarashi[*], T. Nakamura[,**], M. Yamaguchi[*]*

[*]Tokyo Tech, Japan
[**]JST PRESTO, Japan

We propose a thin display that can capture a frontal image of a person gazing at the display. The proposed display is composed of a see-through transparent holographic waveguide, a flat-panel display, a camera at the periphery of the display, and the image reconstruction processing. We verified the proposed concept by simulations and a preliminary experiment.

PRJ1/ FMC2 - 3 15:45 **Novel Holographic Waveguide Display with Kepler Telescope Configuration**

Z. Shen, Y. Zhang, A. Liu, Y. Weng, X. Zhu, X. Li
Southeast Univ., China

This paper proposed a novel holographic waveguide configuration, which includes the micro-display, in-coupling volume holographic grating, waveguide and out-coupling holographic reflective lens. Theoretically, the horizontal field of view of the novel holographic waveguide can reach 40°, and the simulation results are validated with the experiments.

PRJ1/ FMC2 - 4 16:05 **Light Efficiency Modeling for a Holographic Waveguide Display**

X. Zhu, Y. Zhang, Z. Shen, A. Liu, Y. Weng
Southeast Univ., China

A light efficiency model of a holographic waveguide display is constructed in this paper. The model considers both the energy loss of the beam propagating in the waveguide and the loss caused by one-dimensional expansion. The brightness and efficiency accepted by eye can be calculated by this model.

Author Interviews
18:10 – 18:40

16:40 - 18:00 **Room 222**

3D2/DES1: Novel Display Systems

Chair: C.-Y. Chen, Nat. Taiwan Univ. of S&T, Taiwan
Co-Chair: Y. Oyamada, Tottori Univ., Japan

3D2/ DES1 - 1 16:40 ***Invited*** **Hidden Stereo: Synthesizing Ghost-Free Stereoscopic Images for Viewers without 3D Glasses**

T. Fukiage, T. Kawabe, S. Nishida
NTT, Japan

When a conventional stereoscopic display is viewed without 3D glasses, image blurs, or 'ghosts', are visible due to the fusion of stereo image pairs. We overcome this limitation by synthesizing ghost-free stereoscopic images based on phase-based control of stereo disparity.
Also presented in Innovative Demonstration Session (see p. 232)

3D2/ DES1 - 2 17:00 ***Invited*** **Extended Imagery Training for Baseball Batting through High-Reality Virtual Space Using Head Mounted Display**

D. Mikami

NTT, Japan

This paper introduces a system that provides a first-person-view experience for athletes preparing to engage in sports competitions. Our system uses only information captured from locations that will not disturb the athletes or competitions. We describe in this paper how the system worked in a trial with a baseball team.

3D2/ DES1 - 3 17:20 ***Invited*** **An Interactive Fog Display to Express Adaptive Shape-Changing Flow**

T. Koga, K. Otao[*]

Nat. Inst. of Tech., Tokuyama College, Japan
[*]Univ. of Tsukuba, Japan

We propose an interactive fog display to express the adaptive shape-changing flow of a fog screen caused by interactions with the viewer. We present the design specifications of the proposed system, evaluation results of a user study, and some application contents to use the proposed system effectively.

3D2/ DES1 - 4 17:40 **A Miniaturized Multi-Layered Display System with Water Drops**

H.-W. Chen, Y.-A. Kuo, Z.-W. Wang, W.-C. Hsu[*], C.-Y. Chen

Nat. Taiwan Univ. of S&T, Taiwan
[*]Bruvis Multi Media Creative, Taiwan

In this study, we proposed a multi-layered microprojection system. Foremost the water curtain projection system uses an Arduino control panel and an infrared sensor to implement an interactive device. Furthermore, the Light Sculpture Projection System creates a three-dimensional and high-fidelity effect. In combination, a multi-level display system is formed.

Author Interviews
18:10 – 18:40

EXHIBITION

12:00 – 18:00 Wednesday, Dec. 12
10:00 – 18:00 Thursday, Dec. 13
10:00 – 14:00 Friday, Dec. 14
Event Hall (1F, Building 1)
Nagoya Congress Center
Free admission with your registration name tag

Thursday, December 13

9:00 - 10:15 **Room 224**

INP4: AR and Interactive Systems

Chair: T. Komuro, Saitama Univ., Japan
Co-Chair: Y. Ban, Univ. of Tokyo, Japan

INP4 - 1 ***Invited*** **High Precision and High Sensitivity Sheet**
9:00 **Sensor by Printing Technology**

T. Miyoshi[*]*, H. Kondoh*[*]*, S. Nishi*[*]*, T. Kamata*[*,**]
[*]*JAPERA, Japan*
[**]*AIST, Japan*

We have developed a manufacturing line that manufactures flexible TFT arrays only with printing technology. In addition, we have developed pressure sheet sensors using these TFT arrays and printable pressure sensitive materials, and developed novel input devices that can be used for various purposes.

INP4 - 2 ***Invited*** **Illusion Based Shape Display Using the**
9:25 **Visuo-Haptic Interaction**

Y. Ban
Univ. of Tokyo, Japan

Our shape perception can be changed by stimuli simultaneously received through multi senses. Utilizing this phenomenon, we can provide people to haptic experience in which touching various shapes without costly actuators. I introduce examples of illusion-based shape displays that augment our experience by using the effect of the visuo-haptic interaction.

INP4 - 3 ***Invited*** **3D User Interfaces Based on AR/VR**
9:50

T. Komuro
Saitama Univ., Japan

Augmented reality (AR) and virtual reality (VR) is now mainly used for amusement, but we focus on user interfaces that allow direct manipulation of 3D objects using AR/VR. In this paper, we show our recent development of such 3D user interface systems.
Also presented in Innovative Demonstration Session (see p. 235)

Author Interviews
10:40 – 11:10

----- Lunch -----

14:20 - 16:50 **Event Hall**

Poster FMCp1: Display Optics (1)

FMCp1 - 1 **LED Authentication Using a Smartphone for Volume Holograms**

T. Yasuda, Y. Yoshimura, T. Yamauchi

Dai Nippon Printing, Japan

In this paper, we proposed security features based on smartphone authentication with a point light source for volume hologram. The addition of an authentication feature to the volume hologram can further enhance the authentication effect, resulting in an optimized and visually attractive security feature using a smartphone.

14:20 - 16:50 **Event Hall**

Poster 3Dp2: Projection Display Systems

3Dp2 - 1 **Withdrawn**

3Dp2 - 2 **Realization of an Augmented Reality Display Operated with a Tunable Liquid Lens and 3D Integral Imaging**

P.-K. Sung, C.-W. Chien, C.-Y. Chien, C.-R. Sheu

Nat. Cheng Kung Univ., Taiwan

We demonstrate an augmented reality display (ARD) based on the integral imaging projection system. Simultaneously, a tunable focus liquid lens is used to adjust viewing depths of 3D images to prevent the vergence-accommodation conflict.

3Dp2 - 3 **Forming Aerial Omnidirectional Transparent Information Screen**

E. Abe[*], H. Yamamoto[,**]*

[*]Utsunomiya Univ., Japan
[**]JST ACCEL, Japan

This paper proposes a see-through optical system to form an omnidirectional transparent information screen that is floating in the air. The formed screen surrounds the central region. When viewed inside the screen, an omnidirectional image is visible. The displayed image on the screen is also visible from the outside.

3Dp2 - 4 **A Waveguide See-Through Display System Based on a Holographic Lens**

S.-K. Zhou[,**], W.-K. Lin[*,**], B.-S. Lin[*], W.-C. Su[**]*

[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Changhua Univ. of Education, Taiwan

The see-through display system consists of a holographic lens, waveguide, and a projection system. The holographic optical element was utilized to replace eyepiece and offering magnified images for see-through display. The see-through display can give the information at different distances by adjusting the position of the intermediate image.

3Dp2 - 5L **Real-Time Holographic Projection of 3D-Gradation Movie Using Binary-Weighted Computer-Generated Hologram and Multiple GPU Cluster**

T. Sakaguchi, N. Takada, H. Sannomiya, K. Suzuki, M. Oikawa, Y. Mori, T. Kakue[*], T. Shimobaba[*], T. Ito[*]

Kochi Univ., Japan
[*]Chiba Univ., Japan

We report real-time holographic projection to reconstruct 3D-gradation movie on cubic screen by using a multiple bit planes based on binary-weighted computer-generated holograms and a multiple-graphics-processing-unit cluster system. Consequently, we succeeded to reconstruct real-time 3D-gradation movie comprising 4840 points at 120 fps.

3Dp2 - 6L **Near-Eye See-Through Head-Mounted Display Using Aerial Imaging by Retro-Reflection (AIRR)**

C. Trovato[*], K. Kawai[*], K. Shimose[*], S. Morita[*], S. Ito[*], R. Kakinuma[*], H. Yamamoto[,**]*

[*]Utsunomiya Univ., Japan
[**]JST ACCEL, Japan

We propose a new prototype of a near-eye see-through head-mounted display using aerial imaging by retro-reflection (AIRR). We present the optical setup and the limits of the optical design for real-life use. The system allows us to obtain wide field of view images with a see-through capability.

3Dp2 - 7L **Aerial Light Field Display by Retroreflective Mirror Array**

T. Koike, Y. Onishi[*]

Hosei Univ., Japan
[*]Optoceramics, Japan

We present an aerial light field (LF) imaging with a novel retroreflective mirror array (RMA) and an LCD-based LF-display. We designed that the pop-out distance of the aerial 3D image by RMA was 2 m. The LF-display displays pseudoscopic images to produce the aerial 3D image with accurate depth information.

14:20 - 16:50 **Event Hall**

Poster **VHFp6/3Dp3: Applied Vision and Human Factors - Human Factors of AR/VR**

VHFp6/ 3Dp3 - 1 **Study on Subjective Depth Evaluation for Holographic Head-Mounted Display**

H. Kubo, Y. Oguro, Y. Sakamoto

Hokkaido Univ., Japan

We conducted a subjective depth evaluation experiment using a compact holographic head-mounted display (HMD) that can display in color. To correctly represent depth, we corrected the distance of the depth to improve the accuracy. Evaluation results indicate that subjective depth is closer to the same depth as holography.

Also presented in Innovative Demonstration Session (see p. 233)

VHFp6/ 3Dp3 - 2 **Study on Correction of Field Curvature in Head-Mounted Display Using Electro-Holography**

Y. Oguro, H. Kubo, Y. Sakamoto

Hokkaido Univ., Japan

This paper proposes a correction method of field curvature in HMDs using electro-holography. In the proposed method, it is possible to correct field curvature including assembly error by using measured values. An experiment was conducted using an HMD, and the effectiveness of the method is confirmed from the result.

VHFp6/ 3Dp3 - 3L **Development of One-Dimensional Integral Photography**

A. Hasegawa, S. Yano, M.-C. Park[*]

Shimane Univ., Japan
[*]KIST, Korea

We have developed one-dimensional integral photography that displays only horizontal parallax. One-dimensional integral photography depended on a method of generating elemental images by pixel position conversion from multi-view stereoscopic images. We examined the influence of vertical resolution on depth perception using prototype one-dimensional integral photography.

Friday, December 14

9:00 - 10:20 **Room 224**

PRJ4: Wearable

Chair: S. Ouchi, Hitachi, Japan
Co-Chair: T. Suzuki, JVC Kenwood, Japan

PRJ4 - 1
9:00
Can We Overcome the Challenges on the Path to Consumer Adoption of AR Headsets?

Z. Bouhamri, E. Virey, P. Mukish
Yole Développement, France

This presentation will give an overview of what are the requirements for consumer adoption, and address the technical challenges associated with displays and optical systems to better explain the projected trends for the upcoming years for consumer adoption.

PRJ4 - 2
9:20
Invited **Wide-Range Dimming Device on a Plastic Substrate for Augmented Reality Glasses**

T. Kono, A. Machida, K. Kadono, Y. Ishii, H. Takanashi, A. Nishiike, H. Suzuki[*]*, Y. Nakagawa*[*]*, K. Ando*[*]*, D. Kasahara*[*]*, A. Takeda*[*]*, K. Nomoto*
Sony, Japan
[*]*Sony Global Manufacturing & Operations, Japan*

We have developed a wide-range dimming device on a plastic substrate for augmented reality glasses. High transmittance modulation from 70% to less than 10% has achieved. It endures more than 10,000 cycles. The device enables AR glasses to display the clear image in both indoor and outdoor conditions.

PRJ4 - 3
9:40
Fiber Scanning Technology for Projection Unit

S. Onoe, T. Matsuda, T. Nakamura, Y. Seo, S. Ouchi
Hitachi, Japan

We are developing a projection unit by using our fiber scanning technology, which provides high resolution and uniform brightness, which are difficult for conventional fiber scanning technology. Color image projection with an oval scanning method was achieved.

PRJ4 - 4
10:00
Full-Color Waveguide-Coupling Near-Eye Displays Using Chromatic Polarization Volume Gratings

Y. Weng, Y. Zhang, J. Cui, X. Li
Southeast Univ., China

A double-layer waveguide structure with chromatic polarized volume gratings (PVGs) is demonstrated to realize the full-color near-eye display. We built a prototype to verify our design. As a result, a full-color near-eye display with a diagonal FOV of around 35° is realized by proposed structure.

----- Break -----

Author Interviews
12:00 – 12:30

10:40 - 12:05 **Room 222**

VHF6: Virtual Reality

Chair: T. Shibata, Tokyo Univ. of Social Welfare, Japan
Co-Chair: S. Uehara, AGC, Japan

VHF6 - 1
10:40 ***Invited*** **Ergonomic Evaluations of Virtual Reality System and Content**

T. Kawai
Waseda Univ., Japan

This paper introduces evaluation cases for a virtual reality system and its content, in terms of ergonomics/human factors. Specifically, the authors describe experimental studies of behavioral characteristics during the viewing of 360° images, and the effects of the VR experience on heart rate variability in activities of daily living.

VHF6 - 2
11:05 **Comparison of Color Perception Between Head-Mounted Display and Ordinary Display**

T. Nishimura, S. Dozaki, K. Hirai, T. Horiuchi
Chiba Univ., Japan

In this paper, subjective evaluation experiments were conducted to investigate differences of luminance and chroma perception between an HMD (Head-mounted display) and an ordinary display. The results show that the perception of luminance and chroma of the HMD were higher compared with those of the ordinary display.

VHF6 - 3
11:25 **2.02-in. Mini-LEDs Wide Color Gamut Solution for Virtual Reality Display**

H.-H. Wu, C.-S. Li, H.-P. Kuo, Y.-H. Chang, I.-H. Hsieh, Y.-T. Chen
AU Optronics, Taiwan

We have developed a 2.02-in. mini-LEDs backlight that enables high contrast ratio (100,000:1) that compare to OLED for virtual reality display. Because of strobe backlight function, we proposed a nitride solution that can reach NTSC 95% without res residual issue.

VHF6 - 4
11:45 **Design of Machine Vision Aided Measurement System for Near-Eye Display Devices**

S. Hu, Q. Zhu, Y. Cao, Y. Tang, Y. Zheng
Southeast Univ., China

A machine vision aided measurement system for near-eye display devices has been developed. We combined machine vision module with mechanical equipment, made it possible to automatically align the under-test device to the measurement instruments. The results show the machine vision technology can notably improve the measurement system's objectivity and stability.

Author Interviews
12:05 – 12:30

----- Lunch -----

Special Topics of Interest on Automotive Displays

Wednesday, December 12

15:00 - 16:15 **Room 224**

INP2: 3D Sensing for Automotive HMI

Chair: R. Ishiyama, NEC, Japan
Co-Chair: N. Mishima, Toshiba, Japan

INP2 - 1
15:00

Invited **Depth from Asymmetric Defocus Using Color-Filtered Aperture Towards One Shot Depth Acquisition by Single Camera**

N. Mishima, T. Sasaki
Toshiba, Japan

We have developed an imaging technique that can simultaneously acquire a color image and a depth map from a single image taken by a monocular camera. This technique achieves high-precision distance/range detection, comparable to that of a stereo camera, through the combination of a lens device and image processing.

INP2 - 2
15:25

Invited **Hybrid Time-of-Flight Range Image Sensors Using High-Speed Multiple-Tap Charge Modulation Pixels**

S. Kawahito[,**], K. Yasutomi[*], K. Mars[*], K. Kagawa[*], S. Aoyama[**]*
[*]Shizuoka Univ., Japan
[**]Brookman Tech., Japan

This paper presents TOF range image sensors featuring the combination of direct and indirect TOF measurements. This technique uses a short light-pulse modulation and multiple time windows prepared by the multiple-tap pixels and sub-frame readouts and allows us to have high range resolution and high tolerance to ambient light.
Also presented in Innovative Demonstration Session (see p. 234)

INP2 - 3
15:50

Invited **3-D Scan and Image Recognition of Face**

R. Ishiyama
NEC, Japan

Face image can be captured remotely and without any user's action, thus it is useful for such applications as mobile user authentication and surveillance. However, face image recognition is sensitive to the pose and lighting changes. We discuss about how 3D scan technologies assist to solve these problems.

----- Break -----

16:40 - 18:15 **Room 224**

INP3: In-Cell Touch Panels and Automotive HMI

Chair: H. Haga, Tianma Japan, Japan
Co-Chair: N. Takada, Japan Display, Japan

INP3 - 1 ***Invited*** **Capacitive Touch Panel with Non-Conductive and Conductive Object Distinction for In-Cell LCD and OLED Display**
16:40

J. de D. B. Mugiraneza, D. Gallardo, Y. Sugita, T. Maruyama, K. Kida, S. Yamagishi, T. Yamamoto*

Sharp, Japan
**Sharp Labs of Europe, UK*

We describe In-Cell Capacitive Touch Panel with novel electrode pattern and sensing method for detection of conductive and non-conductive objects. Proposed electrode design and driving scheme enables to reduce the number of traces as compared to previous works. This In-cell technology can be applied to both LCD and OLED display.
Also presented in Innovative Demonstration Session (see p. 234)

INP3 - 2 ***Invited*** **Large Size In-Cell Capacitive Touch Panel and Force Touch Development for Automotive**
17:05

N. Takada, C. Tanaka, T. Tanaka, Y. Kakinoki, T. Nakanishi, N. Goto

Japan Display, Japan

World's largest 16.7-in. Pixel Eyes, which is JDI's original in-cell touch panel, has been developed. This panel also has curved-shaped and non-rectangular characteristics.In addition, we have developed force touch panel which is one of the new Human Machine Interface based on Pixel Eyes in automotive display.
Also presented in Innovative Demonstration Session (see p. 234)

INP3 - 3 ***Invited*** **"In-Cell" Force Touch Technology in the OLED Display Panel**
17:30

L. Liu, F. Lu, S. Ma, C. Ma, Q. Yao

Tianma Micro-Elect., China

Force touch sensors have been integrated into a 5.99-in. rigid OLED panel and a 5.99-in. curved flexible OLED panel respectively. In both panels, piezoresistive sensors made of p-doped poly-silicon show strong responses to the applied force, demonstrating high adaptability of the in-cell force touch solution in the OLED display panel.

INP3 - 4 17:55 **Knob on Display: Movable Ring-Shaped Dial Interaction for Automotive Center Display**

Y. Sasaki

Mitsubishi Elec., Japan

We describe a novel user interaction for automotive center information display with movable ring-shaped dial. This device can detect the dial position and fingers in contact with the dial using capacitive type touch display simultaneously, therefore it is possible to interact more safely without visual attention.

Also presented in Innovative Demonstration Session (see p. 234)

Author Interviews
18:15 – 18:40

Thursday, December 13

9:00 - 10:25 **Room 432**

VHF4: Ergonomics for Automotive Applications

Chair: Y. Imai, Mitsubishi Elec., Japan
Co-Chair: Y. Endo, AGC, Japan

VHF4 - 1 9:00 ***Invited*** **Visual Cues with HUD: Driving Behavior Analysis of Elderly and Experienced Drivers in Hazard Anticipation Scenes**

Y. Saito[*], A. Yamasaki[*], S. Inoue[**], T. Ito[***], H. Inoue[****], P. Raksincharoensak[*]

[*]Tokyo Univ. of A&T, Japan
[**]Toyota Motor, Japan
[***]Univ. of Tokyo, Japan,
[****]Kanagawa Inst. of Tech., Japan

This study was designed to further our understanding of how visual cues with Head-Up Display affect an elderly driver's hazard-anticipatory driving performance in potentially hazardous situations.

VHF4 - 2 9:25 **Advanced Optical Characterization Techniques and Simulation of Anti-Glare Cover Glass**

T. Saitoh, T. Kanai

Nippon Elec. Glass, Japan

The light-scattering distribution of anti-glare cover glass was successfully measured at different wavelengths using a goniometer with red, green, and blue laser sources. The relation between the optical properties and surface structure was theoretically established by geometric and wave optics simulation methods.

VHF4 - 3 **Sparkle Measurement of Anti-Glare Displays with**
9:45 **Simulating Human-Eye Perception**

M. Kurashige, G. Furui, K. Ishida, H. Suzuki, M. Tsunekawa, Y. Iwata, N. Nakamura

Dai Nippon Printing, Japan

Sparkle contrast of various Anti-glare displays were measured with the optical imaging system which was designed to simulate human-eye perception. Sparkle contrast was very sensitive to the measurement distance and pinhole diameter of the imaging system. The averaging effect of sparkle contrast by detector pixel was also investigated.

VHF4 - 4 **Automotive Displays and HMI: Past, Present and**
10:05 **Future**

P. M. Knoll

Karlsruhe Inst. of Tech., Germany

In former times only few gauges were necessary to survey the vehicle's functions. Current and future concepts bundle the huge amount of information coming from new driver assistance systems in three information centers: reconfigurable instrument cluster, head-up display, and center console display in conjunction with appropriate operating techniques.

Author Interviews
10:40 – 11:10

----- Lunch -----

14:20 - 16:50 **Event Hall**

Poster **VHFp3: Applied Vision and Human Factors - Automotive Applications**

VHFp3 - 1 **Layer-Wise Analysis of TFT-LCD Reflectivity**

X. Lin, C. Yan, L. Chen, Z. Chen

Shenzhen China Star Optoelect. Tech., China

Reflectivity of TFT-LCD panels to ambient light is an important aspect when evaluating display performance. We propose that reflectivity of TFT-LCD can be decomposed into contributions of the upper polarizer, color filter (CF) Plate and Array Plate. Our analysis of reflectivity is verified by simulation results and experimental data.

VHFp3 - 2 **An Automotive Display with Multi Domains and Changing Viewing Angle Functions**

Y. W. Chang, Y. E. Wu

AU Optronics, Taiwan

An automotive display with multi domains and changing viewing angle functions is developed. A multi layer backlight system is specially designed for this application. The display is customized for automotive which could display individual information to driver and shotgun, which is safer and less information disturb to each one.

17:10 - 18:10 **Room 224**

INP5: Fingerprint Sensors and Secure Devices

Chair: D. Suzuki, Japan Display, Japan
Co-Chair: K. Yamazaki, Corning Japan, Japan

INP5 - 1 ***Invited*** **Glass-Based Capacitive Fingerprint Sensor Package**
17:10

D. Suzuki, T. Uehara, Y. Suzuki, F. Nakano, Y. Ozeki

Japan Display, Japan

A glass-based fingerprint sensor package has been newly developed, integrating silicon-based packaging technology with glass-based TFT technology. A fingerprint image has been successfully sensed by the glass sensor package. Even after a reliability test, the fingerprint sensor performance maintained the same quality, showing the possibility of commercialization.

Also presented in Innovative Demonstration Session (see p. 234)

INP5 - 2 **Near Filed Communication (NFC) Antenna on Display Integrated on Touch In-Cell (TIC) Panel**
17:35

C.-J. Liu, J. Liao, C.-Y. Hsu, H.-H. Chen, H.-M. Su, W.-T. Tseng

Chunghwa Picture Tubes, Taiwan

we successful developed novel interface by using an integrated near field communication antenna on 5-in. HD touch in-cell panel. The integrated NFC antenna on touch in cell panel technology have good quality display with high touch sensitivity above 41.1 dB signal noise ratio for 8ϕ Copper rods.

INP5 - 3L
17:55

NFC Antenna Integrated Capacitive Touch Display

T. Maruyama, K. Kida, S. Yamagishi,
J. de D. B. Mugiraneza, T. Yamamoto, Y. Sugita
Sharp, Japan

We describe a novel user interface solution by using an integrated transparent NFC antenna and a capacitive touch panel on a display. Compared to our previous work, new approach enables to improve the transparency and allows user a more compact, advanced design and lower cost NFC-integrated touch display.
Also presented in Innovative Demonstration Session (see p. 234)

Author Interviews
18:40 – 19:10

Friday, December 14

9:00 - 10:20 **Room 133**

DES2/UXC4: AI Applied to Display

Chair: T. Sato, AIST, Japan
Co-Chair: Y. Ando, Fuji Xerox, Japan

DES2/UXC4 - 1
9:00

Invited **3D Image Processing Based on Machine Learning**

T. Fujii
Nagoya Univ., Japan

Recently, Deep neural network (DNN) and convolutional neural network (CNN) are successfully applied to 3D image processing problems, such as light field display calculation, coded aperture based light field acquisition, and view interpolation. In this paper, we introduce examples where DNN and CNN are efficiently applied to these problems.

DES2/UXC4 - 2
9:20

Invited **Road Scene Understanding Using Image Recognition for Safety and Autonomous Driving**

T. Watanabe
Toshiba, Japan

On-board camera is widely used to understand road scene around automobile for driver assistance. This paper introduce image recognition methods that we developed for ADAS (Advanced Driver Assistance System). We also explain our efficient automobile LSIs that runs image recognition algorithms in real-time with low power consumption.

DES2/ UXC4 - 3 9:40 ***Invited*** **Font Image Conversion Using Style Transfer and Cross Domain Transfer Learning**

W. Shimoda, A. Narusawa, K. Yanai
Univ. of Electro-Commun., Japan

In this paper we study about font generation and conversion. We extract features from font images and transferring texture or pattern using deep learning. In experiments we construct unique datasets and improve image generation quality for readability of character by combining neural style transfer with cross domain learning.

DES2/ UXC4 - 4 10:00 **Multimodal User Interface Application to Support Drawing-in-Talking**

X. Xu, H. Shibata
Fuji Xerox, Japan

This paper proposes a multimodal user interface system using pen and voice to draw diagrams, especially system configuration diagrams. To support actual presentation, we aim to support smooth mode switching that does not interfere with natural talking.

----- Break -----

10:40 - 11:55 **Room 224**

PRJ5: Automotive Displays and Sensors

Chair: K. Ohara, Marubun, Japan
Co-Chair: M. Kuwata, Mitsubishi Elec., Japan

PRJ5 - 1 10:40 ***Invited*** **Use of Aerial Agent for Smart Cockpit**

M. Morita, H. Yamamoto[*]*, K. Yoshihara, N. Nara*
Clarion, Japan
[*]*Utsunomiya Univ., Japan*

For visual representation of in-car AI agent, we chose aerial image display, and we developed aerial image display optimized automotive. Then, The aerial agent tell the driver what kind of automatically executed function by driver action prediction.

PRJ5 - 2 11:00 **Improving Image Quality of Lensless Light-Field Imaging Using Pattern Projection Technique**

Y. Nakamura, K. Yamaguchi, K. Tajima, T. Shimano
Hitachi, Japan

A lensless light-field imaging technology with a Fresnel zone aperture has previously been developed. To improve the image quality of the reconstructed image in this system, it is necessary to improve a signal to noise ratio of the sensor image. Accordingly, in the present study, a pattern projection technique is proposed.

PRJ5 - 3
11:20

Optimization of Vertical View Human Skeleton Recognition from Range Images

A. Watanabe, T. Kamimura

Hitachi, Japan

We developed the rule base technique of the sequential joint search method as a posture estimate technique from upward view range image of TOF sensor and confirmed the average correct prediction ratio of the sequential search technique is over 90% and the detection ratio is 97%.

Also presented in Innovative Demonstration Session (see p. 233)

PRJ5 - 4L
11:40

Laser Scanning Headlamp

T. Kitazono, Y. Kita, T. Mori, S. Harata, T. Saito, S. Hoshino, Y. Yatsuda

Stanley Elec., Japan

The our study was conducted to verify that the laser scanning headlamp system with its seamless moving light gives the driver a safer visibility and hence is an effective means of reducing road accident fatalities.

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:30 **Room 222**

3D5/DES4: Display Systems for Automotive

Chair: K. Morita, Chuo Univ., Japan
Co-Chair: H. Yamamoto, Utsunomiya Univ., Japan

3D5/
DES4 - 1
13:10

Invited **3D Head-Up Display System**

Y. Takaki

Tokyo Univ. of A&T, Japan

3D head-up displays employing super multi-view displays have been developed to enable stable superposition of 3D images on real objects. The optical system using a polarizing beam splitter is proposed to reduce the system size.

3D5/ DES4 - 2 13:30 **Low Crosstalk Glassless 3D HUD with Expanded Viewing Area in All Directions Using Novel Eye Tracking System**

T. Matsumoto, K. Kusafuka, H. Nakamura, G. Hamagishi*, K. Yoshimoto*, H. Takahashi**

Kyocera, Japan
**Osaka City Univ., Japan*

We propose Glassless 3D HUD that enables binocular virtual image stereopsis with low crosstalk. In this system, 3D image processing algorithm and the crosstalk reduction method which perform processing based on the position of the driver's eye sensed by the driver monitor camera are applied.

3D5/ DES4 - 3 13:50 **10.4-in. Ultra-Slim a-Si TFT LCD with Tracking Gate Line in Pixel Technology for Automotive Display**

C.-H. Kuan, J.-S. Liao, C.-Y. Du, C.-C. Chang, H.-H. Chen, H.-M. Su, W.-Z. Zeng

Chunghwa Picture Tubes, Taiwan

In this work, we developed of 10.4-in. (1280 x RGB x 720) automotive display with Tracking Gate line in Pixel technique. In this case, we can keep panel transmittance to achieve ultra-slim panel border (0.7 mm) for automotive display. This panel structure has been important link to realize the next generation of automotive industry applications.

3D5/ DES4 - 4 14:10 **An Automotive Grade Local Dimming Display System**

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

Chunghwa Picture Tubes, Taiwan

In this paper, we applied different dimming area design corresponding to backlight unit separately. Through the local dimming display, the driver could recognize the car information clearly day and night. It should lead to greatly improve the driving safety.

Author Interviews
16:20 – 16:50

Special Topics of Interest on Wide Color Gamut and Color Reproduction

Thursday, December 13

14:20 - 16:50 **Event Hall**

Poster **FMCp5: WCG Color Filter**

FMCp5 - 1 **Wide Gamut Display Using Red Color Filter - Technical Developments and Actual Products**

D. M. Lee, S.-J. Yang, J.-Y. Lee, Y.-W. Kim, H.-J. Kim

LG Chem., Korea

In order to display images close to natural colors, WCG color filter photoresist is one of the most important components in flat panel display devices. In this paper, the development direction and some results for the WCG colorant will be discussed.

14:20 - 16:50 **Event Hall**

Poster **VHFp2: Applied Vision and Human Factors - Color Gamut Metrology**

VHFp2 - 1 **Analysis of Color Gamuts and Tone Characteristics of Tablet Display Under Different Ambient Light Levels**

T.-Y. Chiang, H.-S. Chen

Nat. Taiwan Univ. of S&T, Taiwan

When ambient light levels are changed from dark room to bright room, there are the tendencies in smaller gamut volume and narrower lightness range for a tablet display. Meanwhile, the γ values of the calibrated tone reproduction curves become smaller when the ambient light conditions are brighte.

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers selected from those presented at IDW '18.
The 2018 award winners will be announced on the IDW website: http://www.idw.or.jp/award.html

Friday, December 14

10:40 - 11:40 **Room 131**

LCT6: Wide Color Gamut LCDs

Chair: S. Shibahara, Sony Visual Products, Japan
Co-Chair: S. Kawasaki, JNC Korea, Korea

LCT6 - 1
10:40 ***Invited*** **Applications of Wide Color Gamut (WCG) Technology in Display**

M. S. Kwak, Y. H. Kim, S. H. Han, A. K. Kim, S. I. Kim, M. Jun, I. B. Kang

LG Display, Korea

In the development of display product, color colorant is one of the indispensable technologies to implement. The WCG standard has been widely defined for each product, and various researches for increasing the color reproduction ratio are required. We will introduce the importance of color colorant materials in developing future WCG.

LCT6 - 2
11:00 ***Invited*** **Sunlight Readable FFS LCD with High Contrast Ratio and Wide Color Gamut Under High Ambient Light Situations**

Y. Kawahira, K. Murata, T. Nakai, M. Hasegawa, A. Sakai, K. Minoura, N. Smith[*]

Sharp, Japan
[*]Sharp Labs. of Europe, UK

A novel wide-view LCD with reduced unwanted reflection has been developed to enhance ambient contrast ratio. By combining an FFS-based new LC mode with a circular polarizer, our 3.2-in. prototype has successfully demonstrated high contrast ratio and wide color gamut in high ambient light situations without boosting the backlight brightness.

LCT6 - 3
11:20 **Analyzing and Improving the Bluish Issue at VA Dark State**

C. Chen, Y. Wang, Y. Lin, B. Hai, Y. Hsiao

Shenzhen China Star Optoelect. Tech., China

The bluish issue in VA dark state when the ambient light is low, like movie mode, and it will be easy to be inspected. In this paper we analyzed the factor of bluish issue at dark state firstly, then we provided the solution to improve the issue.

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:40 **Room 432**

VHF7: Color Gamut Metrology

Chair: K. Masaoka, NHK, Japan
Co-Chair: K. Hirai, Chiba Univ., Japan

VHF7 - 1
13:10

Invited **Visual Evaluation of Display Color Gamut**

Y. Kwak, Y. S. Baek

Ulsan Nat. Inst. of S&T, Korea

Visual color gamut evaluation method is introduced. Two images having different color gamuts are shown to the subjects to choose the images having more richness in color. The experimental results show that three dimensional color gamut volume should be calculated considering the chromaticity differences and also the luminance differences.

VHF7 - 2
13:35

Invited **Subjective Verification for Color Gamut Volume of HDR WCG Display**

F. Jiang, K. Masaoka[*]*, M. Fairchild*

Rochester Inst. of Tech., USA
[*]*NHK, Japan*

Nine selected HDR images were visually evaluated through paired-comparison method in regard of colorfulness and details. HDR images are clipped into different peak luminance levels but keeping the same diffuse white setting. Psychophysical experiment results indicated an overall linear relationship between log10 of peak luminance and subjective score.

VHF7 - 3
14:00

Fast and Accurate Colour Gamut Volume Measurements of RGB Displays with Degenerate Colours

J. Bergquist

Consult., Japan

Colour additivity and gamut volume of various displays were measured as functions of input grey value and number of grid points, respectively. The volume reached 95% of the convergence value at 98 grid points for an RGBW LCD with a strongly concave hull. The measurement time was less than 60 s.

VHF7 - 4
14:20

A Color Quality Volume Metric for HDR Displays

W. Lv, H. Xu, Z. Ye, J. Qiu

Zhejiang Univ., China

The existing color volume metrics usually fail to represent the image quality of HDR TVs. Through physical measurements and visual evaluations, a novel color quality volume metric (CQVM) was proposed, which would well predict the image quality of HDR displays.

----- Break -----

14:50 - 16:10 **Room 432**

VHF8: Color Vision

Chair: K. Masaoka, NHK, Japan
Co-Chair: Y. Kwak, Ulsan Nat. Inst. of S&T, Korea

VHF8 - 1
14:50

Invited **Applicability of CIELAB Volume Metric to the Latest Electronic Display**

H. Yoshida, K. Hirai, Y. Mizokami**

Sharp, Japan
**Chiba Univ., Japan*

We investigated the applicability of the CIELAB color gamut volume metric to the latest self-emissive displays. Where to set the reference white is the key. The luminance of maximum white, full-screen white and absolute value are appropriate. The weighted average can give the criteria of the display color performance.

VHF8 - 2
15:15

Helmholtz-Kohlrausch Effect Estimation Considering Lightness

Y. Hayami, D. Takasu, H. Aoyanagi, H. Takamatsu*, Y. Shimodaira, G. Ohashi*

Shizuoka Univ., Japan
**NEC Display Solutions, Japan*

The purpose of this study is to add lightness parameter to the Helmholtz-Kohlrausch (H-K) effect estimation equation of Nayatani et al. and verify its effectiveness in order to improve the estimation accuracy in natural images.

VHF8 - 3
15:35

Observer Metamerism for Anomalous Trichromats and the Elderly in a Wide Color Gamut Display

*S. Sunaga, R. Suto, S. Katsura, H. Yaguchi**

Kyushu Univ., Japan
**Chiba Univ., Japan*

It was reported that observer metamerism is obvious in a wide color gamut display. In this study, the effects of color deficiency and/or aging on color appearance on a wide color gamut display were investigated. Significant deviations from the standard observer were observed.

VHF8 - 4L
15:55

A Comparison of Perceptual Color Differences of 3D Objects Presented on a HDR Display and Real Scene

Y.-Z. Lai, P.-L. Sun, W.-C. Hung

Nat. Taiwan Univ. of S&T, Taiwan

Perceptual color differences of glossy 3D objects were viewed in both real and HDR display conditions. The results are highly correlated and optimal weights apply for color difference calculation to predict the visual differences. In terms of image differences, perceptual differences are well-correlated to 95th percentile of image color differences.

Author Interviews
16:20 – 16:50

Special Topics of Interest on Haptics Technologies

Wednesday, December 12

13:25 - 14:50 **Room 224**

INP1: Haptic Technologies

Chair: Y. Tanaka, Nagoya Inst. of Tech., Japan
Co-Chair: H. Ishizuka, Kagawa Univ., Japan

INP1 - 1 13:25 ***Invited*** **Smart Rubber Technology and Its Applications**

K. Nakano, T. Murase

Sumitomo Riko, Japan

We have developed special rubber material "Smart Rubber(SR)" that is flexible and current-carrying, using Polymer-material Technique and Overall Technical Evaluation. We also have developed "SR Sensor", apply SR to flexible sheet rubber, and "SR Actuator", apply characteristic feature of rubber that stretch by electric stimulation and rubber contractility.

Also presented in Innovative Demonstration Session (see p. 234)

INP1 - 2 13:50 ***Invited*** **Development of Electrovibration Tactile Displays with Microfabrication and Digital Fabrication**

H. Ishizuka

Kagawa Univ., Japan

In this study, we explain the electrovibration tactile displays with microfabrication process and digital fabrication. First, we explain a flexible sheet type electrovibration tactile display. Next, we explain a multi-electrode electrovibration tactile display. Also, the printed electrovibration tactile display is explained.

INP1 - 3 14:15 **Toward the Modeling of Tactile Sensation on Electrostatic Tactile Display**

H. Tomita, S. Takahashi, S. Saga[*]*, S. Vasilache, H. Kajimoto*[**]

Univ. of Tsukuba, Japan
[*]*Kumamoto Univ., Japan*
[**]*Univ. of Electro-Commun., Japan*

As one method of displaying tactile sensation on the touchscreen, electrostatic tactile displays have been developed. We evaluated the magnitude of tactile sensation on an electrostatic tactile display. Based on the result, we proposed a preliminary model to predict the magnitude of tactile sensation from the results of several inputs.

INP1 - 4L 14:35 **Force Sensitive Tactile Feedback Touchscreen Featuring Texture and Click Sensations**

Y. Yang, H. Haga, H. Sasaki, T. Asai, K. Shigemura
Tianma Japan, Japan

A force sensitive tactile feedback touchscreen integrated with an electrostatic tactile display, linear solenoid actuators and force sensors was demonstrated. This touchscreen enables the possibility of locating objects shown on a visual display using only tactile sensations on fingertip without vision and giving realistic tactile feedback for confirmed action.

Also presented in Innovative Demonstration Session (see p. 234)

Author Interviews
18:15 – 18:40

Topical Session on User Experience and Cognitive Engineering

Wednesday, December 12

13:20 - 13:25 **Room 133**

Opening

Opening Remarks
13:20

M. Mori, Hosei Univ., Japan

13:25 - 14:40 **Room 133**

UXC1: Visual Experience

Chair: E. Amasawa, Univ. of Tokyo, Japan
Co-Chair: M. Mori, Hosei Univ., Japan

UXC1 - 1 **Visualizing Measurement Weather Data Based on**
13:25 **Behavioral Scenarios**

K. Go, F. Watanabe, Y. Kinoshita, H. Ishidaira, K. Soma, J. Magome

Univ. of Yamanashi, Japan

In this paper, we show experimental results of efficient visualization method of weather data measurement based on behavioral scenario assigned to users. It was found that the user's preference for the visualization method depends on the importance of the scenario.

UXC1 - 2 **Difference in Fixation of Designers and Non-**
13:45 **Designers in Flyers**

Y. Andoh

GfK, Japan

This study demonstrates the difference in fixation time of Area of Interest between designers and non-designers, and demonstrates whether there is a difference in what order they looked at parts of flyers. This study showed in that designers and non-designers had different strategies in the order of seeing the flyers.

UXC1 - 3 14:05 **Determination of Evaluation Index of Multi-Information Display Printing Using Lenticular**

K. Shibuta

Tokyo Tech, Japan

There exists a method of printing known as lenticular printing. The images produced by lenticular printing change depending on the viewing angle and obtain a stereoscopic effect. Our experiment has quantitatively confirmed, the effect of lenticular printed promotional items and attempted to construct an evaluation indicator to properly produce.

UXC1 - 4L 14:25 **Quiz Study Using Multi-Mouse Quiz System in the Period for Integrated Studies**

J. Zhou, M. Mori[*], H. Kita[**]

Ritsumeikan Univ., Japan
[*]Hosei Univ., Japan
[**]Kyoto Univ., Japan

Multi-Mouse Quiz (MMQ) is a quiz application of Single Display Groupware (SDG) to treat quizzes in a classroom or other learning environments. We conducted a practice of using MMQ to support collaborative learning combined with visit of a museum. MMQ quiz learning inspires children with reflection in museum and out of class.

Author Interviews
18:10 – 18:40

Thursday, December 13

9:00 - 10:30 **Room 131**

UXC2: Tangible Interface and Education

Chair: H. Shibata, Fuji Xerox, Japan
Co-Chair: K. Go, Univ. of Yamanashi, Japan

UXC2 - 1 9:00 ***Invited*** **Technology and Application of Tactile Presentation**

Y. Hashimoto[,**]*

[*]Univ. of Tsukuba, Japan
[**]JST PRESTO, Japan

With the development of the Virtual Reality, tactile display technology is receiving a lot of attention now. In this presentation, I share the latest knowledge on tactile presentation technology by introducing our research and trends of the current tactile field.

UXC2 - 2 **Withdrawn**

UXC2 - 4L ***Invited*** **Dissemination Activities of Simple Haptic**
9:25 **Devices**

S. Takeuchi

Freelance Engineer / Researcher, Japan

I have been developing various haptic applications based on open source hardware to disseminate force haptic technology. I will also release a simple force feedback device. I intend to sell it in a relatively low cost as a module as wel.

Also presented in Innovative Demonstration Session (see p. 232)

UXC2 - 3 ***Invited*** **Facilitating Problem Solving with Stimulating**
9:50 **Unconscious Cognitive Process**

S. V. Suzuki

Osaka Univ. of Economics & Law, Japan

Recent studies in psychology, cognitive science, and neuroscience have suggested that unconscious cognitive process plays the important role in problem solving. The author introduces the studies on facilitating problem solving with visually stimulating unconscious cognitive processes and discusses the problems and possibilities of application for learning and working environment.

UXC2 - 5L ***Invited*** **Prospects of Digital Textbooks in Japan**
10:15

N. Kutomi

Kyoto Univ., Japan

Many people and organizations have been recognizing the importance of digital devices in Japanese Schools, but the introduction of digital devices in Japanese schools is quite slow. From 2019 April, the revised School Education Act will be valid. To pay sufficient attention to the needs of current teachers is required.

10:30 - 10:32 **Room 131**

Short Presentation UXCp1:
Interaction Design and Recommendation

All authors of poster papers for the UXCp1 session will give 1-minute oral presentations with no discussion time.

Author Interviews
10:40 – 11:10

----- Lunch -----

14:20 - 16:50 **Event Hall**

Poster **UXCp1: Interaction Design and Recommendation**

UXCp1 - 1L **Timing Control of Notification Environment in Museums**

H. Wu, J. Zhou, H. Takada

Ritsumeikan Univ., Japan

We propose an automatic notification system based on the visitors' state in the museum. The visitors will receive different notifications according to the position and the staying time. We aim to reduce the disturbing frequencies, increase the motivation to study new knowledge, and enhance the experiences of visitors.

UXCp1 - 2L **Investigation of Input Gestures for Deformable Smartwatches**

T. Totsuka, Y. Kinoshita, K. Go

Univ. of Yamanashi, Japan

Smartwatches have specific touch input restrictions because of their small size display. The present study focuses on the strategy to mitigate these input restrictions using the smartwatches' deformation. An observation study elicited various types of user-defined gestures suitable for certain applications. Their analysis revealed useful gestures for deformable smartwatches.

17:10 - 18:35 **Room 133**

EP4/UXC3: Approaches to Ideal Replacement of Paper Media

Chair: M. Omodani, Tokai Univ., Japan
Co-Chair: J. Kobayashi, Dai Nippon Printing, Japan

EP4/ UXC3 - 1 17:10 ***Invited*** **Diffusion of e-Book in Japan from the View Point of Consumer Activities**

M. Ueda

Kyoto Sangyo Univ., Japan

We collected 3,000 samples in March 2016 by online survey and found a tendency of consumption of e-book by Japanese consumers. Our major findings are following; 1) attachment to physical objects in Japanese consumers, 2) high MWTP for device and providers, and 3) consuming pattern is different by age groups.

EP4/ UXC3 - 2 17:35

Evaluation of Ease of Handling for Electronic Paper Devices

H. Shibata, M. Omodani[*]

Fuji Xerox, Japan
[*]Tokai Univ., Japan

This paper evaluates people's conscious for digital devices from their behavior. Results showed that participants' behavior for a new A4-size electronic paper device was close to that for a sheet of paper rather than that for digital devices. This indicates that they handled the device like a stationery.

EP4/ UXC3 - 3 17:55

Comparative Analysis of Reading Experience in Paper Book, e-Reader, and Flexible e-Reader Based on Kano Model

E. Amasawa, T. Ihara, K. Hanaki

Univ. of Tokyo, Japan

This study presents a comparative analysis of book reading experience with three different reading media based on Kano model. Among the three media, we found that the average satisfaction level of e-reader to be greater than that of paper books, and comparable to that of flexible e-reader.

