Society for Information Display

DISPLAY WEEK 2015

International Symposium, Seminar, and Exhibition

May 31–June 5, 2015
San Jose Convention Center
San Jose, California, USA

Final Program

Short Courses	Sunday, May 31
Technical Seminars	Monday, June 1
Business Conference	Monday, June 1
Investors Conference	Tuesday, June 2
Symposium	Tuesday–Friday, June 2–5
Exhibition	Tuesday–Friday, June 2–5
Exhibitor Forum	Tuesday–Thursday, June 2–4
I-Zone	Tuesday & Wednesday, June 2 & 3
Market Focus Conferences	Wednesday & Thursday, June 3 & 4

NEW

MINI-SYMPOSIA COMPOSED OF SPECIAL TECHNOLOGY TRACKS

Imaging Technologies & Applications	Tuesday, June 2
SID/IES Lighting	Thursday, June 4
Vehicle Displays & Trends	Thursday, June 4

Keynote Speakers

Mr. Brian Krzanich
CEO, Intel Corp., Santa Clara, CA, USA
"Toward an Immersive Image Experience"

The relentless advances in computing technologies, utilizing the power of Moore's Law, will be described. These advances, coupled with remarkable innovations in sensing and display technologies, are transforming computing, communication and entertainment devices, systems, and applications. Human–device interactions have morphed from text inputs to GUIs. Efforts are under way at Intel and in the industry to usher in a new era of interactivity, where devices can "see," "hear," "feel," and "understand," transforming our experiences with the content on displays of all form factors to be more engaging and immersive.

Mr. Dongsheng Li
Chairman, CEO, and Founder, TCL Corp., Shenzhen, China
"The Booming Display Industry in China"

As the supply chain becomes more and more integrated, China's display industry has been rapidly growing, and it's end-products have become more diversified and are continually being advanced. How to ride the tide and win the marketplace by synergy will be discussed.

Dr. In-Byeong Kang
CTO and Senior Vice-President, LG Display Co., Ltd., Gyeonggi-do, Korea
"The Opportunities and Challenges Facing the Display Industry"

The IT environment is leaping into the next generation with faster and better technologies such as the Internet of Things, 5G mobile communications, *etc.* New opportunities and potential for the display industry are a result of this change. The opportunities and challenges facing the display industry will be discussed. This will not be an easy challenge. But it is our firm belief that if we work together as an industry, we could realize the dream of having major breakthroughs for displays in the near future.

Luncheon Speaker

Professor Brian A. Wandell
Issac and Madeline Stein Family Professor, Stanford University, and Deputy Director of the Stanford Neuroscience Institute
"Surprising Stories about the Living Human Brain"

Magnetic resonance imaging makes it possible to measure activity and structure in the living human brain at millimeter scale. Stories about the development of MRI technology for measuring brain systems (neuroimaging) will be described. Then the measuring of the signals and the organization in the visual parts of the human brain will be discussed. Some surprises from the last 25 years involving remarkable patients, experiments in sight restoration, and how children learn to rapidly and efficiently see words will be shared.

Display Week Business Track

BUSINESS CONFERENCE

The Business Conference will kick off the Business Track for Display Week 2015 on Monday, June 1, 2015. The theme of this year's rendition is "Game Changers: Finding Ways to Increase Profitability." IHS/DisplaySearch analysts will anchor each session, presenting market and technology analysis and up-to-date forecasts. Each session will include industry executives and marketing managers speaking on the following topics:

- Is Good Enough, Good Enough? Can LCDs Persevere?
- A Better Consumer Experience: Display Customers Point of View on Increasing Profitability
- Financial Implications that Can Lead to Success
- Emerging Technologies and Applications to Increase Profit Point

INVESTORS CONFERENCE

The SID/Cowen & Company Investors Conference will take place on Tuesday, June 2. Co-sponsored by Cowen & Company, LLC, a securities and investment banking firm, this conference will feature presentations from leading public and private display companies, intended to appeal primarily to securities analysts, portfolio managers, investors, M&A specialists, and display-company executives. The topics to be covered include:

- Quantum Dots: From the Lab to Commercial Success
- Evolution of the Immersive Experience
- Innovations Driving Wearable Displays
- New Incentives Driving Display Performance
- Advanced Technologies Impacting the Display Ecosystem

MARKET FOCUS CONFERENCES

The Market Focus Conferences scheduled for 2015 will once again be held in conjunction with Display Week. Each Market Focus Conference will concentrate on the critical market development issues facing each of the emphasized technologies. Developed in collaboration with IHS/ DisplaySearch, the Conferences will feature presentations and panel discussions from executives and marketing mangers throughout the display supply chain. This year's Conferences will cover the following two topics:

- **Touch** (Wednesday, June 3, 2015)
- **Wearable–Flexible** (Thursday, June 4, 2015)

Touch: This year's theme, "The Changing Landscape of Traditional Touch Technologies and Applications," will be addressed in the following sessions:

- Finding the Right Touch Technology
- Existing and Emerging Touch Applications in Transition
- The Battle for ITO Alternatives
- Extensions of Touch

Wearable—Flexible: This year's theme, "Challenges and Opportunities for New Form Factors and Applications," will be addressed in the following sessions:

- What Are Wearables for Anyway?
- Wearable–Flexible Market Overview
- Power: The Elephant in the Room
- Software: Diversity or Monoculture
- Enabling Fresh Design Ideas: Designer's Dilemmas and Solutions

SPECIAL NETWORKING EVENT

Evening Reception at the San Jose Museum of Art – Sponsored by Henkel

This year's Special Networking Event will be a hosted reception at the San Jose Museum of Art. This year's event is generously sponsored by Henkel. Established in 1969, the San Jose Museum of Art is a distinguished museum of modern and contemporary art and a lively center of arts activity in Silicon Valley. Please join us at this hosted reception on Wednesday evening from 7:00 to 10:00 pm. For more details regarding the San Jose Museum of Art, please visit www.sjmusart.org. Tickets are $65 per person and can be purchased at the SID Registration Desk.

Henkel

Ribbon-Cutting Ceremony

Please join us for a Special Ribbon Cutting Ceromony to declare the opening of the Display Week Exhibition on Tuesday morning at 10:30 am directly outside the Exhibit Hall. This event will be presided over by SID President Amal Ghosh along with local dignitaries and major exhibitor executives.

NEW

Special Mini-Symposia

New to Display Week in 2015 is the addition of three Mini-Symposia in the form of Special Technology Tracks on Imaging Technologies and Applications, Lighting, Vehicle Displays and Trends.

Imaging Technologies and Applications

The Mini-Symposium on Imaging Technologies and Applications will feature invited papers covering the areas of imaging technologies, products, applications, advanced developments, and emerging trends. This focused track will bring together scientists, engineers, business professionals, market analysts, academic, and industry leaders pioneering the end-to-end chain of imaging to display technologies and applications. Scheduled for Tuesday, June 2, it will consist of three sessions of invited papers that include:

- "On the Duality of Compressive Imaging and Display," Gordon Wetzstein, *Stanford University*
- "Image Systems Simulation," Joyce Farrell, *Stanford University*
- "The Importance of Focus Cues in Stereo 3D Displays," Martin Banks, *University of California at Berkeley*
- "Light-Field Imaging," Kurt Akeley, *Lytro*
- "Immersive Applications Based on Depth-Imaging and 3D Sensing Technology," Achin Bhowmik, *Intel Corp.*

SID/IES Lighting

There has always been a great deal of overlap in the technology behind lighting and displays. In recognition of the newly signed Friendship Agreement between SID and the Illuminating Engineering Society of North America (IESNA), the SID/IES Lighting Track aims to deliver in-depth coverage in a diverse range of topics of common interest to both lighting and display professionals. This Mini-Symposium is scheduled for Thursday, June 4, and will consist of the following four sessions:

- Advanced Light Sources, Components, and Systems I
- Advanced Light Sources, Components, and Systems II
- Effects of Lighting on Health and Perception
- Advanced Lighting Applications

Vehicle Displays and Trends

This event will bring together scientists, engineers, market analysts, and industry leaders from the display, touch, photonics, and vehicle systems communities for a unique one of a kind event exploring the recent developments and trends of vehicle displays. This Mini-Symposium is scheduled for Thursday, June 4, and will consist of a morning plenary talk presented by Peter M. Knoll from Bosch, who will speak on "The Evolution of Automotive Displays: Past, Present, and Future," and the following four sessions:

- Next-Generation Automotive Display Technologies I: HUDs
- Automotive Display Applications and Systems
- Touch, Interactivity, and Human-Machine Interface
- Next-Generation Automotive Display Technologies II: Flexible, Curved, Coatings

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CONTENTS

WELCOME TO DISPLAY WEEK 2015

Come join us in San Jose, California, from May 31 to June 5, 2015, at Display Week 2015 to be held at the San Jose Convention Center. This year, three Mini-Symposia consisting of special technology tracks will be included as part of the technical program. The first one, a result of a Friendship Agreement with the Illuminating Engineering Society (IES), is the SID/IES Lighting Track, which will deliver in-depth coverage of a diverse range of topics of common interest to both lighting and display professionals. The other special technology tracks will focus on Vehicle Displays and Trends and Imaging Technology and Applications. This year's special topics include Oxide and LTPS TFTs, Wearable Displays, Disruptive Display Materials, and Curved and High-Resolution Displays.