EP4/ UXC3 - 4 18:15

Smart Devices Enabled by e-Paper Displays and IoT

K. Blankenbach, D. Bogner, A. Marsal, K. Schuhmacher, P. Duchemin[*], B. Rist[**]

Pforzheim Univ., Germany
[*]MSC Techs., Germany
[**]August Faller, Germany

IoT and Cloud Computing are on the rise. However, many applications require clients with sensors and actuators as well as human interaction. We developed several prototype IoT systems using e-paper for better usability. The examples include smart tags, connected office lighting and advanced pharmaceutical packaging.

Author Interviews
18:40 – 19:10

EXHIBITION

12:00 – 18:00 Wednesday, Dec. 12
10:00 – 18:00 Thursday, Dec. 13
10:00 – 14:00 Friday, Dec. 14
Event Hall (1F, Building 1)
Nagoya Congress Center
Free admission with your registration name tag

Friday, December 14

9:00 - 10:20 **Room 133**

DES2/UXC4: AI Applied to Display

Special Topics of Interest on Automotive Displays

Chair: T. Sato, AIST, Japan
Co-Chair: Y. Ando, Fuji Xerox, Japan

DES2/ UXC4 - 1 9:00 ***Invited*** **3D Image Processing Based on Machine Learning**

T. Fujii

Nagoya Univ., Japan

Recently, deep neural network (DNN) and convolutional neural network (CNN) are successfully applied to 3D image processing problems, such as light field display calculation, coded aperture based light field acquisition, and view interpolation. In this paper, we introduce examples where DNN and CNN are efficiently applied to these problems.

DES2/ UXC4 - 2 9:20 ***Invited*** **Road Scene Understanding Using Image Recognition for Safety and Autonomous Driving**

T. Watanabe

Toshiba, Japan

On-board camera is widely used to understand road scene around automobile for driver assistance. This paper introduce image recognition methods that we developed for ADAS (Advanced Driver Assistance System). We also explain our efficient automobile LSIs that runs image recognition algorithms in real-time with low power consumption.

DES2/ UXC4 - 3 9:40 ***Invited*** **Font Image Conversion Using Style Transfer and Cross Domain Transfer Learning**

W. Shimoda, A. Narusawa, K. Yanai

Univ. of Electro-Commun., Japan

In this paper we study about font generation and conversion. We extract features from font images and transferring texture or pattern using deep learning. In experiments we construct unique datasets and improve image generation quality for readability of character by combining neural style transfer with cross domain learning.

DES2/ UXC4 - 4 10:00 **Multimodal User Interface Application to Support Drawing-in-Talking**

X. Xu, H. Shibata

Fuji Xerox, Japan

This paper proposes a multimodal user interface system using pen and voice to draw diagrams, especially system configuration diagrams. To support actual presentation, we aim to support smooth mode switching that does not interfere with natural talking.

Author Interviews
12:00 – 12:30

----- Lunch -----

SPECIAL EVENT

PROJECTION MAPPING

Live demonstrations of leading-edge technologies
Wednesday, Dec. 12 – Friday, Dec. 14, 2018
Room221 (2F, Building 2)
Nagoya Congress Center

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters
Thursday, Dec. 13, 2018
11:40 – 15:50
Event Hall (1F, Building 1)
Nagoya Congress Center

Workshop on LC Science and Technologies

Wednesday, December 12

13:20 - 14:35 **Reception Hall 2**

LCT1: Liquid Crystal Alignment Technology

Chair: M. Inoue, TOYOTech, USA
Co-Chair: H. Okada, Univ. Toyama, Japan

LCT1 - 1
13:20 **The Effect of Hybrid Reactive Mesogen System in Polymer-Stabilized Vertical Alignment Liquid Crystal Display**

H. Wei, Q. Li, T.-J. Tseng, C.-C. Hsieh, C.-Y. Chiu, H.-C. Lin
Shenzhen China Star Optoelect. Tech., China

In this paper, we have studied the process and reliability properties of hybrid reactive mesogen (RM) system in PSVA LC, factors affecting the small breaking point (SBP), LC alignment and reliability were found, with a series of attempts. This paper shares some of our experience during our exploration.

LCT1 - 2
13:40 **Fabrication of a Polymer-Stabilized Liquid Crystal Cell through Low-Temperature UV Curing Process for Control of Haze Value**

B.-G. Jeon, T.-H. Choi, S.-M. Do, T.-H. Yoon
Pusan Nat. Univ., Korea

We investigated the effects of the curing temperature on electro-optical characteristics of a polymer-stabilized liquid crystal (PSLC) cell. With low-temperature curing process, we can achieve high performance in both transparent and translucent states of a PSLC cell. In addition, we can achieve fast switching between the transparent and translucent states.

LCT1 - 3
14:00 **Image Sticking Reduction in Full-Screen LCDs with Ultra Narrow Border**

B. Chen, Y. Zeng, A. Ling, P. Shen, J. Li
Xiamen Tianma Microelect., China

In this paper, we investigated the relevant factors of Image Stick (IS) phenomenon on the full-screen LCDs. We have clarified the key point of IS phenomenon on the full-screen LCDs which is the distance of seal to active area and then the methods for reducing the IS of full-screen LCDs are discussed.

LCT1 - 4L **Azo Dye, Liquid Crystals Polymer Composite**
14:20 **Photo-Alignment Layer for Modern Liquid Crystal Displays**

C. Meng

Hong Kong Univ. of S&T, Hong Kong

In this article, two different azo dye stabilization methods were demonstrated. One is realized by two-step exposure while the other is simplified one-shot irradiation on a thin film. Various stabilization methods provide more flexibility on alignment layer preparation. Both methods offer an alignment layer with highly acceptable thermal and photo-stability.

----- Break -----

15:00 - 16:15 **Reception Hall 2**

LCT2: Novel LCD Technologies

Chair: F. Araoka, RIKEN, Japan
Co-Chair: K. Miyachi, JSR, Japan

LCT2 - 1 ***Invited*** **High Performance LCD Technology for 3D**
15:00 **Head-Up Displays**

Y. Tanaka, M. Murata, R. Yokoyama, Y. Mochizuki, T. Hosokawa, K. Ogura, Y. Yanagihara, K. Kusafuka, T. Matsumoto

Kyocera, Japan

We achieved high transmittance and high contrast with keeping high response speed by using high aperture ratio technology and high efficiency liquid crystal. Transmittance is improved by 153% from initial mass production by using this technology. We have implemented this new liquid crystal technology for 3D-HUD with parallax barrier.

LCT2 - 2 ***Invited*** **Fast Switching LC Device and Directional**
15:20 **Beam Splitter Array for 3D Display**

J. Lu

Shanghai Jiao Tong Univ., China

A 2D/3D switchable display with novel structure Fresnel-type LC lens is proposed which may achieve low cross-talk. And a scanning type 3D display with impulsive driving collimate backlight is proposed to solve the problems resolution degradation and dynamic crosstalk whose BPLC scanning prism was demonstrated with an impulsive blinking backlight.

LCT2 - 3
15:40

Invited **Modern Display Applications Based on ESH Ferroelectric Liquid Crystals**

A. K. Srivastava, L. Shi, H.-S. Kwok
Hong Kong Univ. of S&T, Hong Kong

By leveraging the potential of the photo-alignment and ESHFLCs, we developed the field sequential color displays for micro-displays and TFT pane, which are characterized by the less power consumption, high contrast ratio, and fast response time. Thus displays could find applications in a variety of modern devices.

Also presented in Innovative Demonstration Session (see p. 232)

LCT2 - 4L
16:00

Driving Experiment of Ferroelectric Liquid Crystal Using 1-μm-pitch Stripe Electrodes for Holographic Displays

Y. Isomae[,**], Y. Shibata[*], T. Ishinabe[*], H. Fujikake[*]*
[*]Tohoku Univ., Japan
[**]JSPS., Japan

We evaluated light modulation of ferroelectric liquid crystal (FLC) in 1-μm-pitch 1-dimensional pixels for amplitude-type spatial light modulator to realize electronic holographic displays with wide field of view. Experimental results showed that FLC can modulate light with higher modulation ratio and lower driving voltage than nematic LC.

----- Break -----

16:40 - 18:00 **Reception Hall 2**

PRJ2/LCT3: LC-Based Eye Devices

Chair: O. Akimoto, Sony Semiconductor Solutions, Japan
Co-Chair: T. Ishinabe, Tohoku Univ., Japan

PRJ2/ LCT3 - 1
16:40

Invited **Liquid Crystal Lenses for Augmented Reality**

Y.-H. Lin, Y.-J. Wang
Nat. Chiao Tung Univ., Taiwan

Optical-see-through systems are demonstrated via liquid crystal lenses for augmented reality (AR) in order to solve the challenges of vision correction and image registration. For vision correction, we show optical zoom function for reducing spatial resolution of virtual images by adjusting the magnification of virtual images at fixed spatial locations.

PRJ2/ LCT3 - 2
17:00

Design of Liquid Crystal Based Switchable Contact Lenses

D. Cuypers[,**], R. Verplancke[*,**], H. D. Smet[*,**]*
[*]imec, Belgium
[**]Ghent Univ., Belgium

Switchable liquid crystal based Fresnel lenses fabricated on thin, semi-flexible foils are introduced and discussed, focusing on manufacturability and practical usefulness. The design options are reviewed and commented on.

PRJ2/ LCT3 - 3 17:20 **Liquid Crystal Displays Compatible with Contact Lenses for Vision Correction Applications**

A. V. Quintero, P. Pérez-Merino, R. Verplancke, J. Vanfleteren, H. D. Smet*

Ghent Univ., Belgium
**Fundación Jiménez Díaz, Spain*

This paper presents the measurements of light transmission and spectral radiance of guest-host liquid crystal cells compatible with contact lenses for vision correction applications. From these measurements a contrast of 1:2 was calculated and its optical quality was qualitatively compared to ND filters (1:3 contrast).

PRJ2/ LCT3 - 4 17:40 **Applications of Liquid Crystal Lens with Focal Length Variable from Negative to Positive Values**

J. Gao, J. L. Yeh, J. W. Pan, S. C. Jeng

Nat. Chiao Tung Univ., Taiwan

DFLC lens can be controlled between positive lens and negative lens by changing the driving frequency. Depending on the driving frequency, the LC directors align either toward the homeotropic state (perpendicular to the substrate) or toward the planar state (parallel to the substrate). The LC lens can be applied for AR/VR applications.

Author Interviews
18:10 – 18:40

Thursday, December 13

9:00 - 10:35 **Reception Hall 2**

LCT4/FMC4: New Materials and Components for LCDs

Chair: S. Oka, Japan Display, Japan
Co-Chair: R. Yamaguchi, Akita Univ., Japan

LCT4/ FMC4 - 1 9:00 ***Invited*** **The Application of Quantum Dot in TV Display Technology**

N. Chen, H. Ji, H. Xu, Z. Li, L. Liang

TCL Elect. Holdings, China

This paper discusses the important role of quantum dot technology in TV industry. Based on the analysis of the development trend and characteristics of quantum dot materials used in TV display technology, the engineering issues and challenges in the field of quantum dot technology are discussed in this paper.

LCT4/ FMC4 - 2 9:20 ***Invited*** **Cholesteric Liquid Crystals as Solution-Processable Holographic Optical Elements**

H. Yoshida[,**], S. Cho[*], M. Ono[*], Y. Tsuboi[*], Z. Fan[*], M. Ozaki[*]*

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

Cholesteric LCs can be used as holographic optical elements (HOEs) with functions defined by the orientation pattern on the supporting substrate. By using reactive mesogens, it is possible to make free-standing HOE films by solution processing.

LCT4/ FMC4 - 3 9:40 **Novel Black Photo Spacer Structure Applied in Liquid Crystal Display Technology**

W. Cao, M. Liu, Z. Deng, Y. Lin, C. Chiu, L. Ray

Shenzhen China Star Optoelect. Tech., China

Here gray tone-like mask was applied on color filter layer to carry out height difference between the predefined patterns, followed by black photo spacer film coating. Therefore mainPS and subPS were obtained respectively. A 28-in. HD LCD Module with inorganic passivation layer was demonstrated with good optical performance finally.

LCT4/ FMC4 - 4 10:00 **New Reflective Polarizer Film for Automotive e-Mirror Application**

H. Matsuda, K. Toyooka, M. Kugue[*]

3M Japan Prods., Japan
[*]3M Japan, Japan

Recently, automotive electrification is a technical trend, and the e-Mirror which can switch between display and mirror mode, is one of them. The reflective polarizer is a component utilized to improve the e-Mirror performance, so 3M has developed a new reflective polarizer film which can meet automotive mirror requirements.

LCT4/ FMC4 - 5L 10:20 **New Architecture of QD-on-Chip Encapsulation System**

M. Uchida, K. Yoshida, H. Minamisawa, T. Masukawa, A. Miyanaga[*], A. Moriyasu[*], H. Nishikawa[*], K. Iida[*], M. Saeki[*], J. Kaneno[*]

JNC Petrochem., Japan
[*]NS Materials, Japan

It has taken a long time since QD-on-Chip device could be allegedly a candidate of excellent color coordinate display. However, no one has been able to realize it because of low reliability of emission layer with QD. This report shows a possible solution from the view point of encapsulation system.

Author Interviews
10:40 – 11:10

10:40 - 13:10 **Event Hall**

Poster LCTp1: High Reliability

LCTp1 - 1 **Analysis of LCDs Vibration Mura for Automotive Applications**

Q. Feng, Z. Hu, S. Xu, L. Yu*, G. Lv*

Hefei Univ. of Tech., China
**Wuhu Token Sci., China*

Vibration Mura happens on automotive LCDs. The paper tries to put forward a method to analyze vibration Mura. Based on such method, some vibration-related factors on optical performance of a bonding LCD are analyzed. It is suggested to choose thicker bonding glass and softer anti-vibration foam to resist vibration Mura.

LCTp1 - 2 **The Investigation and Analysis on the Lower Limit of LCDs Liquid Crystal Margin**

Y. Hasio, X. Xu, P. Zhang, H. Shu, Z. Wang, D. Shao , G. Tang, C. Chen

Shenzhen China Star Optoelect. Tech., China

In this paper, we analyze the mechanism of the lower limit of liquid crystal (LC) margin of LCD. Several factors that influence the lower limit of LC margin are investigated. A series of simulation experiments are carried out to figure out the extent of each factor's impact.

LCTp1 - 3 **Withdrawn**

LCTp1 - 4 **Analysis of TFT-LCD Ink-Jet-Printing Mura Mechanism**

F. Yuan, Y. Zhao, Y. Song, C.-C. Hsieh, C.-Y. Chiu

Shenzhen China Star Optoelect. Tech., China

IJP (Ink-Jet-Printing) mura is a common defect in TFT-LCD display manufacturing. In this paper, the influence of PI (polyimide) film thickness and via hole structure design on IJP mura risk for LCD panels is studied. With a new Via hole design, IJP mura ratio reduced and the total yield rate risen significantly.

LCTp1 - 5 **Withdrawn**

LCTp1 - 6L **Novel Viewpoints on Image-Sticking Caused by Residual DC Voltage in FFS Mode LCDs**

D. Inoue, T. Miyake, M. Sugimoto

Tianma Japan, Japan

We discuss the image-sticking problem caused by residual DC voltage from the viewpoints of the DC offset-transmittance (D-T) property varying like a quadratic function and the just noticeable difference of brightness at each gray level. The flexoelectric effect affects the image-sticking because it changes the bottom position of D-T property.

LCTp1 - 7L **A Study on the Composition Analysis and Image Improvement of Organic Alignment layers for TFT-LCDs**

H. Song, P. Jung

LG Display, Korea

Various alignment layers of the hybrid type (phase separation to upper and lower) were applied to improve the image quality of TFT-LCDs. To characterize them with considering the image quality, it is necessary to analyze the compositional distribution of the mixture.

LCTp1 - 8L **Gaussian Fitting Analysis of Transient Current Waveform Caused by Ionic Impurities in LC-Cell**

T. Miyake, D. Inoue, M. Sugimoto

Tianma Japan, Japan

We analyzed the transient current waveform of a liquid crystal (LC)-cell after back light stress and found that the waveform of an LC-cell using negative-type LCs can be separated into multiple waveforms with different mobility. We also calculated the ion density, mobility, and radius from the separated transient current waveform.

LCTp1 - 9L **Ameliorated Method in Measuring Flexoelectric Coefficient $e_{11}+e_{33}$ by Means of Symmetric Oblique Incident Transmission Ellipsometry**

M. Kimura, T. Onishi, R. Sawara

Nagaoka Univ. of Tech., Japan

Ameliorated method in measuring the sum two flexoelectric coefficient ($e_{11}+e_{33}$) by means of symmetric oblique incident transmission ellipsometry is demonstrated. Two alignment regions are fabricated in one cell of nematic liquid crystal, in which fundamental device parameters and $e_{11}+e_{33}$ are estimated separately by numerical fitting procedure for phase difference D.

10:40 - 13:10 **Event Hall**

Poster LCTp2: Liquid Crystal Alignment Technology

LCTp2 - 1 **Withdrawn**

LCTp2 - 2 **Withdrawn**

LCTp2 - 3 **Withdrawn**

LCTp2 - 4L **Thresholdless Electro-Optical Properties in Homogeneous and Homeotropic Liquid Crystal Cells**

R. Yamaguchi

Akita Univ., Japan

Hybrid aligned cells were designed using strong and weak polar anchoring surfaces and the LC director distribution was numerically analyzed. When the anchoring is a critical one, LCs align homogeneously or homeotropicly. Such cells have no threshold voltage LCs reorient homeotropicly or homogeneously with very low driving voltage, respectively.

LCTp2 - 5L **A Novel Reactive Monomer for Polymer Sustained Alignment LCD**

M. Gushiken, Y. Aoki, M. Horiguchi, Y. Inoue

DIC, Japan

For Polymer Sustained Alignment LCD, we report a novel reactive monomer with higher reactivity and reliability than previously reported monomers. The novel monomer shortens the polymerization time, and so improves the productivity of LCD panels. In addition, the monomer could be used in applications utilizing highly-luminant backlight.

10:40 - 13:10 **Event Hall**

Poster LCTp3: High Image Quality

LCTp3 - 1 **Withdrawn**

LCTp3 - 2 **Enhancement of Color Gamut Using New Advanced Phosphors in Nano IPS**

J. Choi, Y. Park, K. Kim, J. Shin, D.-J. Lee, J. Park

LG Display, Korea

Nano IPS using new advanced phosphors is fully covered DCI–P3 color space. The advanced phosphors are impressively helpful to reduce the mixed color area between red and green. This technology improves color gamut by expanding green color and red color.

LCTp3 - 3 **Study of Optimized Design to Achieve Wide-Viewing Performance for Automotive Displays**

C. C. Huang, W. T. Liao, Y. C. Liu, Y. C. Lai, Y. L. Cheng, H. P. Chiu

Chunghwa Picture Tubes, Taiwan

In order to enhance the wide view angle of the vehicle display, utilized transverse of chevron-type ITO, rear polarizer with compensation film and ACLF BL, such an optimized design can improve the viewing angle at mechanical rubbing, and almost achieved the requirements of most OEM 5.0 specifications.

LCTp3 - 4 Research on White Stains Failure Analysis Simulation with ADS LCD

S. Yuan, X. Liu, Y. Chen, M. Wang, C. Wu, Z. Zheng, R. Zhang, Y. Sun, Y. Ma, X. Zheng

BOE Display Tech., China

10.1WU has white stains, which affect the quality of product seriously. According to failure analysis, some novel pixel structures are designed and their simulations are run by TechWiz 3D software. Based on the simulation results, the best choice will be used to minimize the white stains defect ratio of 10.1WU.

LCTp3 - 5 Withdrawn

LCTp3 - 6 Research the Effect of Different Circular Polarizers on Reflective LCDs

Y. Chen, X. Liu, M. Wang, S. Yuan, Y. Ma, C. Wu, Z. Zheng, R. Zhang, Y. Sun, J. Chen

Beijing BOE Display Tech., China

In this paper, the effect of three types of circular polarizer on reflective liquid crystal displays (LCDs) was researched. The results show that the type of circular polarizer has little effect on color gamut. The type with higher reflectance has lower contrast ratio, and the reason is analyzed.

LCTp3 - 7 Effect of Low Pre-Tilt Angle on Transmittance in Photo Aligned Vertical LCDs

W. Gao, Z. Liu, G. Ma, J. Xuan, H. Zhao, C. Zhu, F. He, B. Gu

Nanjing CEC Panda FPD Tech., China

The width of the disclination of the photo-aligned VA-LCD, which appears as a dark line under the crossed polarizer, depends on the pre-tilt angle. At low pre-tilt angles, mass production panels demonstrated that the dark line became thinner, transmittance was high, and there was no problem of image sticking.

LCTp3 - 8L Fabrication of Axis-Symmetric Alignment Using Substrate Surface Structure for Twisted-VA mode LCDs

Y. Kuge, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

We fabricated a mortar-shaped surface structure using an ultraviolet pattern exposure technique to realize twisted vertical alignment (TVA) mode reflective liquid crystal devices (LCDs) with rapid switching speed. We demonstrated that the mortar-shaped structure enables axis-symmetric LC alignment in TVA-mode LCDs.

10:40 - 13:10 **Event Hall**

Poster LCTp4: Novel LCD Technology

LCTp4 - 1 **Peripheral Liquid Crystal Efficiency in Pixel of Vertical Alignment Display**

K. Qu, S. Hao, Z. Liu, Y. Fan, Z. Cao, M. Zhu

Shenzhen China Star Optoelect. Tech., China

We studied the peripheral liquid crystal efficiency of pixel of vertical alignment display. Structures open edge and close edge are discussed. According to our study, open edge without PFA process can obtain high liquid crystal efficiency, while close edge needs PFA process to obtain high liquid crystal efficiency.

LCTp4 - 2 **Color Polymer-Dispersed Liquid Crystal Displays by Mean of Photo-Polymerization Method**

G. H. Kim, W.-J. Lee, C.-S. Hwang

ETRI, Korea

A color PDLCDs doped with dye molecules selectively are developed by using photo-polymerization reaction. These obtained devices did not show changes in power-off transmittance and power-on transmittance, and operation speed over a wide temperature range (-20 ~ 60°C).

LCTp4 - 3 **Reduction of Driving Voltage of Reverse-Mode LC Light-Scattering Device by Incorporating UV Curable Silica NPs**

E. Fukuda, M. Akimoto, S. Kobayashi, M. Miyazaki

Sanyo-Onoda City Univ., Japan

Electro-optical properties of a reverse-mode PDLC film based on reactive mesongens implemented with UV curable silica nanoparticles and UV curable monomers are investigated. It is found that the threshold and working voltage of this hybridized scattering-type LCD are reduced but the contrast ratio is decreased.

LCTp4 - 4 **Effect of UV Irradiation on Bandwidth of Selective Transmittance Spectra in Polymer Stabilized Cholesteric Liquid Crystals**

A. Ogiwara, H. Kakiuchida[*]

Kobe City College of Tech., Japan
[*]*AIST, Japan*

Optical tunable properties for basis of smart windows are investigated at infrared wavelength in solar ray using polymer stabilized cholesteric liquid crystals (PSCLCs) formed by different UV irradiation conditions. The experimental results show that the bandwidth of selective transmittance spectra in PSCLCs is controllable by UV irradiation for polymerization.

LCTp4 - 5 Memory Properties of Silica-Dispersed LCDs

C.-L. Lee, S.-C. Jeng

Nat. Chiao Tung Univ., Taiwan

Silica-dispersed liquid crystals have been demonstrated with the memory effect, and it depends on the surface modification, concentration, driving voltage and driving frequency. The mechanism of driving frequency-dependent memory effect is not clear. We show the frequency-dependent dielectrophoresis force plays an important role for the property.

LCTp4 - 6 An Anti-Aliasing Design for Full Screen Display of Rounded Corner

B. Zheng, Y. Yang, Y. Zeng, L. Wu, P. Shen, J. Li

Xiamen Tianma Microelect., China

An anti-aliasing algorithm of rounded corner for full screen display was proposed based on the principle of equal brightness in spatial domain. And a smooth rounded boundary utilizing an anti-aliasing design could be obtained from three examples of driving voltage, the AR of CF and the length of pixel electrode.

LCTp4 - 7 Analysis of Vertical Moiré-Like Phenomenon of a Half-Source-Driving Liquid Crystal Display

Z. Li, B. Han, H. Chang, C. Wu, H. Wang, J. Gao, M. Shi, Z. Chen, R. Lu

Chongqing HKC Optoelect. Tech., China

We present a new method of analyzing Vertical Moiré-like phenomenon on LCD. We have first categorized the main factors of the Vertical Moiré-like phenomenon and then analyzed how to judge whether each factor does work. Finally, we proposed a method to optimize timing code to relieve the phenomenon.

LCTp4 - 8 Novel RGBW Color System with White Incorporated in Subpixels

Z. Jiang, H. Xu, T. Ou, C. Liu, C. Su, C. Lee

Shenzhen China Star Optoelect. Tech., China

In this paper, we propose a novel RGBW color system with the W pixels incorporated in the RGB subpixels. With W pixel incorporated in Blue subpixel, the transmittance can be increased by 4.6% while the resolution is maintained and no complex algorithm is required for the IC design.

LCTp4 - 9 Withdrawn

LCTp4 - 10 **Dye-Doped Chiral-Nematic Liquid Crystals with Enhanced Opaque State**

S.-H. Kim, S.-W. Oh, T.-H. Yoon

Pusan Nat. Univ., Korea

We demonstrate that hybrid anchoring of dye-doped chiral-nematic liquid crystals (CNLCs) could be used for the simultaneous control of the haze and transmittance. To avoid degradation of dichroic dyes, we propose a dye-doped CNLC cell using alignment layers instead of polymer structures.

LCTp4 - 11 **The Novel TN LCD of the Lowest Driving Voltage**

K. Takatoh, I. Watanabe, Y. Yonezawa, K. Goda

Sanyo-Onoda City Univ., Japan

The LCD of low driving voltage called Stabilized Reverse TN (RTN) mode has been developed. By polymer matrix formation in the vicinity of alignment layer, twist direction of azimuthal angle is fixed. The authors believe that the LCDs of the lowest driving voltage could be realized by this mode.

LCTp4 - 12 **Switching of an LC Mixture without Ion Dopants Between Transparent and Translucent States by the Electro-Hydrodynamic Effect**

Y.-S. Jo, T.-H. Choi, J.-W. Huh, S.-M. Ji, S.-M. Nam, T.-H. Yoon

Pusan Nat. Univ., Korea

We observed dynamic scattering in an LC mixture without ionic dopants. Random orientation of nematic (N) LCs is maintained via the rotation of SmC^* LCs, which resulted in a high-haze translucent state. The SmC^*/N-LC mixture exhibited a very high haze in the translucent state while maintaining the haze-free transparent state.

LCTp4 - 13 **Withdrawn**

LCTp4 - 14L **Proposal of Energy-Harvesting Liquid Crystal Displays**

M. Shigeta, I. Fujieda, Y. Tsutsumi

Ritsumeikan Univ., Japan

One can harvest energy from ambient light by incorporating the idea of a luminescent solar concentrator in a liquid crystal display. An external configuration would have a higher power harvesting efficiency while an in-cell configuration would offer advantages of compactness and image resolution.

LCTp4 - 15L **Design of a Liquid Crystal Device Suitable for Automotive Smart Windows**

S.-J. Lee[*], S.-Y. Eom[*], D.-S. Yoon[**], H.-S. Yang[*], E.-J. Kim[*], H.-S. Yoo[**], S.-B. Kwon[,**]*

[*]Hoseo Univ., Korea
[**]NDIS, Korea

We developed a liquid crystal device with gray off-state transmittance and the viewing angle characteristics suitable for automotive smart window, providing low power consumption and most effective shading of sunlight. The design method of the device and the electro-optical properties of the device so designed are presented.

Also presented in Innovative Demonstration Session (see p. 232)

LCTp4 - 16L **Effect of LC Flow Orientation to Capacitance Change for Highly-Sensitive Flexible Pressure Sensors**

N. Fukunaga, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

In this study, we proposed the novel pressure sensing devices utilizing flow orientation of a nematic-phase liquid crystal as a pressure sensitive layer. We clarified that the optimized vertically-aligned liquid crystal cell exhibited relative larger capacitance change with the applied pressure of about 200 Pa.

14:20 - 16:50 **Event Hall**

Poster **FLXp2/LCTp5: Flexible LCD Technologies**

FLXp2/ LCTp5 - 1L **Evaluation of Holding Effect of Cell Gap in Curved Flexible LCDs with Polymer Spacers**

S. Takahashi, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

We evaluated a holding effect of cell gap in flexible LCDs by measuring wavelength-dependent phase retardation of LCDs in curved and non-curved states. As a result, we clarified a combination of lattice shaped polymer spacers and post shaped photo spacers can realize high-quality flexible LCDs with small radius of curvature.

FLXp2/ LCTp5 - 2L **Evaluation of Mechanical Durability and Self-Recovery Property of Liquid Crystal Gels for Stretchable Displays**

R. Saito, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

To realize stretchable liquid crystal (LC) displays, we evaluated the mechanical durability and self-recovery property of the LC-gel. The LC-gel didn't rupture under shear strain of 0.8 mm. Also, the LC-gel can be recovered from damaged state to original state by heating process, and restored its optical property.

FLXp2/ LCTp5 - 3L **Fabrication Technique of Flexible Liquid Crystal Display Using In-Plane Micro-Contact Printing Electrode**

M. Kataoka, H. Okada

Univ. of Toyama, Japan

In this research, we aimed at a display method with In-plane electrodes for LC driving using micro contact printing (μ-CP) method which enables fabrication of electrodes at low temperature and can fabricate devices on plastic substrates.

17:10 - 18:30 **Reception Hall 2**

FLX3/LCT5: Advanced Flexible Displays

Chair: M. Kimura, Nagaoka Univ. of Tech., Japan
Co-Chair: T. Eguchi, Sumitomo Bakelite, Japan

FLX3/ LCT5 - 1 17:10 ***Invited*** **Technology Advances for Flexible Transparent AMOLED and Electronics**

M.-H. Yang, Y.-T. Tsai, J.-C. Ho, S. Chiu, C.-C. Lee

ITRI, Taiwan

ITRI has developed flexible and foldable OLED display technology by its proprietary FlexUP platform technology. Furthermore, we continue to drive FlexUP to meet the requirements of flexible transparent display system and extend its application to non-display filed like fan-out panel level package, flexible system in package and flexible hybrid electronics.

FLX3/ LCT5 - 2 17:35 **6.9-in. Flexible Transparent Display Using by SALC Technology and Applications**

C. C. Chiou, C. H. Chen, J. T. Lian

Chunghwa Picture Tubes, Taiwan

In this paper, Chunghwa Picture Tubes(CPT) of the flexible transparent display was using by Surface Anchoring Liquid Crystal (SALC) technology can achieve high transparent and excellent contrast ratio. In addition, CPT also developed flexible substrate to make the Flexible Transparent Display.

FLX3/ LCT5 - 3 17:55 **The Research and Design of Transparency Hole Screen**

X. Zhou, G. Lai, H. Wu, H. Zhou, J. Liu, X. Yang, X. Lan, Y. Yang, P. Shen, J. Li

Xiamen Tianma Microelect., China

Opening camera holes in the screen has become a solution to higher screen-to-body ratio. The openings in the screen will encounter a series of problems such as vertical crosstalk, RA, and Process Issue. Tianma developed a transparency hole screen which screen-to-body ratio could up to 90%.

FLX3/ LCT5 - 4L 18:15 **Formation Mechanism of Polymer Layered Structure in Polymer-Dispersed LCs with Anisotropic UV Irradiation**

Y. Horii, T. Ishinabe, Y. Shibata, H. Fujikake

Tohoku Univ., Japan

We investigated the formation mechanism of polymer layered structure in polymer-dispersed liquid crystals, to precisely control the light diffusion distribution. Micro-convex structures on the substrate surface produced an uneven ultraviolet illuminance distribution in the LC–monomer mixture. The monomer was polymerized selectively at the positions where ultraviolet illuminance was high.

Author Interviews
18:40 – 19:10

Friday, December 14

10:40 - 11:40 **Room 131**

LCT6: Wide Color Gamut LCDs
Special Topics of Interest on Wide Color Gamut and Color Reproduction

Chair: S. Shibahara, Sony Visual Products, Japan
Co-Chair: S. Kawasaki, JNC Korea, Korea

LCT6 - 1 10:40 ***Invited*** **Applications of Wide Color Gamut (WCG) Technology in Display**

M. S. Kwak, Y. H. Kim, S. H. Han, A. K. Kim, S. I. Kim, M. Jun, I. B. Kang

LG Display, Korea

In the development of display product, color colorant is one of the indispensable technologies to implement. The WCG standard has been widely defined for each product, and various researches for increasing the color reproduction ratio are required. We will introduce the importance of color colorant materials in developing future WCG.

LCT6 - 2 11:00 ***Invited*** **Sunlight Readable FFS LCD with High Contrast Ratio and Wide Color Gamut Under High Ambient Light Situations**

Y. Kawahira, K. Murata, T. Nakai, M. Hasegawa, A. Sakai, K. Minoura, N. Smith[*]

Sharp, Japan
[*]Sharp Labs. of Europe, UK

A novel wide-view LCD with reduced unwanted reflection has been developed to enhance ambient contrast ratio. By combining an FFS-based new LC mode with a circular polarizer, our 3.2-in. prototype has successfully demonstrated high contrast ratio and wide color gamut in high ambient light situations without boosting the backlight brightness.

LCT6 - 3 11:20 **Analyzing and Improving the Bluish Issue at VA Dark State**

C. Chen, Y. Wang, Y. Lin, B. Hai, Y. Hsiao

Shenzhen China Star Optoelect. Tech., China

The bluish issue in VA dark state when the ambient light is low, like movie mode, and it will be easy to be inspected. In this paper we analyzed the factor of bluish issue at dark state firstly, then we provided the solution to improve the issue.

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:30 **Reception Hall 2**

LCT7: Liquid Crystal Phase Shifter

Chair: K. Miyachi, JSR, Japan
Co-Chair: H. Yoshida, Osaka Univ., Japan

LCT7 - 1 13:10 ***Invited*** **Liquid Crystal Based Tunable Antenna Systems**

H. Maune, M. Jost, R. Reese, M. Nickel, E. Polat, R. Jakoby

Darmstadt Univ. of Tech., Germany

During the last decade, liquid crystals (LC), well known from the display technology, have become increasingly popular in the field of microwave engineering. There are many different technologies available for the realization of components for reconfigurable systems. This paper gives an overview on the recent development in LC-based microwave components.

LCT7 - 2 13:30 ***Invited*** **Structurally Simplified LC Millimeter-Wave Phase Shifter Based on Microstrip Line**

T. Nose, K. Iiyama, M. Masaka[*]*, K. Ito*[*]*, R. Ito, M. Honma*

Akita Pref. Univ., Japan
[*]*Yurikogyo, Japan*

LC phase shifter working in millimeter-wave region is investigated by adopting simple device structure based on the microstrip line, which is common planar waveguide for high-frequency circuits. Since the device doesn't need any extra parts for LC materials integration, it becomes easier to fabricate and the device loss is improved.

LCT7 - 3 *Invited* **Microwave, Milliwave and Terahertz Wave**
13:50 **Phase Shifter Using LC-Loaded Transmission Line**

H. Moritake, V. B. Bui, Y. Inoue
Nat. Defense Ac., Japan

We introduce two types of phase shifters using liquid crystal (LC)-loaded microstrip line and coplanar waveguide, and improvement method of the response time is discussed. Furthermore, property of Terahertz phase shifter using LC-loaded non-radiative dielectric (NRD) waveguide is also discussed.

LCT7 - 4 **A High-Efficiency Beam Steering LCoS Device**
14:10

C. Sun, S. Zha, J. Lu
Shanghai Jiao Tong Univ., China

A liquid crystal on silicon (LCoS) device with high diffraction efficiency, more than 59.4% at the deflection angle of 4.5° at 1550 nm, is achieved by using the high-phase retardation modulation method. With the multi-pixel driving, LCoS may get high precision angular deflection, less than 0.004°.

----- Break -----

14:50 - 16:10 **Reception Hall 2**

LCT8: Liquid Crystal Applications

Chair: T. Nose, Akita Pref. Univ., Japan
Co-Chair: H. Moritake, Nat. Defense Ac., Japan

LCT8 - 1 **Reflective Color Liquid Crystal Display Using a**
14:50 **Guided-Mode Resonator Grating as a Reflector**

C.-T. Wang, P.-C. Chang, J.-J. Lin, Y.-J. Hung, T.-H. Lin
Nat. Sun Yat-Sen Univ., Taiwan

This work demonstrates a reflective color display using a color reflector hybrid with the tunable 90° twisted nematic liquid crystal (TNLC). The color reflector based on a guided-mode resonator grating structure reflects strongly at the resonance wavelength, and a 90° TNLC is used to control the intensity of reflection.

LCT8 - 2 **10.1-in. Active-Matrix Reflective Display by Using**
15:10 **Proprietary Surface Anchoring Liquid Crystal and High Performance Front-Light Module**

T.-L. Lin, C.-H. Chen, J.-T. Lian
Chunghwa Picture Tubes, Taiwan

We have succeeded to develop 10.1-in. reflective display by using surface anchoring liquid crystal technology and high performance front light module. The reflective display shows outstanding performance. In addition, the 10.1-in. reflective display have lots of advantages, such as polarizer free, environment friendly, driving voltage satisfied with active-matrix TFT.

LCT8 - 3
15:30

Polarization-Selective Multi-Wavelength Bragg Diffractions Using Slanted Holographic Polymer Dispersed Liquid Crystals

H. Kakiuchida, A. Ogiwara[*]

AIST, Japan
[*]Kobe City College of Tech., Japan

We developed slanted HPDLCs producing multiple Bragg diffractions with different polarizations for every angle of incidence. The fabrications were achieved by photo-polymerization induced phase separation (PPIPS) by one-step interferential exposure. The Bragg diffractions were analyzed separately from Raman-Nath ones by slanting periodic structures of the HPDLCs.

LCT8 - 4
15:50

A Model for the Formation of Mura During the One-Drop-Filling Process

J. R. L. Cousins, S. K. Wilson, N. J. Mottram, D. Wilkes[*], L. Weegels[*], K. Y. Lin[**]

Univ. of Strathclyde, UK
[*]Merck KGaA, Germany
[**]Merck PM, Taiwan

The One-Drop-Filling (ODF) process for manufacturing liquid crystal cells can lead to alignment defects called ODF mura. We propose a theoretical model for the coalescence of droplets and elastic/inelastic deformation to the director structure during ODF to provide insight into the formation of ODF mura.

Author Interviews
16:20 – 16:50

Workshop on Active Matrix Displays

Wednesday, December 12

13:20 - 14:35 **Reception Hall 1**

AMD1: 8K Display

Chair: K. Nomoto, Sony, Japan
Co-Chair: K. Omoto, Apple, Japan

AMD1 - 1 ***Invited*** **8K Super Hi-Vision Broadcasting**
13:20 **and Related Display Technologies**

H. Tsuji

NHK, Japan

Regular satellite broadcasting service of 4K/8K Super Hi-Vision started on December 1, 2018. In this paper, we outline the image and audio features of 8K broadcasting and describe our recent work on the development of basic technologies for large-sized 8K flexible displays.

AMD1 - 2 ***Invited*** **The World's First 85-in. 8K x 4K 120 Hz**
13:45 **VA-LCD Driven by BCE IGZO GOA**

L.-Q. Shi, Y.-F. Chou, Y.-C. Zhao, S.-J. Chen, F. Zhao, S.-M. Ge, Z.-J. Kong, F.-C. Xu, P. Du, C.-Y. Chiu, R. Lin

Shenzhen China Star Optoelect. Semiconductor Display Tech., China

An 85-in. 8K4K 120 Hz VA-LCD was successfully developed. BCE IGZO GOA was adopted for gate driving to fulfill the slim border and cost reduction requirement. It is so far the largest and high super resolution, and ultra-high refresh rate in the world.

AMD1 - 3 ***Invited*** **Current Status and Future Technology**
14:10 **for Large-Screen 8K IGZO Display**

H. Kitagawa, Y. Hara, Y. Iwase, T. Kikuchi, J. Morinaga, H. Ohgami, H. Imai, T. Daitoh

Sharp, Japan

In this paper, we report the development of the latest IGZO-TFT (IGZO5) and low resistance wiring technologies for a large-screen 80-in. 8K display with 120 Hz driving and single data-line structure with no center split.

----- Break -----

15:00 - 16:10 **Reception Hall 1**

AMD2: Active-Matrix Micro-LED Display

Chair: M. Inoue, Huawei Techs. Japan, Japan
Co-Chair: H. Hamada, Kinki Univ., Japan

AMD2 - 1 **Withdrawn**

AMD2 - 4L ***Invited*** **Pixel Grouping Micro-LED Module**
15:00 **Based on Digital Electro-Optics Platform**

C.-Y. Shieh, J. Yue, T. Lin, K. Tai

Jasper Display, Taiwan

JDC has successfully demonstrated that Micro LED module based on Digital Electro-optics Platform. According to X-on-Silicon technology roadmap, Micro LED module was applied in lighting, display, and automotive light source. Micro LED module benefit compared to conventional LCD and OLED, renders higher contrast ratio, brighter, and much faster response time.

AMD2 - 2 ***Invited*** **Device Structure and Manufacturing Process**
15:25 **for Highly Flexible Micro-LED Display**

K. Kajiyama, Y. Suzuki, T. Hirano, Y. Yanagawa, K. Fukaya, N. Okura, A. Shimoura

V-Tech., Japan

We report the manufacturing process and equipment used for micro-light-emitting diode (LED) displays that can be applied to mass production. The new technologies involve Laser Lift Off, reconstitution and color conversion. When these technologies are combined, it makes mass production of micro-LED displays possible.

AMD2 - 3 **A New Compensation Pixel Circuit for AMLED**
15:50 **with a-IGZO TFTs**

Y. Su, D. Geng, Y. Gong[*]*, X. Shi, C. Lu, N. Lu, L. Li, M. Liu*

Univ. of Chinese Ac. of Sci., China
[*]*Shandong Univ., China*

We present a new active-matrix micro-pixelated light-emitting diode (AMLED) pixel circuit based on amorphous indium-gallium-zinc-oxide thin-film transistors (a-IGZO TFTs). The proposed circuit compensates the threshold voltage (V_{th}) shifts of driving TFT. The simulation results reveal the relative current error rate is below 1.07% under the V_{th} deviation of 1 V.

Author Interviews
18:10 – 18:40

Thursday, December 13

9:00 - 9:50 **Reception Hall 1**

AMD3: Advanced Process OTFT

Chair: T. Okamoto, Univ. of Tokyo, Japan
Co-Chair: Y. Fujisaki, NHK, Japan

AMD3 - 1 **Withdrawn**

AMD3 - 3L ***Invited*** **Inkjet-Printed Organic Transistor Circuits**
9:00 **for Sensor Applications**

H. Matsui, R. Shiwaku, K. Nagamine, S. Tokito
Yamagata Univ., Japan

Inkjet-printed organic thin-film transistors (OTFTs) and integrated circuits for sensor applications are demonstrated. The OTFTs exhibit textbook properties such as highly-linear transfer characteristics, small threshold voltage, small hysteresis, and small subthreshold swing. The printed inverters operate at low supply voltages down to 0.3 V, and are applicable to biosensor applications.

AMD3 - 2 ***Invited*** **Industrialisation of OLCD: Manufacturing**
9:25 **and Performance Attributes of OTFT-Based LCDs**

P. Cain
FlexEnable, UK

As OLCD is moving into mass production, we describe key elements of the OTFT process, equipment requirements and particular processing attributes of low temperature OTFT production, such as a unique and simple substrate handling technique, much of which is a direct result of the low temperature processing requirements of OTFT.

Author Interviews
10:40 – 11:10

10:40 - 13:10 **Event Hall**

Poster AMDp1: Oxide TFTs

Special Topics of Interest on Oxide-Semiconductor TFT

AMDp1 - 1 **Organic Passivation Layer in Back-Channel-Etch Amorphous InGaZnO Thin Film Transistor with Color Filter on Array Structure for Large Size High Resolution Display Application**

G. T. Li[,**], W. Wu[**], F. Zhu[**], J. J. Liu[**], Y. H. Meng[**], S. Li[**], H. Zhou[*]*

[*]Peking Univ., China
[**]Shenzhen China Star Optoelect. Tech., China

We improved the NBTS stability of BCE a-IGZO TFT with COA structure by using organic PV2 layer, which is attributed to less residual H_2O molecule in the device resulting from high vapor penetration of organic PV2. We also optimized PV1 deposition condition to achieve good PBTS stability and uniformity.

AMDp1 - 2 **Detecting Thickness of Accumulation Layer in a-IGZO Thin Film Transistors by Kelvin Probe Force Microscopy**

X. Shi[,**], C. Lu[*], D. Geng[*], N. Lu[*], J. Wang[*], L. Li[*], M. Liu[*]*

[*]Chinese Ac. of Sci., China
[**]Univ. of Chinese Ac. of Sci., China

The thickness of accumulated charges in a-IGZO thin film transistors was firstly directly measured by Kelvin Probe Force Microscopy. From morphology and surface potential information, it is demonstrated that: I) in subthreshold region, the accumulation layer almost keeps constant regardless of change of gate voltages, II) when the gate voltage exceed threshold, the thickness of accumulation layer firstly increases precipitously and finally reaches a situation value almost 20 nm.

AMDp1 - 3 **Highly Stable Self-Aligned Coplanar Bulk Accumulation a-IGZO TFTs Under High Temperature Bias Stress**

H. Kim, S. Lee, J. Lee, J. Jang

Kyung Hee Univ., Korea

In our study, we fabricate top-gate self-align (SA) bulk-accumulation (BA) coplanar amorphous indium-gallium-zinc oxide (a-IGZO) thin film transistors (TFTs), and evaluate the high temperature and bias stabilities. The performance of BA TFTs with SA structure shows excellent stability under the gate bias at 120°C.

AMDp1 - 4 **In-O-N Thin-film Transistors with Superior Stability**

H.-D. Kim, H.-S. Kim

Chungnam Nat. Univ., Korea

In this work, a relatively new type of semiconductor, indium oxynitride (InON) is studied by experimental evaluation of thin films and TFT devices. It is demonstrated that InON films has superior air stability compared to ZnON films.

AMDp1 - 5 Comparator for Integrated Readout Circuits with a-IGZO TFTs

Y. Gong[,**], D. Geng[*], Y. Su[*], X. Shi[*], C. Lu[*], N. Lu[*], J.Chen[**], L. Li[*], M. Liu[*]*

[*]Chinese Ac. of Sci., China
[**]Shandong Univ., China

We propose an integrated comparator design based on a-IGZO TFTs. The comparator contains two amplification stages that can compare 500 mV difference between the reference and the input signal. Simulation shows that the circuit can work under a clock frequency of 100 kHz and power consumption is around 1.036 mW.

AMDp1 - 6 A Study on Degradation Mechanism of Flexible a-InGaZnO Thin Film Transistor Under Repetitive Bending Stress Using Simulation

K.-L. Han, H.-J. Jeong, B.-S. Kim, S. Oh, J.-S. Park

Hanyang Univ., Korea

We examined the degradation mechanism of the oxide TFT under repetitive bending stress. As the bending cycle accumulated, the transfer characteristics of the TFTs are degraded. We tried to interpret the cause of degradation by mapping the stress distribution under bending situation using simulation program.

AMDp1 - 7 a-IGZO TFT Gate Driver Circuit for Suppressing Ripple Voltage without Pull-Down Unit

C.Y. Park, Y.-S. Kim

Sungkyunkwan Univ., Korea

This paper proposes the gate driver circuit which is able to overcome the degradation of TFTs using additional circuit configuration instead of the pull-down unit. In addition, proposed circuit only uses two clock bus lines to realize bezel-less display and it can be applied to FHD graphics display panel.

AMDp1 - 8 High Performance In-Ga-Zn-O Thin-Film Transistors via Microwave and Electron-Beam Radiation at Room Temperature

S.-C. Jang, H.-D. Kim, H.-S. Kim

Chungnam Nat. Univ., Korea

In this work, to fabricate low temperature processed high performance amorphous InGaZnO thin film transistors (a-IGZO TFTs), microwave and electron beam annealing process were investigated. It is shown that both annealing process are suitable to replace high temperature (>300°C) annealing.

AMDp1 - 9 **Low-Temperature Processed IGTO Thin-Film Transistors with High Mobility by Reducing Deposition Pressure**

H.-A. Kim, J. O. Kim, J. S. Hur, J. K. Jeong

Hanyang Univ., Korea

We focused on the chamber-pressure (P_C) dependence on the structural and chemical properties of IGTO thin film: as the P_C decreased, the surface morphology and film density were improved, which translated to the remarkable enhancement in terms of the μ_{FE} and SS of IGTO TFTs at the low annealing temperature.

AMDp1 - 10 **IGZO TFT Gate Driver Circuit Capable of Compensating Threshold Voltage Shift for Pull-Down Unit**

J. Oh, J.-H. Kim, K.-H. Lee[*], E. S. Ha[*], K. C. Park[**], J.-H. Jeon[***], Y.-S. Kim

Sungkyunkwan Univ., Korea
[*]Gyeonggi Sci. High School, Korea
[**]Konkuk Univ., Korea
[***]Korea Aerospace Univ., Korea

This paper proposes the gate driver circuit which is able to compensate V_{TH} shift for pull-down unit. Using 4T1C circuit configuration, we can improve the reliability of pull-down unit for continuous bias stress. In addition, a simplified circuit is obtained since Q and V_{OUT} node share the same circuit configuration.

AMDp1 - 11 **Double-Layered Indium-Zinc-Oxide Thin Film Transistors with an Addition of Hydrogen Peroxide**

W. Jeon, B. Choi

Sungkyunkwan Univ., Korea

Hydrogen peroxide (H_2O_2) incorporated double-stacked indium-zinc-oxide thin-film-transistors (IZO TFTs) were fabricated and evaluated. Devices showed the enhanced electrical properties of on-off ratio, threshold voltage shift, and subthreshold swing with an incorporation of the H_2O_2 into the channel layer. Finally, superior electrical properties were achieved with the H_2O_2 incorporated double-stacked TFTs.

AMDp1 - 12 **Withdrawn**

AMDp1 - 13L **a-IGZO TFT Fabrication Using Advanced Imprint Lithography**

H. Chae, S. Kim[*], J. Cho, S. Cho

Sungkyunkwan Univ., Korea
[*]Samsung Inst. of Tech., Korea

The imprint lithography has advantage of decreased process step. This study aims to fabricate a-IGZO TFT of bottom gate-type using the advanced imprint lithography. Before the imprinting, layers were deposited on the substrate. The surface was coated with resin to make pattern. Multi-layers were dry etched using the process gas.

AMDp1 - 14L Solution-processed Metal Oxide Semiconductors Fabricated with Oxygen Radical Assisting Perchlorate Precursors through a New Reaction Route

P. Gao, L. Lan

South China Univ. of Tech., China

An innovative and simple chemical route for fabricating MO semiconducting films at relatively low temperature is demonstrated. The precursor, which consisted of perchlorate and nitrate, is easily converted into In_2O_3 at an annealing temperature of 250°C due to oxygen radical assisting decomposition and large amount of heat generation.

AMDp1 - 15L Dynamic Bipolar Pulsed DC Sputtered IGZO for Mura-Free AMOLED Backplanes

Y.-C. P. Tsai, H.-W. Chang, J. Grillmayer, A. S. Bhoolokam[*], J. B. Kim[**], D. K. Yim[**], M. Bender[*]

Applied Materials Taiwan, Taiwan
[*]Applied Materials, Germany
[**]Applied Materials, USA

Applied Materials' dynamic PVD system (New Aristo) has been developed to provide high throughput, excellent target utilization and uniform thin film performance by combining a novel rotary target technology with a continuous coating architecture. It has been optimized for stable and uniform, mura-free IGZO for large-area AMOLED backplanes.

AMDp1 - 16L Development of Rare Metal Free Al/Ga-Sn-O/Al Cell Structure Switching Resistance Memory

S. Sugisaki, A. Kurasaki, R. Tanaka, T. Matsuda, M. Kimura

Ryukoku Univ., Japan

We are developing an amorphous Ga-Sn-O (GTO) thin film for a switching resistance memory (SRM). The a-GTO SRM device was fabricated by physical vapor deposition at low temperature (150°C). The a-GTO SRM showed a bipolar switching characteristic of ON/OFF ratio (~10) with endurance (~100).

AMDp1 - 17L Withdrawn

10:40 - 13:10 **Event Hall**

Poster AMDp2: Active-Matrix Devices

AMDp2 - 1 **Corner and Binning Model Simulation of TFT for GOA Driver Circuit in G8.6 Large-Size TFT-LCDs**

Q.-H. Mo, A.-T. Cho, J. Hsu, K.-J. Liu, Justin, Y.-Q. Hu, W. Chen, Y. Lu , X.-B. Fan, Scott*, L.-F. Wu**

Chongqing HKC Optoelect. Tech., China
**Huada Empyrean Softwere, China*

In this paper, high reliable A-Si TFT gate driving circuit (GOA) was designed by combining Corner model and Binning model because that TFT compact models are key for technology innovation. In this paper, it relates modeling of process fluctuation and simulation easily optimize the W/L size for GOA drive circuit.

AMDp2 - 2 **Analysis of CMOS Inverters on AC Operation Formed by Low Temperature Poly-Silicon TFTs with Metal Source-Drain Using BLDA**

K. Lee, K. Shimai, W. Choi, T. Okada, T. Noguchi**

Nihon Synopsys, Japan
**Univ. of the Ryukyus, Japan*

Fully LTPS with metal source-drain thin-film transistor based CMOS are reported using BLDA without adopting ion-implantation for low-cost fabrication. This new TFTs satisfied barrier height and metal overlap distance possible to get sufficient gain, and high resonance frequency with seven stage Ring Oscillator formed by CMOS Inverter circuit.

AMDp2 - 3 **New Pixel Circuit with Parallel Addressing Scheme to Compensate for Variations of LTPS TFTs for AMOLED Displays**

J.-H. Chang, P.-S. Chen, C.-L. Lin

Nat. Cheng Kung Univ., Taiwan

This work proposes a new pixel circuit using parallel-addressing scheme to increase compensation time for accurately detecting threshold voltage variations of LTPS TFTs. Simulation results show that relative current error rates are below 4.44% for all gray levels, verifying the feasibility of the circuit for use in high-resolution AMOLED displays.

AMDp2 - 4 **Withdrawn**

AMDp2 - 5 **A Novel Method to Modify Over-Current Protection Threshold Current Miss Trigger Problem in Gate Driver on Array TFT-LCD**

X. Lv, S. Chen, P. Chiang, L. Zeng, J. Zhu, W. Shao, Q. Liu, S. Xi, L. Shi, Y. Chou, M. Chen, C. Chiu, R. Lin

Shenzhen China Star Optoelect. Semiconductor Display Tech., China

A novel method to modify over-current protection threshold current miss trigger problem is proposed. The temperature of GOA signal busline can be restrict using this method while GOA busline short to each other. Detailed theoretical anlysis and potential risk are disscussed. The solution were sucessfully applied to UD 120 Hz mass production TV.

AMDp2 - 6 **Pixel Circuit to Prevent Flicker Using Voltage Programming Method for AMOLED Displays**

Y.-C. Chu, L.-J. Chen, C.-L. Lin

Nat. Cheng Kung Univ., Taiwan

A pixel circuit with 4T2C structure and simulation emission driving scheme is proposed for generating three-dimensional (3D) images for high-frame-rate AMOLED displays. Proposed pixel circuit availably compensates for threshold voltage (V_{TH}) variation of LTPS-TFTs and prevent flicker phenomenon.

AMDp2 - 7 **High Performance Pentacene TFTs with a Solution Processed PMMA/AlZrO$_X$ Gate Dielectric**

K.-M. Jung, J. Oh, J. M. Kim, K. C. Park[*]*, J.-H. Jeon*[**]*, Y.-S. Kim*

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

Organic thin film transistors (OTFTs) with a solution processed hybrid gate dielectric made of PMMA/AlZrO$_X$ (ε_r = 9.2) were demonstrated. The optimized OTFTs show high output current, low threshold voltage (~ -4.4 V), and reliable leakage characteristics due to the advantages of each gate dielectric material.

AMDp2 - 8 **Collocation of Differential Circle and Film Filter on Embedded Luminance Sensor**

S.-B. Liu, J. C. Zhang, W. F. Fan, C.-T. Liao, H.-C. Lai, T.-C. Chung

InfoVision Optoelect., China

This adscititious film filter indeed increased the operating range on embedded photo sensor by lessening the light sensitivity of sensor. But the mis-convergence of output signal come with the use of differential circuit mode. This collocation of differential circle and film filter can improve the stability of electrically output signals.

AMDp2 - 9 **A New Formation of Multi-Layered n$^+$ Silicon Films Using Four-Mask Process Architecture for Image Sticking Improvement in 32-in. TV Product**

F. Y. Yang, A.-T. Cho, J. Hsu, Z. Liu, K.-J. Liu, Q.-H. Mo, W. Chen, Y. Lu

Chongqing HKC Optoelect. Tech., China

A new method of multi n$^+$ and thicker n$^+$ film were used to lower the leakage current of A-Si TFT to improve the image sticking in 4-mask process. The improvement of the leakage current and the V_{th} shift by using the multi n$^+$ and thicker n$^+$ layer will be investigated.

AMDp2 - 10 A Method to Reduce N^+ Tail in Four-Mask Process of Gen 8.6 LCDs

T. Fu, J. Hsu, J. Zhou, B. Ge, M. Li, Y. Yao, Y. Lu, W. Chen

Chongqing HKC Optoelect. Tech., China

In 4-mask process, the N^+ tail in the channel is thought to affect the transport of the carrier in the back channel. To solve this problem, we add O_2 ashing treatment during the two wet and two dry process and it works.

AMDp2 - 11L High Quality 75-in. 8K4K 120 Hz VA-LCD Driven by a-Si TFT Gate Driving Circuit

L.-Q. Shi, Y.-F. Chou, Y.-C. Zhao, X.-W. Lv, M. Wang, N. Zhang, J.-J. Yu, J.-S. Lee, W.-F. Li, X. Li, F. Zhao, Y.-X. Wang, Y.-L. Lin, H.-Y. Xu, C.-Y. Chiu, R. Lin

Shenzhen China Star Optoelect. Semiconductor Display Tech., China

75-in. 8K4K 120 Hz TFT-LCD TV driven by a-Si GOA was demonstrated. TFT Ion is optimized by 70%; metal resistance is reduced to 0.032 R/□. New HG2D driving mode is adopted to maximize pixel charging time. Novel pixel structure can enlarge AR to 41% and Tr is reached up to 3.1%.

AMDp2 - 12L Enhanced Performance of Solution-Processable Organic Floating-Gate Transistor Memories Using Binary Small Molecules Dispersed Polymer Storage Layers

H. Abe, T. Nagase, T. Kobayashi, H. Naito

Osaka Pref. Univ., Japan

We report the enhancement of the performance of solution-processable organic transistor memories with organic floating gates. Organic transistor memories with polymer:TIPS-pentacene blend storage layers containing a small amount of soluble fullerene derivatives exhibit a large memory window of 35 V and a long extrapolated retention time of $>10^9$ s.

AMDp2 - 13L The Methods to Reduce the RC Delay Issues for the Real-Time External Compensation AMOLED Circuit

C.-H. Lin, Y.-H. Tai

Nat. Chiao Tung Univ., Taiwan

In this paper, we study on the RC delay issues for the external compensation method for AMOLED circuit. Because the proposed circuit is a real-time feedback, the delayed signal and wrong sensing current may cause incorrect signal input. We propose a method of analog computer to adjust the signal delay.

AMDp2 - 14L GOA Drived 31-in. AMOLED Display with 3 mm Border

Y. Xue[,**], B. Han[**], C. Nie[**], G. Chaw[**]*

[*]Peking Univ., China

[**]Shenzhen China Star Optoelect. Semiconductor Display Tech., China

Reducing production cost and border size are the key issues for the commercialization of AMOLED displays. In this paper, a depletion-mode GOA intrgrated circuit was designed and intrdoduced for a 31-in. AMOLED display. Moreover, a novel panel structure was developed to obtain slim border with border size of 3 mm.

AMDp2 - 15L Proposal of Stable Laser Crystallization of Si Film for Flexible Panel

R. Nakatsura, Y. Ishiki, T. Okada, T. Noguchi

Univ. of the Ryukyus, Japan

We calculated temperature distribution in Si films on flexible polyimide (PI) substrate during ELA. By devising under thermal buffer layer, we found that the Si film can be effectively crystallized with a reduced pulse energy density lower than that on the glass without damaging the PI.

----- Lunch -----

17:10 - 18:00 Reception Hall 1

AMD4: High-Performance OTFT

Chair: P. Cain, FlexEnable, UK
Co-Chair: Y. Shibata, Tohoku Univ., Japan

AMD4 - 1 17:10 *Invited* Equivalent-Circuit Approach for the Interpretation of Modulus Spectra of Organic Field-Effect Transistors

H. Naito, Y. Suenaga, T. Nagase, T. Kobayashi

Osaka Pref. Univ., Japan

Complex impedance of an equivalent circuit of organic field-effect transistors (OFETs) with electrode overlap between source/drain and gate electrodes has been derived. The modulus spectra of OFETs are well reproduced in terms of the equivalent circuit, and physical quantities characterizing OFET characteristics can be determined from the modulus spectra.

AMD4 - 2 ***Invited*** **High Mobility Single-Crystalline Organic**
17:35 **Semiconductors Exhibiting Chemical and Thermally Robustness**

T. Okamoto[*,**]

[*]*Univ. of Tokyo, Japan*
[**]*JST PRESTO, Japan*

The functions of π-conjugated organic materials are generated from rational molecular designs. To develop practical and useful organic semiconducting materials, we newly designed and studied a series of sulfur-bridged bent-shaped π-conjugated cores regarding their syntheses, physical properties, aggregated structures, and carrier transporting capability in single-crystalline thin-film transistors.

AMD4 - 3 **Withdrawn**

Author Interviews
18:40 – 19:10

Friday, December 14

9:00 - 10:05 **Reception Hall 1**

AMD5: Emerging TFT

Chair: S.-H. K. Park, KAIST, Korea
Co-Chair: T. Noguchi, Univ. of the Ryukyus, Japan

AMD5 - 1 ***Invited*** **Development of P-type Transparent**
9:00 **Amorphous Semiconductor**

J. Kim, T. Jun, J. Bang, K. Aoyama, H. Hosono

Tokyo Tech, Japan

We propose the material design concept of p-type transparent amorphous semiconductor (TAS), amorphous Cu-Sn-I (a-CuSnI). The a-CuSnI thin film is revealed to possess high transparency and high mobility of 9 cm^2/Vs, which is comparable with conventional n-type amorphous oxide semiconductors (AOSs).

AMD5 - 2 **Near-Infrared Thin Film Phototransistor with Energy**
9:25 **Band-Tunable Zinc Oxynitride Semiconductor**

H. M. Lee, H. J. Jeong, E. J. Park, Y. S. Rim[*]*, J. S. Park*

Hanyang Univ., Korea
[*]*Sejong Univ., Korea*

We propose low-bandgap zinc oxynitride semiconductors not only because of high electrical performance, but also their high photoresponsivity in the Vis-NIR regions and tunable bandgap with controlling nitrogen gas ratio during deposition. We also fabricated low PPC phototransistors with tandem structure of IGZO and ZnON thin film.

AMD5 - 3 9:45 **A 5.46-in. Advanced LTPS TFT-LCD Using Top-Gate Oxide TFT in Pixel**

M. Uchida, M. Tada, K. Mochizuki, T. Tsunashima, H. Tanaka, T. Ito, H. Watakabe, A. Hanada, R. Kimura

Japan Display, Japan

TFT structure and panel reliability, up to 1000-h at 70°C, are reported for advanced low-temperature polycrystalline silicon TFT-LCD. The supporting reliability data of oxide TFT ensures the availability of the advanced LTPS TFT-LCD in actual applications.

----- Break -----

10:40 - 11:50 **Reception Hall 1**

AMD6: Oxide TFT: Device

Special Topics of Interest on Oxide-Semiconductor TFT

Chair: J. Kim, Tokyo Tech, Japan
Co-Chair: K. Takatori, Huawei Techs. Japan, Japan

AMD6 - 1 10:40 ***Invited*** **Spreading Currents in Oxide TFTs**

S. Lee, T. -W. Kim, J. Jang*

Kyung Hee Univ., Korea
**Samsung Display, Korea*

We report the spreading currents in a-IGZO and its application to TFT and TFT circuit designs. It is confirmed that the drain currents are same with and without stripe patterns. This can reduce the overlap capacitance between gate and source/drain electrodes without degrading the drain currents.

AMD6 - 2 11:05 ***Invited*** **Top-Gate Oxide TFT Technologies for Advanced LCDs**

I. Suzumura, Y. Yamaguchi, H. Kawanago

Japan Display, Japan

We have developed an oxide thin-film-transistor (TFT) technology for advanced liquid crystal displays (LCDs). To realize plastic-film LCDs, top-gate oxide TFTs with channel lengths L = 2 and 3 μm were fabricated at approximately <300°C using Generation 4.5 mother glass. Sufficient TFT performance and reliability were simultaneously obtained.

AMD6 - 3 11:30 **Oxide Semiconductor Based Vertical TFT for Ultra High-Resolution Backplane Technology**

K.-H. Lee, S. Lee, H.-I. Yeom, J.-B. Ko, C.-S. Hwang, S.-H. K. Park*

KAIST, Korea
**ETRI, Korea*

Recently, ultra high-resolution and super-brightness for HDR are critical issues for display. To realize them, 'Vertical TFT' can be an appropriate candidate. Because of its vertical channel structure & short channel length, smaller footprint and powerful current-driving capability are available. Now, we are conducting study on fabricating array structure.

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:35 **Reception Hall 1**

AMD7: Oxide TFT: Stability and Fundamental (1)

Special Topics of Interest on Oxide-Semiconductor TFT

Chair: I. Suzumura, Japan Display, Japan
Co-Chair: H. Kumomi, Tokyo Tech, Japan

AMD7 - 1
13:10 ***Invited*** **Electronic Structure and Defects in Amorphous Oxide Semiconductor: A Comprehensive Review**

T. Kamiya, H. Kumomi, H. Hosono

Tokyo Tech, Japan

This paper will summarize the knowledge about carrier transport mechanisms, electronic structures, defect structures of amorphous oxide semiconductor (AOS) including controversial models and proposals.

AMD7 - 2
13:35 **Enhancing Reliability of Amorphous In-Ga-Zn-O Thin Film Transistors by Nitrogen Doping**

T. Sung, K. Park, J. H. Kim[*], H.-W. Park[**], P. Yun[***], J. Noh[***], S. W. Lee[***], K.-S. Park[***], S. Y. Yoon[***], I. B. Kang[***], K.-B. Chung[**], H.-S. Kim[*], J.-Y. Kwon

Yonsei Univ., Korea
[*]Chungnam Nat. Univ., Korea
[**]Dongguk Univ., Korea
[***]LG Display, Korea

Device stability and electrical properties of the a-IGZO Thin-film Transistors (TFTs) were analyzed in relation to the amount of nitrogen incorporated in the a-IGZO channel. The stability of the a-IGZO TFTs was enhanced owing to the incorporated nitrogen, and the corresponding mechanism was studied by simulation and experiment.

AMD7 - 3
13:55 **Simulation Study of Self-Heating Effects on Amorphous Oxide Semiconductor TFTs: Channel-Length Dependence**

K. Abe, M. Fujinaga, T. Kuwagaki

Silvaco Japan, Japan

A new device model to study self-heating effects of amorphous oxide semiconductor TFTs for a device simulator is proposed. Simulation results with the model including the self-heating effects can reproduce ON-properties of the TFTs with channel-length between 4 and 40 μm. The self-heating under the ON-operation.

AMD7 - 4
14:15

A 31-in. 4K2K AMOLED Display Using High Mobility and Reliability Top-Gate Self-Aligned IGZO TFTs with Cu Electrode

Z.-S. Liu[,**], Y.-J. Hsu[*,**], S.-N. Zhao[*,**], J.-S. Im[*,**], Y.-C. Wu[*,**], P.-Y. Lu[*,**]*

[*]Nat. Eng. Lab. For AMOLED Process Tech., China
[**]Shenzhen China Star Optoelect. Semiconductor Display Tech., China

A top-gate self-aligned oxide TFT with Cu electrode for AMOLED display was developed. The oxidation of Cu electrode in SiO_X deposition process was studied and solved. The performance and reliability of TFTs with different structure were studied. Finally, high-mobility and high-reliability top-gate self-aligned IGZO TFTs with Cu electrode was obtained.

----- Break -----

14:50 - 16:10 **Reception Hall 1**

AMD8: Oxide TFT: Stability and Fundamental (2)
Special Topics of Interest on Oxide-Semiconductor TFT

Chair: T. Kamiya, Tokyo Tech, Japan
Co-Chair: S. Horita, JAIST, Japan

AMD8 - 1
14:50

Invited **Highly Stable High Mobility Oxide TFT for High Resolution AMOLED**

J. B. Ko, S.-H. Lee, K. W. Park, J.-R. Lee[*], W.-W. Park[*], S.-H. K. Park

KAIST, Korea
[*]AVACO, Korea

We report the methodologies of the way to the highly stable high mobility top gate Al:ITZO TFT. We introduced ECR high density plasma sputtering method and proper plasma treatment, followed by the proper H supply to the active layer for negligible charge trapping characteristics to yield high stability.

AMD8 - 2
15:15

Improvement of the Stability Under High Voltage and High Temperature Stress by Using Nitrogen Doped IGZO TFTs

I.-T. Cho, J. Noh, P. Yun, J. Jang, D. Lee, J.-H. Baeck, S.-W. Lee, K.-S. Park, S. Y. Yoon, J.-Y. Kwon[*], I. Kang

LG Display, Korea
[*]Yonsei Univ., Korea

The stability under high temperature and voltage stress is the most important property for the commercial display and automobile display. We report the improvement results about the abnormal behavior of V_{th}(-) shift under high temperature PBTS and hump degradation of subthreshold slope under high voltage stress by using IGZO:N TFTs.

AMD8 - 3
15:35

Development of Tunneling Contact a-IGZO TFT with Graphene Interlayer

L. Wang, L. Zhang, X. Zhang*, Z. Zhu, H. Zhu*

Visionox Tech., China
**Shenzhen Univ., China*

Tunneling contact (TC) a-IGZO TFT is demonstrated. The TC TFT shows much lower saturation voltage as compared with conventional a-IGZO TFT, owing to the graphene interlayer between active and source/drain metal. Performance enhancement of the TC a-IGZO TFT is discussed and performed.

AMD8 - 4L
15:55

High Stress Stability Imparted by Sn Addition Effect in High Mobility Amorphous IGZTO TFTs

M. Ochi, K. Nishiyama, Y. Teramae, H. Goto, T. Kugimiya

Kobe Steel, Japan

The electrical characteristics of TFTs based on a-IGZO with Sn dopant (a-IGZTO) realized not only enhancement of saturation mobility (μ_{sat}) but also drastic improvement in stability under negative bias thermal illumination stress (NBTIS). The electronic states on back-channel side of the a-IGZTO were clearly correlated to improve the stress stability.

Author Interviews
16:20 – 16:50

Supporting Organizations:
Thin Film Materials & Devices Meeting
Technical Committee on Electronic Information Displays, Electronics Society, IEICE

Workshop on FPD Manufacturing, Materials and Components

Wednesday, December 12

13:20 - 14:40 **Room 131**

FMC1: MicroLED Display

Chair: H. Fujioka, Univ. of Tokyo, Japan
Co-Chair: K. Käläntär, Global Optics Solutions, Japan

FMC1 - 1 13:20 ***Invited*** **Feasibility of Nitride Micro-LEDs Prepared by Sputtering**

H. Fujioka[,**], K. Ueno[*], A. Kobayashi[*]*
[*]Univ. of Tokyo, Japan
[**]JST ACCEL, Japan

We have developed a new epitaxial growth technique named PSD (pulsed sputtering deposition) for fabrication of large area group III nitride devices. We have demonstrated fabrication of RGB InGaN LEDs on various low-cost substrates such as glass plates or metal foils.

FMC1 - 2 13:40 ***Invited*** **Wavelength-Stable and Narrow-Band Red LED for Monolithic Micro-LED Display**

Y. Fujiwara, T. Inaba, K. Shiomi, S. Ichikawa, J. Tatebayashi
Osaka Univ., Japan

The invention of a red LED using the intra-4f shell transitions of Eu^{3+} ions doped in GaN enables us to monolithically integrate the three primary colors, and realize nitride-based small-size, full-color, high-resolution displays. The control of photon mode densities is very effective for enhancement of light output power from the LED.

FMC1 - 3 14:00 ***Invited*** **Smart Micro-LED Display with Synchronized Information Broadcast for Enhanced User Interaction**

X. Li[,**], B. Hussain[*,**], J. Kang[*,**], H. S. Kwok[**], C. P. Yue[*,**]*
[*]HKUST Shenzhen Res. Inst., China
[**]Hong Kong Univ. of S&T, Hong Kong

Information synchronization between displays and users' portable devices is an important technology to provide additional information for enhanced user interaction. In this paper, information synchronization is demonstrated based on a micro-LED display with 400×240 pixels. The transmitted information is received by a PD-based VLC receiver and a smartphone camera, respectively.

FMC1 - 4 14:20 **Status and Prospects of Micro LED Displays Advancements**

E. Virey, Z. Bouhamri, P. Mukish

Yole Développement, France

MicroLED is a new, self-emissive display technology. It offers unique features that could disrupt the display market as well as trigger significant changes in the supply chain. The authors have thoroughly analyzed the MicroLED industry landscape, including MicroLED's technological status and its strengths and weaknesses for all major display applications.

----- Break -----

15:05 - 16:25 **Room 131**

PRJ1/FMC2: Waveguide for AR-Near Eye Display

Special Topics of Interest on AR/VR and Hyper Reality

Chair: D. Cuypers, CMST, Belgium
Co-Chair: K. Käläntär, Global Optical Solutions, Japan

PRJ1/ FMC2 - 1 15:05 ***Invited*** **A Plastic Holographic Waveguide Combiner for Light-Weight and Highly-Transparent Augmented Reality Glasses**

T. Yoshida, K. Tokuyama, Y. Takai, D. Tsukuda, T. Kaneko, N. Suzuki, T. Anzai[*], A. Yoshikaie, K. Akutsu, A. Machida

Sony, Japan
[*]Sony Global Manufacturing & Operations, Japan

We have developed a unique production process of a full-color plastic holographic waveguide combiner with a light-weight and see-through capability. The novel plastic waveguide technology enables us to increase design flexibility in the eyewear and to expand the market for augmented reality (AR). This paper presents the approach to production.

PRJ1/ FMC2 - 2 15:25 **Waveguide-HOE-Based Camera That Captures a Frontal Image for Flat-Panel Display**

H. Konno[*], S. Igarashi[*], T. Nakamura[,**], M. Yamaguchi[*]*

[*]Tokyo Tech, Japan
[**]JST PRESTO, Japan

We propose a thin display that can capture a frontal image of a person gazing at the display. The proposed display is composed of a see-through transparent holographic waveguide, a flat-panel display, a camera at the periphery of the display, and the image reconstruction processing. We verified the proposed concept by simulations and a preliminary experiment.

PRJ1/ FMC2 - 3 15:45

Novel Holographic Waveguide Display with Kepler Telescope Configuration

Z. Shen, Y. Zhang, A. Liu, Y. Weng, X. Zhu, X. Li
Southeast Univ., China

This paper proposed a novel holographic waveguide configuration, which includes the micro-display, in-coupling volume holographic grating, waveguide and out-coupling holographic reflective lens. Theoretically, the horizontal field of view of the novel holographic waveguide can reach 40°, and the simulation results are validated with the experiments.

PRJ1/ FMC2 - 4 16:05

Light Efficiency Modeling for a Holographic Waveguide Display

X. Zhu, Y. Zhang, Z. Shen, A. Liu, Y. Weng
Southeast Univ., China

A light efficiency model of a holographic waveguide display is constructed in this paper. The model considers both the energy loss of the beam propagating in the waveguide and the loss caused by one-dimensional expansion. The brightness and efficiency accepted by eye can be calculated by this model.

----- Break -----

16:40 - 18:00 **Room 131**

FMC3: Display Optics

Chair: S. Suyama, Tokushima Univ., Japan
Co-Chair: H. Yamamoto, Utsunomiya Univ., Japan

FMC3 - 1 16:40

See-Through Aerial Secure Display with Head-Tracking Function

S. Ito[*], K. Uchida[*], H. Yamamoto[,**]*
[*]Utsunomiya Univ., Japan
[**]JST ACCEL, Japan

We have realized a novel aerial secure display. The proposed display forms a secure information screen that is floating in the air and is visible for the limited person who is detected with a 3D camera. Although the formed screen is noticeable from the other side, the information is scrambled.

FMC3 - 2
17:00

Functional Projection Screen Using Diverted Corner Cube Retroreflector (D-CCR)

T. Uchida[, **], R. Ohtera[*], K. Wako*, Y. Ishitaka[**], M. Kano[**], K. Käläntär ****

[*]Nat. Inst. of Tech. Sendai College, Japan
[**]Tohoku Univ., Japan
[***]Global Optical Solutions, Japan

We have devised and developed a novel screen D-CCR with a remarkably high gain by deforming the corner cube reflector. In this paper we report on further improvement of the uniformity of reflected light intensity in the diffusing region and elimination of unnecessary reflected light.

FMC3 - 3
17:20

Curved Aerial Information Display by Use of a Half-Mirror-Coated Fresnel Lens

K. Shimose, M. Yasugi, T. Iwane[*], M. Nakajima[*], H. Yamamoto

Utsunomiya Univ., Japan
[*]Nikon, Japan

We propose a new aerial display by combining a half-mirror-coated Fresnel lens and a half mirror. The optics forms a curved display in the mid-air. The curvature is derived from the curvature of image field, which was conventionally considered as a defect. However, the experimental result shows a good performance.

FMC3 - 4
17:40

Optical Characteristics and Metrology of Flexible Light Sources (FLS)

K. Käläntär[, **], S. Maeda[*]*

[*]CEREBA AIST, Japan
[**]Global Optical Solutions, Japan

The metrology issues of curved flexible light sources (FLSs) with small radii were studied and the differences with that of planar FLSs were revealed, and the verifications were performed by measuring the variations in luminous intensity of cylindrically shaped OLEDs.

Author Interviews
18:10 – 18:40

Thursday, December 13

9:00 - 10:35 **Reception Hall 2**

LCT4/FMC4: New Materials and Components for LCDs

Chair: S. Oka, Japan Display, Japan
Co-Chair: R. Yamaguchi, Akita Univ., Japan

LCT4/FMC4 - 1
9:00

Invited **The Application of Quantum Dot in TV Display Technology**

N. Chen, H. Ji, H. Xu, Z. Li, L. Liang
TCL Elect. Holdings, China

This paper discusses the important role of quantum dot technology in TV industry. Based on the analysis of the development trend and characteristics of quantum dot materials used in TV display technology, the engineering issues and challenges in the field of quantum dot technology are discussed in this paper.

LCT4/FMC4 - 2
9:20

Invited **Cholesteric Liquid Crystals As Solution-Processable Holographic Optical Elements**

H. Yoshida[,**], S. Cho[*], M. Ono[*], Y. Tsuboi[*], Z. Fan[*], M. Ozaki[*]*
[*]Osaka Univ., Japan
[**]JST PRESTO, Japan

Cholesteric LCs can be used as holographic optical elements (HOEs) with functions defined by the orientation pattern on the supporting substrate. By using reactive mesogens, it is possible to make free-standing HOE films by solution processing.

LCT4/FMC4 - 3
9:40

Novel Black Photo Spacer Structure Applied in Liquid Crystal Display Technology

W. Cao, M. Liu, Z. Deng, Y. Lin, C. Chiu, L. Ray
Shenzhen China Star Optoelect. Tech., China

Here gray tone-like mask was applied on color filter layer to carry out height difference between the predefined patterns, followed by black photo spacer film coating. Therefore mainPS and subPS were obtained respectively. A 28-in. HD LCD Module with inorganic passivation layer was demonstrated with good optical performance finally.

LCT4/FMC4 - 4
10:00

New Reflective Polarizer Film for Automotive e-Mirror Application

H. Matsuda, K. Toyooka, M. Kugue[*]
3M Japan Prods., Japan
[*]3M Japan, Japan

Recently, automotive electrification is a technical trend, and the e-Mirror which can switch between display and mirror mode, is one of them. The reflective polarizer is a component utilized to improve the e-Mirror performance, so 3M has developed a new reflective polarizer film which can meet automotive mirror requirements.

LCT4/ FMC4 - 5L 10:20 **New Architecture of QD-on-Chip Encapsulation System**

M. Uchida, K. Yoshida, H. Minamisawa, T. Masukawa, A. Miyanaga[*]*, A. Moriyasu*[*]*, H. Nishikawa*[*]*, K. Iida*[*]*, M. Saeki*[*]*, J. Kaneno*[*]

JNC Petrochem., Japan
[*]*NS Materials, Japan*

It has taken a long time since QD-on-Chip device could be allegedly a candidate of excellent color coordinate display. However, no one has been able to realize it because of low reliability of emission layer with QD. This report shows a possible solution from the view point of encapsulation system.

Author Interviews
10:40 – 11:10

----- Lunch -----

14:20 - 16:50 **Event Hall**

***Poster* FMCp1: Display Optics (1)**
Special Topics of Interest on AR/VR and Hyper Reality

FMCp1 - 1 **LED Authentication Using a Smartphone for Volume Holograms**

T. Yasuda, Y. Yoshimura, T. Yamauchi

Dai Nippon Printing, Japan

In this paper, we proposed security features based on smartphone authentication with a point light source for volume hologram. The addition of an authentication feature to the volume hologram can further enhance the authentication effect, resulting in an optimized and visually attractive security feature using a smartphone.

14:20 - 16:50 **Event Hall**

Poster FMCp2: Display Optics (2)

FMCp2 - 1 **Fundamental Solutions of Interlaced Microstructures for Photo-Electric Device and the Pseudo Negative Refractive Index Modeling for Display Component**

C.-J. Ou, J.-F. Qian, K.-Y. Chen, Z.-W. Wang, F.-R. Lin

Hsiuping Univ. of S&T, Taiwan

This report demonstrates a fundamental solution F(a,b) of the prism structures. Through the combinations of the fundamental solution, behavior of the prism like structures for various photo-electronic device an be analysis and design in a more delicate way. Equivalent model for negative refractive material can be designed.

FMCp2 - 2 **Withdrawn**

FMCp2 - 3 **The Process and Reliability of Mini-LED Displays**

I.-H. Hsieh, C.-H. Kuo, Y.-W. Chang, H.-H. Wu, K.-Y. Lee, H.-P. Kuo, Y.-H. Chang, T.-L. Niu, C. Fuh, C.-M. Yang, M.-T. Ho, Y.-T. Lee, Y.-W. Chen

AU Optronics, Taiwan

We have developed several 1/2/3/6/8/12/13/15-in. display with high color gamut mini-LED backlight system concept enables various display designs. The 1000 hours reliability field test result data indicates that the bonding process is the main yield lost factor.

FMCp2 - 4L **Measurement of Optical Power Recovered by Planar Fluorescent Waveguides for Single-Spot Excitation**

I. Fujieda, M. Ohta, M. Okuyama, Y. Tsutsumi

Ritsumeikan Univ., Japan

Photoluminescence intensity distributions measured at edges of a fluorescent waveguide provide insight for designing an energy-harvesting device. For a single-spot excitation near the center of a 5 cm x 5 cm device, efficiency of power recovery decreases from 0.46 to 0.39 by decreasing its thickness from 10 mm to 4 mm.

FMCp2 - 5L **Spatial Luminance Uniformity Improvement of Flexible Backlight Using Notch-Type Variable Light Distribution Film**

T. Shoji, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

In this study, we proposed the notch-type variable light distribution film to improve the uniformity of luminance distribution in curved state for the application of flexible backlight. As the results of the optical simulation, we clarified optimization of the film structure enables improvement of emitted light distribution from flexible backlight.

FMCp2 - 6L **Flexible Marble-Chain Letter-Strings Display System by Adjusting Intervals of Letters and All Dots**

H. Mori, Y. Aoki, K. Sakamoto

Konan Univ., Japan

A neon sign is a lighting display made of glass tubes filled with a gas and bent into the shape of letters. This paper shows the lettering display using marble chains which enables to adjust intervals of letters. Moreover the authors describe how to make variable mechanisms and light-emitting displays.

14:20 - 16:50 **Event Hall**

Poster FMCp3: FPD Manufacturing Technologies

FMCp3 - 1 **Exposure Test Results of Organic Insulation Films with DUV Broadband Illumination for High Resolution Panels**

K. Takasaki, N. Izumi, M. Hakko, M. Ando, N. Yabu, K. Nagano

Canon, Japan

We have focused on use of DUV broadband illumination to improve of lithography resolution. Organic insulation films are indispensable for high resolution panels. It is necessary that organic insulation films have fine resolution and stability. We present the exposure test results of organic insulation films with DUV broadband illumination.

FMCp3 - 2 **Study on One Infrequent Influencing Factor of TFT Mask**

M. Wang, J. Liu, F. Li, Y. Jia, X. Ding, W. Chen

Beijing BOE Display Tech., China

A rare failure caused by self-defect of ITO mask is studied. Fluctuation of exposure dose in overlap area causes defect of mask, then it transfers to ITO film and causes periodic fluctuation of ITO CD, ultimately, streak mura occurs in TFT-LCD. As precision of overlap improve, the failure is improved.

FMCp3 - 3 **Acceptor Doping of ZnO Films by NO Gas Decomposition on a Heated Ir Wire Surface in a Catalytic Reaction-Assisted CVD**

Y. Adachi, R. Iba, A. M. Hashim[*], A. Kato, K. Yasui

Nagaoka Univ. of Tech., Japan
[*]Univ. Tech. Malaysia, Malaysia

Nitrogen doping of ZnO films by decomposition of NO gas on heated Ir wire surface was tried in a catalytic-reaction CVD. ZnO films were grown on a-plane sapphire substrates under various NO gas pressures. In XPS, the relative intensity of the Zn-N peak was large when the heated Ir wire was used.

FMCp3 - 4 **A Study and Improvement about Corrosion Mechanism of Mo/Cu Bilayer in Cleaning Process**

Y. Yin, J. Li, X. Hu, L. Cai, X. Wei, Q. Lin, J. Wang, J. Liu, C. Hu, S. Sun, W. Zhang

Shenzhen China Star Optoelect. Tech., China

The corrosion mechanism of Mo/Cu in the cleaning process was clarified, we confirm that the water dissolved micro-solution and pure water are strong correlation of the corrosion. The measures of shortening washing time, improving the conductivity or reducing amount of air in water are confirmed that can reduce the corrosion.

FMCp3 - 5 **A Study and Improvement about Corrosion Mechanism of Mo/Cu Bilayer in CVD**

Y. Yin, J. Wang, X. Hu, J. Li, L. Cai, X. Wei, Q. Lin, J. Liu, C. Hu, S. Sun, W. Zhang

Shenzhen China Star Optoelect. Tech., China

The corrosion mechanism of Mo/Cu in CVD process was clarified, which confirms that the gas, temperature and time conditions of CVD are strong correlation of the corrosion. The Mo/Cu corrosion in CVD can be improved by means of pre-deposition drying, controlled Q-time, reduce the time of deposition and inhibition recrystallization.

FMCp3 - 6 **Four-Mask Process Architecture Using NH_3 Plasma Treatment Technology for Image Sticking Improvement in 32-in. TV Product**

F.-Y. Yang, A.-T. Cho, J. Hsu, Z. Liu, K.-J. Liu, W. Chen, Y. Lu

Chongqing HKC Optoelect. Tech., China

A new method to improve the interface of a-Si backchannel in TFT process, the influence of H content in PECVD and the a-Si remain induced image sticking are studied. The suitable NH_3 plasma pretreatment power and time, and reduced a-Si remain thickness can overcome the image sticking in four-mask process.

FMCp3 - 7 **Optimization Design of Silicone PAD for Bended Window Lamination in the OLED Display**

D.-H. Jang, B.-M. Park, S.-W. Lim, K.-Y. Han

Dankook Univ., Korea

Recently, the window glass of smartphone has been developed to have curvature at the left and right corners. In this study, we optimized the design of the silicone pads for lamination of the bended window and evaluated the lamination characteristics using actual pads.

FMCp3 - 8L **Reduction of Residual OH Content in a Low-Temperature Si Oxide Film at Less than 200°C**

S. Horita

JAIST, Japan

Residual OH bonds in the low-temperature deposited SiO_2 film are removed much effectively by annealing with NH_3 gas at the low temperature of 175°C, compared with normal N_2 gas. It is considered that this effect is caused by catalysis effect of NH_3 which is a strong Lewis base.

FMCp3 - 9L **Study on Wet Etching Behavior of Amorphous CuZr Thin Film in Hydrogen Peroxide Solution for Stretchable Display**

J.-W. Bae, M.-J. Kim, J. H. Seo

Korea Aerospace Univ., Korea

Amorphous CuZr was chosen for copper metallization of stretchable display due to excellent elongation properties compared to conventional metals. In this paper, wet etching behavior of amorphous CuZr thin films in hydrogen peroxide based copper wet etchant was studied using electrochemical potentio-dynamic technique and surface analysis.

14:20 - 16:50 **Event Hall**

Poster FMCp4: FPD Materials and Components

FMCp4 - 1 **Withdrawn**

FMCp4 - 2 **A Novel Liquid Crystal Displays Using Dye-Type In-Cell Polarizer**

Z.-X. Chen, L.-X. Chen, H.-H. Chen

Shenzhen China Star Optoelect.Tech., China

An in cell polarizer has been developed which can be used internally in liquid-crystal-display cells. Based on this in cell polarizer, a manufacturing process has been developed for the fabrication of LCDs. And in this novel LCD, dye type in-cell polarizer can be well protecting from environment.

FMCp4 - 3 **Withdrawn**

FMCp4 - 4 **Reduction of Charge Trapping in High-k $HfZrO_4$ Gate Insulators**

A. R. Park, B. D. Choi

Sungkyunkwan Univ., Korea

Hafnium-zirconium-oxide ($HfZrO_4$) films prepared by incorporating hydrogen peroxide (H_2O_2) exhibited reduced capacitance-voltage hysteresis compared to virgin $HfZrO_4$. These were resulted from the reduction of the oxygen vacancies and charge trapping. The impact of H_2O_2 on the electrical behaviors was identified by analyzing border and interface traps.

FMCp4 - 5L **Morphological and Electrochemical Properties of Nickel Oxide Prepared by Wet-Chemical Method**

K. H. Kim, S. Motoyama, Y. Abe, M. Kawamura, T. Kiba

Kitami Inst. of Tech., Japan

Porous nanowall-structured nickel oxide (NiO) thin films were directly prepared on transparent conductive oxide (TCO) via a cost effective wet-chemical method. After annealed at 250°C, it showed better electrochemical performance than the nanostructure sample annealed at 500°C.

FMCp4 - 6L **Improvement in Optical Performance of GH-Type Polarizer Using Polarization Converting Film**

S. Nonomura, Y. Iimura

Tokyo Univ. of A&T, Japan

A coatable GH-type polarizer with a polarization-converting (PC) film has been studied for realizing a high-performance in-cell polarizer. By using photo-alignment and unidirectional coating methods, we improve optical performance of a cholesteric film in a PC film and succeed in making a pixelized polarizer having the contrast ratio over ~800.

FMCp4 - 7L **Study on LCST-Type Phase Behavior in Ionic Liquid Device with Blend Polyimide**

Y. Izumi, K. Goda

Sanyo-onoda City Univ., Japan

In this study, the LCST behavior of ILD with blend polyimide was investigated. We found that the transmittance in the opaque state increased with decreasing density of alkyl side chain, because decreased van der Waals interaction between alkyl side chain of polyimide and the butyl chain of [$^{n}Bu_4P$] cation.

FMCp4 - 8L **Effect of Surface Treatment by Atmospheric-Pressure Plasma on Optical Property for Ionic Liquid Device**

K. Matsubara, N. Oshima, K. Goda

Sanyo-Onoda City Univ., Japan

In this study, the effect of the surface treatment by the atmospheric-pressure plasma on the transmittance in the opaque state for the ILD utilizing the polyimide with alkyl side chain was investigated. It was found that the transmittance in the opaque state become a stable by the atmospheric-pressure plasma treatment.

14:20 - 16:50 **Event Hall**

***Poster* FMCp5: WCG Color Filter**

Special Topics of Interest on Wide Color Gamut and Color Reproduction

FMCp5 - 1 **Wide Gamut Display Using Red Color Filter - Technical Developments and Actual Products**

D. M. Lee, S.-J. Yang, J.-Y. Lee, Y.-W. Kim, H.-J. Kim

LG Chem., Korea

In order to display images close to natural colors, WCG color filter photoresist is one of the most important components in flat panel display devices. In this paper, the development direction and some results for the WCG colorant will be discussed.

14:20 - 16:50

***Poster* FMCp6: Quantum Dot Technologies in FPD Components**

Special Topics of Interest on Quantum Dot Technologies

FMCp6 - 1L **Stability Improvement of Quantum Dot Color Conversion Films by Direct Bonding Between Designed Ligands and Polymer Matrix**

E. Nam, C. Lee, H. K. Chung, H. Chae

Sungkyunkwan Univ., Korea

New preparing method of the reactive ligand substituted quantum dot (QD) was presented. The designed QD formed direct bond with siloxanes matrix via hydrosilylation. The prepared QD-matrix was studied stability for application on-chip packaging as a color converter on blue light-emitting diodes (LEDs).

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters
Thursday, Dec. 13, 2018
11:40 – 15:50
Event Hall (1F, Building 1)
Nagoya Congress Center

14:20 - 16:50

***Poster* FMCp7: Manufacturing and Materials of Oxide TFTs**

Special Topics of Interest on Oxide-Semiconductor TFT

FMCp7 - 1L Deposition of Insulator Film by Inductively Coupled Plasma CVD System with Low Impedance Antennas

T. Sakai, M. Fujiwara, D. Azuma, S. Nakata, Y. Setoguchi, Y. Andoh

Nissin Elec., Japan

Thin-film transistor (TFT) for flat panel display (FPD) is expected to be applied to the next-generation large and high-definition. For this reason, we developed the inductively coupled plasma (ICP) CVD system with low impedance antennas applicable to the Gen. 6 and larger substrates.

FMCp7 - 2L Deposition of Crystalline InGaZnO Film at Low Temperature Process by Inductively Coupled Plasma Sputtering System

D. Matsuo, R. Miyanaga[*]*, T. Ikeda, S. Kisida, Y. Setoguchi, Y. Andoh, M. Fujii*[*]*, Y. Uraoka*[*]

Nissin Elec., Japan
[*]*NAIST, Japan*

We report the correlation between the crystallinity of the IGZO film and the ICP-sputtering conditions. When an IGZO film is formed by ICP-sputtering, crystallization of the IGZO film was confirmed regardless of the presence of heating. Crystallinity was increased remarkably as the oxygen ratio in the sputtering gas increased.

FMCp7 - 3L ZnO:Ga Thin Film with Hydrogen and Nitrogen Post Annealing and Applications in Transparent RRAM

L. W. Wang, C.-C Lin, S.-Y. Chu

Nat. Cheng Kung Univ., Taiwan

In this article is talking about Ga:ZnO (GZO) which is kind of transparent conductive oxide with non-toxic and stability. In order to reduce the resistance and improve the device performance, uses the nitrogen and hydrogen mixture furnace annealing as post treatment. Discuss about the GZO electrode with hydrogen post treatment.

17:10 - 18:30 **Room 131**

FMC5: Manufacturing

Chair: T. Nonaka, Merck PM, Japan
Co-Chair: Y. Inoue, Corning Japan, Japan

FMC5 - 1
17:10

The Effect of Flash Lamp Annealing on the Performance of MOTFTs

M. Junghaehnel, T. Preussner, J. Westphalen

Fraunhofer Inst. for Organic Elect., Germany

We report about investigations on non-IGZO TFTs (MOTFTs) based on IAZO and IZO. The metal-oxides were coated by rf sputtering on 550x670 mm² glass substrates. The films were annealed by in-line flash lamp annealing (FLA). We investigated the effect of FLA on the carrier mobility and stability of the MOTFTs.

FMC5 - 2
17:30

Novel High Resolution Photolithography Process (Resolution Enhancement Technology)

H. Ikeda, T. Suzuki, Y. Toyama, T. Nonaka

Merck PM, Japan

Novel high resolution photolithography process is presented in this paper. New process and materials can use conventional exposure apparatuses with ghi-line UV light to form high resolution pattern beyond the resolution limit of exposure apparatus.

FMC5 - 3
17:50

Copper Undercut Mechanism Due to Side-Etch of Dry Process in Four-Mask Fabrication for High Resolution TFT-LCDs

M. Chen, L. Guo, C.-Y. Chiou, Z.-W. Tan, S. Sun, H. Xia, F. Long, W.-G. Liu, J.-X. Li

Shenzhen China Star Optoelect. Tech., China

Increasing copper film thickness is needed for high resolution TFT-LCDs fabrication. We investigated the copper undercut that might deteriorate the reliability of LCDs in this work. The difference of directional velocities in wet etching process and side-etch of dry process would be the root causes of copper undercut.

FMC5 - 4
18:10 **Mass-Production-Feasible Three-Mask Technology for HVA-LCD TV**

M.-X. Zhu, H.-Y. Xu, Z.-X. Jiang, T. Ou, S.-J. Chen, C.-Y. Lee, H. C. Lin

China Star Optoelect. Tech., China

We successfully fabricated high-optical-quality 3-mask HVA-LCD panel. High-low-power-ash is implemented into 3-mask LCD fabrication for the first time and it effectively solved the problem of by-product residual and improved optical performance. By using this technology, the optical performance was improved and the 3-mask process stability had been promoted.

Author Interviews
18:40 – 19:10

Friday, December 14

9:00 - 10:20 **Room 131**

FMC6: Light Polarizing Technologies

Chair: I. Amimori, A51Tech, Japan
Co-Chair: S. Namekawa, Nippon Steel & Sumikin Chem., Japan

FMC6 - 1
9:00 ***Invited*** **Design, Synthesis and Optical Properties of Chiral Polymers Emitting Efficient Circularly Polarized Light as OLED Materials**

T. Nakano

Hokkaido Univ., Japan

Chiral, hyperbranched and linear polymers were prepared as circularly polarized light (CPL)-emitting materials. Such polymers were synthesized using a chiral initiator or a chiral monomer as well as through CPL irradiation to optically inactive polymers. Polymers exhibited chirality amplification in excited states to lead to efficient CPL emission.

FMC6 - 2
9:20 ***Invited*** **Chiral Intertwined Spirals and Chiroptical Properties Dictated by Cylinder Helicity: The Most Intense Circularly Polarized Luminescence in Organic Compounds**

S. Sato[*,**]

[*]*Univ. of Tokyo, Japan*
[**]*JST, Japan*

For molecular helical carbon nanotubes, we revealed interesting properties originated from the chirality. The molecular chirality resulted in chirality of larger dimensions as a double-helix assembly. Cylinder chirality in solution gave rise to an unprecedented dissymmetry factor that is the largest yet reported for metal-free entities in circularly polarized luminescence.

FMC6 - 3
9:40

Influence of Packaging Materials to Nano-Wire Grating Polarization Characteristics

H. Jun

Shenzhen China Star Optoelect. Semiconductor Display Tech., China

This text utilizes FDTD solutions to analogy procedure to analysis the influence of WGP polarization generating by packaging materials with different refractive index and packaging structures. It turns out that low refractive index materials and half packaging structure are benefit for keeping benign polarization characteristics.

FMC6 - 4
10:00

Proposal of Novel Random Polarization Film with Birefringent Crystals for Real-Color Displays

M. Udono[,**], Y. Koike[*,**]*

[*]Keio Univ., Japan
[**]Keio Photonics Res. Inst., Japan

We proposed the novel film, random depolarization film, which is the polymer film doped with the birefringent crystal particles. With using this film, we succeeded to solve the blackout problem of displays and to achieve much lower chromaticity change with polarized sunglasses.

----- Break -----

10:40 - 12:00 **Reception Hall 2**

FLX5/FMC7: Advanced Materials and Components for Flexible Electronics

Chair: T. Furukawa, Yamagata Univ., Japan
Co-Chair: A. Fujita, JNC, Japan

FLX5/
FMC7 - 1
10:40

Thin and High-Quality ITO/Ag Alloy/ITO Structure for Display Electrodes

Y. Toshimori, S. Nonaka, T. Nagase

Mitsubishi Materials, Japan

We have developed new Ag alloy for ITO/Ag/ITO multilayer which has thinner total thickness and excellent optical and electrical properties. New Ag alloy enables to form thinner and more durable Nano-Ag film, even if deposited in atmosphere with residual water vapor, such as mass-production sputtering chamber.

FLX5/
FMC7 - 2
11:00

Improvement of Mura and CD by Adjusting Black Matrix Component in G8.6 TFT-LCD Color Filter

R. Wang, D. Zhang, D. Lei, X. Wang, J. Hung, J. Hsu, W. Chen, Y. Lu

Chongqing HKC Optoelect. Tech., China

In this paper, BM (black matrix) photoresist component was adjusted to thoroughly solve VCD (vacuum dry) mura, twill mura, as well as over-sized CD (critical dimension) quality that happened in BM manufacture process in G8.6 TFT-LCD color filter.

FLX5/ FMC7 - 3 11:20 **Black Photoresist Achieving Patterns with Extremely Low Reflection and Smooth Line Edge on Flexible Substrate**

A. Igawa, M.-A. Hsu[*]

eChem Solutions Japan, Japan
[*]Consistent Elect. Materials, Taiwan

A novel black photoresist achieving patterns with extremely low reflection and very smooth pattern line edge is developed. Instead of adding black particles, combinations of solvents and special substances are used. Introducing special flexible matrix resin, this photoresist can be applied not only on glass but also on flexible substrate.

FLX5/ FMC7 - 4 11:40 **The Effects of Surfactants and Dielectrophoresis on the Electrical Property of Single-Wall Carbon Nanotube Films**

C. Wei, Z.-L. Yan

Tatung Univ., Taiwan

Carbon nanotubes are used as a transparent conductor film due to its nano size. The degree of dispersion is essential in such application. Different surfactants with dielectrophoresis are utilized to seek the optimal performance. SDS with 1 M dielectrophoresis has shown to be the best recipe.

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:30 **Room 131**

FMC8: Advanced Materials

Chair: T. Tomono, Toppan Printing, Japan
Co-Chair: M. Arai, ULVAC, Japan

FMC8 - 1 13:10 **Thin Cycloolefin Polymer Film with Low Ultraviolet Transmittance**

Y. Hata, K. Inoue, N. Murata, H. Nakahori, S. Yamada

Zeon, Japan

We succeeded in developing a very thin optical film capable of blocking ultraviolet rays to the display device. The film thickness is 25 µm, and the light transmittance at 380 nm is 0.5% or less. We will explain the use of this film in the display device.

FMC8 - 2
13:30

High-Transmittance and Photopatternable High-k Insulating Film

C.-Y. Tung, S.-C. Lee, T.-H. Liao, W.-S. Yu, M.-W. Shen, W.-C. Tsai

AU Optronics, Taiwan

The high-k photoresist has developed and demonstrated as insulating film in TFT-LCD. This high-k film is photopatternable and shows excellent transmittance of 98% in visible region. The measured dielectric constant of this insulating film is about 7.4 that can be used in displays.

FMC8 - 3
13:50

A Study and Estimate Method about Mo and MoTi Barrier Endurance for Cu Diffusion

X. Hu, L. Zhan, Y. Yin, J. Li, Y. Zhai, W. Cao, W. Huang, H. Yu, J. Zhang, S. Sun, W. Zhang

Shenzhen China Star Optoelect. Tech., China

By testing the capacitance of the TFT device before and after high temperature deterioration, the barrier property of different materials, such as MoTi and Mo, on Cu diffusion were estimated. This method can obtain the test results fastly and efficiently, the experiments showed that the barrier property of MoTi is superior to that of Mo.

FMC8 - 4
14:10

The Research Focusing on Form Mechanism and Ameliorated Methods of Aluminum Thorn Grown on Gate Electrode Constructed Al/Mo Bi-layer

J. Wang, Y. Yin, J. Li, X. Wei, L. Cai, Q. Lin, J. Liu, C. Hu, S. Sun, W. Zhang

Shenzhen China Star Optoelect. Tech., China

The research reveals the thorn formation mechanism the interfacial state of Al/Mo induces abundant local galvanic battery reaction,along with local anodization, jointly resulting in the generation of alternate holes. In addition that capillary forces of hole bring about ER disparity between top and bottom, finaly hole shape into thorn.

Author Interviews
16:20 – 16:50

Supporting Organizations:

The Japanese Society of Printing Science and Technology
Japan Society of Colour Material
The Technical Association of Photopolymers, Japan
The Society of Photography and Imaging of Japan
RadTech Japan
The Japanese Research Association for Organic Electronics Materials
Japan Electronics Packaging and Circuits Association

Workshop on Inorganic Emissive Display and Phosphors

Thursday, December 13

10:40 - 13:10 **Event Hall**

***Poster* PHp1: QD Phosphors and Devices**

Special Topics of Interest on Quantum Dot Technologies

PHp1 - 1 **Withdrawn**

PHp1 - 2 **Thermal Stability of $CsPbBr_3$ Quantum Dots and Their Application to Light-Emitting Diodes**

H. Sasaki, N. Kamata, Z. Honda

Saitama Univ., Japan

We investigated the thermal stability of $CsPbBr_3$ QDs with different ligands, and fabricated inverted-type $CsPbBr_3$ QD light-emitting diodes. $CsPbBr_3$ QDs with DDAB ligands showed higher thermal stability compared with those with OLA and OA ligands, and furthermore we improved luminance up to 1057 cd/m^2 from 79 cd/m^2.

PHp1 - 3 **Withdrawn**

PHp1 - 4 **Withdrawn**

10:40 - 13:10 **Event Hall**

***Poster* PHp2: Phosphors for General**

PHp2 - 1 **Withdrawn**

PHp2 - 2L **Wavelength Conversion Agricultural Sheets Dispersed with Mg_2TiO_4:Mn Red Phosphor for Promoting Photosynthesis**

K. Kuzukawa, M. Suhama, N. Doumoto, T. Ishigaki, E. Nishihara, H. Okura[*]*, R. Yamanashi*[*]*, K. Ohmi*

Tottori Univ., Japan

[*]*Merck, Japan*

Wavelength conversion sheets dispersed with red phosphor Mg_2TiO_4:Mn (MTO) have been developed to promote photosynthesis. A holy basil has been cultured by a tunnel culture. By using the MTO sheet, the dry weight is increased by 20%. The index of promoting photosynthesis of MTO has also been proposed.

PHp2 - 3L **Charge Transfer State of $Y_4Si_2O_7N_2:Eu^{3+}$ Red Phosphor Synthesized by Solid State Reaction in NH_3 Atmosphere**

K. Nakamoto, M. Kawashima, T. Ishigaki, T. Kunimoto[*]*, T. Honma*[**]*, K. Ohmi*

Tottori Univ., Japan
[*]*Tokushima Bunri Univ., Japan*
[**]*JASRI, Japan*

$Y_4Si_2O_7N_2:Eu^{3+}$ red phosphor was synthesized in NH_3 atmosphere. The synthesized phosphor had a broad excitation band with peak wavelength of 344 nm due to Eu^{3+} charge transfer state (CTS). The corresponding CTS energy was 3.61 eV, which is almost the same as that of $La_2O_2S:Eu^{3+}$.

17:10 - 18:40 **Room 432**

PH1: Phosphors for Display and Lighting Applications

Chair: D. Y. Jeon, KAIST, Korea
Co-Chair: K. Ohmi, Tottori Univ., Japan

PH1 - 1 ***Invited*** **Nanocolumn LEDs for Monolithic Micro-LED**
17:10 **Display**

K. Kishino, K. Narita, A. Yanagihara, T. Oto, R. Togashi

Sophia Univ., Japan

The emission color of InGaN/GaN densely-packed nanocolumn arrays was controlled by the nanocolumn diameter, by which RGBY micro (μ)-LED pixel units were monolithically integrated to be arranged two dimensionally. Here the crystal growth and process of the devices are described. Red-emitting nanocolumn LEDs with the directional radiation beam were fabricated.

PH1 - 2 ***Invited*** **Self-Healing Phosphor: New Paradigm for**
17:35 **High-Power LED Lighting**

W. B. Im, Y. H. Kim, H. B. Cho

Chonnam Nat. Univ., Korea

A blue-emitting phosphor that a zero-thermal-quenching (self-healing) is shown zero-emission-loss even up to 250°C for the first time. This phenomena portrays the ability of phosphor in resurrecting the emission loss and sustaining the luminescence with increasing temperature. This finding would initiate the exploration of many self-healing phosphors for high-power LED.

PH1 - 3
18:00
$La_3Si_6N_{11}$:Ce Phosphor-in-Glass Film as a Novel Nitride Color Converter for High-Brightness Laser-Driven Automotive Lighting and Display

S. You, S. Li, P. Zheng, T. Zhou, R.-J. Xie

Xiamen Univ., China

A well designed $La_3Si_6N_{11}$:Ce phosphor-in-glass film on sapphire substrate was applied in laser-driven lighting and displays for the first time, which can afford a laser power density of 12.91 W/mm^2, and give a luminous emittance of 2143 lm/mm^2, showing the potential applicability of nitride phosphors pumped by high-power laser.

PH1 - 4
18:20
Achieving Efficient β-Sialon:Eu Phosphors for High-Brightness LCD Backlights by Reducing the Eu^{3+} Luminescence Killer

S. Li, T. Takeda[*]*, N. Hirosaki*[*]*, R.-J. Xie*

Xiamen Univ., China
[*]*NIMS, Japan*

A direct reduction strategy was applied to increase the concentration of Eu^{2+} and to minimize the amount of Eu^{3+} in β-Sialon:Eu. Consequently, the IQE is enhanced from 52.2 to 96.5%. The as-fabricated white LED backlight demonstrates a high luminous efficacy of 136 lm/W and a wide color gamut (~96% NTSC).

Author Interviews
18:40 – 19:10

Friday, December 14

10:40 - 12:10 **Room 432**

PH2/OLED6: QD Phosphors and Devices

Special Topics of Interest on Quantum Dot Technologies

Chair: R.-J. Xie, Xiamen Univ., China
Co-Chair: Y. Sakai, Mitsubishi Chem., Japan

PH2/
OLED6 - 1
10:40
Invited **Narrow Band-Edge Emission from $AgInS_2$ Semiconductor Quantum Dots by the Formation of Amorphous III-VI Semiconductor Shells**

T. Uematsu

Osaka Univ., Japan

A spectrally narrow band-edge photoluminescence was achieved for the first time by coating silver indium sulfide ($AgInS_2$) colloidal semiconductor quantum dots with indium sulfide (InS_x) or gallium sulfide (GaS_x) shells. Photoluminescence quantum yield as high as 56% was achieved by the surface modification of shells with phosphine compounds.

PH2/ OLED6 - 2 11:00

Novel Ligand Materials to Enhance Luminous Efficiency and Stability of Perovskite Quantum Dot

S.-Y. Cheng, C.-T. Chiu, J.-T. Lian, B.-K. Hsu[*]*, T.-Y. Lin*[*]

Chunghwa Picture Tubes, Taiwan
[*]*Nat. Taiwan Ocean Univ., Taiwan*

Perovskite quantum dots (PeQDs) have attracted much attention in recent years. However, because of the poor stability against temperatures, polar solvents, and UV light, the application of PeQDs is limited. We have succeeded in synthesizing a wavelength tunable(420~670 nm) PeQDs with high-stable, high photoluminescence quantum yields and narrow FWHM.

PH2/ OLED6 - 3 11:20

Improved Stability of $CsPbBr_3$ Perovskite Quantum Dots by Suppressing the Interligand Proton Transfer and Applying the Polystyrene Coating

Y. Cai, Y. Li, R.-J. Xie

Xiamen Univ., China

We first adopted hexadecyl trimethyl ammonium bromide to synthesize $CsPbBr_3$ QDs. The interligand proton transfer was thus suppressed and the obtained $CsPbBr_3$ QDs showed enhanced stability against acetone. Then, a polymer of carboxyl-functional polystyrene (cPS) was used to coat $CsPbBr_3$ QDs and the composite shows improved thermal and moisture stability.

PH2/ OLED6 - 4

Withdrawn

PH2/ OLED6 - 5L 11:40

Perovskite Quantum Dots with Enhanced Thermal Stability for Display Application

L. Sinatra, M. Lutfullin, M. Mahmud, J. Pan[*]*, O. Bakr*[*]

Quantum Solutions , Saudi Arabia
[*]*King Abdullah Univ. of S&T, Saudi Arabia*

We report here Zero-Dimensional perovskite (Cs_4PbBr_6) that has similar optical properties as Perovskite $CsPbBr_3$ QDs with FHWM <20 nm and PLQY >80-90%. However, the former material has incredibly higher thermal baking stability (180°C for 3 hours in air) and also higher photodegradation resistivity (300 hours at 85°C).

PH2/ OLED6 - 6L 11:55 **Enhancement of Optical Intensity and Color Gamut in White OLED Display Using Photoresist Dispersed Quantum Dot/TiO_2 Mixed Film**

H.-J. Kim, H.-B. Yang, W. R. Kim, Y. H. Kim*, M. S. Kwak*, Y.-J. Kim*

Yonsei Univ., Korea
**LG Display, Korea*

We applied patterned QD/TiO_2 mixed film to white OLED display to enhance both optical intensity and color gamut. In experimental data, optical intensity of red and green light was increased by 49.3% and 14.5%, respectively with the enhanced color gamut after adding photoresist film dispersed with QD/TiO_2 mixture.

Author Interviews
12:10 – 12:30

----- Lunch -----

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

Workshop on OLED Displays and Related Technologies

Wednesday, December 12

13:20 - 14:40 **International Conference Room**

OLED1: OLED Materials

Chair: T. Komatsu, JOLED, Japan
Co-Chair: T. Ikuta, JNC, Japan

OLED1 - 1 ***Invited*** **High Performance Blue OLED by New**
13:20 **Fluorescent Materials**

Y. Nakano, T. Masuda, S. Tasaki, Y. Takahashi, H. Ito, T. Haketa, K. Okinaka, E. Kambe, Y. Kawamura, H. Kuma

Idemitsu Kosan, Japan

We developed a new fluorescent blue host (BH) with smaller ionization potential. The new BH achieved lower driving voltage with maintaining long lifetime and high efficiency over ~170 cd/A/CIEy in the wide current density range when the top-emission device structure was applied.

OLED1 - 2 ***Invited*** **High Efficiency and Low Efficiency Roll-Off**
13:40 **Deep Blue TADF Emitter**

D. H. Ahn, S. W. Kim, H. Lee, J. Y. Lee, J. H. Kwon

Kyung Hee Univ., Korea

We report two highly efficient and deep blue thermally activated delayed fluorescence materials. These two emitters exhibit great photo-physical properties. High efficiency of 21.7% with real deep blue color coordinate of (0.14, 0.07) and extremely high efficiency of 39.8% with low roll-off characteristic were achieved.

OLED1 - 3 **Phosphorescent OLED Technologies with**
14:00 **Breakthrough Spectral Emission for Automotive Lighting Applications**

E. A. Margulies, P.-L. T. Boudreault, V. I. Adamovich, B. D. Alleyne, M. S. Weaver, J. J. Brown

Universal Display, USA

We highlight recent breakthroughs enabling higher performance PHOLEDs for deep red automotive applications through the development of narrow line shape. We achieve a 640 nm emission maximum, 43 nm FWHM and resultant 625 nm dominant wavelength. This results in a 16 cd/A LE and a 14,000 hr LT95 at 2,000 nits in a bottom emission device.

OLED1 - 4 ***Invited*** **Outcoupling Enhancement by Organic Materials Inside OLEDs: Control of Molecular Orientation and Refractive Index**
14:20

D. Yokoyama

Yamagata Univ., Japan

Since internal quantum efficiencies of OLEDs have reached ~100%, the remaining source for further improvement of external quantum efficiencies is only outcoupling enhancement. However, light propagation in OLEDs has been controlled mainly by inorganic materials outside the device, not by organic semiconductors themselves. This presentation will introduce and discuss recent techniques for outcoupling enhancement by control of molecular orientation and refractive index of organic materials inside the device.

----- Break -----

15:00 - 16:20 **International Conference Room**

OLED2: OLED Devices

Chair: T. Uchida, Tokyo Polytechnic Univ., Japan
Co-Chair: K. Kishino, Sony, Japan

OLED2 - 1 ***Invited*** **Recent Progress in Air-Stable Inverted OLEDs: Key Materials, Fabrication Process and Application to Flexible Display**
15:00

H. Fukagawa, T. Sasaki, T. Oono, T. Shimizu

NHK, Japan

This presentation focuses on the key materials and fabrication process of electron injection layer in inverted OLEDs. Spin-coated boron compounds were found to be suitable for realizing highly efficient and operationally stable inverted OLEDs. A flexible display using inverted OLEDs exhibits much higher air stability than one using conventional OLEDs.

OLED2 - 2 **Dark Spot Growth and its Acceleration Factor in Organic Light-Emitting Diodes with Single or Multilayered Barrier Structure**
15:20

T. Okada, A. Yoshida, T. Tsuji

Pioneer, Japan

Using organic light-emitting diodes (OLEDs) with single or multilayered barrier, dark spot growth and its acceleration factor in high temperature and humidity were measured and modeled. The acceleration factor of dark spot delay time was smaller than that of dark spot growth rate.

OLED2 - 3 **Withdrawn**

OLED2 - 5L **A Modern Approach for Characterizing Burn-In**
15:40 **Artifacts for High Dynamic Range Displays**

J. S. Park, J. Kim, S. Jung, J. Langehennig, D. Lee, B. Min*

Samsung Elect., Korea
**Samsung Elect. America, USA*

Based on analysis of burn-in of displays, multi-primary color based burn-in assessment (MPCBA) method for HDR displays is presented. To validate effectiveness, a wide range of experiments are designed and carried out for an extended period. From various assessment results, effectiveness and robustness of the proposed MPCBA method are proven.

Also presented in Innovative Demonstration Session (see p. 232)

OLED2 - 4 **Comparison of Multi Optical Simulation Methods for**
16:00 **the Functional Color Layer**

W. Kim, S. Lee, S. Kim, Y. Kim, M. Kwak, M. Jun, I. Kang

LG Display, Korea

This Paper presents the results of the study of the Functional Color Layer with Multi Optical Simulation Tools that are based on ray and wave optics. By this method using Multi Optical Simulations, we could have estimated experimental errors in the various efficiency structure case and determined theoretical matching models.

----- Break -----

16:40 - 18:00 **International Conference Room**

OLED3: OLED Soluble Materials and Process Technologies

Chair: K. Nakayama, Osaka Univ., Japan
Co-Chair: T. Tsuji, Pioneer, Japan

OLED3 - 1 ***Invited*** **Fundamentals and Device Performance of**
16:40 **Polymer-OLED Materials**

N. Akino, Y. Tsubata, D. Fukushima, S. Tanaka

Sumitomo Chem., Japan

Materials for polymer OLED have been developed to improve the efficiency and lifetime. The fundamental guidelines of material design for higher performance, some developments to close the gap between evaporation and printing, and the latest progress of polymer organic light-emitting diode (p-OLED) are reported and discussed.

OLED3 - 2 ***Invited*** **Ink-Jet Printed OLEDs for Display**
17:00 **Applications**

S. Stolz, K. M. Scheible, S. Meyer, A. Hayer, P. Hibon, M. Engel, R. Linge, B. Burkhart, N. Koenen, M. Hamburger, G. Béalle, H.-R. Tseng, M. Wucherer-Plietker, G. Bernatz, R. Anémian

Merck KGaA, Germany

We present recent advances of the performance of ink-jet printed OLEDs, focusing on the transition from individual, monochrome pixels towards a true R,G,B device stack with harmonized, i.e. common, transport layers. We furthermore discuss inks optimized for flat films which will enable the fabrication of printed top-emission devices.

OLED3 - 3 ***Invited*** **Important Technologies of Inkjet Printer and**
17:20 **VF Unit for OLED Display Fabrication**

T. Hayashi, A. Shimamura, Y. Konta, K. Oshima

Tokyo Electron Kyushu, Japan

We reported the advantages of inkjet printing and the Vacuum-dry Film-formation (VF) unit for OLED display fabrication. The swath-mura caused by IJ head variations was already resolved by Gen.8.5 IJP equipment technologies. And we developed the new vacuum drying equipment (VF) by adopting three new concepts.

OLED3 - 4 **Matrix Quantum Dot Light-Emitting Diodes**
17:40 **Patterned by Photolithography Technology**

C.-T. Chiu, S.-Y. Cheng, J.-T. Lian

Chunghwa Picture Tubes, Taiwan

Matrix quantum dot light-emitting diodes (M-QLEDs) were fabricated through photolithography process using photoresist. A photolithographic technique was used with quantum dot materials that was low-cost and simple process for patterning the QD emissive layer. The performance of M-QLEDs exhibit low turn-on voltage of 3.0-3.5 V, maximum luminance of 5263-8070 cd/m^2.

Author Interviews
18:10 – 18:40

Thursday, December 13

9:00 - 10:20 **International Conference Room**

OLED4: OLED Display

Chair: Y. Kijima, Huawei Techs. Japan, Japan
Co-Chair: H. Kuma, Idemitsu, Japan

OLED4 - 1 ***Invited*** **High Performance OLED and Its Application**
9:00

T. Kim, K. Song, J. Kim, J. Park, H. Choi, K. Kim, C. Han, H. Choi, I. Kang

LG Display, Korea

We have demonstrated UHD OLED TV based on tandem WOLEDs from 55 to 77 inch size where the benefits of high resolution can be seen most impressively. Moreover, we have also successfully demonstrated OLEDs can open the way for new application such as automobile industry with tandem RGB OLED.

OLED4 - 2 ***Invited*** **4032ppi High-Resolution OLED Microdisplay**
9:20

T. Fujii, C. Kon, Y. Motoyama, K. Shimizu, T. Shimayama, T. Yamazaki[*], T. Kato[*], S. Sakai[**], K. Hashikaki[**], K. Tanaka[***], Y. Nakano[***]

Sony Semiconductor Solutions, Japan
[*]Sony, Japan
[**]Sony LSI Design, Japan
[***]Sony Semiconductor Manufacturing, Japan

A 0.5-in. UXGA OLED microdisplay has been developed with 6.3 µm pixel pitch. 4032 ppi high resolution, high frame rate, low power consumption, wide viewing angle and high luminance have been achieved simultaneously. This newly developed OLED microdisplay is suitable for Near-to-Eye display applications, especially electronic viewfinders.

OLED4 - 3 **High Transmission Opening Active Matrix OLED Display**
9:40

M. Adachi, Y. Matsumoto, M. Gunji, N. Maeda, Y. Kimura, H. Kato, T. Nakanishi, A. Hasegawa, H. Tabatake

Japan Display, Japan

A transparent active matrix OLED display with a high transmission opening was fabricated. A prototype of the transparent OLED display demonstrated 78% transmission opening, 163 ppi pixel density, and 63% transmittance. In this prototype, fine metal masks were not used in any of the OLED layers for manufacturability.

OLED4 - 4 **Influence of Power VDD IR Drop on Picture Quality**
10:00

B. Lei, Y. Zheng, Y. Ma, P. Dang, Z. Duan

Visionox Tech., China

AMLOED is leading self-emitting, and its display brightness depends on the current flowing through LED. When current flows through panel, the resistance of metal line can result in the power VDD IR drop along with the power line, which will limit the maximum brightness of display.

Author Interviews
10:40 – 11:10

10:40 - 13:10 **Event Hall**

***Poster* OLEDp1: OLED Poster**

OLEDp1 - 1 Blue Fluorescence Organic Light-Emitting Diode with Novel Anthracene Derivatives

T.-L. Chiu, C.-H. Chen, B.-A. Fan*, J.-H. Lee*, L.-J. Ho*, M.-K. Leung**

Yuan Ze Univ., Taiwan
**Nat. Taiwan Univ., Taiwan*

Two novel anthracene derivatives was synthesized by respectively conjugating anthracene with oxadiazole moiety and imidazole moiety, which were employed as the fluorescent emitter inside blue organic light emitting diodes to achieve the external quantum efficiency of 3.7% and 4.7%.

OLEDp1 - 2 Optical Analysis of Circularly Polarized Emission in Surface-Treated Mesogenic Conjugate Polymer

D.-M. Lee, B.-J. Kang, J.-H. Woo, C.-J. Yu, J.-H. Kim

Hanyang Univ., Korea

This study describes an optical analysis of the circularly polarized(CP) luminescence in mesogenic conjugate polymer depending on a surface rubbing strength. The dissymmetric factor of the CP luminescence was directly proportional to the ordering of the mesogenic polymer governed by the rubbed surface.

OLEDp1 - 3 An Excellent Performance of Pixel Definition Layer Effects on High Quality OLED Devices Fabricated by Inkjet Printing Process

K.-P. He, X.-X. Zhang, J. Tang, J.-S. Im

Shenzhen China Star Optoelect. Tech., China

Good hydrophobic property and no residual on anode of pixel definition layer (PDL) are of great benefit to inkjet printed OLED devices. These key factors affect not only spreading of ink, process windows but also the display quality. The performance of different inks in different PDL were researched in this work.

OLEDp1 - 4 Withdrawn

OLEDp1 - 5 **Nickel Oxide Nano-Particles Replacing of Hole Injection Layer in Organic Light-Emitting Diodes**

S. Lee[*], G. Yun[*], A. Turak[**], W. Kim[,**]*

[*]Hoseo Univ., Korea

[**]McMaster Univ., Canada

We synthesized nickel oxide (NiO_x) nano-particles (NPs) via reversed micelle process rendering the work function of ITO anode increased to improve hole injection capability of ITO and getting rid of current HILs in organic light-emitting diodes(OLEDs) and observed their electrical properties through hole only device(HOD) tests.

OLEDp1 - 6 **MoO_3 Nanoparticle Doped NiO_x As a Hole Injection Layer for OLEDs**

M. Kim, M. S. Cho, Y. S. Jung, D. Y. Jeon

KAIST, Korea

Nickel (II) oxide (NiO_X) is the p-type semiconductor material which has wide-bandgap (~3.7 eV). Excellent material properties of NiO_X make it possible to use NiO_X as hole injection layer (HIL) for many optoelectronic devices. In this work, we introduce charge transfer doing in NiO_X by MoO_3 nanoparticles blending.

OLEDp1 - 7 **Designing Micro-Lens Structure for Enhancing the External Quantum Efficiency of OLED Device**

D. Lee, S.-H. Song, J.-W. Yoo, S.-J. Park, J.-K. Song

Sungkyunkwan Univ., Korea

Enhancing OLED display property becomes the issue for the next generation displays. Outdoor readability is one of the issues, so we propose a new structure to enhance the external quantum efficiency with micro-lens structure, and depositing carbon layer on the structures to increase outdoor readability by absorbing the light.

OLEDp1 - 8 **Reliability Improvement of Organic Light-Emitting Diodes Using Organic/Inorganic Hybrid Nanocomposite Passivation Film with Good Surface Hardness**

B.-M. Park, H. J. Chang, K.-Y. Han

Dankook Univ., Korea

We investigated the characteristics of nanoparticles embedded hybrid passivation film (HPF). The HPF used a urethane acrylate containing a multi-functional group as a matrix and monodispersed alumina nanoparticles as a filler for improving surface hardness. The optimized HPF exhibited excellent surface hardness as well as extended lifetime of OLED device.

OLEDp1 - 9 AMOLED Linear Crosstalk Failure Analysis and Improvement

Y. Zheng, B. Lei, P. Dang, J. Cheng, Z. Duan, X. Zhu, X. Huang

Visionox Tech., China

Nowadays, the AMOLED products linear crosstalk is still not satisfied the experiences of visual, as shown in Fig1. This paper proposes the main influencing factors and improvement measures, including coupling capacitance and driver IC capability. Meanwhile, a linear crosstalk evaluation method is proposed to compare different products and designs.

OLEDp1 - 10 Techniques to Achieve 814 ppi in AMOLED Display for Virtual Reality

Q. Liu, L. Zhang, S. Hu, H. Zhu, X. Zhu

Kunshan Govisionox Optoelect., China

A particular design is introduced to optimize LTPS and OLED design on pixel to achieve 814 ppi in AMOLED display for Virtual Reality (VR) in this paper. In order to make the design more compact and effective, new pixel circuit and new pixel arrangement are implemented respectively.

OLEDp1 - 11L Study on Device Stability of Green PHOLEDs with Ultrathin Interface Tunneling Layer

S.-R. Park, J. Y. Lee, M. C. Suh

Kyung Hee Univ., Korea

We have focused on interface modification of green phosphorescent organic light-emitting diodes. In other words, we inserted unique interface tunneling layer (ITL) at both sides of emitting layers (EML) to improve the injection behavior which minimizes a charge accumulation at EML interfaces. Consequently, we obtained a significantly improved device lifetime.

OLEDp1 - 12L Improvement of Viewing Angle Dependence with Random Wrinkle Structure inside TEOLED Showing Strong Microcavity Effect

S. H. Jung, N. S. Kim, I.-U. -D. Q. Muhammad, M. C. Suh

Kyung Hee Univ., Korea

In this work, we applied various random wrinkle structure with different morphology for top organic light emitting diodes (TEOLEDs) showing strong microcavity effect. This application could dramatically improve viewing angle dependence and greatly suppress a poor color shift property.

OLEDp1 - 13L Enhanced Field-Effect Mobility of Top-Gate Organic Transistors with Channel Length of 5 µm Using Solution-Processed MoO_3 Hole Injection Layers

T. Aiba, T. Nagase, T. Kobayashi, Y. Sadamitsu[*]*, H. Naito*

Osaka Pref. Univ., Japan
[*]*Nippon Kayaku, Japan*

We have investigated the electrical characteristics of C_8-BTBT-based top-gate organic FETs having solution-processed MoO_3 hole injection layers. By treating with UV/O_3 to MoO_3 layers, contact resistance is reduced to 0.4 kΩcm at V_G=–30 V, and short-channel devices with L=5 µm exhibit high effective mobilities up to 1.4 cm^2/Vs.

OLEDp1 - 14L Modeling OLED Compensation Technology for OLED TV

S.-J. Tang, J. He, J. Ancich, T. Doodnauth

Ignis Innovation, Canada

The main objective is to develop a model for predicting OLED degradation found on current commercial OLED TVs. Correction is achieved by increasing grey level of input image signal corresponding to the predicted value in the compensation algorithm periodically correcting the input image signal to prevent image burn-in.

OLEDp1 - 15L Photo-Cross-Linkable Hole Transporting Material for Efficient Solution Processed Light Emitting Diode

Q. M. Saqib, S.-R. Park, M. C. Suh

Kyung Hee Univ., Korea

A novel photo-cross-linkable hole transporting material (HTM) for efficient solution processed OLED is reported. The result shows much lower operating voltage (at 1000 cd/m^2) of 5.4 V (8.2 V for control device) with moderate external quantum efficiency (EQE) of 11.19% which represent about twice enhancement over the control device.

OLEDp1 - 16L Full Roll-to-Roll Fabrication Process of Large-Area Flexible OLED with Silver-Nanowire Transparent Electrode

C. Kim, S. Jeong, S. M. Cho

Sungkyunkwan Univ., Korea

Large-area flexible OLED panels were fabricated by a roll-to-roll thermal evaporator. The panels were fabricated on silver-nanowire embedded transparent electrode with barrier layer inserted between electrode and PET substrate. All fabrication process for OLED panels were roll-to-roll process. For lighting applications, phosphorescent blue OLEDs were down-converted to white using phosphors.
Also presented in Innovative Demonstration Session (see p. 232)

OLEDp1 - 17L Optimization of Ir(ppy)$_3$ Dopant Concentration to Variable Electron Injection Rates for High Efficiency OLED

D. J. Kwon, S. J. Park, S. H. Jang, Y. J. Kim

Yonsei Univ., Korea

We studied the optimum layer configurations for high efficiency phosphorescent OLED through dopant concentration control when the electron injection rate of ETL is increased with the addition of ZnO nanoparticles. It was found experimentally that the Ir(ppy)$_3$ dopant concentration of 5 wt% was optimized to show the best luminance over 8,200 cd/m^2.

10:40 - 13:10 Event Hall

***Poster* OLEDp2: OLED/QDT Poster**

Special Topics of Interest on Quantum Dot Technologies

OLEDp2 - 1 Efficiency Improvement of Quantum Dot Light Emitting Diode by Using DMSO Treated PEDOT: PSS

T. J. Bae, S. H. Song, S. J. Park, S. S. Kim, J. K. Song

Sungkyunkwan Univ., Korea

We suggest dimethyl sulfoxide (DMSO) doped poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) as hole injection layer for quantum dot light emitting diode(QLED). Due to an elimination of PSS-PEDOT bonding in PEDOT:PSS, the performance of device increased. The result showed improvement in luminance, power efficiency, external quantum efficiency and current efficiency up to 31.87%.

OLEDp2 - 2 Organic Electron Transport Layer for High Performance Green Inverted Quantum Dot Light Emitting Diodes

C. Y. Lee, H. W. Bae, K. J. Eun, N. N. Mude, J. H. Kwon

Kyung Hee Univ., Korea

We report a new organic electron transport layer(ETL) for high performance of green inverted quantum dot light emitting diodes(QLED). We anticipate that this organic ETL not only delay electron flow to match charge balance but also reduce exciton quenching between inorganic zinc oxide(ZnO) layer and quantum dot(QD) layer.

OLEDp2 - 3L A Charge Injection Model for QLEDs Based on Dynamic Equilibrium Conditions

S.-K. Kim, Y.-S. Kim

Hongik Univ., Korea

Charge injection phenomenon into layers of QLED was analyzed under a dynamic equilibrium condition. Assuming traps are distributed exponentially in forbidden energy band, effects of major parameters on the injection behavior were investigated to elucidate their effects on the current-voltage relationship in QLEDs.

OLEDp2 - 4L Metal Oxide Nanoparticles in an Electron Transport Layer for Efficient Charge Balance in Inverted Quantum Dot Light-Emitting Diodes

H. Kim, W. Lee, H. K. Chung, H. Chae

Sungkyunkwan Univ., Korea

In this work, a facile method is proposed to improve the charge balance of quantum dot light-emitting diodes (QLEDs) by controlling concentration ratio of two metal oxide nanoparticles (MON, ZnO) with different electron mobility. Charge balance in QLED improved with 0.063 wt% MON mixed with ZnO by lowering electron injection.

OLEDp2 - 5L High Brightness and Low Roll-Off Quantum-Dot Light Emitting Diodes Using Doped Metal Oxide Electron Transport Layer

Y. Lee, H.-M. Kim, J. Kim, J. Jang

Kyung Hee Univ., Korea

We report a doped metal oxide electron transport layer (ETL) for inverted green QLEDs (G-QLEDs). The G-QLED with doped metal oxide ETL exhibited low efficiency roll-off characteristic compared to that with pristine ETL. The efficiency roll-off of the G-QLED was improved from 57% to 3% at 10,000 cd/m^2.

Friday, December 14

9:00 - 10:20 **Room 432**

OLED5: OLED Device Technology

Special Topics of Interest on Quantum Dot Technologies

Chair: T. Wakimoto, Merck PM, Japan
Co-Chair: T. Shimizu, NHK, Japan

OLED5 - 1 *Invited* Monochromatic LEDs Based on Perovskite Quantum Dots: Opportunities and Challenges
9:00

C.-J. Shih, S. Kumar, J. Jagielski

ETH Zurich, Switzerland

Perovskite quantum dots (QDs) are emerging as one of the most promising candidates for the monochromatic light-emitting diodes (LEDs) approaching the Rec. 2020 color gamut due to their extremely narrow emission bandwidth. Here we briefly summarize the opportunities and challenges in both fundamental and technological aspects, based on our recent work in this field.

OLED5 - 2 9:20 **Negative Capacitance as a Diagnostic Tool for Recombination in Purple Quantum Dot LEDs**

C. Blauth[,**], T. Hirai[**], P. Mulvaney[*]*

[*]Univ. of Melbourne, Australia

[**]CSIRO Manufacturing, Australia

Impedance spectroscopy (IS) and the study of the capacitance are strong and non-destructive approaches to determining the recombination properties in quantum dot light emitting diodes (QLEDs). We report here for the first time unique capacitance behaviour in wide band gap QLEDs due to the ligands present around the nanocrystals.

OLED5 - 3 **Withdrawn**

OLED5 - 5L 9:40 **Controllable Variations for High Performance Perovskite Light Emitting Diodes Device Fabrication in Solution Process**

D. Y. Kim, D. H. Kwak, M. C. Suh

Kyung Hee Univ., Korea

We report 3 important factors for efficient Perovskite LED. We have inserted interlayer between hole transport layer and emitting layer to obtain an appropriate perovskite morphology. We also varied the perovskite precursor concentration and the solvent for additive-nanocrystal pinning(A-NCP). Consequently, we could obtain moderately high performance from our PeLED.

OLED5 - 4 10:00 **High-Performance, Solution-Processed Quantum Dots Hybrid Light-Emitting Field-Effect Transistors**

P. He, L. Lan, J. Peng

South China Univ. of Tech., China

The high-performance quantum-dots hybrid light-emitting field-effect transistors (QDs-HLEFETs) were demonstrated, which combined high luminous-efficiency quantum dots (QDs) and solution-processed scandium-incorporated indium oxide ($Sc:In_2O_3$) semiconductor as light-emitting layer and electron transport layer, respectively.

----- Break -----

10:40 - 12:10 **Room 432**

PH2/OLED6: QD Phosphors and Devices

Special Topics of Interest on Quantum Dot Technologies

Chair: R.-J. Xie, Xiamen Univ., China
Co-Chair: Y. Sakai, Mitsubishi Chem., Japan

PH2/OLED6 - 1
10:40

Invited **Narrow Band-Edge Emission from $AgInS_2$ Semiconductor Quantum Dots by the Formation of Amorphous III-VI Semiconductor Shells**

T. Uematsu

Osaka Univ., Japan

A spectrally narrow band-edge photoluminescence was achieved for the first time by coating silver indium sulfide ($AgInS_2$) colloidal semiconductor quantum dots with indium sulfide (InS_x) or gallium sulfide (GaS_x) shells. Photoluminescence quantum yield as high as 56% was achieved by the surface modification of shells with phosphine compounds.

PH2/OLED6 - 2
11:00

Novel Ligand Materials to Enhance Luminous Efficiency and Stability of Perovskite Quantum Dot

S.-Y. Cheng, C.-T. Chiu, J.-T. Lian, B.-K. Hsu, T.-Y. Lin**

Chunghwa Picture Tubes, Taiwan
**Nat. Taiwan Ocean Univ., Taiwan*

Perovskite quantum dots (PeQDs) have attracted much attention in recent years. However, because of the poor stability against temperatures, polar solvents, and UV light, the application of PeQDs is limited. We have succeeded in synthesizing a wavelength tunable (420~670 nm) PeQDs with high-stable, high photoluminescence quantum yields and narrow FWHM.

PH2/OLED6 - 3
11:20

Improved Stability of $CsPbBr_3$ Perovskite Quantum Dots by Suppressing the Interligand Proton Transfer and Applying the Polystyrene Coating

Y. Cai, Y. Li, R.-J. Xie

Xiamen Univ., China

We first adopted hexadecyl trimethyl ammonium bromide to synthesize $CsPbBr_3$ QDs. The interligand proton transfer was thus suppressed and the obtained $CsPbBr_3$ QDs showed enhanced stability against acetone. Then, a polymer of carboxyl-functional polystyrene (cPS) was used to coat $CsPbBr_3$ QDs and the composite shows improved thermal and moisture stability.

PH2/OLED6 - 4 **Withdrawn**

PH2/ OLED6 - 5L 11:40 **Perovskite Quantum Dots with Enhanced Thermal Stability for Display Application**

L. Sinatra, M. Lutfullin, M. Mahmud, J. Pan, O. Bakr**

Quantum Solutions , Saudi Arabia
**King Abdullah Univ. of S&T, Saudi Arabia*

We report here Zero-Dimensional perovskite (Cs_4PbBr_6) that has similar optical properties as Perovskite $CsPbBr_3$ QDs with FHWM <20 nm and PLQY >80-90%. However, the former material has incredibly higher thermal baking stability (180°C for 3 hours in air) and also higher photodegradation resistivity (300 hours at 85°C).

PH2/ OLED6 - 6L 11:55 **Enhancement of Optical Intensity and Color Gamut in White OLED Display Using Photoresist Dispersed Quantum Dot/TiO_2 Mixed Film**

H.-J. Kim, H.-B. Yang, W. R. Kim, Y. H. Kim*, M. S. Kwak*, Y.-J. Kim*

Yonsei Univ., Korea
**LG Display, Korea*

We applied patterned QD/TiO_2 mixed film to white OLED display to enhance both optical intensity and color gamut. In experimental data, optical intensity of red and green light was increased by 49.3% and 14.5%, respectively with the enhanced color gamut after adding photoresist film dispersed with QD/TiO_2 mixture.

Author Interviews
12:10 – 12:30

----- Lunch -----

13:10 - 14:25 **Room 133**

OLED7: OLED Advanced Technology

Chair: M. Adachi, Japan Display, Japan
Co-Chair: S. Aratani, Samsung Elect., Korea

OLED7 - 1 13:10 **Study of Viewing Angle on Fluorescence Dye Photo Resist for OLED Display**

S. Kim, S. Lee, W. Kim, Y. Kim, M. Kwak, M. Jun, I. Kang

LG Display, Korea

Additional layer of fluorescence dye (FD) as photoresist (PR) between white OLED and color filter was proposed. In real panel, the viewing angle characteristics according to FD PR design and the efficiency were investigated. As viewing angles go up, it can offer less color shift and higher luminescence.

OLED7 - 2
13:30

High Transparency and High Reliability Transparent Cathode Fabricated by Thermal Evaporation for Transparent OLED Application

M.-G. Song, J. E. Yeom, K.-S. Kim, J. H. Kwon

Kyung Hee Univ., Korea

We report a new cathode unit and it was fabricated by co-deposition with silver and aluminum by thermal evaporation. Our new cathode shows 90% peak transmittance, a sheet resistance of 7.0 Ω/□. This cathode shows good electron injection and no specific agglomeration at 85°C, 240 hours.

OLED7 - 3
13:50

High Reliability Flexible Device with Atomic Layers Deposition Layers

G. T. Fu, L. Rui, W. Kan, N. Jing, W. J. Yuan, L. J. Jia, B. Y. Mei, H. Jing, H. H. Lun

Wuhan China Star Optoelect. Semiconductor Display Tech., China

In this paper, we report the variant thin film encapsulation to composite with atomic layer deposition layer. All structures had been tested for bending, optical performance, view angle and high temperature/high humidity reliability test. The results indicated ALD layer deposited on EL directly is the best for TFE design.

OLED7 - 4L
14:10

A Study on the Improvement of POLED Panel Performance by Evaluation of PI and PAC Planarization Layer Characteristics

H. Park, K. Sung

LG Display, Korea

We studied various characteristics which were analyzed by changing the layer formation conditions for both types of PLN. The mechanical properties of the PI were lower than those of the PAC. On the other hand, the reliability characteristics of the PAC were poorer than the ones of PI.

Author Interviews
16:20 – 16:50

Supporting Organizations:
The Japanese Society of Printing Science and Technology
The Society of Photography and Imaging of Japan

Workshop on 3D/Hyper-Realistic Displays and Systems

Wednesday, December 12

15:00 - 16:20 **Room 222**

3D1: Display Systems for AR

Special Topics of Interest on AR/VR and Hyper Reality

Chair: S. Yano, Shimane Univ., Japan
Co-Chair: D. Mikami, NTT, Japan

3D1 - 1
15:00

Invited **The Optimization of a Light-Field Holographic Projection System**

C.-Y. Chen, C.-H. Chuang[*]

Nat. Taiwan Univ. of S&T, Taiwan
[*]Nat. Taiwan Univ., Taiwan

A prototype system of head-mounted holographic display is presented with multi-depth. The system adopts modified Gerchberg-Saxton algorithm to produce the phase-only function. Furthermore, the proposed system could achieve multi-depth by using human eyes focus and zoom mechanism. Finally, the quality of images in this study are also analyzed and evaluated.

3D1 - 2
15:20

Large-Size and See-Through Color Light Field Display Using Projector and DDHOE

B. J. Jackin, L. Jorissen[*], R. Oi, K. Wakunami, Y. Ichihashi, M. Okui, K. Yamamoto

NICT, Japan
[*]Hasselt Univ., Belgium

A Light field display system that uses projector and holographically fabricated micro-lens array is presented. The ability of the display system to reconstruct 3D scenes in full color and large size, is being reported for the first time. The system being simple without any bulky optics is the added advantage.

3D1 - 3
15:40

Geometric Phase Doublet Lens for Augmented Reality

C.-K. Lee, W. Seo, G. Sung, S. Kim, B. Shin, Y.-T. Kim, J. Seo, J.-S. Chung, J. An, H. Song, Y. Kim, H. Kim, C.-S. Choi, Y. Kim, K. Won, S.-H. Lee, M. Jeon, H.-S. Lee, D. Lee

Samsung Elect., Korea

Novel optical combiner for augmented/mixed (AR/MR) reality is proposed by implementing doublet of geometric phase lenses. Depending on the polarization state of light, the real world scene directly transmits the lens and the virtual images are generated by the function of positive power of the lens.

3D1 - 4
16:00 **A Simulation Platform to Convert Viewing Geometry of a Transparent Display for AR Applications**

Y.-M. Chen, P.-L. Sun, C.-J. Li[*]*, H.-Y. Chen*[*]

Nat. Taiwan Univ. of S&T, Taiwan
[*]*ITRI, Taiwan*

A simulation platform for designing an optic see-through AR system with various viewing parameters of transparent display is proposed. It consider whole environment parameters. Platform can simulate AR system with different parameters and it also can optimize the design of the AR system with different transparent displays and camera settings.

----- Break -----

16:40 - 18:00 **Room 222**

3D2/DES1: Novel Display Systems

Special Topics of Interest on AR/VR and Hyper Reality

Chair: C.-Y. Chen, Nat. Taiwan Univ. of S&T, Taiwan
Co-Chair: Y. Oyamada, Tottori Univ., Japan

3D2/
DES1 - 1
16:40 ***Invited*** **Hidden Stereo: Synthesizing Ghost-Free Stereoscopic Images for Viewers without 3D Glasses**

T. Fukiage, T. Kawabe, S. Nishida

NTT, Japan

When a conventional stereoscopic display is viewed without 3D glasses, image blurs, or 'ghosts', are visible due to the fusion of stereo image pairs. We overcome this limitation by synthesizing ghost-free stereoscopic images based on phase-based control of stereo disparity.
Also presented in Innovative Demonstration Session (see p. 232)

3D2/
DES1 - 2
17:00 ***Invited*** **Extended Imagery Training for Baseball Batting through High-Reality Virtual Space Using Head Mounted Display**

D. Mikami

NTT, Japan

This paper introduces a system that provides a first-person-view experience for athletes preparing to engage in sports competitions. Our system uses only information captured from locations that will not disturb the athletes or competitions. We describe in this paper how the system worked in a trial with a baseball team.

3D2/ DES1 - 3 17:20 ***Invited*** **An Interactive Fog Display to Express Adaptive Shape-Changing Flow**

*T. Koga, K. Otao**

Nat. Inst. of Tech., Tokuyama College, Japan
**Univ. of Tsukuba, Japan*

We propose an interactive fog display to express the adaptive shape-changing flow of a fog screen caused by interactions with the viewer. We present the design specifications of the proposed system, evaluation results of a user study, and some application contents to use the proposed system effectively.

3D2/ DES1 - 4 17:40 **A Miniaturized Multi-Layered Display System with Water Drops**

H.-W. Chen, Y.-A. Kuo, Z.-W. Wang, W. -C. Hsu, C.-Y. Chen*

Nat. Taiwan Univ. of S&T, Taiwan
**Bruvis Multi Media Creative, Taiwan*

In this study, we proposed a multi-layered microprojection system. Foremost the water curtain projection system uses an Arduino control panel and an infrared sensor to implement an interactive device. Furthermore, the Light Sculpture Projection System creates a three-dimensional and high-fidelity effect. In combination, a multi-level display system is formed.

Author Interviews
18:10 – 18:40

Thursday, December 13

14:20 - 16:50 **Event Hall**

Poster **3Dp1: 3D/Hyper-Realistic Display Systems**

3Dp1 - 1 **Distortion Correction of Point-Cloud Object for Projection-Type Holographic Display Based on HOE Screen**

H. Amano,**, Y. Ichihashi**, T. Kakue*, K. Wakunami**, H. Hashimoto*,**, T. Shimobaba*, T. Ito**

**Chiba Univ., Japan*
***NICT, Japan*

By using the holographic optical element screen, an aerial-projection display of three-dimensional images can be realized up close which the scale is free. However, the projected image is distorted when an object is placed far from the hologram plane. In this study, we corrected the distortion by shift point cloud.

3Dp1 - 2 **Acceleration of Hologram Calculation by Background Subtraction for Three-Dimensional Reconstruction of Moving Objects in Real Scene**

H. Yanagihara, T. Kakue, T. Shimobaba, T. Ito

Chiba Univ., Japan

We reduced the computational load of hologram generation by extracting moving objects in real scene using the background subtraction to realize real-time electro-holographic display system. The hologram generation with the background subtraction was approximately 12 times faster than that without the background subtraction.

3Dp1 - 3 **Expansion of Viewing Window for Projection-Type Holographic Display Based on HOE Screen**

H. Hashimoto[,**], Y. Ichihashi[**], T. Kakue[*], K. Wakunami[**], H. Amano[*,**], T. Shimobaba[*], T. Ito[*]*

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

In this study, we verify that the target observation area is shifted and expand viewing window by using off-axis reference light. We confirmed that the target observation area was shifted ±5 mm by changing the angle of off-axis reference from -1.5~+1.5 degree.

3Dp1 - 4 **3D Holographic Display with Controllable Depth of Field Based on Complex Amplitude Modulation**

T. Zhang, Y. Pang, J. Xia

Southeast Univ., China

In this paper, we propose a new initial phase generated by G-S algorithm on the basis of complex amplitude modulation(CAM) using double-phase holograms(DPH). Through this method, we have achieved a suitable balance between the depth of field and the image quality.

3Dp1 - 5 **A Flexible Pipeline from a Single-View Camera to a Stacked-Layer Light-Field Display**

T. Hidaka, K. Maruyama, T. Fujiwara, K. Takahashi, T. Fujii

Nagoya Univ., Japan

We have developed a flexible pipeline from a single-view camera to a layered light-field display. We obtain a color image and a depth map with the aid of structured illumination from the camera. Using these information, we synthesized multi-view images and displayed them on the layered display.

Also presented in Innovative Demonstration Session (see p. 233)

3Dp1 - 6 **Implementation of Table-Top Light-Field Display**

K. Maruyama, H. Kojima, K. Takahashi, T. Fujii

Nagoya Univ., Japan

A stacked layer display is a kind of light field display that can express dozens of viewpoints with several LCDs. We have succeeded in implementation of a vertical type layered display. In this paper, we newly implemented layered display hardware which is suitable for table-top display.

Also presented in Innovative Demonstration Session (see p. 233)

3Dp1 - 7 **Development of Prototype of 36-in. Interactive Tabletop Display System**

W. Jang, H. Shim, D. Lee, J. Park, S. K. Yoon, H. Kim, S. Chun

Korea Photonics Tech. Inst., Korea

We developed tabletop display module composed of tiled-projectors along with micro-lens arrays and diffusers. We further extend display size bytiling several modules up to 72 projectors. In order to play entire display image on 72 tiled projectors, we performed 3D image generation using DRONE pictures and point cloud method and pixel re-alignment procedure through author tooling.

3Dp1 - 8 **Increasing Far Depth Perception by Using Far Stimuli Display in Head Mounted Display**

Y. Abiko, S. Suyama, H. Mizushina

Tokushima Univ., Japan

We have proposed and developed two new methods to increase far depth perception from 4 m to 19 m in both see-through and closed Head Mounted Displays by putting real objects at far position or by changing stimuli display position far away.

3Dp1 - 9 **Very Small Disparity Required for Large Depth Perception by Monocular Motion Parallax in DFD Display**

K. Okamoto, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We have proposed large depth perception in DFD display by using very small but continuous monocular motion parallax. Large perceived depth over 80 arcmin. can be achieved only by very small amount of continuous motion parallax of 4-6 mm width around pupil diameters.

3Dp1 - 10 **Fast Response Time for Image Depth Fusion in DFD Display**

A. Nogami, H. Mizushina, S. Suyama

Tokushima Univ., Japan

We clarified that front and rear DFD images can be successfully fused in one depth even at only one exposure of very short display time of 1.0 msec. Even at this very short display time, perceived depth dependences coincide well with the designed depths with small deviations.

3Dp1 - 11 **Depth Perception Difference by Changing Short Display Time from Long Viewing Distance in Non-Overlapped DFD (Depth-Fused 3D) Display**

S. Mukaeyama, H. Mizushina, S. Suyama

Tokushima Univ., Japan

In Non-overlapped Depth-fused 3D display with long-viewing distances, depth fusion and perceived depth change can be successfully obtained even at short display times of 4.7 ms for moving image. Although depth fusion is slightly difficult in one-time exposure of stimuli, cyclic exposure with long interval makes depth fusion easier.

3Dp1 - 12 **Changing Direction of Stimulus Motion, Not Temporal Stopping, Improves Depth Perception from Monocular Motion Parallax**

Y. Masuda, I. Kanayama, S. Suyama, H. Mizushina

Tokushima Univ., Japan

We have clarified that change of motion direction of stimulus, not temporal stopping and moving, contributes to stable and unambiguous depth perception in monocular motion parallax. In addition, we clarified stable display time ratio of the stimulus in motion parallax can be reduced to only 15% of the total time.

3Dp1 - 13 **Perceived Depth of Aerial Protruding Depth-Fused 3D Display**

Y. Terashima, S. Suyama[*], H. Yamamoto

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

We have realized aerial Depth-Fused 3D (DFD) display by utilizing two-aerial imaging by retro-reflection (AIRR) optics. AIRR forms a slightly blurred real image in the mid-air. This blurred imaging feature is suitable for DFD perception. This paper reports that the perceived depth of aerial protruding DFD display is stable.

3Dp1 - 14 **Evaluation of Radially Patterned Dihedral Corner Reflector Array for Wide Viewing Angle of Floating Image without Virtual Image**

Y. Yoshimizu, E. Iwase

Waseda Univ., Japan

We proposed a new type Dihedral Corner Reflector Array (DCRA) called radially patterned DCRA. By designing the arrangement of reflectors, the radially patterned DCRA could produce a floating image with a wide viewing angle without producing virtual images. We fabricated and evaluated the radially patterned DCRA and demonstrated floating images.

3Dp1 - 15 **Forming Aerial Images at the Center of Triangular Container by Using Polarized Aerial Imaging by Retro-Reflection (pAIRR)**

M. Yasugi[,**], H. Yamamoto[*,**]*

[*]Utsunomiya Univ., Japan
[**]JST ACCEL, Japan

For the application to the behavioral experiment of animals, we proposed the device to present the floating aerial images at the center of the triangular container where the animals are introduced, by using polarized aerial imaging by retro-reflection. The aerial images are automatically switched according to the animal location.

3Dp1 - 16 **Reducing Apparent Blur of an Aerial Signage for Long Viewing Distance**

R. Kakinuma[*], K. Shimose[*], H. Yamamoto[,**]*

[*]Utsunomiya Univ., Japan
[**]JST ACCEL, Japan

We propose a method to reduce apparent blur when an aerial signage is viewed from a long distance. Our proposed method forms an aerial image by use of a digitized retro-reflector. The special retro-reflector is composed of retro-reflective patches with an enough spacing in order to reduce the noticeable blur.

3Dp1 - 17 **Multi-Modal Underwater Information Display in Combination of Speakers and an Underwater Screen with by AIRR**

K. Fujii[*], H. Yamamoto[,**]*

[*]Utsunomiya Univ., Japan
[**]JST ACCEL, Japan

This paper gives multi-modal sensation on a viewer who put their hand inside a water, where an underwater information screen is formed with AIRR. The water tank, on which two speakers was attached, gives stimulation through water vibration. Thus, visual and haptic multi-modal display was realized with a water.

3Dp1 - 18L **Large Autostereoscopic Display Using Subpixel Parallax Barrier**

M. Ito[,**], Y. Ushio[**], Y. Kokumai[**], Y. Makino[*], H. Shinoda[*]*

[*]Univ. of Tokyo, Japan
[**]Nikon, Japan

We fabricated an autostereoscopic display using parallax barrier control by subpixel shift. The size of the prototype display is 55 inches and the resolution is 4K. We generated a distribution of rays at the viewing positions and confirmed that the control accuracy of the luminance distribution improved by 50%.

3Dp1 - 19L **Light Field Video Camera and Display Using Similar Microlens Array**

M. Ito[,**], M. Nakajima[**], T. Iwane[**], Y. Kokumai[**], Y. Makino[*], H. Shinoda[*]*

[*]Univ. of Tokyo, Japan
[**]Nikon, Japan

We fabricated a prototype light field video system. The image is taken with a light field camera and displayed on the light field display of the same micro lens array arrangement. The resolution of the image is 4K and the display speed is 13 fps.
Also presented in Innovative Demonstration Session (see p. 233)

3Dp1 - 20L **3D Model Enhancement for Augmented Reality Using Transparent Displays**

C.-Y. Hung, P.-L. Sun, C.-J. Li[*], H.-Y. Chen[*]

Nat. Taiwan Univ. of S&T, Taiwan
[*]ITRI, Taiwan

To reconstruct 3D model from the behind target object using a rear depth camera would have unacceptable results as some part of the object will be blocked of one perspective view. we proposed a pre-scan process to use multiple views of the object to make the 3D model more complete.

3Dp1 - 21L **High-speed 3-D Spatiotemporal Division Multiplexing Holographic Movie Playback with High Image Quality by SSD and DMD**

N. Takada, M. Tao, H. Sannomiya, T. Sakaguchi, H. Nakayama[*], M. Oikawa, Y. Mori, T. Kakue[**], T. Shimobaba[**], T. Ito[**]

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

We report high-speed 3-D spatiotemporal division multiplexing holographic movie playback using the packed data of computer-generated hologram stored in high-performance solid state drive. Consequently, we succeeded to play high image quality 3-D movie of the 3-D object comprising about 900,000 points at 60 frames per second.

3Dp1 - 22L Real-Time Spatiotemporal Division Multiplexing Electroholography Using Multiple GPU Cluster System with Gigabit Ethernet Network

H. Sannomiya, N. Takada, T. Sakaguchi, H. Nakayama[*], M. Oikawa, Y. Mori, T. Kakue[**], T. Shimobaba[**], T. Ito[**]

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

We demonstrated real-time electroholographic 3-D movie reconstruction using spatiotemporal division multiplexing technique on a multiple GPU cluster system including 13 GPUs connected through gigabit ethernet network. We succeeded to display reconstructed 3-D movie consisting of 477,511 object points at 36 fps.

3Dp1 - 23L Image Quality Improvement for 3D Structure Exhibiting Multiple 2D Patterns Using Convolutional Neural Networks

T. Murase, D. Matsumoto, R. Hirayama[,**], H. Nakayama[***], T. Shimobaba, T. Ito, A. Shiraki*

Chiba Univ., Japan
[*]JSPS, Japan
[**]Tokyo Univ. of Sci., Japan
[***]Nat. Astronomical Observatory of Japan, Japan

Our research group developed a directional volumetric display that exhibits images in multiple directions. However, the images exhibited from the display contain many noise. Therefore, we proposed an image quality improvement algorithm using deep learning and showed its effectiveness.

3Dp1 - 24L Withdrawn

3Dp1 - 25L Resolution-Enhanced Light-Field Imaging System Utilizing Virtual-Moving Microlens Array

T.-H. Lee, M.-K. Park, K.-I. Joo, J.-W. Lee, H.-R. Kim

Kyungpook Nat. Univ., Korea

We propose the resolution-enhanced light-field (LF) imaging system utilizing virtual-moving microlens array (MLA). In our LF imaging system, the resolution of the reconstructed image in LF imaging system with virtual moving MLA was improved by four times compared to that obtained with conventional LF imaging system.

14:20 - 16:50 **Event Hall**

Poster 3Dp2: Projection Display Systems

Special Topics of Interest on AR/VR and Hyper Reality

3Dp2 - 1 **Withdrawn**

3Dp2 - 2 **Realization of an Augmented Reality Display Operated with a Tunable Liquid Lens and 3D Integral Imaging**

P.-K. Sung, C.-W. Chien, C.-Y. Chien, C.-R. Sheu

Nat. Cheng Kung Univ., Taiwan

We demonstrate an augmented reality display (ARD) based on the integral imaging projection system. Simultaneously, a tunable focus liquid lens is used to adjust viewing depths of 3D images to prevent the vergence-accommodation conflict.

3Dp2 - 3 **Forming Aerial Omnidirectional Transparent Information Screen**

E. Abe[*], H. Yamamoto[,**]*

[*]Utsunomiya Univ., Japan
[**]JST ACCEL, Japan

This paper proposes a see-through optical system to form an omnidirectional transparent information screen that is floating in the air. The formed screen surrounds the central region. When viewed inside the screen, an omnidirectional image is visible. The displayed image on the screen is also visible from the outside.

3Dp2 - 4 **A Waveguide See-Through Display System Based on a Holographic Lens**

S.-K. Zhou[,**], W.-K. Lin[*,**], B.-S. Lin[*], W.-C. Su[**]*

[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Changhua Univ. of Education, Taiwan

The see-through display system consists of a holographic lens, waveguide, and a projection system. The holographic optical element was utilized to replace eyepiece and offering magnified images for see-through display. The see-through display can give the information at different distances by adjusting the position of the intermediate image.

3Dp2 - 5L **Real-Time Holographic Projection of 3D-Gradation Movie Using Binary-Weighted Computer-Generated Hologram and Multiple GPU Cluster**

T. Sakaguchi, N. Takada, H. Sannomiya, K. Suzuki, M. Oikawa, Y. Mori, T. Kakue[*], T. Shimobaba[*], T. Ito[*]

Kochi Univ., Japan
[*]Chiba Univ., Japan

We report real-time holographic projection to reconstruct 3D-gradation movie on cubic screen by using a multiple bit planes based on binary-weighted computer-generated holograms and a multiple-graphics-processing-unit cluster system. Consequently, we succeeded to reconstruct real-time 3D-gradation movie comprising 4840 points at 120 fps.

3Dp2 - 6L **Near-Eye See-Through Head-Mounted Display Using Aerial Imaging by Retro-Reflection (AIRR)**

C. Trovato[*], K. Kawai[*], K. Shimose[*], S. Morita[*], S. Ito[*], R. Kakinuma[*], H. Yamamoto[,**]*

[*]Utsunomiya Univ., Japan
[**]JST ACCEL, Japan

We propose a new prototype of a near-eye see-through head-mounted display using aerial imaging by retro-reflection (AIRR). We present the optical setup and the limits of the optical design for real-life use. The system allows us to obtain wide field of view images with a see-through capability.

3Dp2 - 7L **Aerial Light Field Display by Retroreflective Mirror Array**

T. Koike, Y. Onishi[*]

Hosei Univ., Japan
[*]Optoceramics, Japan

We present an aerial light field (LF) imaging with a novel retroreflective mirror array (RMA) and an LCD-based LF-display. We designed that the pop-out distance of the aerial 3D image by RMA was 2 m. The LF-display displays pseudoscopic images to produce the aerial 3D image with accurate depth information.

14:20 - 16:50 **Event Hall**

***Poster* VHFp6/3Dp3: Applied Vision and Human Factors - Human Factors of AR/VR**

Special Topics of Interest on AR/VR and Hyper Reality

VHFp6/ 3Dp3 - 1 **Study on Subjective Depth Evaluation for Holographic Head-Mounted Display**

H. Kubo, Y. Oguro, Y. Sakamoto

Hokkaido Univ., Japan

We conducted a subjective depth evaluation experiment using a compact holographic head-mounted display (HMD) that can display in color. To correctly represent depth, we corrected the distance of the depth to improve the accuracy. Evaluation results indicate that subjective depth is closer to the same depth as holography.

Also presented in Innovative Demonstration Session (see p. 233)

VHFp6/ 3Dp3 - 2 **Study on Correction of Field Curvature in Head-Mounted Display Using Electro-Holography**

Y. Oguro, H. Kubo, Y. Sakamoto

Hokkaido Univ., Japan

This paper proposes a correction method of field curvature in HMDs using electro-holography. In the proposed method, it is possible to correct field curvature including assembly error by using measured values. An experiment was conducted using an HMD, and the effectiveness of the method is confirmed from the result.

VHFp6/ 3Dp3 - 3L **Development of One-Dimensional Integral Photography**

*A. Hasegawa, S. Yano, M.-C. Park**

Shimane Univ., Japan
**KIST, Korea*

We have developed one-dimensional integral photography that displays only horizontal parallax. One-dimensional integral photography depended on a method of generating elemental images by pixel position conversion from multi-view stereoscopic images. We examined the influence of vertical resolution on depth perception using prototype one-dimensional integral photography.

17:10 - 18:30 **Room 222**

3D3: Autostereoscopic Display Systems

Chair: M. Yamaguchi, Tokyo Tech, Japan
Co-Chair: K. Takahashi, Nagoya Univ., Japan

3D3 - 1
17:10

Invited **Time-Division Multiplexing Parallax Barrier System for Interactive 3D Visualization**

H. Kakeya

Univ. of Tsukuba, Japan

We realize a full-HD autostereoscopic display system based on time-division multiplexing parallax barrier where the viewing zone is close to the screen so that the viewer can reach a 3D image popping up from the screen.

3D3 - 2
17:30

Realization of Deep Viewing Zone with Adaptive Time-Division Multiplexing Parallax Barrier

A. Hayashishita, H. Kakeya

Univ. of Tsukuba, Japan

In this paper we propose a time-division multiplexing parallax barrier with adaptive time-division to expand the viewing zone in the depth direction. A larger number of time-division is applied when the viewer is close and a smaller number of time-division is applied when the viewer is far from the screen.

Also presented in Innovative Demonstration Session (see p. 232)

3D3 - 3
17:50

Integral Photography Images by Plants

J.-H. Kang[,**], Y. J. Hwang[*], B.-K. Ju[**], S. Yano[***], and M.-C. Park[*,****]*

[*]KIST, Korea
[**]Korea Univ., Korea
[***]Shimane Univ., Japan
[****]Univ. of S&T, Korea

Three-dimensional vision in plants based on integral photography was successfully emulated for the first time. The artificial photosynthetic properties were exploited to obtain elemental images. Elemental images were acquired by measuring the photocurrents generated form photosynthesis. Acquired data was displayed using integral photography and one-dimensional photography.

3D3 - 4
18:10

A Novel Eye Tracking System to Expand Viewing Area in All Directions for Glasses-Free 3D Display Displayable in Both Portrait and Landscape Modes

H. Nakamura, G. Hamagishi, K. Yoshimoto, H. Takahashi, T. Matsumoto[*], K. Kusafuka[*]

Osaka City Univ., Japan
[*]Kyocera, Japan

We propose a novel eye tracking system to expand the viewing area in all directions for glasses-free 3D display displayable in both portrait and landscape modes. Its viewing area is extremely expanded by dividing single screen into multiple areas and controlling binocular images positions of each area.

Also presented in Innovative Demonstration Session (see p. 233)

Author Interviews
18:40 – 19:10

Friday, December 14

9:00 - 10:20 **Room 222**

VHF5/3D4: Human Factors and Image Quality

Chair: S. Uehara, AGC, Japan
Co-Chair: H. Mizushina, Tokushima Univ., Japan

VHF5/
3D4 - 1
9:00

Invited **Simulation of Slanted Color Moirés in IP-Type 3-D Displays**

H. Lee[,**], J. Kim[**], S Yano[*], J.-Y. Son[**], G. Heo[**]*

[*]Shimane Univ., Japan
[**]Konyang Univ., Korea

A method of simulating slanted color moirés in IP (Integral Photography)-type 3-D displays is described for the slanting angle range of 1° to 45°. The simulation reveals that the contrast of the color moirés can be minimized by increasing the slanting angle.

VHF5/
3D4 - 2
9:25

Depth of Field Widening with Increasing Number of Image Projected to Viewers' Eyes

J.-Y. Son[*], H. Lee[,**], B.-R. Lee[***], W. Son[***], S. Yano[**]*

[*]Konyang Univ., Korea
[**]Shimane Univ., Japan
[***]ETRI, Korea

DOF widening and presence of monocular accommodation within the DOF is investigated with a light field imaging. DOF is widened and the monocular accommodation range is extended as the number of images getting into a viewer's eyes increases. The extended range is comparable to that of the real object viewing.

VHF5/ 3D4 - 3 9:45 **Color Breakup Visibility Thresholds for Field Sequential Color Displays**

P. Wang, Y. Zhang, J. Wang
Southeast Univ., China

Perception experiments were designed and implemented to obtain CBU visibility thresholds and subjective evaluation of CBU. The results showed that the visible thresholds value of CBU is limited and the subjective evaluation score of CBU was analyzed with a specific trend.

VHF5/ 3D4 - 4L 10:05 **Subjective Image Quality Evaluation to Compare Algorithms for Designing a Directional Volumetric Display**

D. Matsumoto, T. Murase, R. Hirayama[,**], H. Nakayama[***], T. Shimobaba, T. Ito, A. Shiraki*
Chiba Univ., Japan
[*]JSPS, Japan
[**]Tokyo Univ. of Sci., Japan
[***]Nat. Astronomical Observatory of Japan, Japan

In previous studies, we improved an algorithm for designing a directional volumetric display and enable it to record any image. In this study, we confirmed that the improved algorithm can obtain images of equivalent quality to original algorithm using subjective evaluation. This suggests that the improved algorithm is more effective.

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:30 **Room 222**

3D5/DES4: Display Systems for Automotive

Special Topics of Interest on Automotive Displays

Chair: K. Morita, Chuo Univ., Japan
Co-Chair: H. Yamamoto, Utsunomiya Univ., Japan

3D5/ DES4 - 1 13:10 ***Invited*** **3D Head-Up Display System**

Y. Takaki
Tokyo Univ. of A&T, Japan

3D head-up displays employing super multi-view displays have been developed to enable stable superposition of 3D images on real objects. The optical system using a polarizing beam splitter is proposed to reduce the system size.

3D5/ DES4 - 2 13:30 **Low Crosstalk Glassless 3D HUD with Expanded Viewing Area in All Directions Using Novel Eye Tracking System**

T. Matsumoto, K. Kusafuka, H. Nakamura, G. Hamagishi*, K. Yoshimoto*, H. Takahashi**

Kyocera, Japan
**Osaka City Univ., Japan*

We propose Glassless 3D HUD that enables binocular virtual image stereopsis with low crosstalk. In this system, 3D image processing algorithm and the crosstalk reduction method which perform processing based on the position of the driver's eye sensed by the driver monitor camera are applied.

3D5/ DES4 - 3 13:50 **10.4-in. Ultra-Slim a-Si TFT LCD with Tracking Gate Line in Pixel Technology for Automotive Display**

C.-H. Kuan, J.-S. Liao, C.-Y. Du, C.-C. Chang, H.-H. Chen, H.-M. Su, W.-Z. Zeng

Chunghwa Picture Tubes, Taiwan

In this work, we developed of 10.4-in. (1280 x RGB x 720) automotive display with Tracking Gate line in Pixel technique. In this case, we can keep panel transmittance to achieve ultra-slim panel border (0.7 mm) for automotive display. This panel structure has been important link to realize the next generation of automotive industry applications.

3D5/ DES4 - 4 14:10 **An Automotive Grade Local Dimming Display System**

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

Chunghwa Picture Tubes, Taiwan

In this paper, we applied different dimming area design corresponding to backlight unit separately. Through the local dimming display, the driver could recognize the car information clearly day and night. It should lead to greatly improve the driving safety.

----- Break -----

14:50 - 16:10 **Room 222**

3D6: Holography

Chair: J.-Y. Son, Konyang Univ., Korea
Co-Chair: Y. Takaki, Tokyo Univ. of A&T, Japan

3D6 - 1 ***Invited*** **Creating Enriched Visual Experience with**
14:50 **Holography**

M. Yamaguchi[*], S. Igarashi[*], T. Nakamura[,**], K. Matsushima[***]*

[*]Tokyo Tech, Japan
[**]JST PRESTO, Japan
[***]Kansai Univ., Japan

This paper introduces the applications of holography that enable unique user experience in visual interface systems, such as a hyper-realistic 3D display by integrating light-field and computational holography, holographic 3D-touch interface, and flat-panel eye-contact camera-display system using a waveguide holographic optical element.

3D6 - 2 **Improved the Image Quality of Computer-Generated**
15:10 **Hologram in Holographic Waveguide System**

W.-K. Lin[,**], B.-S. Lin[*], W.-C. Su[**]*

[*]Nat. Chiao Tung Univ., Taiwan
[**]Nat. Changhua Univ. of Education, Taiwan

In this paper, the modified iterative Fourier algorithm was employed to produce holographic images based on a diffractive waveguide combiner. The aberration which was caused by the waveguide element was eliminated via the CGH algorithm. Furthermore, the image quality was enhanced by the iterative process.

3D6 - 3 **Special Purpose Computer for Holography on the**
15:30 **Embedded System**

Y. Yamamoto, N. Masuda[*], T. Nishitsuji[**], T. Kakue, T. Shimobaba, T. Ito

Chiba Univ., Japan
[*]Tokyo Univ. of Sci., Japan
[**]Tokyo Metropolitan Univ., Japan

For realizing electroholography, compact and high-performance computer is required. In this study, we implemented simple and fast cosine approximation method to create computer-generated hologram. As a result, we succeeded in reducing memory use rate 1/23 compared to using the look-up table of the cosine.

3D6 - 4 15:50 **Suppressing the Speckle Noise of Complex Modulation for Holographic Near-Eye Display**

Y. Pang, J. Xia, C. Chang[*]

Southeast Univ., China
[*]*Nanjing Normal Univ., China*

For the purpose of increasing the image quality of holographic display, we propose an improved approach to ameliorate the double-phase encoding method for the complex modulation on a phase-only spatial light modulator. The feasibility of the proposed method is confirmed by simulations and optical experiments.

Author Interviews
16:20 – 16:50

Supporting Organizations:
International Conference on 3D Systems and Applications (3DSA)
Ultra-Realistic Communications Forum (URCF)

Workshop on Applied Vision and Human Factors

Wednesday, December 12

13:20 - 13:25 **Room 432**

Opening

Opening Remarks
13:20

S. Uehara, AGC, Japan

13:25 - 14:45 **Room 432**

VHF1: High Dynamic Range

Chair: N. Hiruma, NHK-ES, Japan
Co-Chair: J. Bergquist, Consult., Japan

VHF1 - 1
13:25

A Study on Prediction of the Maximum Luminance Value of SDR Images for HDR Displays by Using CNN

R. Kano, J. Inahara, M. Obermeier, K. Uruma**, S. Hangai*

Tokyo Univ. of Sci., Japan
**Regensburg Tech. Univ. of Appl. Sci., Germany*
***Kogakuin Univ., Japan*

We have proposed a method to predict the maximum luminance value of SDR image by using CNN. SDR Images are classified into 20 categories based on Exposure Values and converted to HDR images. Prediction performance and subjective evaluated results on LCD and OLED monitors are experimentally derived.

VHF1 - 2
13:45

Picture-Level Control for Managing HDR Images and Power Consumption for Large OLED Displays

T. Okada, T. Usui, Y. Fujisaki

NHK, Japan

In this study, we propose a novel picture level control method to manage the display luminance and regulate the power consumption of large organic light-emitting diode displays. The proposed method is effective to reproduce bright and dark regions on the hybrid-log-gamma images.

VHF1 - 3 ***Invited*** **Advantage of 10,000 cd/m^2 with 8K Full-Spec**
14:05 **HDR TV**

T. Ogura

Sony Visual Prods., Japan

Sony demonstrated 8K Full-Spec HDR TV with 10,000 cd/m² peak luminance at CES2018. It showed adding higher luminance with higher contrast on 8K display, the picture quality delivers immersive impression to the viewers. Advantages of having balanced quality factors on 8K TV with precise control are discussed in this paper.

VHF1 - 4L **Method for HDR to SDR Conversion Considering**
14:30 **HDR Reference White**

K. Nomura, Y. Kusakabe, Y. Ikeda, Y. Nishida

NHK, Japan

To realize the simultaneous production of high dynamic range (HDR) and standard dynamic range (SDR) contents, a method for HDR to SDR conversion is needed. The converted SDR contents should be compatible with the contents produced with the current SDR production. We propose a conversion method to address this issue considering HDR Reference White, and the effectiveness of the proposed method is confirmed.

----- Break -----

15:00 - 16:20 **Room 432**

VHF2: Color Quality

Chair: Y. Endo, AGC, Japan
Co-Chair: N. Hiruma, NHK-ES, Japan

VHF2 - 1 **Advanced RGBW Algorithm for High Image Quality**
15:00 **with Low Power Consumption**

X. Shi, J. Chen, L. Fang, L. Wu, P. Shen, J. Li

Xiamen Tianma Microelect., China

There is always a tradeoff between optical performance and power consumption, limiting the RGBW technology somewhat. Thereby, we proposed an advanced algorithm to improve image quality, with 30% of power saving ratio in average. Besides, RGBW technology with high luminance could be more promising in HUD and HDR display.

VHF2 - 2 **KANSEI Evaluation of Color Images in Different**
15:20 **Color Gamuts**

Y. Inuzuka, S. Kageyama, T. Ishikawa, M. Ayama

Utsunomiya Univ., Japan

To investigate the best color gamut for reddish color reproduction from KANSEI evaluation point of view, subjective evaluation experiment was conducted in wide gamuts with four different red primaries from 610 nm to 640 nm. Red primaries of 630 nm and 640 nm shows higher scores in deep color and impressive feeling, but unnatural.

VHF2 - 3 15:40 **White Appearance of a Tablet Display under Different Ambient Lighting Conditions and Its Impact on Visual Comfort**

H.-P. Huang[,**], M. Wei[*], L.-C. Ou[**]*

[*]The Hong Kong Polytechnic Univ., Hong Kong
[**]Nat. Taiwan Univ. of S&T, Taiwan

The study first investigated the white appearance of a tablet display with 76 chromaticities under 3500 and 6500 K ambient light, and then compared the visual comfort for performing a reading task using five chromaticities for producing different white colors as the display background.

VHF2 - 4 16:00 **KANSEI Evaluation of Skin Color of Young Japanese Women on a Display and the Relation to Colorimetric Values of Whole Face**

S. Shiromizu, K. Kawame, K. Arimoto[*], M. Kimura[*], H. Hata[*], M. Koshino[*], T. Ishikawa, M. Ayama

Utsunomiya Univ., Japan
[*]Shiseido Global Innovation Ctr., Japan

Subjective evaluation experiment was carried out using more than 300 facial images for the same model that shifted the skin color of the face area. Colorimetric values measured in small area in the cheek using spectrodiometer and those in the whole facial area measured using 2D colorimeter were compared.

----- Break -----

16:40 - 18:10 **Room 432**

VHF3: Physiological and Psychophysical Factors

Chair: H. Ujike, AIST, Japan
Co-Chair: T. Shibata, Tokyo Univ. of Social Welfare, Japan

VHF3 - 1 16:40 ***Invited*** **Multimodal Neuroimaging to Visualize Brain Networks for 3-D Object Perception**

S. Iwaki, J. W. Belliveau[*]

AIST, Japan
[*]Massachusetts General Hospital, USA

Recent developments in multimodal neuroimaging are introduced to allow reconstruction of human brain dynamics with high spatial and temporal resolution. We describe a technique to combine data from MEG, MRI and fMRI to analyze neural information flow while perceiving a three-dimensional object shape from two-dimensional retinal motion.

VHF3 - 2
17:05 ***Invited*** **Remote and Non-Contact Extraction Techniques of Autonomic Nervous System Indices and Blood Pressure Variabilities from Video Images**

M. Yoshizawa, N. Sugita, A. Tanaka[*]*, N. Homma, T. Yambe*

Tohoku Univ., Japan
[*]*Fukushima Univ., Japan*

To evaluate human stress in watching TVs or using VR systems, it is desirable that autonomic nervous system indices and blood pressure variabilities can be extracted remotely. We have developed such a system by using an ordinary video camera only. The performance of the system was evaluated by experiments.

VHF3 - 3
17:30 **Physiological Effects of Oscillating Blue Light**

E. Yuda, K. Yamamoto, Y. Yosida, J. Hayano

Nagoya City Univ., Japan

Red and green organic light emitting diodes (OLED) with oscillating illuminance at 0.1 Hz induces resonance in heart rate variability (HRV) at the same frequency. Blue OLED with 0.1 Hz oscillating illuminance, however, did not induce resonance in HRV, while it suppressed cardiac parasympathetic nerve components of HRV.

VHF3 - 4
17:50 **Visual Resolution Measurement of Display Using the Modified Landolt C**

Y. S. Baek, Y. Kwak, S. Park[*]

Ulsan Nat. Inst. of S&T, Korea
[*]*Samsung Elect., Korea*

Visual resolution measurement method is proposed. The modified Londolt C pattern i.e. one-pixel width black square line having one-pixel white hole on a white background is shown to the observers and the threshold of hole detection viewing distance is measured. The proposed method can evaluate the display resolution more effectively.

Author Interviews
18:10 – 18:40

Thursday, December 13

9:00 - 10:25 **Room 432**

VHF4: Ergonomics for Automotive Applications

Special Topics of Interest on Automotive Displays

Chair: Y. Imai, Mitsubishi Elec., Japan
Co-Chair: Y. Endo, AGC, Japan

VHF4 - 1
9:00

Invited **Visual Cues with HUD: Driving Behavior Analysis of Elderly and Experienced Drivers in Hazard Anticipation Scenes**

Y. Saito[*], A. Yamasaki[*], S. Inoue[**], T. Ito[***], H. Inoue[****], P. Raksincharoensak[*]

[*]Tokyo Univ. of A&T, Japan
[**]Toyota Motor, Japan
[***]Univ. of Tokyo, Japan,
[****]Kanagawa Inst. of Tech., Japan

This study was designed to further our understanding of how visual cues with Head-Up Display affect an elderly driver's hazard-anticipatory driving performance in potentially hazardous situations.

VHF4 - 2
9:25

Advanced Optical Characterization Techniques and Simulation of Anti-Glare Cover Glass

T. Saitoh, T. Kanai

Nippon Elec. Glass, Japan

The light-scattering distribution of anti-glare cover glass was successfully measured at different wavelengths using a goniometer with red, green, and blue laser sources. The relation between the optical properties and surface structure was theoretically established by geometric and wave optics simulation methods.

VHF4 - 3
9:45

Sparkle Measurement of Anti-Glare Displays with Simulating Human-Eye Perception

M. Kurashige, G. Furui, K. Ishida, H. Suzuki, M. Tsunekawa, Y. Iwata, N. Nakamura

Dai Nippon Printing, Japan

Sparkle contrast of various Anti-glare displays were measured with the optical imaging system which was designed to simulate human-eye perception. Sparkle contrast was very sensitive to the measurement distance and pinhole diameter of the imaging system. The averaging effect of sparkle contrast by detector pixel was also investigated.

VHF4 - 4 **Automotive Displays and HMI: Past, Present and Future**
10:05

P. M. Knoll

Karlsruhe Inst. of Tech., Germany

In former times only few gauges were necessary to survey the vehicle's functions. Current and future concepts bundle the huge amount of information coming from new driver assistance systems in three information centers: reconfigurable instrument cluster, head-up display, and center console display in conjunction with appropriate operating techniques.

Author Interviews
10:40 – 11:10

----- Lunch -----

14:20 - 16:50 **Event Hall**

Poster **VHFp1: Applied Vision and Human Factors - Image Quality**

VHFp1 - 1 **Reproduction of Perceptual Reality in Standard-Dynamic-Range (SDR) Environments Using High-Dynamic-Range (HDR) Images Compressed by Global Tone Mapping: Further Analysis and Subjective Evaluation of Reproduced Images**

Y. Fukaya, S. Iwaida, S. Hira, S. Ohtsuka

Kagoshima Univ., Japan

Our previously proposed method for converting HDR into SDR uses global tone mapping and preserves perceptual reality. In this paper, we describe a more precise analysis of its conversion characteristics and a subjective evaluation. The results suggest that our proposed method offers quality sufficient for practical use.

VHFp1 - 2 **The Number of the Super Gradation Reconstruction Method of the Gray Image Based on the Interpolation Function**

M. Mizuno, F. Saitoh

Gifu Univ., Japan

This paper proposes a method tone restoration process of gray image using interpolation function. Low-tone image is changed to high-tone image by three patterns of processing. Through experimenting I show that this method is effective visually and quantitatively.

VHFp1 - 3 **Image Contrast Improvement Based on Distribution of Global Differential Gray-Levels Using Stochastic-Relaxation-Method**

N. Matsushita, F. Saitoh

Gifu Univ., Japan

Today, opportunities we take pictures are increasing, but it is not always possible to obtain images with good contrast. This paper proposes a method using global edge taken into account neighboring pixels by using stochastic-relaxation-method as a spatial feature included in an image.

VHFp1 - 4 **Optical Compensation of Arc Angle Design Research**

Y. H. Lo, W. C. Yang, H. C. Huang, W. R. Guo, W. M. Huang

AU Optronics, Taiwan

This article proposes several improved design for the saw-toothed image of freeform panel. Through produced real panel and human factor experiment, we can get the best compensation design for saw-toothed image of freeform panel.

VHFp1 - 5 **A Method for Evaluating the Effect of Visible Low-Frequency Fringe on Image Quality**

L. Xu, Y. Ma, P. Dang, Z. Duan

Visionox Tech., China

A method was proposed to evaluate the effect of visible low-frequency fringe on image quality, which was caused by signal lines in the display. It can detect the risk of visible low-frequency fringe before fabricating photo mask by a special algorithm to process the picture of array layout pattern.

VHFp1 - 6L **Withdrawn**

VHFp1 - 7L **Visibility Improvement of Dark Areas in Image Based on Subjective Experiments**

Y. Takahashi, T. Shiga

Univ. of Electro-Commun., Japan

Visibility of dark area in image is improved by enhancing average luminance and contrast of local region. The pixel values are modified with enhancement function derived from visual subjective experiments under illuminance of typical living room. Over-enhancement of bright area does not occur.

VHFp1 - 8L **Minimum Display Luminance without Blocked-Up Shadows under High Outdoor Illuminance**

T. Yamashita, T. Shiga

Univ. of Electro-Commun., Japan

Minimum luminance without blocked-up shadows of mobile displays under outdoor daylight was measured by subjective assessment. The luminance is shown as a function of illuminance of incident light to the eye. Appropriate minimum luminance for tolerable visibility under outdoor daylight can be determined.

14:20 - 16:50 **Event Hall**

***Poster* VHFp2: Applied Vision and Human Factors - Color Gamut Metrology**

Special Topics of Interest on Wide Color Gamut and Color Reproduction

VHFp2 - 1 **Analysis of Color Gamuts and Tone Characteristics of Tablet Display Under Different Ambient Light Levels**

T.-Y. Chiang, H.-S. Chen

Nat. Taiwan Univ. of S&T, Taiwan

When ambient light levels are changed from dark room to bright room, there are the tendencies in smaller gamut volume and narrower lightness range for a tablet display. Meanwhile, the γ values of the calibrated tone reproduction curves become smaller when the ambient light conditions are brighte.

14:20 - 16:50 **Event Hall**

***Poster* VHFp3: Applied Vision and Human Factors - Automotive Applications**

Special Topics of Interest on Automotive Displays

VHFp3 - 1 **Layer-Wise Analysis of TFT-LCD Reflectivity**

X. Lin, C Yan, L. Chen, Z. Chen

Shenzhen China Star Optoelect. Tech., China

Reflectivity of TFT-LCD panels to ambient light is an important aspect when evaluating display performance. We propose that reflectivity of TFT-LCD can be decomposed into contributions of the upper polarizer, color filter (CF) Plate and Array Plate. Our analysis of reflectivity is verified by simulation results and experimental data.

VHFp3 - 2 **An Automotive Display with Multi Domains and Changing Viewing Angle Functions**

Y. W. Chang, Y. E. Wu

AU Optronics, Taiwan

An automotive display with multi domains and changing viewing angle functions is developed. A multi layer backlight system is specially designed for this application. The display is customized for automotive which could display individual information to driver and shotgun, which is safer and less information disturb to each one.

14:20 - 16:50 **Event Hall**

Poster **VHFp4: Applied Vision and Human Factors - Image Processing**

VHFp4 - 1 **Extraction of Character String Region from Sign in Scene Image by Labeling Process and Edge Information**

M. Noda, F. Saitoh

Gifu Univ., Japan

This paper proposes the method to extract character string from signboards in scene images. Using edge information and labeling process, character strings are extracted. Experimental results show the proposed method is effective to extract many kinds of characters.

VHFp4 - 2 **Detection of Plural Image Areas on Genetic Algorithm with Immune System Added Attenuation Processing**

M. Ito, F. Saitoh

Gifu Univ., Japan

This paper proposed method to keep diversity of individuals and extract plural target image areas, inclination and scale that are similar to template image, and reduce time costs by using the genetic algorithm with immune system added attenuation processing. The attenuation processing is lowering individual immunity when calculate immunity.

VHFp4 - 3 **High-Speed Image Matching Using Characteristic Pixels Based on Density Histogram**

K. Sakai, F. Saitoh

Gifu Univ., Japan

In this paper, we propose an image template matching method based on density histogram. In this method, the highest frequency pixel value of the density histogram is selected, and template matching is executed with only that pixel value. Experimental results showed that it has sufficient detection performance and speed.

VHFp4 - 4 **Image Template Matching Based Incremental Sign of Neighboring Eight Direction**

H. Imaeda, F. Saitoh

Gifu Univ., Japan

We propose a method for image template matching based on the incremental signs in the neighboring area. The incremental signs that is obtained from the density differences between adjacent pixels in the eight directions of the neighboring area are used for matching between the templates and an objective images.

14:20 - 16:50 **Event Hall**

Poster **VHFp5: Applied Vision and Human Factors - Biometrics**

VHFp5 - 1 **The Personal Authentication by Wrist Image Using Selected Block Matching**

T. Yasukawa, F. Saitoh

Gifu Univ., Japan

This paper proposes an individual authentication system using wrist images. This method performs selected block matching using features of the wrist. This method is used to respond to the shape change of the wrist. The experimental results show that the proposed system has enough accuracy to identify an individual.

VHFp5 - 2 **Proposal and Application of Evaluation Method in Health Condition Evaluation System by Eye Movement and Lips Movement**

Y. Kurosawa, T. Miyamoto, Y. Uehara, S. Mochiduki, Y. Hoshino, M. Yamada

Tokai Univ., Japan

In order to solve caregiver shortage, care robots are being actively developed. We have described the influence of changes in an individual's physical condition on eye and lip movement in previous research. This paper proposes a health condition evaluation system that utilizes eye and lip movement.

VHFp5 - 3 **A New Gaze Analysis Method During Playing Sport Using the High Definition of the 4K Picture**

T. Sarugaku, R. Koyama, Y. Kobayashi, S. Mochiduki, M. Yamada

Tokai Univ., Japan

4K broadcasting will be launched in December 2018 for the Tokyo Olympic Games in 2020. Furthermore, in sports science, which is drawing attention ahead of the Olympic Games, it is thought that by observing an athlete's gaze during an event it is possible to determine an outstanding athlete's expertise.

14:20 - 16:50 **Event Hall**

***Poster* VHFp6/3Dp3: Applied Vision and Human Factors - Human Factors of AR/VR**

Special Topics of Interest on AR/VR and Hyper Reality

VHFp6/ 3Dp3 - 1 **Study on Subjective Depth Evaluation for Holographic Head-Mounted Display**

H. Kubo, Y. Oguro, Y. Sakamoto

Hokkaido Univ., Japan

We conducted a subjective depth evaluation experiment using a compact holographic head-mounted display (HMD) that can display in color. To correctly represent depth, we corrected the distance of the depth to improve the accuracy. Evaluation results indicate that subjective depth is closer to the same depth as holography.

Also presented in Innovative Demonstration Session (see p. 233)

VHFp6/ 3Dp3 - 2 **Study on Correction of Field Curvature in Head-Mounted Display Using Electro-Holography**

Y. Oguro, H. Kubo, Y. Sakamoto

Hokkaido Univ., Japan

This paper proposes a correction method of field curvature in HMDs using electro-holography. In the proposed method, it is possible to correct field curvature including assembly error by using measured values. An experiment was conducted using an HMD, and the effectiveness of the method is confirmed from the result.

VHFp6/ 3Dp3 - 3L **Development of One-Dimensional Integral Photography**

A. Hasegawa, S. Yano, M.-C. Park[*]

Shimane Univ., Japan
[*]KIST, Korea

We have developed one-dimensional integral photography that displays only horizontal parallax. One-dimensional integral photography depended on a method of generating elemental images by pixel position conversion from multi-view stereoscopic images. We examined the influence of vertical resolution on depth perception using prototype one-dimensional integral photography.

14:20 - 16:50 **Event Hall**

***Poster* DESp3/VHFp7: Backlight and LED Technology**

DESp3/ VHFp7 - 1 **Waving-Hand Steganography Embedded in a Backlight of an LCD**

S. Morita[*], A. Tsuji[**], T. Tokimoto[,***], H. Yamamoto[*,****]*

[*]Utsunomiya Univ., Japan
[**]Tokushima Univ., Japan
[***]Dao App Tech., Taiwan
[****]JST ACCEL, Japan

This paper proposes a novel steganography that embeds a secret image in the backlight. We have specially developed a high-speed (1250 Hz) LED display by use of FPGA circuits and utilized the LED display for a backlight of an LCD panel. Encoded images were shown on the high-speed backlight.

DESp3/ VHFp7 - 2 **Convolutional Neural Network Driven Localized Backlight Dimming Strategy for Liquid Crystal Displays**

J. Jo, J. S. Park[*], J. W. Soh, N. I. Cho

Seoul Nat. Univ., Korea
[*]Samsung Elect., Korea

This paper presents a convolutional neural network (CNN) for the adaptive localized backlight dimming. We develop a new loss function for training the CNN, which results in efficient dimming and high contrast images. We also try to minimize the complexity of CNN so that it can be practically used.

DESp3/ VHFp7 - 3L **A Novel Super-Resolution Display Technique by Use of Spatiotemporal Coding**

T. Tokimoto[,**], K. Fujii[**], S. Morita[**], H. Yamamoto[**,***]*

[*]DaoApp Tech., Taiwan
[**]Utsunomiya Univ., Japan
[***]JST ACCEL, Japan

We propose a novel super-resolution display technique by use of spatiotemporal coding. When for neighboring image data are displayed dynamically on a coarse LED panel, the resolution becomes higher than the conventional LED display. We examined the cognitive mechanism in the human visual system to explain this experiment result.

Friday, December 14

9:00 - 10:20 **Room 222**

VHF5/3D4: Human Factors and Image Quality

Chair: S. Uehara, AGC, Japan
Co-Chair: H. Mizushina, Tokushima Univ., Japan

VHF5/ 3D4 - 1 9:00 ***Invited*** **Simulation of Slanted Color Moirés in IP-Type 3-D Displays**

H. Lee[,**], J. Kim[**], S Yano[*], J.-Y. Son[**], G. Heo[**]*

[*]Shimane Univ., Japan
[**]Konyang Univ., Korea

A method of simulating slanted color moirés in IP (Integral Photography)-type 3-D displays is described for the slanting angle range of 1° to 45°. The simulation reveals that the contrast of the color moirés can be minimized by increasing the slanting angle.

VHF5/ 3D4 - 2 9:25 **Depth of Field Widening with Increasing Number of Image Projected to Viewers' Eyes**

J.-Y. Son[*], H. Lee[,**], B.-R. Lee[***], W. Son[***], S. Yano[**]*

[*]Konyang Univ., Korea
[**]Shimane Univ., Japan
[***]ETRI, Korea

DOF widening and presence of monocular accommodation within the DOF is investigated with a light field imaging. DOF is widened and the monocular accommodation range is extended as the number of images getting into a viewer's eyes increases. The extended range is comparable to that of the real object viewing.

VHF5/ 3D4 - 3 9:45 **Color Breakup Visibility Thresholds for Field Sequential Color Displays**

P. Wang, Y. Zhang, J. Wang

Southeast Univ., China

Perception experiments were designed and implemented to obtain CBU visibility thresholds and subjective evaluation of CBU. The results showed that the visible thresholds value of CBU is limited and the subjective evaluation score of CBU was analyzed with a specific trend.

VHF5/ 3D4 - 4L 10:05 **Subjective Image Quality Evaluation to Compare Algorithms for Designing a Directional Volumetric Display**

D. Matsumoto, T. Murase, R. Hirayama[,**], H. Nakayama[***], T. Shimobaba, T. Ito, A. Shiraki*

Chiba Univ., Japan
[*]JSPS, Japan
[**]Tokyo Univ. of Sci., Japan
[***]Nat. Astronomical Observatory of Japan, Japan

In previous studies, we improved an algorithm for designing a directional volumetric display and enable it to record any image. In this study, we confirmed that the improved algorithm can obtain images of equivalent quality to original algorithm using subjective evaluation. This suggests that the improved algorithm is more effective.

----- Break -----

10:40 - 12:05 **Room 222**

VHF6: Virtual Reality

Special Topics of Interest on AR/VR and Hyper Reality

Chair: T. Shibata, Tokyo Univ. of Social Welfare, Japan
Co-Chair: S. Uehara, AGC, Japan

VHF6 - 1 10:40 ***Invited*** **Ergonomic Evaluations of Virtual Reality System and Content**

T. Kawai

Waseda Univ., Japan

This paper introduces evaluation cases for a virtual reality system and its content, in terms of ergonomics/human factors. Specifically, the authors describe experimental studies of behavioral characteristics during the viewing of 360° images, and the effects of the VR experience on heart rate variability in activities of daily living.

VHF6 - 2 11:05 **Comparison of Color Perception Between Head-Mounted Display and Ordinary Display**

T. Nishimura, S. Dozaki, K. Hirai, T. Horiuchi

Chiba Univ., Japan

In this paper, subjective evaluation experiments were conducted to investigate differences of luminance and chroma perception between an HMD (Head-mounted display) and an ordinary display. The results show that the perception of luminance and chroma of the HMD were higher compared with those of the ordinary display.

VHF6 - 3 11:25 **2.02-in. Mini-LEDs Wide Color Gamut Solution for Virtual Reality Display**

H.-H. Wu, C.-S. Li, H.-P. Kuo, Y.-H. Chang, I.-H. Hsieh, Y.-T. Chen

AU Optronics, Taiwan

We have developed a 2.02-in. mini-LEDs backlight that enables high contrast ratio (100,000:1) that compare to OLED for virtual reality display. Because of strobe backlight function, we proposed a nitride solution that can reach NTSC 95% without res residual issue.

VHF6 - 4 11:45 **Design of Machine Vision Aided Measurement System for Near-Eye Display Devices**

S. Hu, Q. Zhu, Y. Cao, Y. Tang, Y. Zheng

Southeast Univ., China

A machine vision aided measurement system for near-eye display devices has been developed. We combined machine vision module with mechanical equipment, made it possible to automatically align the under-test device to the measurement instruments. The results show the machine vision technology can notably improve the measurement system's objectivity and stability.

Author Interviews
12:05 – 12:30

----- Lunch -----

13:10 - 14:40 **Room 432**

VHF7: Color Gamut Metrology
Special Topics of Interest on Wide Color Gamut and Color Reproduction

Chair: K. Masaoka, NHK, Japan
Co-Chair: K. Hirai, Chiba Univ., Japan

VHF7 - 1
13:10

Invited **Visual Evaluation of Display Color Gamut**

Y. Kwak, Y. S. Baek
Ulsan Nat. Inst. of S&T, Korea

Visual color gamut evaluation method is introduced. Two images having different color gamuts are shown to the subjects to choose the images having more richness in color. The experimental results show that three dimensional color gamut volume should be calculated considering the chromaticity differences and also the luminance differences.

VHF7 - 2
13:35

Invited **Subjective Verification for Color Gamut Volume of HDR WCG Display**

F. Jiang, K. Masaoka[*]*, M. Fairchild*
Rochester Inst. of Tech., USA
[*]*NHK, Japan*

Nine selected HDR images were visually evaluated through paired-comparison method in regard of colorfulness and details. HDR images are clipped into different peak luminance levels but keeping the same diffuse white setting. Psychophysical experiment results indicated an overall linear relationship between log10 of peak luminance and subjective score.

VHF7 - 3
14:00

Fast and Accurate Colour Gamut Volume Measurements of RGB Displays with Degenerate Colours

J. Bergquist
Consult., Japan

Colour additivity and gamut volume of various displays were measured as functions of input grey value and number of grid points, respectively. The volume reached 95% of the convergence value at 98 grid points for an RGBW LCD with a strongly concave hull. The measurement time was less than 60 s.

VHF7 - 4
14:20

A Color Quality Volume Metric for HDR Displays

W. Lv, H. Xu, Z. Ye, J. Qiu
Zhejiang Univ., China

The existing color volume metrics usually fail to represent the image quality of HDR TVs. Through physical measurements and visual evaluations, a novel color quality volume metric (CQVM) was proposed, which would well predict the image quality of HDR displays.

----- Break -----

14:50 - 16:10 **Room 432**

VHF8: Color Vision

Special Topics of Interest on Wide Color Gamut and Color Reproduction

Chair: K. Masaoka, NHK, Japan
Co-Chair: Y. Kwak, Ulsan Nat. Inst. of S&T, Korea

VHF8 - 1 ***Invited*** **Applicability of CIELAB Volume Metric to the**
14:50 **Latest Electronic Display**

H. Yoshida, K. Hirai[*]*, Y. Mizokami*[*]

Sharp, Japan
[*]*Chiba Univ., Japan*

We investigated the applicability of the CIELAB color gamut volume metric to the latest self-emissive displays. Where to set the reference white is the key. The luminance of maximum white, full-screen white and absolute value are appropriate. The weighted average can give the criteria of the display color performance.

VHF8 - 2 **Helmholtz-Kohlrausch Effect Estimation**
15:15 **Considering Lightness**

Y. Hayami, D. Takasu, H. Aoyanagi[*]*, H. Takamatsu*[*]*,*
Y. Shimodaira, G. Ohashi

Shizuoka Univ., Japan
[*]*NEC Display Solutions, Japan*

The purpose of this study is to add lightness parameter to the Helmholtz-Kohlrausch (H-K) effect estimation equation of Nayatani et al. and verify its effectiveness in order to improve the estimation accuracy in natural images.

VHF8 - 3 **Observer Metamerism for Anomalous Trichromats**
15:35 **and the Elderly in a Wide Color Gamut Display**

S. Sunaga, R. Suto, S. Katsura, H. Yaguchi[*]

Kyushu Univ., Japan
[*]*Chiba Univ., Japan*

It was reported that observer metamerism is obvious in a wide color gamut display. In this study, the effects of color deficiency and/or aging on color appearance on a wide color gamut display were investigated. Significant deviations from the standard observer were observed.

VHF8 - 4L 15:55 **A Comparison of Perceptual Color Differences of 3D Objects Presented on a HDR Display and Real Scene**

Y.-Z. Lai, P.-L. Sun, W.-C. Hung

Nat. Taiwan Univ. of S&T, Taiwan

Perceptual color differences of glossy 3D objects were viewed in both real and HDR display conditions. The results are highly correlated and optimal weights apply for color difference calculation to predict the visual differences. In terms of image differences, perceptual differences are well-correlated to 95th percentile of image color differences.

Author Interviews
16:20 – 16:50

Supporting Organizations:
Technical Group on Information Display, ITE
Technical Committee on Electronic Information Displays, Electronics Society, IEICE

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters
Thursday, Dec. 13, 2018
11:40 – 15:50
Event Hall (1F, Building 1)
Nagoya Congress Center

Workshop on Projection and Large-Area Displays and Their Components

Wednesday, December 12

15:00 - 15:05 **Room 131**

Opening

Opening Remarks
15:00

S. Ouchi, Hitachi, Japan

15:05 - 16:25 **Room 131**

PRJ1/FMC2: Waveguide for AR-Near Eye Display

Special Topics of Interest on AR/VR and Hyper Reality

Chair: D. Cuypers, CMST, Belgium
Co-Chair: K. Käläntär, Global Optical Solutions, Japan

PRJ1/FMC2 - 1
15:05

Invited **A Plastic Holographic Waveguide Combiner for Light-Weight and Highly-Transparent Augmented Reality Glasses**

T. Yoshida, K. Tokuyama, Y. Takai, D. Tsukuda, T. Kaneko, N. Suzuki, T. Anzai[*], A. Yoshikaie, K. Akutsu, A. Machida

Sony, Japan
[*]Sony Global Manufacturing & Operations, Japan

We have developed a unique production process of a full-color plastic holographic waveguide combiner with a light-weight and see-through capability. The novel plastic waveguide technology enables us to increase design flexibility in the eyewear and to expand the market for augmented reality (AR). This paper presents the approach to production.

PRJ1/FMC2 - 2
15:25

Waveguide-HOE-Based Camera That Captures a Frontal Image for Flat-Panel Display

H. Konno[*], S. Igarashi[*], T. Nakamura[,**], M. Yamaguchi[*]*

[*]Tokyo Tech, Japan
[**]JST PRESTO, Japan

We propose a thin display that can capture a frontal image of a person gazing at the display. The proposed display is composed of a see-through transparent holographic waveguide, a flat-panel display, a camera at the periphery of the display, and the image reconstruction processing. We verified the proposed concept by simulations and a preliminary experiment.

PRJ1/ FMC2 - 3 15:45 **Novel Holographic Waveguide Display with Kepler Telescope Configuration**

Z. Shen, Y. Zhang, A. Liu, Y. Weng, X. Zhu, X. Li
Southeast Univ., China

This paper proposed a novel holographic waveguide configuration, which includes the micro-display, in-coupling volume holographic grating, waveguide and out-coupling holographic reflective lens. Theoretically, the horizontal field of view of the novel holographic waveguide can reach 40°, and the simulation results are validated with the experiments.

PRJ1/ FMC2 - 4 16:05 **Light Efficiency Modeling for a Holographic Waveguide Display**

X. Zhu, Y. Zhang, Z. Shen, A. Liu, Y. Weng
Southeast Univ., China

A light efficiency model of a holographic waveguide display is constructed in this paper. The model considers both the energy loss of the beam propagating in the waveguide and the loss caused by one-dimensional expansion. The brightness and efficiency accepted by eye can be calculated by this model.

----- Break -----

16:40 - 18:00 **Reception Hall 2**

PRJ2/LCT3: LC-Based Eye Devices

Chair: O. Akimoto, Sony Semiconductor Solutions, Japan
Co-Chair: T. Ishinabe, Tohoku Univ., Japan

PRJ2/ LCT3 - 1 16:40 ***Invited*** **Liquid Crystal Lenses for Augmented Reality**

Y.-H. Lin, Y.-J. Wang
Nat. Chiao Tung Univ., Taiwan

Optical-see-through systems are demonstrated via liquid crystal lenses for augmented reality (AR) in order to solve the challenges of vision correction and image registration. For vision correction, we show optical zoom function for reducing spatial resolution of virtual images by adjusting the magnification of virtual images at fixed spatial locations.

PRJ2/ LCT3 - 2 17:00 **Design of Liquid Crystal Based Switchable Contact Lenses**

D. Cuypers[,**], R. Verplancke[*,**], H. D. Smet[*,**]*
[*]imec, Belgium
[**]Ghent Univ., Belgium

Switchable liquid crystal based Fresnel lenses fabricated on thin, semi-flexible foils are introduced and discussed, focusing on manufacturability and practical usefulness. The design options are reviewed and commented on.

PRJ2/ LCT3 - 3 17:20 **Liquid Crystal Displays Compatible with Contact Lenses for Vision Correction Applications**

A. V. Quintero, P. Pérez-Merino, R. Verplancke, J. Vanfleteren, H. D. Smet*

Ghent Univ., Belgium
**Fundación Jiménez Díaz, Spain*

This paper presents the measurements of light transmission and spectral radiance of guest-host liquid crystal cells compatible with contact lenses for vision correction applications. From these measurements a contrast of 1:2 was calculated and its optical quality was qualitatively compared to ND filters (1:3 contrast).

PRJ2/ LCT3 - 4 17:40 **Applications of Liquid Crystal Lens with Focal Length Variable from Negative to Positive Values**

J. Gao, J. L. Yeh, J. W. Pan, S. C. Jeng

Nat. Chiao Tung Univ., Taiwan

DFLC lens can be controlled between positive lens and negative lens by changing the driving frequency. Depending on the driving frequency, the LC directors align either toward the homeotropic state (perpendicular to the substrate) or toward the planar state (parallel to the substrate).The LC lens can be applied for AR/VR applications.

Author Interviews
18:10 – 18:40

Thursday, December 13

9:00 - 10:00 **Room 222**

PRJ3: Light Source

Chair: H. Hatanaka, Ushio, Japan
Co-Chair: M. Kuramoto, Stanley Elec., Japan

PRJ3 - 1 9:00 ***Invited*** **Effect of Angular Profile and Wavelength on Speckle Reduction in Laser Projection System**

H. Yamada, K. Moriyasu, H. Sato, H. Hatanaka

Ushio, Japan

Speckle contrast of laser projection system was measured for various angular diversity. The results were analyzed by using top-hat angular distribution or Gaussian distribution. The experimental results were well reproduced by either type of angular distribution. Speckle reduction by both angular diversity and wavelength diversity was also investigated.

PRJ3 - 2 9:20 **An RGB Laser Measuring Instrument for Raster-Scanning Laser Projectors**

K. Hieda, T. Maruyama, F. Narusawa
HIOKI E.E., Japan

We have recently developed TM6102 to accurately evaluate the chromaticity and photometric quantity of raster-scanning laser projectors. It has a new measurement principle focusing on laser displays and a functionality that realizes a stable measurement of the two parameters important for the image quality of raster-scanning laser projectors.

PRJ3 - 3 9:40 **Phosphor-in-Glass (PiG) Films for High-Power and High-Luminance Laser Lighting and Display**

P. Zheng, S. Li, R.-J. Xie
Xiamen Univ., China

Phosphor-in-glass (PiG) films are successfully sintered on one-dimensional photonic crystals (1DPCs) coated sapphire substrates. By choosing appropriate phosphors, this architecture shows great potentials for use in high-power and high-luminance laser lighting and display area due to the excellent packaging efficiency and heat dissipation capability.

10:00 - 10:21 **Room 222**

Short Presentation PRJp1: Projection Technologies

All authors of poster papers for the PRJp1 session will give 3-minute oral presentations with no discussion time.

Author Interviews
10:40 – 11:10

----- Lunch -----

14:20 - 16:50 **Event Hall**

Poster PRJp1: Projection Technologies

PRJp1 - 1 **Speckle Reduction Device Using Two-Axis Resonant Microstage**

Y. Fujimura, T. Tsukamoto[*]*, S. Tanaka*[*]
Ricoh Ind. Solutions, Japan
[*]*Tohoku Univ., Japan*

This paper reports a speckle reduction device using a 2-axis resonant microstage for a laser-type projector. 2-axis motion is achieved by a single PZT thin film actuator. The speckle contrast as low as 0.14 was achieved by the developed device.

PRJp1 - 2 **The Optical Radiation Safety Analysis for Ultra-Short Throw Laser Projection Display**

F. Wang, X. Li, C. Jin, Y. Tu

Southeast Univ., China

In this paper, the characteristics of ultra-short throw laser projection displays are studied, and the apparent source and angular subtense, starting point of measurement distance, and measurement distance are investigated to determine whether existing standards are suitable for ultra-short throw laser projection displays.

PRJp1 - 3 **Withdrawn**

PRJp1 - 4 **Flexible FOV and Shadow Removal in Mobile Projection System Using Multiple Pan Projectors**

T. Sato, D. Iwai, K. Sato

Osaka Univ., Japan

When using a mobile projector, due to the low performance, it is greatly affected by the trade-off between the projection area and luminance, and when occlusion occurs, shadows are generated in the projected image. We propose a mobile projection system that can flexibly adjust FOV and remove shadows.

PRJp1 - 5 **Projection Method for Flat Surface Object to Spherical or Cylindrical Surface**

S. Tominaga, K. Kawai, H. Yamamoto

Utsunomiya Univ., Japan

This paper proposes a method of projection from a flat-surface object to a spherical surface or a cylindrical surface. The proposed method employs putting a curved mirror in the optical path of projection in order to focus the image on the curved surface.

PRJp1 - 6 **Dual Micro-Display Illuminators for Photochemical Fabrications**

C.-J. Ou, C.-J. Chiu, Y.-H. Chiu, C.-F. Lin, P.-X. Huang, J.-F. Qian, W.-R. Lin

Hsiuping Univ. of S&T, Taiwan

In photochemical experiments and fabrications, pathway in chemical reactions needs to be taken under various wavelengths, as well as light intensity and luminosity. Two applications – TiO_2 based Hydrogen generation and Miller experiment for amino-acid production are adopted. Argument show that the non-LED based microdisplay projector is the desirable approach.

PRJp1 - 7 **Contrast Ratio, MTF and Virtual Images for Environmental Science**

C.-J. Ou, M.-Y. Huang, M.-J. Liu, Y.-R. Chen, P.-X. Huang

Hsiuping Univ. of S&T, Taiwan

This article explores the theoretical basis for the use of a virtual projection based contrast ratio methods for air pollution estimation. Results indicate that the present method is comparatively simple, ease of use and faster. It can be directly used on the mobile device and concluded in the shortest time.

PRJp1 - 8 **Analytical Form of Light Source Apodization Distribution Through Display Element**

C.-J. Ou, S.-R. Yang, M.-J. Liu, Y.-H. Chiu, J.-F. Qian, M.-Y. Huang

Hsiuping Univ. of S&T, Taiwan

Analytical expression for Illuminatings on finite surface with two major dimension is derived through the energy conservation. This report fills in the formulae through the component element by means of finite area and emitting apodization, ehich transform the finite-difference operators into the differential form.

Friday, December 14

9:00 - 10:20 **Room 224**

PRJ4: Wearable

Special Topics of Interest on AR/VR and Hyper Reality

Chair: S. Ouchi, Hitachi, Japan
Co-Chair: T. Suzuki, JVC Kenwood, Japan

PRJ4 - 1 **Can We Overcome the Challenges on the Path to**
9:00 **Consumer Adoption of AR Headsets?**

Z. Bouhamri, E. Virey, P. Mukish

Yole Développement, France

This presentation will give an overview of what are the requirements for consumer adoption, and address the technical challenges associated with displays and optical systems to better explain the projected trends for the upcoming years for consumer adoption.

PRJ4 - 2 ***Invited*** **Wide-Range Dimming Device on a Plastic**
9:20 **Substrate for Augmented Reality Glasses**

T. Kono, A. Machida, K. Kadono, Y. Ishii, H. Takanashi, A. Nishiike, H. Suzuki[*], Y. Nakagawa[*], K. Ando[*], D. Kasahara[*], A. Takeda[*], K. Nomoto

Sony, Japan
[*]Sony Global Manufacturing & Operations, Japan

We have developed a wide-range dimming device on a plastic substrate for augmented reality glasses. High transmittance modulation from 70% to less than 10% has achieved. It endures more than 10,000 cycles. The device enables AR glasses to display the clear image in both indoor and outdoor conditions.

PRJ4 - 3
9:40

Fiber Scanning Technology for Projection Unit

S. Onoe, T. Matsuda, T. Nakamura, Y. Seo, S. Ouchi
Hitachi, Japan

We are developing a projection unit by using our fiber scanning technology, which provides high resolution and uniform brightness, which are difficult for conventional fiber scanning technology. Color image projection with an oval scanning method was achieved.

PRJ4 - 4
10:00

Full-Color Waveguide-Coupling Near-Eye Displays Using Chromatic Polarization Volume Gratings

Y. Weng, Y. Zhang, J. Cui, X. Li
Southeast Univ., China

A double-layer waveguide structure with chromatic polarized volume gratings (PVGs) is demonstrated to realize the full-color near-eye display. We built a prototype to verify our design. As a result, a full-color near-eye display with a diagonal FOV of around 35° is realized by proposed structure.

----- Break -----

10:40 - 11:55 **Room 224**

PRJ5: Automotive Displays and Sensors

Special Topics of Interest on Automotive Displays

Chair: K. Ohara, Marubun, Japan
Co-Chair: M. Kuwata, Mitsubishi Elec., Japan

PRJ5 - 1
10:40

Invited **Use of Aerial Agent for Smart Cockpit**

M. Morita, H. Yamamoto[*]*, K. Yoshihara, N. Nara*
Clarion, Japan
[*]*Utsunomiya Univ., Japan*

For visual representation of in-car AI agent, we chose aerial image display, and we developed aerial image display optimized automotive. Then, The aerial agent tell the driver what kind of automatically executed function by driver action prediction.

PRJ5 - 2
11:00

Improving Image Quality of Lensless Light-Field Imaging Using Pattern Projection Technique

Y. Nakamura, K. Yamaguchi, K. Tajima, T. Shimano
Hitachi, Japan

A lensless light-field imaging technology with a Fresnel zone aperture has previously been developed. To improve the image quality of the reconstructed image in this system, it is necessary to improve a signal to noise ratio of the sensor image. Accordingly, in the present study, a pattern projection technique is proposed.

PRJ5 - 3 11:20 **Optimization of Vertical View Human Skeleton Recognition from Range Images**

A. Watanabe, T. Kamimura

Hitachi, Japan

We developed the rule base technique of the sequential joint search method as a posture estimate technique from upward view range image of TOF sensor and confirmed the average correct prediction ratio of the sequential search technique is over 90% and the detection ratio is 97%.

Also presented in Innovative Demonstration Session (see p. 233)

PRJ5 - 4L 11:40 **Laser Scanning Headlamp**

T. Kitazono, Y. Kita, T. Mori, S. Harata, T. Saito, S. Hoshino, Y. Yatsuda

Stanley Elec., Japan

The our study was conducted to verify that the laser scanning headlamp system with its seamless moving light gives the driver a safer visibility and hence is an effective means of reducing road accident fatalities.

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:10 **Room 224**

PRJ6: Projection Applications

Chair: S. Shikama, Setsunan Univ., Japan
Co-Chair: M. Kurashige, Dai Nippon Printing, Japan

PRJ6 - 1 13:10 ***Invited*** **How Can We Standardize Smart Projection Displays with Sensors?**

J. Kinoshita

Osaka Univ., Japan

Image projection technology is rapidly evolving into creating much smarter innovative products combined with various sensor technologies. It will greatly affect the scheme of international standardization of displays, lighting and laser safety. We must carefully and positively consider how to proceed international standardization without jeopardizing the sound industry growth.

PRJ6 - 2
13:30

Pixel-Level Visible Light Communication Projector with Interactive Update of Images and Data

T. Hiraki, S. Fukushima, H. Watase[*], T. Naemura
Univ. of Tokyo, Japan
[*]Tokyo Electron Device, Japan

We previously studied methods leveraging pixel-level visible light communication (PVLC) that embeds human eye imperceptible information in each pixel of an image. In this paper, we propose a dynamic PVLC system that offers high video quality and interactively updates the PVLC information through hardware encoding processing.

PRJ6 - 3
13:50

An Ultrashort Throw Ratio Projection Lens Design Based on a Catadioptric Structure

Y. J. Chen, H. C. Wang, J. W. Pan
Nat. Chiao Tung Univ., Taiwan

We propose a rotational symmetry for an ultrashort throw lens. The UST lens has a throw ratio of 0.23 and a total track of 195 mm. An effective focal length of -1.96 mm and a f-number of 2.4 can be obtained, the MTF values for all fields are above 0.3.

----- Break -----

14:50 - 16:30 **Room 224**

PRJ7: Projection Mapping

Chair: H. Yamamoto, Utsunomiya Univ., Japan
Co-Chair: Y. Asakura, Nittoh, Japan

PRJ7 - 1
14:50

Invited **Dynamic Projection Mapping Toward Post Reality**

Y. Watanabe
Tokyo Tech, Japan

Dynamic projection mapping achieves high-speed sensing of dynamically-changing environment in real time, generates graphics, and projects them onto the target before it moves. This enables the fusion of physical reality and projected unreality. This paper reviews the impact of such 'Post Reality' and how this technology can be realized.

PRJ7 - 2
15:10

Invited **Protection Method from Secret Photography**

I. Suzuki[,**], S. Ando[*,**], Y. Ochiai[*,**]*
[*]Univ. of Tsukuba, Japan
[**]Pixie Dust Techs., Japan

We present a method to protect contents from secret photography by using high-speed projection. We divide an image into parts and project them in succession at a high frame rate in order to make the image visible to human eyes. By contrast, cameras can only capture an incomplete frame.

PRJ7 - 3 ***Invited*** **Appearance Manipulation Using Light-Field**
15:30 **Projection**

T. Amano, K. Murakami, Y. Miyabayashi
Wakayama Univ., Japan

This paper introduces our latest two studies on viewing-direction-dependent appearance manipulation using light-filed projection on an anisotropic reflection surface after the introduction of appearance manipulation using projector-camera feedback, which is our fundamental technology.

PRJ7 - 4 ***Invited*** **Latest Research Trends on Computational**
15:50 **Projection Mapping**

D. Iwai
Osaka Univ., Japan

This invited talk will introduce the latest research trends of both fundamental technologies and applications on computational projection mapping. Especially, this talk will focus on dynamic projection mapping, in which a moving object is augmented by projected imagery, gathering more and more attentions recently.

PRJ7 - 5 ***Invited*** **Projection Explores a New Field of Spatial**
16:10 **Art**

J. Sugimori
J. F. Oberlin Univ., Japan

There is tacit knowing in art. Expression of an art work depends on the experience and the feeling of its creator. This paper reveals backgrounds for the projection-based spatial art works. This paper introduces the production process and expression of art works utilized with projection mapping and creator's thinking.

Author Interviews
16:30 – 16:50

Supporting Organizations:
Technical Group on Information Display, ITE
Laser Display Technology Research Group, Optical Society of Japan
Laser Display and Lighting Conference
Consortium of Visible Laser Diode Applications
The Laser Society of Japan

Workshop on Electronic Paper

Wednesday, December 12

15:00 - 15:05 **Room 133**

Opening

Opening Remarks
15:00

K. Hashimoto, E Ink Japan, Japan

15:05 - 16:20 **Room 133**

EP1: Expansion of Electrophoretic Displays

Chair: G. Zhou, South China Normal Univ., China
Co-Chair: M. Wang, Amazon Lab126, USA

EP1 - 1 ***Invited*** **Technologies Development of EPD for Future Electronic Paper Applications**
15:05

Y.-S. Chang

E Ink, Taiwan

Many reflective type display technologies had been developed in the past two decades targeting for electronic paper application, while only few of them are successfully commercialized. This paper will review the electronic paper display technologies briefly, and then discuss color and flexible EPD technologies which are important for future applications.

EP1 - 2 ***Invited*** **Active Matrix Backplane Technologies for Flexible Electrophoretic e-Papers**
15:30

B.-R. P. Yang, X. Wang[*]*, D. Hu*[*]*, Y. Lin*[*]*, X. Zeng*[*]*, Y. Chen*[*]

Sun Yat-Sen Univ., China
[*]*Guangzhou OED Techs., China*

More and more actual paper applications have been replaced by E-Paper. This paper intends to review the active matrix backplane technologies applied for E-papers in recent years, trying to solicit and inspire more researchers to advance the E-ink development, and create more innovative ideas for future E-paper applications.

EP1 - 3
15:55

Invited **Prototyping of e-Tile**

M. Omodani, Y. Adachi, H. Shibata[*]

Tokai Univ., Japan
[*]Fuji Xerox, Japan

A novel concept for large-area displays, e-Tile, is introduced. A typical e-Tile configuration, in which 100 pixels are mounted on a 100 mm square board, was designed and prototyped. One promising application is an unobtrusive information board, which is far less annoying than the conventional vivid LED/LCD in public spaces.

Also presented in Innovative Demonstration Session (see p. 233)

----- Break -----

16:40 - 18:10 **Room 133**

EP2: Emerging e-Paper Technologies

Chair: A. Suzuki, Chiba Univ., Japan
Co-Chair: N.-S. Roh, Samsung Elect., Korea

EP2 - 1
16:40

Invited **ePaper 2.0 (Full Color + Video) Enable by Retro-Reflective eTIR Technology**

R. J. Fleming, S. Peruvemba, B. Sadlik, B. Holman

CLEARink Displays, USA

This paper will review the optical performance of our novel video rate, full color semi-retroreflective frustrated FTIR electrophoretic display technology across a range of use case conditions. The CLEARink technology exhibits very stable display performance across a broad range of lighting conditions whereas the emissive LCDs show a significant drop in ambient contrast ratio as the ambient lighting is increased.

EP2 - 2
17:05

Invited **Full Color Video on E-Paper: It's Reality Now**

A. Henzen[,**,***], G. Zhou[*,**,***]*

[*]South China Normal Univ., China
[**]GR8 Optoelect., Hong Kong
[***]Shenzhen Guohua Optoelect. Tech., China

Electrowetting displays have been subject to extensive investigation, and many of the problems associated with the electrowetting phenomenon were solved. We have now achieved a new benchmark performance in color, reflectance and speed, making electrowetting displays a viable choice, especially in places where other technologies are less suited.

EP2 - 3 ***Invited*** **Advances in Cholesteric Based eWriter**
17:30 **Technologies and Applications**

A. Khan

Kent Displays, USA

The flexible, roll-to-roll eWriter technology, based on cholesteric liquid crystals, has entered a new paradigm via technological innovations such as exact-erase, semi-transparency, large area, and multiple color. This paper will review the technological advances as well as the key eWriter principles.

EP2 - 4L **Multicolor Electrochromic Device Based on the**
17:55 **Hierarchical Three-Dimensional Nanostructure**

J. Song, J.-L. Lee

Pohang Univ. of S&T, Korea

Three-dimensional (3D) hierarchical ITO branches are implemented to demonstrate various color states such as transparent, mirror, black, violet, blue, yellow, red states in electrochromic devices (ECD). The 3D ITO branches played a role in strongly producing localized surface plasmon resonance (LSPR) to effectively control the optical properties in the ECDs.

Author Interviews
18:10 – 18:40

Thursday, December 13

9:00 - 10:00 **Room 133**

EP3: Advance of Electrochromic Displays

Chair: N. Kobayashi, Chiba Univ., Japan
Co-Chair: Y. Hotta, Ricoh, Japan

EP3 - 1 **Design and Fabrication of Thermally Stable**
9:00 **Electrochromic Device**

S. Mondal, M. Higuchi

NIMS, Japan

A novel approach has been adopted to electrochromic device for high temperature operation with Fe(II)-based metallo-supramolecular polymer (PolyFe) as electrochromic layer, $LiClO_4$-based semi-gel as electrolyte layer and PB as counter layer. Fabricated device showing 98% properties retention at room temperature and 85% properties retention at 100°C temperature.

EP3 - 2 9:20 **Improved Memory Function in Ag Deposition-Based Electrochromic Device Utilizing Prussian Blue on Counter Electrode**

S. Kimura, K. Nakamura, N. Kobayashi

Chiba Univ., Japan

We reported Ag deposition-based multicolor electrochromic device. However the device had poor color retention property because of Cu^{2+} ion, which has a function as a redox reaction material on the counter electrode. To improve both good redox reactivity on the counter electrode and memory property, here we utilized Prussian Blue.

EP3 - 3 9:40 **Effect of Size and Shape of Deposited Silver Nanoparticles on Coloration Properties of Silver Deposition-Based Multicolor Electrochromic Device**

T. Sugita, K. Nakamura, N. Kobayashi

Chiba Univ., Japan

We reported Ag deposition-based electrochromic device which showed reversible color change from transparent to chromatic coloration, black and silver-mirror in a single device. In this study, we newly enabled this device to achieve green coloration and analyzed relationship between optical properties and morphology of silver nanoparticles at four chromatic states.

10:00 - 10:12 **Room 133**

Short Presentation: Electronic Paper

All authors of poster papers for the EPp1 session will give 3-minute oral presentations with no discussion time.

Author Interviews
10:40 – 11:10

14:20 - 16:50 **Event Hall**

***Poster* EPp1: Electronic Paper**

EPp1 - 1 **Effect of Electrical Double Layer Capacitance on Coloration Performance in Multicolor ECD with Hybrid Capacitor Configuration**

Z. Liang, K. Nakamura, N. Kobayshi

Chiba Univ., Japan

We have already designed a novel multicolor electrochromic (EC) device having hybrid capacitor electrochromic device based on 4, 4'-biphenyl dicarboxylic acid diethyl ester and phenothiazine molecule with carbon electrode. In this paper, effect of electrical double layer capacitance on coloration performance was analyzed and discussed.

EPp1 - 2L **Verification of Fabricating Color Rewritable Media with Metal Plate and Interference Color**

Y. Abe, S. Maeda

Tokai Univ., Japan

We have been studying ways to utilize niobium colored by anodic oxidation as rewritable media. There is a limit to the color that can be obtained only by anodic oxidation. Therefore, we mixed colors obtained by anodic oxidation using juxtaposed additive color mixture.

EPp1 - 3L **Flexible Substrate Using Silver Mirror Reaction for Twisting Ball Electronic Paper**

A. Kameda, I. Komatsu, S. Maeda

Tokai Univ., Japan

Novel segment electrodes were fabricated on flexible substrates such as PET film using a silver spray method. After forming silver on the flexible substrate, adhesion and electrical resistivity were confirmed. We have confirmed that a twisting ball system was successfully operated using our electrodes.

EPp1 - 4L **Charging Mechanism of Janus Particles in Twisting-Ball Display**

Y. Komazaki, T. Torii[*]*, S. Uemura*

AIST, Japan
[*]*Univ. of Tokyo, Japan*

In this research, charging mechanism of Janus particles in a twisting-ball display was investigated. By triboelectric series determination and display actuation, we proved that the surface charges of Janus particles were generated by contact charging between Janus particles and cavity walls.

17:10 - 18:35 **Room 133**

EP4/UXC3: Approaches to Ideal Replacement of Paper Media

Chair: M. Omodani, Tokai Univ., Japan
Co-Chair: J. Kobayashi, Dai Nippon Printing, Japan

EP4/UXC3 - 1 **17:10** ***Invited*** **Diffusion of e-Book in Japan from the View Point of Consumer Activities**

M. Ueda

Kyoto Sangyo Univ., Japan

We collected 3,000 samples in March 2016 by online survey and found a tendency of consumption of e-book by Japanese consumers. Our major findings are following; 1) attachment to physical objects in Japanese consumers, 2) high MWTP for device and providers, and 3) consuming pattern is different by age groups.

EP4/ UXC3 - 2 17:35

Evaluation of Ease of Handling for Electronic Paper Devices

H. Shibata, M. Omodani[*]

Fuji Xerox, Japan
[*]Tokai Univ., Japan

This paper evaluates people's conscious for digital devices from their behavior. Results showed that participants' behavior for a new A4-size electronic paper device was close to that for a sheet of paper rather than that for digital devices. This indicates that they handled the device like a stationery.

EP4/ UXC3 - 3 17:55

Comparative Analysis of Reading Experience in Paper Book, e-Reader, and Flexible e-Reader Based on Kano Model

E. Amasawa, T. Ihara, K. Hanaki

Univ. of Tokyo, Japan

This study presents a comparative analysis of book reading experience with three different reading media based on Kano model. Among the three media, we found that the average satisfaction level of e-reader to be greater than that of paper books, and comparable to that of flexible e-reader.

EP4/ UXC3 - 4 18:15

Smart Devices Enabled by e-Paper Displays and IoT

K. Blankenbach, D. Bogner, A. Marsal, K. Schuhmacher, P. Duchemin[*], B. Rist[**]

Pforzheim Univ., Germany
[*]MSC Techs., Germany
[**]August Faller, Germany

IoT and Cloud Computing are on the rise. However, many applications require clients with sensors and actuators as well as human interaction. We developed several prototype IoT systems using e-paper for better usability. The examples include smart tags, connected office lighting and advanced pharmaceutical packaging.

Author Interviews
18:40 – 19:10

Friday, December 14

14:50 - 16:10 **Room 131**

EP5: Various Challenges for e-Paper

Chair: M. Higuchi, NIMS, Japan
Co-Chair: Y. Toko, Stanley Elec., Japan

EP5 - 1 ***Invited*** **Electrochromic Lens for Transparence**
14:50 **Eyewear with High Response Speed**

F. Kaneko, Y. Matsuoka, Y. Takahashi, M. Shinoda, S. Yamamoto, H. Takahashi, T. Yashiro

Ricoh, Japan

We have developed high transparent electrochromic (EC) lens for electronic dimming glasses with high response speed. This EC lens's luminous transmittance changes from 87% to under 18% in 18 seconds. The EC lens meets ISO8980-3, ISO12312-1: Category 0 and 3 simultaneously for the first time in the world.

EP5 - 2 **A Transparent/Reflective Display Using by**
15:15 **Electrochromic**

T.-H. Wang, C.-C. Liao, J.-T. Lian

Chunghwa Picture Tubes, Taiwan

We succeeded to develop a 5 × 5 passive-matrix display by using electrochromic (EC) material. The transparent/reflectance before and after driving can reach over than 70%, the contrast ratio can get about 30. The response time is less than 2 seconds. And the driving voltage is only about 2 to 3 V.

EP5 - 3 **Development of a Video-Available Paper-Like**
15:35 **Display Based on Polarizer-Free Liquid Crystal Technology**

C.-C. Liao[,**], C.-C. Chiou[*], J.-T. Lian[*]*

[*]Chunghwa Picture Tubes, Taiwan
[**]Nat. Tsing Hua Univ., Taiwan

This paper proposes a video-speed paper-like display by using polarizer-free liquid crystal technology. The fabricated display exhibit advantages of high reflectance (reflectance is about 22.1%), good readability (contrast ratio is nearly 3.84), and low-power consumption. Experimental results show that the proposed method may satisfy the practical requirements of electronic paper.

EP5 - 4L 15:55 **2D Coordination Nanosheets as Electrochromic Material**

M. K. Bera, M. Higuchi
NIMS, Japan

The coordination nanosheets (CONASHs) are 2D polymeric materials made by organic ligand and transition metal ion. Herein, we report the preparation and characterization of coordination nanosheets film between bipyridine based ligands and Fe (II) metal ion. As an application, we explore the electrochromic property of the nanosheets films.

Author Interviews
16:20 – 16:50

Reception

Wednesday evening
Dec. 12, 2018
19:00 – 21:00

Atsutajingu Kaikan, Atsuta Shrine
(1F, North Building)

Atsutajingu Kaikan is located 2.3km away from Nagoya Congress Center, approx. 10min. by car.
See page 14 for details

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers selected from those presented at IDW '18.
The 2018 award winners will be announced on the IDW website: http://www.idw.or.jp/award.html

Workshop on MEMS and Emerging Technologies for Future Displays and Devices

Thursday, December 13

10:40 - 13:10 **Event Hall**

***Poster* MEETp1: Quantum Dots and Nanotechnologies**

Special Topics of Interest on Quantum Dot Technologies

MEETp1 - 1 Enhancement of Optical Emission from Quantum Dots by Photonic Crystal Cavities Fabricated on SOI Substrates

T. Matsutomi, T. Hayashi, Y. Takamatsu, K. Tanaka, K. Yasui

Nagaoka Univ. of Tech., Japan

To enhance optical emission from quantum dots, photonic crystal cavities were fabricated in a silicon-on-insulator (SOI) substrate using electron beam lithography and dry etching. Quantum dots trapped in these cavities, having various air hole diameters, exhibited increased emission.

MEETp1 - 2 High Efficiency Green Cd-Free Quantum Dot Light-Emitting Diodes with Cross-Linked Hole Transport Layer

K. J. Eun, M. N. Naik, C. Y. Lee, J. H. Kwon

Kyung Hee Univ., Korea

We report highly efficient green Cd-free quantum dot light-emitting diodes (QLEDs) with cross linked hole transport layer (HTL). Our HTL has deep HOMO level with prevention of interlayer intermixing between QD and HTL layer. Fabricated Cd-free QLEDs device with our cross-linked HTL shows maximum external quantum efficiency (EQE) of 4.75%.

10:40 - 13:10 **Event Hall**

***Poster* MEETp2: Novel Components and Process Technologies**

MEETp2 - 1 Calibrating CdS Based Sensors for Visual and Display Interactive Control under Natural Light Environment

C.-J. Ou, F.-R. Lin, Y.-R. Chen, Y.-H. Chiu, C.-J. Chiu

Hsiuping Univ. of S&T, Taiwan

This paper describes the method of developing a lightweight visible light sensor and near-infrared light sensing recorder for interactive display and illumination technology or visual perception research. Present result reach the weight less than 1/8 and a price less than 1/50 than the standard light meter.

MEETp2 - 2 **Analytical Solution of Natural Frequency for Optimized Grating Light Valve**

C.-J. Ou, C.-F. Lin, M.-J. Liu, S.-R. Yang, Z.-W. Wang, C.-C. Chiang

Hsiuping Univ. of S&T, Taiwan

Grating Light valve (GLV) is a promising structures in micro-electromechanical components. A mechanical model derived from the results of elasticity is proposed. Founded along the theory from mechanics of materials, the dynamic behavior and the formulae for natural frequency is directed.

MEETp2 - 3L **Pixel Speaker in Display**

M. Lu

Shenzhen China Star Optoelect. Semiconductor Display Tech., China

Pixel level micro speaker was fabricated in the Top Gate Oxide TFT back panel, and it could be drive to vibrant by 10 voltage bias. It maybe plays a role as in cell speaker in Micro LED and other solid phase display technology in the future.

17:10 - 17:15 **International Conference Room**

Opening

Opening Remarks
17:10

M. Nakamoto, Shizuoka Univ., Japan

17:15 - 18:55 **International Conference Room**

MEET1: Novel Materials, Fundamental Components and Process Technologies

Chair: J. Jang, Kyung Hee Univ., Korea
Co-Chair: A. Dussaigne, CEA-LETI, France

MEET1 - 1 ***Invited*** **Underpinning the United Kingdoms' "Zero Plastic Waste Policy"; the Use of Phosphors in Labelling and Tagging as Aids to Plastics Packaging Recycling Using Intelligent Separation Technologies**
17:15

J. Silver, T. G. Ireland, G. R. Fern, P. G. Harris, R. Li, K. Tarverdi, E. Kosior, M. Kay*, J. Mitchell*, K. Davies**

Brunel Univ. London, UK
**Nextek, UK*

Methods of labelling plastic waste with luminescent markers to aid recycling are discussed. Additional luminescent markers can be used to identify both the contents of the plastic waste (e.g. of a bottle; allowing those containing solvents/bleach to be recycled separately from those that contained drinks.) as well as the manufacturer.

MEET1 - 2 ***Invited*** **Gaussian Density of State in Organic Thin**
17:35 **Film Transistor Model**

Y. Bonnassieux, Y. Lee, S. Jung[*]*, G. Horowitz*

Ecole Polytechnique, France
[*]*Pohang Univ. of S&T, Korea*

For disordered organic semiconductors, Gaussian density-of-states (Gaussian DOS) and hopping transport are often proposed, by analytical expressions for the charge carrier mobility. We proposed an analytical model, easy adaptable to spice model, for the linear regime transfer characteristics of OFETs with power-law dependent mobility and contact resistances.

MEET1 - 3 ***Invited*** **Cathodoluminescence from Undoped**
17:55 **$BaAl_2O_4$ in a Transmission Electron Microscope**

G. R. Fern, D. D. Engelsen, F. Yang, T. G. Ireland, J. Silver

Brunel Univ. London, UK

We describe preliminary results of a study on the CL of undoped $BaAl_2O_4$ in a TEM. Exciting undoped $BaAl_2O_4$ with an e-beam of 200 keV at room temperature we detected blue-green CL. The emission band of this undoped material coincides with the CL emission bands of $BaAl_2O_4$:Eu^{2+}, $BaAl_2O_4$:Sm^{2+} and $BaAl_2O_4$:Yb^{2+}.

MEET1 - 4 ***Invited*** **Flat Panel Deep Ultraviolet(UV) Light**
18:15 **Sources with Carbon Nanotube Cold Cathode**

K. C. Park, S. T. Yoo

Kyung Hee Univ., Korea

Flat panel deep ultraviolet light with carbon nanotube (CNT) cold cathode electron beam was studied. The excitation wavelength depends on the bandgap energy of anode materials and defect state in the gap. We obtained various wavelength UV light from 365 nm to 240 nm, depend on the anode and cathode.

MEET1 - 5 ***Invited*** **Laser Diode with New Polymer Using**
18:35 **Extrusion Technology for Acceleration of Plant Growth in Polytunnels**

K. Tarverdi, G. R. Fern, T. G. Ireland, J. Silver, P. Marsh, Q. Qi

Brunel Univ. London, UK

Methods of introducing phosphor particles into polymers using twin-screw extrusion technology are reported. The extrusion of phosphor/polymer combinations containing different percentages of phosphor was studied. The phosphor/polymer films had their light emitting properties optimised to closely match plant growth requirements. The final films performance was evaluated for horticultural applications.

Author Interviews
18:55 – 19:10

Friday, December 14

9:00 - 10:20 **International Conference Room**

MEET2: Micro/NanoDisplays and Nanotechnology Application (1)

Chair: P. Kathirgamanathan, Brunel Univ. London, UK
Co-Chair: K. C. Park, Kyung Hee Univ., Korea

MEET2 - 1 ***Invited*** **Full InGaN Based LED: Towards a Native**
9:00 **Full-color Micro-Display Solution**

A. Dussaigne, A. Even, B. Samuel, F. Barbier, M. Lafossas, F. Lévy, S. Chenot[*], B. Damilano[*], O. Ledoux[**], D. Sotta[**], E. Guiot[**]

CEA-LETI, France
[*]CRHEA/CNRS, France
[**]Soitec, France

Reaching RGB pixels with same material is important for full-color micro-displays. Reducing strain in LED structure is one possibility to overcome green gap issue. Combining full InGaN structure and InGaNOS substrate leads to enhanced In content with increasing lattice parameter. Blue to red emissions, and red electroluminescence, will be presented.

MEET2 - 2 ***Invited*** **Design, Fabrication, Transfer Bonding and**
9:20 **Active Matrix Driving of GaN-Based Micro-LEDs Displays**

Z. Liu[*], K. Zhang[,**], C. Qiu[*], K. M. Lau[*], H. S. Kwok[**], X. Sun[*]*

[*]Southern Univ. of S&T, China
[**]Hong Kong Univ. of S&T, Hong Kong

We will discuss the development of Micro-LED which attracted increasing attention recently and share our thoughts about how to make better Micro-LEDs and its applications for displays and beyond. The specific technologies including device fabrication and characterization, improvement of electrical uniformity and fine-pitch pixelated-addressed Micro-LED arrays will also be introduced.

MEET2 - 3 ***Invited*** **Mass Production of Holographic Transparent**
9:40 **Components for Wearable Applications**

J. M. Russo, S. Coe-Sullivan, M. Sanchez, J. Padiyar, F. Dimov

Luminit LCC, USA

Holographic optical elements provide transparent and narrow band components with arbitrary incident and diffracted angles for near-to-eye commercial electronic products for augmented and smart glass applications. We will summarize the parameters and general optical geometries relevant for near-to-eye displays, the holographic substrates available, and their ease of manufacture.

MEET2 - 4 ***Invited*** **Manufacturing Solutions for Micro-LED Displays**
10:00

A. Paranjpe

Veeco Instrs., USA

The aggressive performance and yield requirements for micro-LED displays while adhering to strict cost targets create many challenges for the manufacturing of such displays. In this talk, we will present advances in MOVCD epitaxy and mass transfer to enable micro-LED display adoption for signage and consumer applications.

----- Break -----

10:40 - 12:00 **International Conference Room**

MEET3: Micro/NanoDisplays and Nanotechnology Application (2)

Chair: S. Coe-Sullivan, Luminit, USA
Co-Chair: Y. Bonnassieux, Ecole Polytechnique, France

MEET3 - 1 ***Invited*** **Future Microdisplays Through Integration of Micro-LEDs**
10:40

I. Kymissis[,**], V. Lee[**], B. Tull[**]*

[*]Columbia Univ., USA
[**]Lumiode, USA

MicroLED technologies allow for the formation of emissive displays using LED elements that are formatted and controlled at the individual pixel level in high resolution displays. Such components offer the potential for extraordinary efficiency, luminance, and speed, addressing a number of potential display and non-display related applications.

MEET3 - 2 ***Invited*** **MicroLED Driving the Third Wave of Technology Revolution of Information Display**
11:00

Q. F. Yan

Fuzhou Univ., China

With LED size shrinking to micrometer, high speed response time and high brightness allow high density Micro-LED arrays generating a floating image in space, an exciting technology capable producing true 3D images in space at real time. Overview of Micro-LED display technology as well as its application will be discussed.

MEET3 - 3 ***Invited*** **Key Material and Production Equipment Requirements to Realize High-Yield MicroLED Mass-Production**
11:20

F. J. Henley

Tesoro Scientific, USA

Realizing cost-effective microLED mass-production is considered a worthy challenge due to the great promise of MicroLED displays. Unique microLED test and mass-transfer challenges will be discussed. Novel EL test and mass-transfer technologies will be introduced and compared for their compatibility with requirements to achieve high-speed, cost-effective microLED mass-production.

MEET3 - 4 11:40 **Process Optimization for TFT Integrated MEMS Shutter Display**

S. A. A. Nusayer, P. Schalberger, H. Baur, C. Jurgschat, N. Fruehauf

Univ. of Stuttgart, Germany

Prestressed microelectromechanical shutter co-fabricated with top-gate a-Si:H TFTs showed promises as digital spatial light modulators for display application. The fabrication process has been optimized for lower actuation voltage, higher light outcoupling efficiency and simpler fabrication by replacing the structural and sacrificial material without hampering the compatibility with TFT fabrication process.

Also presented in Innovative Demonstration Session (see p. 234)

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:30 **International Conference Room**

MEET4: EL Quantum Dots Technologies

Special Topics of Interest on Quantum Dot Technologies

Chair: F. Yan, Fuzhou Univ., China
Co-Chair: Z. Liu, Southern Univ. of S&T, China

MEET4 - 1 13:10 ***Invited*** **Solution Processed Charge Generation Junctions for Highly Efficient Quantum-Dot Light Emitting Diodes**

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

Kyung Hee Univ., Korea

This paper reviews the solution processed charge generation junctions (CGJs) for highly efficient quantum-dot light-emitting diodes (QLEDs). Various CGJs with organic/organic semiconductors were proposed for tandem OLEDs, while metal-oxide/metal-oxide junctions were proposed for QLEDs. We developed a new p-type oxide, Cu_2SnS_3, and n-type oxide, Li doped ZnO, for OLED and QLEDs.

MEET4 - 2 13:30 ***Invited*** **Efficient Inverted Quantum Dot Light-Emitting Diodes Fabricated by Inkjet Printing Technique**

D. Ko, H. Roh, J. Kwak, C. Lee*

Seoul Nat. Univ., Korea
**Univ. of Seoul, Korea*

Inkjet printing is most promising method for full-color patterning of quantum dot-based light-emitting diodes displays because the QD ink can be deposited on demand in required subpixel area with little materials loss. We report efficient inkjet-printed QLEDs fabricated by controlling the QD ink formulation and inkjet printing conditions.

MEET4 - 3 ***Invited*** **The Color Revolution: Towards Ultra-Wide**
13:50 **Color Gamut**

C. Zhang, Y. Yang, M. Marus, B. Xu, K. Wang, X. W. Sun
Southern Univ. of S&T, China

We will present a much narrower candidate for color revolution, namely quantum nanoplatelets (NPLs) having an emission linewidth of 9 nm, which significantly smaller than QD (~30 nm) and perovskite QDs (~20 nm). Color gamut, which significantly larger than Rec. 2020 by using green emission 4-layer NPLs, could be achieved.

MEET4 - 4 ***Invited*** **Highly Saturated Color Quantum-Dot LEDs**
14:10

P. Kathirgamanathan
Brunel Univ. London, UK

Room temperature intense pulsed light annealing transforms the sol-gel derived ZnO films highly conductive and hydrophobic with improved interface with colloidal quantum dots. Thermally aged devices comprising IPL/ZnO gave a maximum current efficiency of 23 cd/A and a power efficiency of 30 lm/W.

----- Break -----

14:50 - 15:50 **International Conference Room**

MEET5: Emerging Quantum Dots and Nanotechnologies

Special Topics of Interest on Quantum Dot Technologies

Chair: I. Kymissis , Columbia Univ., USA
Co-Chair: X. W. Sun, Southern Univ. of S&T, China

MEET5 - 1 ***Invited*** **Cadmium-Free Quantum Dot Inkjet Inks for**
14:50 **Color Conversion Devices**

A. Ishizuka, E. Otsuki, T. Kizaki, T. Miki, S. Yoshihara, I. Kiyoto, E. Lee, R. Tangirala*, C. Hotz*, H. Kim**
DIC, Japan
**Nanosys, USA*

Quantum dot color conversion layers have the potential to revolutionize displays by improving efficiency and color gamut. To achieve these changes, QDs have to be deposited at sub-pixel pitch. Here we report on the fabrication and characterization of QD inks, as well as films made from inkjet deposition of these materials.

MEET5 - 2 ***Invited*** **Tailoring Quantum Dot Structure for Enhanced Device Lifetime of Quantum-Dot Light-Emitting Diodes (QLEDs)**
15:10

Y. Yang, W. Cao, C. Xiang, L. Wu, L. Qian, X. Yan
TCL Corporate Res., China

The stability issue of QLEDs remains challenging and the mismatch of energy levels within QLED is believed to be one of the primary reasons for efficiency decay. We tailored the structure of QDs, instead of transport layers in conventional strategy, and achieved enhanced device lifetime of QLEDs.

MEET5 - 3 ***Invited*** **Synthesis and Optical Properties of Colloidal InN Quantum Dots**
15:30

J. Nagakubo, M. Hirakawa, T. Nishihashi, H. Murakami
ULVAC, Japan

To prove the effectiveness of rapid synthesis for Indium-Nitride (InN) quantum dots, we investigated their crystal structure, energy level diagrams and compared with that of InN bulk. The values could be explained from previous studies, which was similar to the calculated value from the effective mass approximation.

Author Interviews
16:20 – 16:50

Workshop on Display Electronic Systems

Wednesday, December 12

16:40 - 18:00 **Room 222**

3D2/DES1: Novel Display Systems

Special Topics of Interest on AR/VR and Hyper Reality

Chair: C.-Y. Chen, Nat. Taiwan Univ. of S&T, Taiwan
Co-Chair: Y. Oyamada, Tottori Univ., Japan

3D2/DES1 - 1 16:40 ***Invited*** **Hidden Stereo: Synthesizing Ghost-Free Stereoscopic Images for Viewers without 3D Glasses**

T. Fukiage, T. Kawabe, S. Nishida

NTT, Japan

When a conventional stereoscopic display is viewed without 3D glasses, image blurs, or 'ghosts', are visible due to the fusion of stereo image pairs. We overcome this limitation by synthesizing ghost-free stereoscopic images based on phase-based control of stereo disparity.
Also presented in Innovative Demonstration Session (see p. 232)

3D2/DES1 - 2 17:00 ***Invited*** **Extended Imagery Training for Baseball Batting through High-Reality Virtual Space Using Head Mounted Display**

D. Mikami

NTT, Japan

This paper introduces a system that provides a first-person-view experience for athletes preparing to engage in sports competitions. Our system uses only information captured from locations that will not disturb the athletes or competitions. We describe in this paper how the system worked in a trial with a baseball team.

3D2/DES1 - 3 17:20 ***Invited*** **An Interactive Fog Display to Express Adaptive Shape-Changing Flow**

*T. Koga, K. Otao**

Nat. Inst. of Tech., Tokuyama College, Japan
**Univ. of Tsukuba, Japan*

We propose an interactive fog display to express the adaptive shape-changing flow of a fog screen caused by interactions with the viewer. We present the design specifications of the proposed system, evaluation results of a user study, and some application contents to use the proposed system effectively.

3D2/ DES1 - 4 17:40 **A Miniaturized Multi-Layered Display System with Water Drops**

H.-W. Chen, Y.-A. Kuo, Z.-W. Wang, W. -C. Hsu, C.-Y. Chen*

Nat. Taiwan Univ. of S&T, Taiwan
**Bruvis Multi Media Creative, Taiwan*

In this study, we proposed a multi-layered microprojection system. Foremost the water curtain projection system uses an Arduino control panel and an infrared sensor to implement an interactive device. Furthermore, the Light Sculpture Projection System creates a three-dimensional and high-fidelity effect. In combination, a multi-level display system is formed.

Author Interviews
18:10 – 18:40

Thursday, December 13

14:20 - 16:50 **Event Hall**

Poster **DESp1: Display Electronic Systems**

DESp1 - 1 **Novel LCD Devices with Circular Hole in Active Area for Camera Integration**

X. Lan, Y. Huang, Y. Zhu, X. Wang, S. Lan, L. Bei, C. Deng, Z. Zhu, G. Lai, G. Chen, J. Li, L. Wang

Xiamen Tianma Microelect., China

Full-screen-display with circular hole in active area for camera assembly was developed and fabricated successfully. For the development of this novel LCD device, key technologies including glass-punching technology, backlight-punching technology and routing layout solution were studied. Finally, the prototype demonstration was shown in SID and attracted a lot of attentions.

DESp1 - 2 **An Improved Image Super-Resolution Method Based on Collaborative Interpolation Mechanism**

J. Zhu, Y. Wu, M.-J. Jou, B. Zhao

Shenzhen China Star Optoelect. Tech., China

In this work, an efficient method is proposed to promote image resolution. The proposed method mainly consists of three parts: an interpolation algorithm for reducing image edges roughness, a luminance constraint mechanism for preventing overshoot caused by edge enhancement, and color-purifying algorithm for improving saturation of the high-resolution image edge.

DESp1 - 3 **FPGA Implementation for Computational Ghost Imaging**

I. Hoshi, T. Shimobaba, T. Kakue, T. Ito

Chiba Univ., Japan

We propose a calculation circuit for Computational Ghost Imaging. Computational ghost imaging is a unique technique that allows single pixel imaging. However, this technique needs much calculation time. Therefore, we tried to shorten the calculation time by designing a circuit for computational ghost imaging and implementing it into a FPGA.

DESp1 - 4 **Design of Highly Reliable a-Si Gate Driving Circuit for 32-in. SNB TFT-LCD Panel**

W.-Y. Li, Y.-F. Chou, J. Zhu, W. Shao, L.-Q. Shi, W. Cao, C.-Y. Chiu

Shenzhen China Star Optoelect. Tech., China

In this paper, a new structure a-Si:H TFT gate driver circuit (GOA) for high reliable and low power consumption is proposed and fabricated. Finally, a 32-in. FHD 60 Hz with 3 mm super narrow border (SNB) TFT-LCD panel was successfully demonstrated based on the study above.

DESp1 - 5L **Multi-Output LTPS TFT Shift Register with Node Sharing Structure**

Y. I. Kim, S. Park, K.-H. Seol, S.-J. Song, H. Nam

Kyung Hee Univ., Korea

This paper demonstrates a small area shift register for narrow bezel display applications. The proposed circuit reduces the number of TFTs by sharing pull-up and pull-down nodes over multiple output pulses without bootstrapping degradation. For 4 outputs per stage, the number of TFTs is reduced to 57%.

DESp1 - 6L **Support Vector Machine (SVM) Based Stylus Touch Screen Panel**

K.-H. Seol, S. Park, S.-J. Song, Y. I. Kim, H. Nam

Kyung Hee Univ., Korea

This paper presents a support vector machine (SVM) based stylus capacitive touch screen panel that allows stylus and finger to be distinguished when they are placed on the screen at the same time. The resultant bit error rate (BER) is measured as less than 10-6 for all types of touches.

14:20 - 16:50 **Event Hall**

Poster DESp2: Display Electronic Systems for Automotive

Special Topics of Interest on Automotive Displays

DESp2 - 1 **Withdrawn**

14:20 - 16:50 **Event Hall**

***Poster* DESp3/VHFp7: Backlight and LED Technology**

DESp3/ VHFp7 - 1 **Waving-Hand Steganography Embedded in a Backlight of an LCD**

S. Morita[*], A. Tsuji[**], T. Tokimoto[,***], H. Yamamoto[*,****]*

[*]Utsunomiya Univ., Japan
[**]Tokushima Univ., Japan
[***]Dao App Tech., Taiwan
[****]JST ACCEL, Japan

This paper proposes a novel steganography that embeds a secret image in the backlight. We have specially developed a high-speed (1250 Hz) LED display by use of FPGA circuits and utilized the LED display for a backlight of an LCD panel. Encoded images were shown on the high-speed backlight.

DESp3/ VHFp7 - 2 **Convolutional Neural Network Driven Localized Backlight Dimming Strategy for Liquid Crystal Displays**

J. Jo, J. S. Park[*], J. W. Soh, N. I. Cho

Seoul Nat. Univ., Korea
[*]Samsung Elect., Korea

This paper presents a convolutional neural network (CNN) for the adaptive localized backlight dimming. We develop a new loss function for training the CNN, which results in efficient dimming and high contrast images. We also try to minimize the complexity of CNN so that it can be practically used.

DESp3/ VHFp7 - 3L **A Novel Super-Resolution Display Technique by Use of Spatiotemporal Coding**

T. Tokimoto[,**], K. Fujii[**], S. Morita[**], H. Yamamoto[**,***]*

[*]DaoApp Tech., Taiwan
[**]Utsunomiya Univ., Japan
[***]JST ACCEL, Japan

We propose a novel super-resolution display technique by use of spatiotemporal coding. When for neighboring image data are displayed dynamically on a coarse LED panel, the resolution becomes higher than the conventional LED display. We examined the cognitive mechanism in the human visual system to explain this experiment result.

Friday, December 14

9:00 - 10:20 **Room 133**

DES2/UXC4: AI Applied to Display

Special Topics of Interest on Automotive Displays

Chair: T. Sato, AIST, Japan
Co-Chair: Y. Ando, Fuji Xerox, Japan

DES2/UXC4 - 1
9:00

Invited **3D Image Processing Based on Machine Learning**

T. Fujii

Nagoya Univ., Japan

Recently, Deep neural network (DNN) and convolutional neural network (CNN) are successfully applied to 3D image processing problems, such as light field display calculation, coded aperture based light field acquisition, and view interpolation. In this paper, we introduce examples where DNN and CNN are efficiently applied to these problems.

DES2/UXC4 - 2
9:20

Invited **Road Scene Understanding Using Image Recognition for Safety and Autonomous Driving**

T. Watanabe

Toshiba, Japan

On-board camera is widely used to understand road scene around automobile for driver assistance. This paper introduce image recognition methods that we developed for ADAS (Advanced Driver Assistance System). We also explain our efficient automobile LSIs that runs image recognition algorithms in real-time with low power consumption.

DES2/UXC4 - 3
9:40

Invited **Font Image Conversion Using Style Transfer and Cross Domain Transfer Learning**

W. Shimoda, A. Narusawa, K. Yanai

Univ. of Electro-Commun., Japan

In this paper we study about font generation and conversion. We extract features from font images and transferring texture or pattern using deep learning. In experiments we construct unique datasets and improve image generation quality for readability of character by combining neural style transfer with cross domain learning.

DES2/UXC4 - 4
10:00

Multimodal User Interface Application to Support Drawing-in-Talking

X. Xu, H. Shibata

Fuji Xerox, Japan

This paper proposes a multimodal user interface system using pen and voice to draw diagrams, especially system configuration diagrams. To support actual presentation, we aim to support smooth mode switching that does not interfere with natural talking.

----- Break -----

10:40 - 12:00 **Room 133**

DES3: Micro-LED and OLED Driving

Chair: R. Oke, Panasonic Liquid Crystal Display, Japan
Co-Chair: C.-W. Lu, Nat. Tsing Hua Univ., Taiwan

DES3 - 1
10:40

Invited **Stability of Micro-LED Pixel Circuit Based on Amorphous InGaZnO Thin Film Transistors and Digital Driving Theme**

C. Dong, W. Zhang, Y. Zhou, L. Zhou, Y. Zhang, H. Xie
Shanghai Jiao Tong Univ., China

Both uniformity and stability of digitally-addressed micro-LED displays on the basis of a-IGZO TFTs were studied by modeling and simulations. A novel driving method was proposed and verified to make the digitally-addressed micro-LED pixel current during Glow stage more stable.

DES3 - 2
11:00

High-Efficiency Backlight Module Optical Design

C. Weng, C. Y. Li, C. L. Huang, P. S. Hu, J. W. Pan
Nat. Chiao Tung Univ., Taiwan

We propose a high-efficiency backlight module without BEFs and achieve almost the same half-luminance angle as the conventional backlight module does. This backlight module guides light with two different modes. We can get the two-fold improvement in both total optical efficiency and on-axis luminance by controlling the arrangement of microstructures.

DES3 - 3
11:20

P-Type Gate Driver Circuit Using One Driving TFT for AMOLED Pixel Circuit

P.-T. Lee, C.-H. Tseng, C.-L. Lin
Nat. Cheng Kung Univ., Taiwan

A p-type low-temperature polycrystalline silicon active-matrix organic light-emitting diode (LTPS) gate driver composed of 11T1C realizes simultaneous-emission (SE) driving schemes which are simultaneous signals and progressive signals for driving high-resolution active-matrix organic light-emitting diode (AMOLED) pixel circuits.

DES3 - 4
11:40

A High-Efficient Compression Algorithm for AMOLED Compensation Table

L. Cheng, Y. Deng, Y. Jin, M.-J. Jou

Shenzhen China Star Optoelect. Tech., China

In this paper, a new method is presented to compress the compensation table for display panel. Considering the feature of the compensation table and system requirements, multiple prediction modes and hardware-friendly transform are introduced into this algorithm.

Author Interviews
12:00 – 12:30

----- Lunch -----

13:10 - 14:30 **Room 222**

3D5/DES4: Display Systems for Automotive

Special Topics of Interest on Automotive Displays

Chair: K. Morita, Chuo Univ., Japan
Co-Chair: H. Yamamoto, Utsunomiya Univ., Japan

3D5/
DES4 - 1
13:10

Invited **3D Head-Up Display System**

Y. Takaki

Tokyo Univ. of A&T, Japan

3D head-up displays employing super multi-view displays have been developed to enable stable superposition of 3D images on real objects. The optical system using a polarizing beam splitter is proposed to reduce the system size.

3D5/
DES4 - 2
13:30

Low Crosstalk Glassless 3D HUD with Expanded Viewing Area in All Directions Using Novel Eye Tracking System

T. Matsumoto, K. Kusafuka, H. Nakamura[*]*, G. Hamagishi*[*]*, K. Yoshimoto*[*]*, H. Takahashi*[*]

Kyocera, Japan
[*]*Osaka City Univ., Japan*

We propose Glassless 3D HUD that enables binocular virtual image stereopsis with low crosstalk. In this system, 3D image processing algorithm and the crosstalk reduction method which perform processing based on the position of the driver's eye sensed by the driver monitor camera are applied.

3D5/ DES4 - 3 13:50 **10.4-in. Ultra-Slim a-Si TFT LCD with Tracking Gate Line in Pixel Technology for Automotive Display**

C.-H. Kuan, J.-S. Liao, C.-Y. Du, C.-C. Chang, H.-H. Chen, H.-M. Su, W.-Z. Zeng

Chunghwa Picture Tubes, Taiwan

In this work, we developed of 10.4-in. (1280 x RGB x 720) automotive display with Tracking Gate line in Pixel technique. In this case, we can keep panel transmittance to achieve ultra-slim panel border (0.7 mm) for automotive display. This panel structure has been important link to realize the next generation of automotive industry applications.

3D5/ DES4 - 4 14:10 **An Automotive Grade Local Dimming Display System**

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

Chunghwa Picture Tubes, Taiwan

In this paper, we applied different dimming area design corresponding to backlight unit separately. Through the local dimming display, the driver could recognize the car information clearly day and night. It should lead to greatly improve the driving safety.

----- Break -----

14:50 - 16:00 **Room 133**

DES5: 8K Systems

Chair: R. Oke, Panasonic Liquid Crystal Display, Japan
Co-Chair: S. Takamura, NTT, Japan

DES5 - 1 14:50 ***Invited*** **8K UHDTV Imaging Technology: Cameras and Image Sensors**

K. Tomioka

NHK, Japan

In this paper, we describe the development of 8K UHDTV imaging technologies, including full-featured 8K cameras and high-speed imaging for 8K slow-motion systems. We also describe NHK's 8K UHDTV display technologies and expected specifications for 8K UHDTV displays.

DES5 - 2 15:15 ***Invited*** **HEVC Software Media Player for Ultra-High-Quality Video: 8K and Beyond**

M. Alvarez-Mesa, C. C. Chi

Spin Digital Video Techs., Germany

A software media player for ultra-high-quality video including 8K and 16K video is presented. It is based on a high-performance CPU-based HEVC decoder, and a high-quality GPU-based video rendering engine. Experimental results show that is possible to play up to 16Kp60 video using a single workstation PC system.

Also presented in Innovative Demonstration Session (see p. 234)

DES5 - 3
15:40

Color Sequential Display with High Resolution Backlights

G. Li, Y. Zhang, J. Wang, D. Geng, J. Tang

Southeast Univ., China

An evaluation method for predicting color breakup (CBU) visibility in field sequential color (FSC) display is proposed. The results show that when division number of matrix backlight reaches fourteen thousands, the CBU can be eliminated, a better performance can be achieved when applied in a four-field sequential compared with three-field.

Author Interviews
16:20 – 16:50

Supporting Organizations:

Special Interest Group on Mixed Reality (SIG-MR), The Virtual Reality Society of Japan
Technical Committee on Image Engineering (IE), Information and Systems Society, IEICE
Technical Group on Information Sensing Technologies (IST), ITE
Nagoya Section, IEEE
Technical Group on Information Display, ITE
Technical Committee on Electronic Information Displays (EID), Electronics Society, IEICE
The Society of Automotive Engineers of Japan

Workshop on Flexible Electronics

Wednesday, December 12

13:20 - 13:25 **Room 222**

Opening

Opening Remarks
13:20

T. Kamata, AIST, Japan

13:25 - 14:40 **Room 222**

FLX1: Wearable Sensors and Devices

Chair: T. Kamata, AIST, Japan
Co-Chair: T. Nagase, Osaka Pref. Univ., Japan

FLX1 - 1 ***Invited*** **Novel Smart Apparel Technology Based on**
13:25 **Stretchable Electronics and Its Applications**

I. Amimori, O. Sawanobori, M. Nakajima

Xenoma, Japan

A smart apparel is a novel human-machine interface which connects human with internet. We have developed a novel smart apparel e-skin based on stretchable electronics, resulting in comfortable, mechanically robust, well-insulated and machine washable. Our e-skin is one of the most ideal interfaces to monitor our activity and vital information.

FLX1 - 2 ***Invited*** **Flexible Self-Sufficient Energy System for**
13:50 **Wearable Electronics**

T. Tomono

Toppan Printing, Japan

Recently, personal health-monitoring is expected to be one of the most attractive applications of wearable electronics. The proposed circuit will make it possible to use the devices more than 30 days without sunshine when we put on clothes of more than 960 g such as thick coat or outerwear.

FLX1 - 3 ***Invited*** **Development of Flexible Sheet Sensor for**
14:15 **Evaluating Wind Pressure Distribution**

S. Kanazawa, H. Ushijima

AIST, Japan

A new sensor matrix based on the concept of flexible mechatronics is reported. A printed strain sensor matrix detects wind pressure distribution utilizing the motion of the shaped film. This achievement shows that a mechanically functionalized substrate opens up new avenues for flexible electronics.

----- Break -----

16:40 - 17:40 **Reception Hall 1**

FLX2: Organic Electronics Technologies

Chair: M. Ito, Toppan Printing, Japan
Co-Chair: H. Endo, NEC, Japan

FLX2 - 1 ***Invited*** **Development of Polymer Semiconductors**
16:40 **Towards Simpler Fabrication Process in Flexible Electronics**

T. Murase, Y. Takeda[*], R. Shiwaku[*], H. Matsui[*], D. Kumaki[*], S. Tokito[*]

Mitsubishi Chem., Japan
[*]Yamagata Univ., Japan

We present novel donor/acceptor type polymer semiconductor that enables simpler organic complimentary circuit fabrication process. Our polymer semiconductor has unique feature that mobility of its organic thin-film transistor is not strongly affected both by presence or absence of self-assembled monolayer and by its species on printed electrode.

FLX2 - 2 **Manufacture of Organic Transistors on Large-Area**
17:05 **Flexible Substrate Using Direct Imaging Exposure System by Wet Process Suitable for Roll to Roll Production**

S. Koizumi, M. Hori, Y. Hayashida, K. Naito, S. Kawabata, Y. Ishigaki, M. Nakazumi, K. Iwahori, Y. Kito

Nikon, Japan

We have developed a method for fabricating an organic thin-film transistor (OTFT) on a flexible substrate by a wet process utilizing electroless plating. In addition, we successfully fabricated an OTFT on a large-area substrate by using a roll-to-roll direct imaging exposure system that we had developed.

FLX2 - 3 **Withdrawn**

FLX2 - 4L 17:25 **Development of High Gas Barrier Film Using Novel Precursor by Roll to Roll PECVD**

K. Taira, T. Suzuki, W. Konno, H. Chiba, H. Itoh**, M. Koden, T. Takahashi, T. Furukawa*

Yamagata Univ., Japan
**TOSOH, Japan*
***TEIJIN, Japan*

The novel precursor TG-41 (Tosoh Corporation) was used for depositing barrier layers on PEN films by Roll to Roll PECVD. Barrier films with good gas barrier property and excellent transparency were obtained. It was found that the structure of the barrier layers was a multilayer structure.

Author Interviews
18:10 – 18:40

Thursday, December 13

14:20 - 16:50 **Event Hall**

***Poster* FLXp1: Flexible Electronics Technologies**

FLXp1 - 1 **Flexible Oxide Thin-Film Transistor with High Process Temperature by Means of Peel-off and Transfer Method**

J. B. Ko, S.-H. Lee, T.-I. Lee, T.-S. Kim, H. Kim, S.-H. K. Park*

KAIST, Korea
**DAVO C&M, Korea*

For the flexible transparent display driving device, we realize the flexible oxide TFT with high process temperature up to 300°C by using inorganic exfoliation layer. The low adhesive energy between oxide TFT and exfoliation layer was measured, and the device shows reasonable electrical characteristics.

FLXp1 - 2 **Study of Poly(3-hexylthiophene) Transistors with Different Blending Materials**

Y.-W. Wang, W.-C. Su, W.-K. Lin, M. T. Chung, T. M. Chen, K.-C. Fan, M.-H. Chih, N.-H. Ho, Y.-H. Cheng, J.-H. Lin*

Nat. Changhua Univ. of Education, Taiwan
**Nat. Chiao Tung Univ., Taiwan*

The correlations between microstructure and electrical properties of rr-P3HT blended with different materials transistors are investigated. The blended rr-P3HT transistors exhibit a high on/off current ratio of ~10^4, a low leakage current of <10^{-11} A, a small sub-threshold swing of ~2.09 V/dec, and a highest mobility of ~8.18×10^{-3} cm^2/Vs.

FLXp1 - 3 **Organic-inorganic Hybrid Gate Dielectrics with Improved Dielectric Properties via UV Treatment for Flexible Electronics**

J. S. Hur, J. O. Kim, H. A. Kim, J. K. Jeong

Hanyang Univ., Korea

Metal-insulator-metal (MIM) capacitors with poly(4-vinylphenol-co-methylmethacrylate) (PVP-co-PMMA) based organic-inorganic hybrid gate dielectrics were fabricated at a low temperature (150°C) after UV treatment. The resulting hybrid dielectric films showed a low leakage current density, a high breakdown E-field strength, and a high dielectric constant via UV treatment.

FLXp1 - 4 **Ultrathin Flexible Organic Thin Film Transistors by Water-Debonding Process**

J. M. Kim, J. Oh, K.-M. Jung, K. C. Park[*]*, J.-H. Jeon*[**]*, Y.-S. Kim*

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

We fabricated ultrathin flexible organic thin film transistors with fluoropolymer encapsulations by using water-debonding process. The total thickness of free-standing TFTs was about 2 μm. We conducted the bending test to the bending radius down to 2.5 mm and confirmed that the electrical characteristics were maintained.

FLXp1 - 5 **Folding Stability of Organic-Inorganic Multilayer Near Neutral Plane**

S. Kim, S. Ham, S. Cho

Sungkyunkwan Univ., Korea

We developed a barrier structure that has stability of WVTR characteristics after folding by using a neutral plane. 10 dyad of Al_2O_3 and n-hexane multilayer barrier was placed on the neutral plane. We measure change of before and after WVTR property by folding at a bending radius 1 mm.

FLXp1 - 6 **Withdrawn**

FLXp1 - 7 **A Study on a Characteristics of Hybrid Window Substrate for Foldable OLED Display**

J.-K. Choi, B.-M. Park, K.-Y. Han

Dankook Univ., Korea

In flexible displays, substrate technology is becoming a very important factor. In this paper, the buffer layer and the plastic substrate are used to relieve the stress of the glass substrate, and a hybrid structure capable of being flexible is manufactured and its characteristics are confirmed.

FLXp1 - 8 Deposition and Characterization of ITO Thin Films on Cellulose Nanofiber Paper

H. Tambo, M. Nasuno, T. Obata, S. Iwatsubo

Toyama Ind. Tech. R&D Ctr., Japan

A cellulose nanofiber (CNF) suspension was cast onto Si with a fluorine compound, heated, and subjected to lateral hot pressing. Indium tin oxide (ITO) films were then deposited by sputtering. The period of the interference pattern in the transmission spectrum for the ITO/CNF sheet increased with decreasing sputtering power.

FLXp1 - 9L Electromechanical Stability of Low Temperature Polycrystalline Silicon (LTPS) Transistor (TFT) Embedding on Plastic Films

C. Park

China Star Optoelect. Semiconductor Display Tech., China

The electromechanical integrity of devices (TFTs) was obtained against the mechanical strain of compressive stress although the strong electrical failure was followed after being subjected to tensile stress. The deformation phenomenon of multiple films under the stress accumulation was investigated with regard to the flexible backplane arrays.

FLXp1 - 10L High Gas Barrier Films with Heterogeneous Multilayer

T. Suzuki, W. Konno, K. Taira, H. Chiba[*], H. Itoh[**], M. Koden, T. Takahashi, T. Furukawa

Yamagata Univ., Japan
[*]TOSOH, Japan
[**]TEIJIN, Japan

Novel gas barrier layers with heterogeneous multilayer were developed using a Roll-to-Roll PECVD equipment. By using the developed gas barrier layer, we fabricated high transparent barrier films with transparent conducting Indium Zinc Oxide (IZO) layer. In addition, the thinning of IZO was found to suppress the sputtering damages.

FLXp1 - 11L High Bending Resistant Al-Nd Alloy Thin Film for Gate Electrode

Y. Teramae, C. Kura, Y. Tauchi, H. Goto[*], H. Okuno[*]

Kobe Steel, Japan
[*]Kobelco Res. Inst., Japan

Bending resistance is a crucial issue to materials for the foldable devices. In this study, we have investigated the characteristics of aluminum (Al)-alloy thin films and proven their excellent bending resistance and thermal stability as gate electrodes for low temperature poly silicon (LTPS) thin-film transistors (TFTs).

14:20 - 16:50 **Event Hall**

***Poster* FLXp2/LCTp5: Flexible LCD Technologies**

FLXp2/ LCTp5 - 1L **Evaluation of Holding Effect of Cell Gap in Curved Flexible LCDs with Polymer Spacers**

S. Takahashi, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

We evaluated a holding effect of cell gap in flexible LCDs by measuring wavelength-dependent phase retardation of LCDs in curved and non-curved states. As a result, we clarified a combination of lattice shaped polymer spacers and post shaped photo spacers can realize high-quality flexible LCDs with small radius of curvature.

FLXp2/ LCTp5 - 2L **Evaluation of Mechanical Durability and Self-Recovery Property of Liquid Crystal Gels for Stretchable Displays**

R. Saito, Y. Shibata, T. Ishinabe, H. Fujikake

Tohoku Univ., Japan

To realize stretchable liquid crystal (LC) displays, we evaluated the mechanical durability and self-recovery property of the LC-gel. The LC-gel didn't rupture under shear strain of 0.8 mm. Also, the LC-gel can be recovered from damaged state to original state by heating process, and restored its optical property.

FLXp2/ LCTp5 - 3L **Fabrication Technique of Flexible Liquid Crystal Display Using In-Plane Micro-Contact Printing Electrode**

M. Kataoka, H. Okada

Univ. of Toyama, Japan

In this research, we aimed at a display method with In-plane electrodes for LC driving using micro contact printing (μ-CP) method which enables fabrication of electrodes at low temperature and can fabricate devices on plastic substrates.

17:10 - 18:30 **Reception Hall 2**

FLX3/LCT5: Advanced Flexible Displays

Chair: M. Kimura, Nagaoka Univ. of Tech., Japan
Co-Chair: T. Eguchi, Sumitomo Bakelite, Japan

FLX3/ LCT5 - 1 17:10 ***Invited*** **Technology Advances for Flexible Transparent AMOLED and Electronics**

M.-H. Yang, Y.-T. Tsai, J.-C. Ho, S. Chiu, C.-C. Lee

ITRI, Taiwan

ITRI has developed flexible and foldable OLED display technology by its proprietary FlexUP platform technology. Furthermore, we continue to drive FlexUP to meet the requirements of flexible transparent display system and extend its application to non-display filed like fan-out panel level package, flexible system in package and flexible hybrid electronics.

FLX3/ LCT5 - 2 17:35 **6.9-in. Flexible Transparent Display Using by SALC Technology and Applications**

C. C. Chiou, C. H. Chen, J. T. Lian

Chunghwa Picture Tubes, Taiwan

In this paper, Chunghwa Picture Tubes (CPT) of the flexible transparent display was using by Surface Anchoring Liquid Crystal (SALC) technology can achieve high transparent and excellent contrast ratio. In addition, CPT also developed flexible substrate to make the Flexible Transparent Display.

FLX3/ LCT5 - 3 17:55 **The Research and Design of Transparency Hole Screen**

X. Zhou, G. Lai, H. Wu, H. Zhou, J. Liu, X. Yang, X. Lan, Y. Yang, P. Shen, J. Li

Xiamen Tianma Microelect., China

Opening camera holes in the screen has become a solution to higher screen-to-body ratio. The openings in the screen will encounter a series of problems such as vertical crosstalk, RA, and Process Issue. Tianma developed a transparency hole screen which screen-to-body ratio could up to 90%.

FLX3/ LCT5 - 4L 18:15 **Formation Mechanism of Polymer Layered Structure in Polymer-Dispersed LCs with Anisotropic UV Irradiation**

Y. Horii, T. Ishinabe, Y. Shibata, H. Fujikake

Tohoku Univ., Japan

We investigated the formation mechanism of polymer layered structure in polymer-dispersed liquid crystals, to precisely control the light diffusion distribution. Micro-convex structures on the substrate surface produced an uneven ultraviolet illuminance distribution in the LC–monomer mixture. The monomer was polymerized selectively at the positions where ultraviolet illuminance was high.

Author Interviews
18:40 – 19:10

Friday, December 14

9:00 - 10:05 **Reception Hall 2**

FLX4: Advanced Process and Evaluation Technologies

Chair: Y. Mishima, JAPERA, Japan
Co-Chair: K. Uemura, Nippon Steel & Sumitomo Metal, Japan

FLX4 - 1 9:00 ***Invited*** **High Performance Flexible TFT Technology Prepared by Low Temperature Process**

J. Peng

South China Univ. of Tech., China

The presentation will report Nd doped oxide semiconductor used for TFT. A flexible AMOLED was realized based on the TFT array.

FLX4 - 2 9:25 **Analysis of Mechanical Stresses on Foldable Devices**

N. Ando, K. Hyodo, H. Sasaki, Y. Ota

YUASA Sys., Japan

Knowledge of mechanical stresses on foldable devices is the key factor to develop them. When you study stresses, you should control motion profile then study dynamic stress. In our study, we reproduce some motions with our folding tester, compare a result of simulation and real mechanical stress.

FLX4 - 3 9:45 **R2R Fabrication of Thin-Film Coatings on Ultra-Thin Glass for Flexible Devices**

M. Junghaehnel, M. Fahland, T. Preussner

Fraunhofer Inst. for Organic Elect., Germany

Flexible glass opens up new fields of applications for flexible devices. With bendability similar to other web materials, flexible glass excels in dimensional stability, thermal capability and chemical compatibility. Roll-to-roll processing using PVD deposition would allow efficient low-cost production of functional layers and layer stacks.

----- Break -----

10:40 - 12:00 **Reception Hall 2**

FLX5/FMC7: Advanced Materials and Components for Flexible Electronics

Chair: T. Furukawa, Yamagata Univ., Japan
Co-Chair: A. Fujita, JNC, Japan

FLX5/ FMC7 - 1 10:40

Thin and High-Quality ITO/Ag Alloy/ITO Structure for Display Electrodes

Y. Toshimori, S. Nonaka, T. Nagase

Mitsubishi Materials, Japan

We have developed new Ag alloy for ITO/Ag/ITO multilayer which has thinner total thickness and excellent optical and electrical properties. New Ag alloy enables to form thinner and more durable Nano-Ag film, even if deposited in atmosphere with residual water vapor, such as mass-production sputtering chamber.

FLX5/ FMC7 - 2 11:00

Improvement of Mura and CD by Adjusting Black Matrix Component in G8.6 TFT-LCD Color Filter

R. Wang, D. Zhang, D. Lei, X. Wang, J. Hung, J. Hsu, W. Chen, Y. Lu

Chongqing HKC Optoelect. Tech., China

In this paper, BM (black matrix) photoresist component was adjusted to thoroughly solve VCD (vacuum dry) mura, twill mura, as well as oversized CD (critical dimension) quality that happened in BM manufacture process in G8.6 TFT-LCD color filter.

FLX5/ FMC7 - 3 11:20

Black Photoresist Achieving Patterns with Extremely Low Reflection and Smooth Line Edge on Flexible Substrate

A. Igawa, M.-A. Hsu[*]

eChem Solutions Japan, Japan
[*]Consistent Elect. Materials, Taiwan

A novel black photoresist achieving patterns with extremely low reflection and very smooth pattern line edge is developed. Instead of adding black particles, combinations of solvents and special substances are used. Introducing special flexible matrix resin, this photoresist can be applied not only on glass but also on flexible substrate.

FLX5/ FMC7 - 4 11:40 **The Effects of Surfactants and Dielectrophoresis on the Electrical Property of Single-Wall Carbon Nanotube Films**

C. Wei, Z.-L. Yan

Tatung Univ., Taiwan

Carbon nanotubes are used as a transparent conductor film due to its nano size. The degree of dispersion is essential in such application. Different surfactants with dielectrophoresis are utilized to seek the optimal performance. SDS with 1 M dielectrophoresis has shown to be the best recipe.

Author Interviews
12:00 – 12:30

----- Lunch -----

IDW Best Paper Award

IDW Outstanding Poster Paper Award

These awards will go to the most outstanding papers selected from those presented at IDW '18.
The 2018 award winners will be announced on the IDW website: http://www.idw.or.jp/award.html

EXHIBITION

12:00 – 18:00 Wednesday, Dec. 12
10:00 – 18:00 Thursday, Dec. 13
10:00 – 14:00 Friday, Dec. 14
Event Hall (1F, Building 1)
Nagoya Congress Center
Free admission with your registration name tag

Workshop on Touch Panels and Input Technologies

Wednesday, December 12

13:20 - 13:25 **Room 224**

Opening

Opening Remarks
13:20

H. Hashimoto, Citizen Watch, Japan

13:25 - 14:50 **Room 224**

INP1: Haptic Technologies

Special Topics of Interest on Haptics Technologies

Chair: Y. Tanaka, Nagoya Inst. of Tech., Japan
Co-Chair: H. Ishizuka, Kagawa Univ., Japan

INP1 - 1 ***Invited*** **Smart Rubber Technology and Its**
13:25 **Applications**

K. Nakano, T. Murase

Sumitomo Riko, Japan

We have developed special rubber material "Smart Rubber(SR)" that is flexible and current-carrying, using Polymer-material Technique and Overall Technical Evaluation. We also have developed "SR Sensor", apply SR to flexible sheet rubber, and "SR Actuator", apply characteristic feature of rubber that stretch by electric stimulation and rubber contractility.

Also presented in Innovative Demonstration Session (see p. 234)

INP1 - 2 ***Invited*** **Development of Electrovibration Tactile**
13:50 **Displays with Microfabrication and Digital Fabrication**

H. Ishizuka

Kagawa Univ., Japan

In this study, we explain the electrovibration tactile displays with microfabrication process and digital fabrication. First, we explain a flexible sheet type electrovibration tactile display. Next, we explain a multi-electrode electrovibration tactile display. Also, the printed electrovibration tactile display is explained.

INP1 - 3
14:15 **Toward the Modeling of Tactile Sensation on Electrostatic Tactile Display**

H. Tomita, S. Takahashi, S. Saga[*], S. Vasilache, H. Kajimoto[**]

Univ. of Tsukuba, Japan
[*]Kumamoto Univ., Japan
[**]Univ. of Electro-Commun., Japan

As one method of displaying tactile sensation on the touchscreen, electrostatic tactile displays have been developed. We evaluated the magnitude of tactile sensation on an electrostatic tactile display. Based on the result, we proposed a preliminary model to predict the magnitude of tactile sensation from the results of several inputs.

INP1 - 4L
14:35 **Force Sensitive Tactile Feedback Touchscreen Featuring Texture and Click Sensations**

Y. Yang, H. Haga, H. Sasaki, T. Asai, K. Shigemura

Tianma Japan, Japan

A force sensitive tactile feedback touchscreen integrated with an electrostatic tactile display, linear solenoid actuators and force sensors was demonstrated. This touchscreen enables the possibility of locating objects shown on a visual display using only tactile sensations on fingertip without vision and giving realistic tactile feedback for confirmed action.

Also presented in Innovative Demonstration Session (see p. 234)

----- Break -----

15:00 - 16:15 **Room 224**

INP2: 3D Sensing for Automotive HMI

Special Topics of Interest on Automotive Displays

Chair: R. Ishiyama, NEC, Japan
Co-Chair: N. Mishima, Toshiba, Japan

INP2 - 1
15:00 ***Invited*** **Depth from Asymmetric Defocus Using Color-Filtered Aperture Towards One Shot Depth Acquisition by Single Camera**

N. Mishima, T. Sasaki

Toshiba, Japan

We have developed an imaging technique that can simultaneously acquire a color image and a depth map from a single image taken by a monocular camera. This technique achieves high-precision distance/range detection, comparable to that of a stereo camera, through the combination of a lens device and image processing.

INP2 - 2
15:25 ***Invited*** **Hybrid Time-of-Flight Range Image Sensors Using High-Speed Multiple-Tap Charge Modulation Pixels**

S. Kawahito[,**], K. Yasutomi[*], K. Mars[*], K. Kagawa[*], S. Aoyama[**]*

[*]Shizuoka Univ., Japan
[**]Brookman Tech., Japan

This paper presents TOF range image sensors featuring the combination of direct and indirect TOF measurements. This technique uses a short light-pulse modulation and multiple time windows prepared by the multiple-tap pixels and sub-frame readouts and allows us to have high range resolution and high tolerance to ambient light.
Also presented in Innovative Demonstration Session (see p. 234)

INP2 - 3
15:50 ***Invited*** **3-D Scan and Image Recognition of Face**

R. Ishiyama

NEC, Japan

Face image can be captured remotely and without any user's action, thus it is useful for such applications as mobile user authentication and surveillance. However, face image recognition is sensitive to the pose and lighting changes. We discuss about how 3D scan technologies assist to solve these problems.

----- Break -----

16:40 - 18:15 **Room 224**

INP3: In-Cell Touch Panels and Automotive HMI

Special Topics of Interest on Automotive Displays

Chair: H. Haga, Tianma Japan, Japan
Co-Chair: N. Takada, Japan Display, Japan

INP3 - 1
16:40 ***Invited*** **Capacitive Touch Panel with Non-Conductive and Conductive Object Distinction for In-Cell LCD and OLED Display**

J. de D. B. Mugiraneza, D. Gallardo, Y. Sugita, T. Maruyama, K. Kida, S. Yamagishi, T. Yamamoto*

Sharp, Japan
**Sharp Labs of Europe, UK*

We describe In-Cell Capacitive Touch Panel with novel electrode pattern and sensing method for detection of conductive and non-conductive objects. Proposed electrode design and driving scheme enables to reduce the number of traces as compared to previous works. This In-cell technology can be applied to both LCD and OLED display.
Also presented in Innovative Demonstration Session (see p. 234)

INP3 - 2 ***Invited*** **Large Size In-Cell Capacitive Touch Panel**
17:05 **and Force Touch Development for Automotive**

N. Takada, C. Tanaka, T. Tanaka, Y. Kakinoki, T. Nakanishi, N. Goto

Japan Display, Japan

World's largest 16.7-in. Pixel Eyes, which is JDI's original in-cell touch panel, has been developed. This panel also has curved-shaped and non-rectangular characteristics.In addition, we have developed force touch panel which is one of the new Human Machine Interface based on Pixel Eyes in automotive display.

Also presented in Innovative Demonstration Session (see p. 234)

INP3 - 3 ***Invited*** **"In-Cell" Force Touch Technology in the**
17:30 **OLED Display Panel**

L. Liu, F. Lu, S. Ma, C. Ma, Q. Yao

Tianma Micro-Elect., China

Force touch sensors have been integrated into a 5.99-in. rigid OLED panel and a 5.99-in. curved flexible OLED panel respectively. In both panels, piezoresistive sensors made of p-doped poly-silicon show strong responses to the applied force, demonstrating high adaptability of the in-cell force touch solution in the OLED display panel.

INP3 - 4 **Knob on Display: Movable Ring-Shaped Dial**
17:55 **Interaction for Automotive Center Display**

Y. Sasaki

Mitsubishi Elec., Japan

We describe a novel user interaction for automotive center information display with movable ring-shaped dial. This device can detect the dial position and fingers in contact with the dial using capacitive type touch display simultaneously, therefore it is possible to interact more safely without visual attention.

Also presented in Innovative Demonstration Session (see p. 234)

Author Interviews
18:15 – 18:40

Thursday, December 13

9:00 - 10:15 **Room 224**

INP4: AR and Interactive Systems

Special Topics of Interest on AR/VR and Hyper Reality

Chair: T. Komuro, Saitama Univ., Japan
Co-Chair: Y. Ban, Univ. of Tokyo, Japan

INP4 - 1
9:00 ***Invited*** **High Precision and High Sensitivity Sheet Sensor by Printing Technology**

T. Miyoshi[*], H. Kondoh[*], S. Nishi[*], T. Kamata[,**]*
[*]JAPERA, Japan
[**]AIST, Japan

We have developed a manufacturing line that manufactures flexible TFT arrays only with printing technology. In addition, we have developed pressure sheet sensors using these TFT arrays and printable pressure sensitive materials, and developed novel input devices that can be used for various purposes.

INP4 - 2
9:25 ***Invited*** **Illusion Based Shape Display Using the Visuo-Haptic Interaction**

Y. Ban
Univ. of Tokyo, Japan

Our shape perception can be changed by stimuli simultaneously received through multi senses. Utilizing this phenomenon, we can provide people to haptic experience in which touching various shapes without costly actuators. I introduce examples of illusion-based shape displays that augment our experience by using the effect of the visuo-haptic interaction.

INP4 - 3
9:50 ***Invited*** **3D User Interfaces Based on AR/VR**

T. Komuro
Saitama Univ., Japan

Augmented reality (AR) and virtual reality (VR) is now mainly used for amusement, but we focus on user interfaces that allow direct manipulation of 3D objects using AR/VR. In this paper, we show our recent development of such 3D user interface systems.

Also presented in Innovative Demonstration Session (see p. 235)

Author Interviews
10:40 – 11:10

----- Lunch -----

17:10 - 18:10 **Room 224**

INP5: Fingerprint Sensors and Secure Devices
Special Topics of Interest on Automotive Displays

Chair: D. Suzuki, Japan Display, Japan
Co-Chair: K. Yamazaki, Corning Japan, Japan

INP5 - 1 ***Invited*** **Glass-Based Capacitive Fingerprint Sensor Package**
17:10

D. Suzuki, T. Uehara, Y. Suzuki, F. Nakano, Y. Ozeki
Japan Display, Japan

A glass-based fingerprint sensor package has been newly developed, integrating silicon-based packaging technology with glass-based TFT technology. A fingerprint image has been successfully sensed by the glass sensor package. Even after a reliability test, the fingerprint sensor performance maintained the same quality, showing the possibility of commercialization.
Also presented in Innovative Demonstration Session (see p. 235)

INP5 - 2 **Near Filed Communication (NFC) Antenna on Display Integrated on Touch In-Cell (TIC) Panel**
17:35

C.-J. Liu, J. Liao, C.-Y. Hsu, H.-H. Chen, H.-M. Su, W.-T. Tseng
Chunghwa Picture Tubes, Taiwan

we successful developed novel interface by using an integrated near field communication antenna on 5-in. HD touch in-cell panel. The integrated NFC antenna on touch in cell panel technology have good quality display with high touch sensitivity above 41.1 dB signal noise ratio for 8ϕ Copper rods.

INP5 - 3L **NFC Antenna Integrated Capacitive Touch Display**
17:55

T. Maruyama, K. Kida, S. Yamagishi,
J. de D. B. Mugiraneza, T. Yamamoto, Y. Sugita
Sharp, Japan

We describe a novel user interface solution by using an integrated transparent NFC antenna and a capacitive touch panel on a display. Compared to our previous work, new approach enables to improve the transparency and allows user a more compact, advanced design and lower cost NFC-integrated touch display.
Also presented in Innovative Demonstration Session (see p. 235)

Author Interviews
18:40 – 19:10

Supporting Organizations:
Human Interface Society
Technical Group on Information Sensing Technologies, ITE
State of the Technologies in Expression Association
Holographic Display Artists and Engineers Club (HODIC),
The Optical Society of Japan

Technical Committee on Haptics, System Integration Division,
The Society of Instrument and Control Engineers

I-DEMO
(Innovative Demonstration Session)

Live demonstrations
of emerging information display technologies
by oral and poster presenters
Thursday, Dec. 13, 2018
11:40 – 15:50
Event Hall (1F, Building 1)
Nagoya Congress Center

SPECIAL EVENT

PROJECTION MAPPING

Live demonstrations of leading-edge
technologies
Wednesday, Dec. 12 – Friday, Dec. 14, 2018
Room221 (2F, Building 2)
Nagoya Congress Center

TOKAI ZONE

Special Exhibition
Outgoing Unique Technologies from Tokai-Region

Tuesday, Dec. 12 – Friday, Dec. 14, 2018
Event Hall (1F, Bldg. 1)
Nagoya Congress Center

Innovative Demonstration Session

Thursday, December 13

11:40 - 15:50 **Event Hall**

Innovative Demonstration Session

UXC2 - 4L **Dissemination Activities of Simple Haptic Devices**

S. Takeuchi

Freelance Engineer / Researcher, Japan

LCT2 - 3 **Modern Display Applications Based on ESH Ferroelectric Liquid Crystals**

A. K. Srivastava, L. Shi, H. S. Kwok

Hong Kong Univ. of S&T, Hong Kon

LCTp4 - 15L **Design of a Liquid Crystal Device Suitable for Automotive Smart Windows**

S.-J. Lee[*], S.-Y. Eom[*], D.-S. Yoon[**], H.-S. Yang[*], E.-J. Kim[*], H.-S. Yoo[**], S.-B. Kwon[,**]*

[*]Hoseo Univ., Korea

[**]NDIS, Korea

OLED2 - 5L **A Modern Approach for Characterizing Burn-In Artifacts for High Dynamic Range Displays**

J. S. Park, J. Kim, S. Jung, J. Langehennig[*], D. Lee, B. Min

Samsung Elect., Korea
[*]Samsung Elect. America, USA

OLEDp1 - 16L **Full Roll-to-Roll Fabrication Process of Large-Area Flexible OLED with Silver-Nanowire Transparent Electrode**

C. Kim, S. Jeong, S. M. Cho

Sungkyunkwan Univ., Korea

3D2/ DES1 - 1 **Hidden Stereo: Synthesizing Ghost-Free Stereoscopic Images for Viewers without 3D Glasses**

T. Fukiage, T. Kawabe, S. Nishida

NTT, Japan

3D3 - 2 **Realization of Deep Viewing Zone with Adaptive Time-Division Multiplexing Parallax Barrier**

A. Hayashishita, H. Kakeya

Univ. of Tsukuba, Japan

3D3 - 4 **A Novel Eye Tracking System to Expand Viewing Area in All Directions for Glasses-Free 3D Display Displayable in Both Portrait and Landscape Modes**

H. Nakamura, G. Hamagishi, K. Yoshimoto, H. Takahashi, T. Matsumoto[*], K. Kusafuka[*]

Osaka City Univ., Japan

[*]Kyocera, Japan

3Dp1 - 5 **A Flexible Pipeline from a Single-View Camera to a Stacked-Layer Light-Field Display**

T. Hidaka, T. Fujiwara, K. Maruyama, K. Takahashi, T. Fujii

Nagoya Univ., Japan

3Dp1 - 6 **Implementation of Table-Top Light-Field Display**

K. Maruyama, H. Kojima, K. Takahashi, T. Fujii

Nagoya Univ., Japan

3Dp1 - 19L **Light Field Video Camera and Display Using Similar Microlens Array**

M. Ito[,**], M. Nakajima[**], T. Iwane[**], Y. Kokumai[**], Y. Makino[*], H. Shinoda[*]*

[*]Univ. of Tokyo, Japan

[**]Nikon, Japan

VHFp6/ 3Dp3 - 1 **Study on Subjective Depth Evaluation for Holographic Head-Mounted Display**

H. Kubo, Y. Oguro, Y. Sakamoto

Hokkaido Univ., Japan

PRJ5 - 3 **Optimization of Vertical View Human Skeleton Recognition from Range Images**

A. Watanabe, T. Kamimura

Hitachi, Japan

EP1 - 3 **Prototyping of e-Tile**

M. Omodani, Y. Adachi, H. Shibata[*]

Tokai Univ., Japan

[*]Fuji Xerox, Japan

MEET3 - 4 **Process Optimization for TFT Integrated MEMS Shutter Display**

S. A. A. Nusayer, P. Schalberger, H. Baur, C. Jurgschat, N. Fruehauf

Univ. of Stuttgart, Germany

DES5 - 2 **HEVC Software Media Player for Ultra-High-Quality Video: 8K and Beyond**

M. Alvarez-Mesa, C. C. Chi

Spin Digital Video Techs., Germany

INP1 - 1 **Smart Rubber Technology and Its Applications**

K. Nakano, T. Murase

Sumitomo Riko, Japan

INP1 - 4L **Force Sensitive Tactile Feedback Touchscreen Featuring Texture and Click Sensations**

Y. Yang, H. Haga, H. Sasaki, T. Asai, K. Shigemura

Tianma Japan, Japan

INP2 - 2 **Hybrid Time-of-Flight Range Image Sensors Using High-Speed Multiple-Tap Charge Modulation Pixels**

S. Kawahito[,**], K. Yasutomi[*], K. Mars[*], K. Kagawa[*], S. Aoyama[**]*

[*]Shizuoka Univ., Japan
[**]Brookman Tech., Japan

INP3 - 1 **Capacitive Touch Panel with Non-Conductive and Conductive Object Distinction for In-Cell LCD and OLED Display**

J. de D. B. Mugiraneza, D. Gallardo, Y. Sugita, T. Maruyama, K. Kida, S. Yamagishi, T. Yamamoto*

Sharp, Japan
[*]Sharp Labs of Europe, UK

INP3 - 2 **Large Size In-Cell Capacitive Touch Panel and Force Touch Development for Automotive**

N. Takada, C. Tanaka, T. Tanaka, Y. Kakinoki, T. Nakanishi, N. Goto

Japan Display, Japan

INP3 - 4 **Knob on Display: Movable Ring-Shaped Dial Interaction for Automotive Center Display**

Y. Sasaki

Mitsubishi Elec., Japan

INP4 - 3 **3D User Interfaces Based on AR/VR**

T. Komuro

Saitama Univ., Japan

INP5 - 1 **Glass-Based Capacitive Fingerprint Sensor Package**

D. Suzuki, T. Uehara, Y. Suzuki, F. Nakano, Y. Ozeki,

Japan Display, Japan

INP5 - 3L **NFC Antenna Integrated Capacitive Touch Display**

T. Maruyama, K. Kida, S. Yamagishi,
J. de D. B. Mugiraneza, T. Yamamoto, Y. Sugita

Sharp, Japan

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VHF	Y. Imai	Mitsubishi Elec.
PRJ	K. Ohara	Marubun
EP	T. Fujisawa	DIC
MEET	J. Moon	Shizuoka Univ.
DES	Y. Oyamada	Tottori Univ.
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Program Chair:	Y. Oyamada	Tottori Univ.
General Secretary:	R. Tanida	NTT
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	R. Hattori	Kyushu Univ.
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	T. Kishigami	Mitsubishi Elec.
	H. Koo	Minghsin Univ. of S&T
	O. Kwon	Hanyang Univ.
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	K. Morita	Chuo Univ.
	H. Nam	Kyung Hee Univ.
	H. Nitta	Japan Display
	R. Oke	Panasonic Liquid Crystal Display
	S. Ono	Apple
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	M. Ito	Toppan Printing
	M. Kimura	Nagaoka Univ. of Tech.
	H. Maeda	Dai Nippon Printing
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	S. Ono	Kagoshima Univ.
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Special Topics of Interest on Oxide-Semiconductor TFT

Facilitator:	M. Kimura	Ryukoku Univ.
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FMC	K. Tamai	AGC
FLX	M. Nakata	NHK

Special Topics of Interest on Quantum Dot Technologies

Facilitator:	T. Ikuta	JNC
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VHF	T. Shibata	Tokyo Univ. of Social Welfare

PRJ	K. Ohara	Marubun
DES	Y. Oyamada	Tottori Univ.
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VHF	Y. Imai	Mitsubishi Elec.
PRJ	K. Ohara	Marubun
DES	K. Morita	Chuo Univ.
FLX	Y. Uraoka	NAIST
INP	Y. Sugita	Sharp
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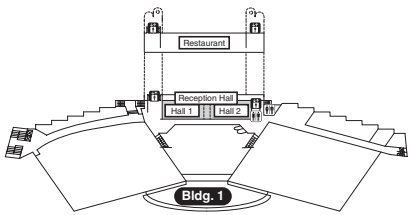
COFERENCE SITE OVERVIEW

7F

4F



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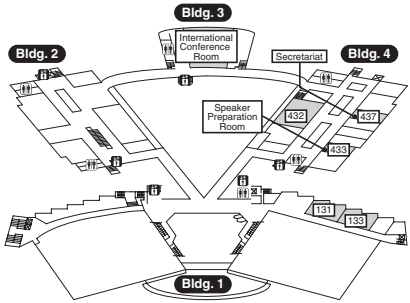

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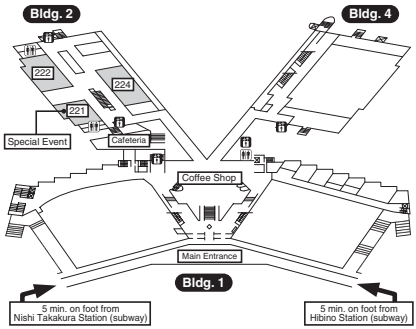

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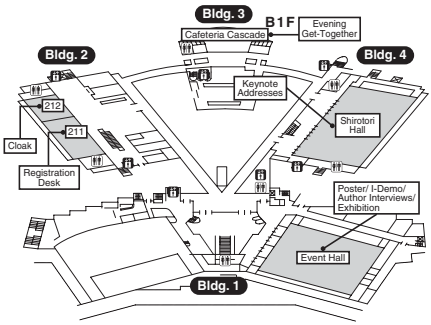

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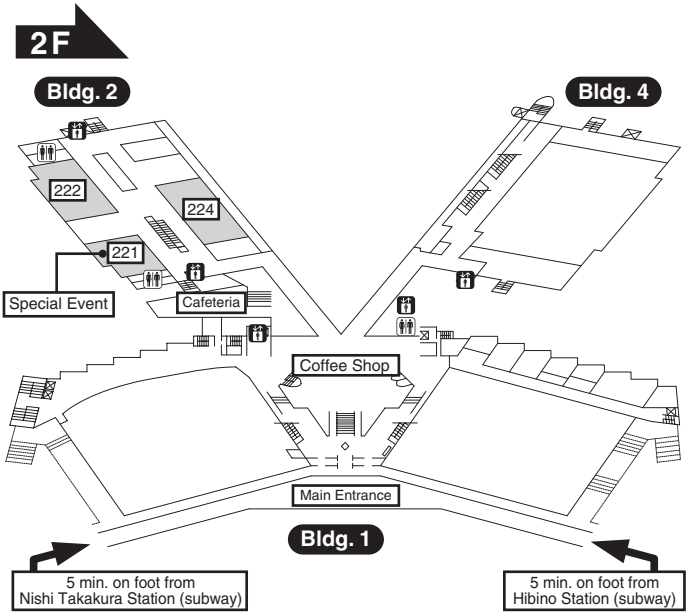

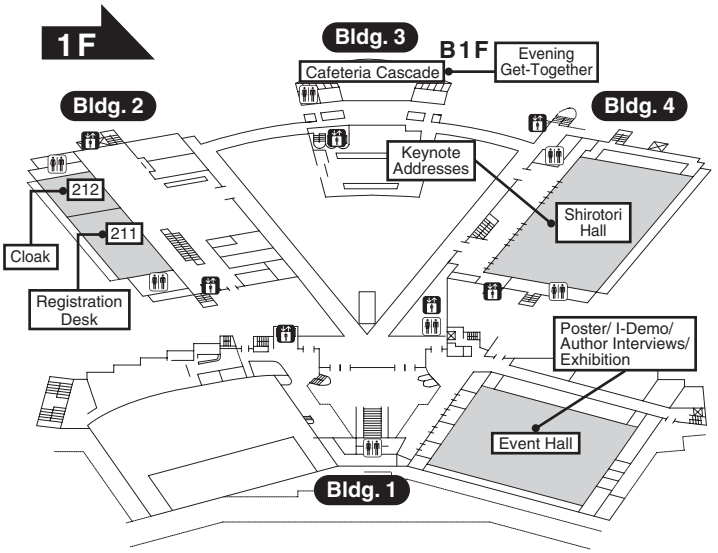

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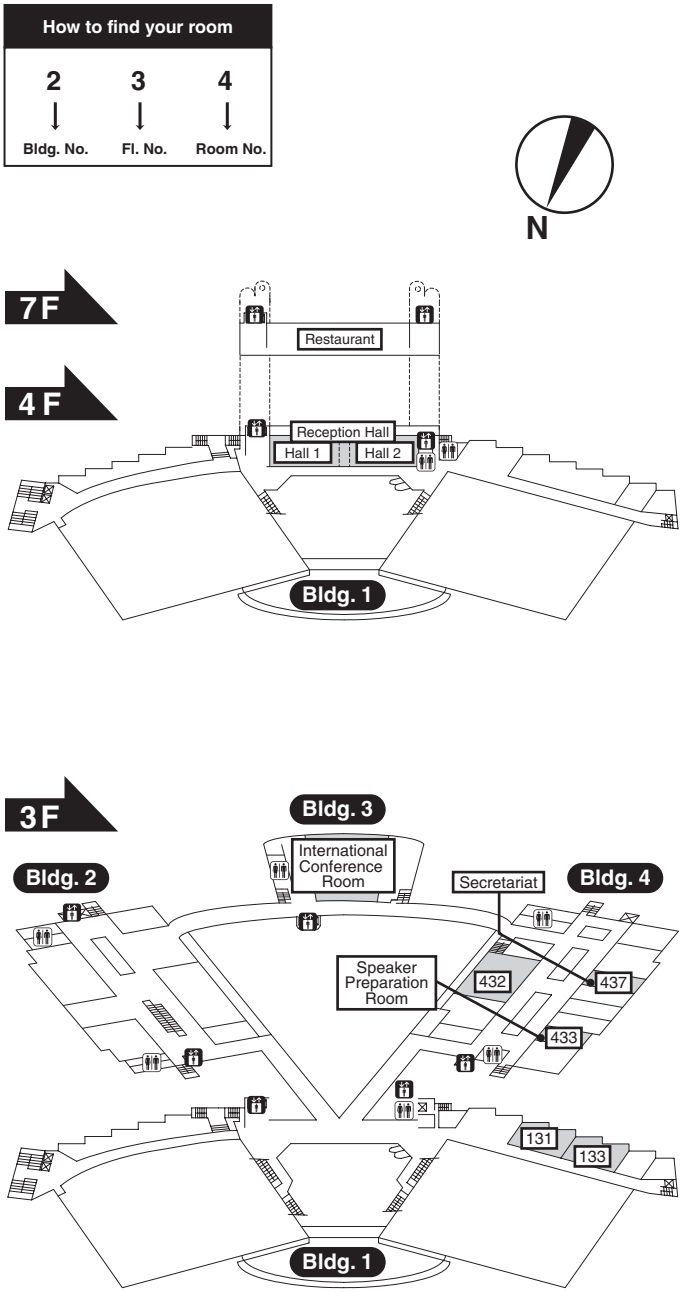

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IDW '18 Workshop Timetable

	Bldg. 2	Bldg. 4		Bldg. 3	Bldg. 2		Bldg. 1				
	1F	1F	3F	3F	2F		3F		4F		1F
Date	Room 211	Shirotori Hall	Room 432	International Conference Room	Room 222	Room 224	Room 131	Room 133	Reception Hall 1	Reception Hall 2	Event Hall
Tue., Dec. 11	Registration 17:00 - 20:00	Evening Get-Together at Cafeteria Cascade (B1F, Bldg. 3) 18:00 - 20:00									
Wednesday, December 12	Registration 8:00 - 18:00	Opening, Keynote Address 9:30 - 11:55									
		Lunch									
			VHF1 13:20 - 14:45	OLED1 13:20 - 14:40	FLX1 13:20 - 14:40	INP1 13:20 - 14:50	FMC1 13:20 - 14:40	UXC1 13:20 - 14:40	AMD1 13:20 - 14:35	LCT1 13:20 - 14:35	Exhibition 12:00 - 18:00
		Break									
			VHF2 15:00 - 16:20	OLED2 15:00 - 16:20	3D1 15:00 - 16:20	INP2 15:00 - 16:15	PRJ1/FMC2 15:00 - 16:25	EP1 15:00 - 16:20	AMD2 15:00 - 16:10	LCT2 15:00 - 16:15	
		Break									
			VHF3 16:40 - 18:10	OLED3 16:40 - 18:00	3D2/DES1 16:40 - 18:00	INP3 16:40 - 18:15	FMC3 16:40 - 18:00	EP2 16:40 - 18:10	FLX2 16:40 - 17:40	PRJ2/LCT3 16:40 - 18:00	
											Author Interviews 18:10 - 18:40
		Reception at Atsutajingu Kaikan (1F, North Bldg.) 19:00 - 21:00									
Thursday, December 13	Registration 8:00 - 18:00		VHF4 9:00 - 10:25	OLED4 9:00 - 10:20	PRJ3† 9:00 - 10:21	INP4 9:00 - 10:15	UXC2† 9:00 - 10:32	EP3† 9:00 - 10:02	AMD3 9:00 - 9:50	LCT4/FMC4 9:00 - 10:35	
		Break									
											Author Interviews 10:40 - 11:10
											LCTp,AMDp, OLEDp,PHp, MEETp 10:40 - 13:10
											UXCp,FMCp,PRJp, VHFp,DESp, 3Dp,EPp,FLXp 14:20 - 16:50
											Innovative Demonstration Session 11:40 - 15:50
		Break									
			PH1 17:10 - 18:40	MEET1 17:10 - 18:55	3D3 17:10 - 18:30	INP5 17:10 - 18:10	FMC5 17:10 - 18:30	EP4/UXC3 17:10 - 18:35	AMD4 17:10 - 18:00	FLX3/LCT5 17:10 - 18:30	
											Author Interviews 18:40 - 19:10
											Exhibition 10:00 - 18:00
Friday, December 14	Registration 8:00 - 13:00		OLED5 9:00 - 10:20	MEET2 9:00 - 10:20	VHF5/3D4 9:00 - 10:20	PRJ4 9:00 - 10:20	FMC6 9:00 - 10:20	DES2/UXC4 9:00 - 10:20	AMD5 9:00 - 10:05	FLX4 9:00 - 10:05	
		Break									
			PH2/OLED6 10:40 - 12:10	MEET3 10:40 - 12:00	VHF6 10:40 - 12:05	PRJ5 10:40 - 11:55	LCT6 10:40 - 11:40	DES3 10:40 - 12:00	AMD6 10:40 - 11:50	FLX5/FMC7 10:40 - 12:00	
											Author Interviews 12:00 - 12:30
		Lunch									
			VHF7 13:10 - 14:40	MEET4 13:10 - 14:30	3D5/DES4 13:10 - 14:30	PRJ6 13:10 - 14:10	FMC8 13:10 - 14:30	OLED7 13:10 - 14:25	AMD7 13:10 - 14:35	LCT7 13:10 - 14:30	
		Break									
			VHF8 14:50 - 16:10	MEET5 14:50 - 15:50	3D6 14:50 - 16:10	PRJ7 14:50 - 16:30	EP5 14:50 - 16:10	DES5 14:50 - 16:00	AMD8 14:50 - 16:10	LCT8 14:50 - 16:10	
											Author Interviews 16:20 - 16:50
											Exhibition 10:00 - 14:00

† Including Short Presentations

IDW '18 Session Navigator

	Wednesday, December 12				Thursday, December 13						Friday, December 14					
	PM			A.I.	AM	A.I.	AM Poster	PM Poster	PM	A.I.	AM		A.I.	PM		A.I.
	13:20-14:40	15:00-16:20	16:40-18:00	18:10-18:40	9:00-10:20	10:40-11:10	10:40-13:10	14:20-16:50	17:10-18:30	18:40-19:10	9:00-10:20	10:40-12:00	12:00-12:30	13:10-14:30	14:50-16:10	16:20-16:50
User Experience & Cognitive Engineering	Room 133			Event Hall	Room 131	Event Hall		Event Hall	Room 133	Event Hall	Room 133		Event Hall			
	Visual Experience			A.I.	Tangible Interface & Education	A.I.		A.I.	Approaches to Ideal Replacement of Paper Media*	A.I.	AI Applied to Display*		A.I.			
3D/Hyper-Realistic Displays		Room 222		Event Hall				Event Hall	Room 222	Event Hall	Room 222		Event Hall	Room 222		Event Hall
		Display Systems for AR	Novel Display Systems*	A.I.				Posters	Autostereoscopic Display Systems	A.I.	Human Factors & Image Quality*		A.I.	Display Systems for Automotive*	Holography	A.I.
Active-Matrix Displays	Reception Hall 1			Event Hall	Reception Hall 1	Event Hall	Event Hall		Reception Hall 1	Event Hall	Reception Hall 1		Event Hall	Reception Hall 1		Event Hall
	8K Display	Active-Matrix Micro-LED Display		A.I.	Advanced Process OTFT	A.I.	Posters		High-Performance OTFT	A.I.	Emerging TFT	Oxide TFT: Device	A.I.	Oxide TFT: Stability & Fundamental (1)	Oxide TFT: Stability & Fundamental (2)	A.I.
Display Electronic Systems			Room 222	Event Hall				Event Hall			Room 133		Event Hall	Room 222	Room 133	Event Hall
			Novel Display Systems*	A.I.				Posters			AI Applied to Display*	Micro-LED & OLED Driving	A.I.	Display Systems for Automotive*	8K Systems	A.I.
Emissive Technologies							Event Hall		Room 432	Event Hall	Int. Conf. Room		Event Hall	International Conference Room		Event Hall
							Posters		Phosphors for Display & Lighting Applications	A.I.	Micro/NanoDisplays & Nanotechnology Application (1)	Micro/NanoDisplays & Nanotechnology Application (2)	A.I.	EL Quantum Dots Technologies	Emerging Quantum Dots & Nanotechnologies	A.I.
												Room 432	Event Hall			
												QD Phosphors & Devices*	A.I.			
e-Paper		Room 133		Event Hall	Room 133	Event Hall		Event Hall	Room 133	Event Hall					Room 131	Event Hall
		Expansion of Electrophoretic Displays	Emerging e-Paper Technologies	A.I.	Advance of Electrochromic Displays	A.I.		Posters	Approaches to Ideal Replacement of Paper Media*	A.I.					Various Challenges for e-Paper	A.I.
Flexible Electronics	Room 222		Reception Hall 1	Event Hall				Event Hall	Reception Hall 2	Event Hall	Reception Hall 2		Event Hall			
	Wearable Sensors & Devices		Organic Electronics Technologies	A.I.				Posters	Advanced Flexible Displays*	A.I.	Advanced Process & Evaluation Technologies	Advanced Materials & Components for Flexible Electronics*	A.I.			
Interactive Technologies	Room 224			Event Hall	Room 224	Event Hall			Room 224	Event Hall						
	Haptic Technologies	3D Sensing for Automotive HMI	In-Cell Touch Panels & Automotive HMI	A.I.	AR & Interactive Systems	A.I.			Fingerprint Sensors & Secure Devices	A.I.						
Human Factor	Room 432			Event Hall	Room 432	Event Hall		Event Hall			Room 222		Event Hall	Room 432		Event Hall
	High Dynamic Range	Color Quality	Physiological & Psychophysical Factors	A.I.	Ergonomics for Automotive Applications	A.I.		Posters			Human Factors & Image Quality*	Virtual Reality	A.I.	Color Gamut Metrology	Color Vision	A.I.
Liquid-Crystal Technologies	Reception Hall 2		Reception Hall 2	Event Hall	Reception Hall 2	Event Hall	Event Hall		Reception Hall 2	Event Hall		Room 131	Event Hall	Reception Hall 2		Event Hall
	Liquid Crystal Alignment Technology	Novel LCD Technologies	LC-Based Eye Devices*	A.I.	New Materials & Components for LCDs*	A.I.	Posters		Advanced Flexible Displays*	A.I.		Wide Color Gamut LCDs	A.I.	Liquid Crystal Phase Shifter	Liquid Crystal Applications	A.I.
Manufacturing, Process & Equipment	Room 131			Event Hall				Event Hall	Room 131	Event Hall						
	MicroLED Display			A.I.				Posters	Manufacturing	A.I.						
Materials & Components		Room 131		Event Hall	Reception Hall 2	Event Hall		Event Hall			Room 131	Reception Hall 2	Event Hall	Room 131		Event Hall
		Waveguide for AR-Near Eye Display*	Display Optics	A.I.	New Materials & Components for LCDs*	A.I.		Posters			Light Polarizing Technologies	Advanced Materials & Components for Flexible Electronics*	A.I.	Advanced Materials		A.I.
MEMS							Event Hall		Int. Conf. Room	Event Hall						
							Posters		Novel Materials, Fundamental Components & Process Technologies	A.I.						
Organic Light-Emitting Displays & Organic Devices	International Conference Room			Event Hall	Int. Conf. Room	Event Hall	Event Hall				Room 432		Event Hall	Room 133		Event Hall
	OLED Materials	OLED Devices	OLED Soluble Materials & Process Technologies	A.I.	OLED Display	A.I.	Posters				OLED Device Technology	QD Phosphors & Devices*	A.I.	OLED Advanced Technology		A.I.
Projection & Large Area Displays		Room 131	Reception Hall 2	Event Hall	Room 222	Event Hall		Event Hall			Room 224		Event Hall	Room 224		Event Hall
		Waveguide for AR-Near Eye Display*	LC-Based Eye Devices*	A.I.	Light Source	A.I.		Posters			Wearable	Automotive Displays & Sensors	A.I.	Projection Applications	Projection Mapping	A.I.

A.I.: Author Interviews
* Joint Session

IDW '18 Special Topics of Interest Navigator

		Oxide-Semiconductor TFT		Quantum Dot Technologies			AR/VR & Hyper Reality				Automotive Displays					Wide Color Gamut & Color Reproduction			Haptics Technologies
		Reception Hall 1	Event Hall	International Conference Room	Room 432	Event Hall	Room 131	Room 222	Room 224	Event Hall	Room 133	Room 222	Room 224	Room 432	Event Hall	Room 131	Room 432	Event Hall	Room 224
Wed., Dec. 12	PM																		INP1: Haptic Technologies 13:20 - 14:50
							PRJ1/FMC2: Waveguide for AR-Near Eye Display 15:00 - 16:25	3D1: Display Systems for AR 15:00 - 16:20					INP2: 3D Sensing for Automotive HMI 15:00 - 16:15						
								3D2/DES1: Novel Display Systems 16:40 - 18:00					INP3: In-Cell Touch Panels & Automotive HMI 16:40 - 18:15						
Thu., Dec. 13	AM								INP4: AR & Interactive Systems 9:00 - 10:15					VHF4: Ergonomics for Automotive Applications 9:00 - 10:25					
			AMDp1: Poster 10:40 - 13:10			PHp1,OLEDp2 MEETp1 : Poster 10:40 - 13:10													
	PM		FMCp7: Poster 14:20 - 16:50			FMCp6: Poster 14:20 - 16:50				FMCp1,3Dp2, VHFp6/3Dp3 : Poster 14:20 - 16:50					VHFp3: Poster 14:20 - 16:50			FMCp5,VHFp2: Poster 14:20 - 16:50	
													INP5: Fingerprint Sensors & Secure Devices 17:10 - 18:10						
Fri., Dec. 14	AM				OLED5:OLED Device Technology 9:00 - 10:20				PRJ4:Wearable 9:00 - 10:20		DES2/UXC4: AI Applied to Display 9:00 - 10:20								
		AMD6: Oxide TFT: Device 10:40 - 11:50			PH2/OLED6:QD Phosphors & Devices 10:40 - 12:10			VHF6: Virtual Reality 10:40 - 12:05					PRJ5:Automotive Displays & Sensors 10:40 - 11:55			LCT6: Wide Color Gamut LCDs 10:40 - 11:40			
	PM	AMD7: Oxide TFT: Stability & Fundamental (1) 13:10 - 14:35		MEET4:EL Quantum Dots Technologies 13:10 - 14:30								3D5/DES4: Display Systems for Automotive 13:10 - 14:30						VHF7: Color Gamut Metrology 13:10 - 14:40		
		AMD8: Oxide TFT: Stability & Fundamental (2) 14:50 - 16:10		MEET5:Emerging Quantum Dots & Nanotechnologies 14:50 - 15:50														VHF8: Color Vision 14:50 - 16:10		

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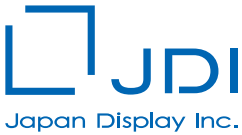

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