This year, the Technical Symposium will feature 75 technical sessions consisting of over 275 oral presentations and 185 poster presentations. In addition to the Technical Symposium, Display Week will feature a Business Track consisting of a Business Conference, an Investors Conference, and two Market Focus Conferences. The Business Conference, with organizational support from IHS DisplaySearch, on Monday, June 1, will feature presentations given by high-level executives from the display industry. This year's theme is "Game Changers: Finding Ways to Increase Profitability." The Investors Conference, organized by Cowen & Co., LLC, on Tuesday, June 2, will feature presentations from leading public and private display companies. This event is intended to appeal primarily to securities analysts, portfolio managers, investors, market and analysis specialists, and display company executives. This year's Market Focus Conferences, also organized by IHS DisplaySearch, will take place on Wednesday and Thursday, June 3 and 4. These conferences will deliver complementary market insights and analyses in the areas of "Touch" and "Wearables–Flexible," respectively.

The Symposium opens on Tuesday morning, June 2, with Keynote Addresses from the following speakers: Mr. Brian Krzanich, CEO, Intel Corp., who will discuss "The Era of Immersive Interactions; Mr. Dongsheng Li, Chairman, CEO, and Founder of TCL Corp., Shenzhen, China, who will speak on "The Booming Display Industry in China"; and Dr. In-Byeong Kang, CTO and Vice-President, LG Display Co., Ltd., who will discuss "The Opportunities and Challenges Facing the Display Industry." The annual SID Awards Luncheon is scheduled for Wednesday afternoon, June 3. During the Luncheon, the 2015 SID Display Industry and "Best-in-Show" awards will be presented. Also, the 2015 SID Honors and Awards recipients will be acknowledged.

This year's Luncheon Speaker will be Professor Brian A. Wandell, Director of the Stanford Neurosciences Institute, who will relate "Surprising Stories about the Living Human Brain."

The usual informative selection of Short Courses and Display Technology/Applications Seminars will once again be presented on Sunday and Monday, May 31 and June 1, respectively. And do not forget to spend some time at the largest electronic-information-display exhibition in North America – open from Tuesday through Thursday, June 2–4. A special Ribbon-Cutting Ceremony will officially open the exhibition at 10:30 am directly outside the Exhibit Hall. After its successful inaugural debut at Display Week 2012, the Innovation Zone (I-Zone) will provide a forum for live demonstrations of emerging information-display technologies in an area set aside in the main exhibit hall. The I-Zone, sponsored by E Ink, offers researchers an opportunity to demonstrate their prototypes or other hardware demos for 2 days (Tuesday and Wednesday). Over 20 exciting prototypes from small companies, startups, universities, research labs, and major corporations are expected to participate.

On Wednesday evening, June 3, our annual Special Networking Event, sponsored by Henkel, will take place at the San Jose Museum of Art. Please join us at this evening reception sponsored by Henkel from 7:00 to 10:00 pm.

We extend our warmest welcome to you and pledge our commitment to make your visit technically productive and personally enjoyable. Display Week 2015 will be a unique experience featuring exciting and informative events throughout the week. We certainly hope that you will greatly benefit from attending this international event, both technically and socially.

Shin-Tson Wu
University of Central Florida
Display Week 2015 General Chair

Seonki Kim
Samsung Display
Display Week 2015 Symposium
Technical Program Chair

PROGRAM HIGHLIGHTS

SID 2015 International Symposium

The four-day Symposium features more than 275 papers from speakers from around the world in 75 technical sessions. Following the Tuesday morning Plenary Session, presentations begin in parallel sessions through Friday morning. The Poster Session on late Thursday afternoon will feature 185 papers organized around selected topics. Author interview sessions each afternoon round out the Symposium schedule. On Sunday, you can register for the Symposium until 6:00 pm and on Monday from 7:00 am to 6:00 pm.

Annual Awards Luncheon

The annual SID Awards Luncheon will take place at 12:00 noon on Wednesday, June 3, will be held in Room 230BC of the San Jose Convention Center. This year's luncheon speaker will be Brian A. Wandell, first Isaac and Madeline Stein Family Professor, Standard University, and Deputy Director of the Stanford Neurosciences Institute, who will relate "Surprising Stories about the Living Human Brain." Also, the 2015 Display Industry Awards honoring the best of the industry in 2014 and the 2015 SID Best-in-Show and I-Zone award winners will be announced. The SID 2015 Honors and Awards recipients will be acknowledged.

Display of the Year

Gold Award: Samsung's YOUM Bended Display
Silver Award: LG Display's 65-in. UHD Curved OLED-TV Panel

Display Application of the Year

Gold Award: Apple's iMac with 5K Retina Display
Silver Award: LG Display's 1.3-in. Circular Plastic OLED for G Watch R

Display Component of the Year

Gold Award: Merck KGaA's LCI Materials for Ultra-Brightness FFS LCDs
Silver Award: Intel's RealSense Technology

Honors and Awards Banquet

The 2015 SID Honors and Awards Banquet will take place on Monday, June 1, at the Fairmont Hotel. Tickets ($95) for the banquet must be purchased in advance and will not be sold on-site.

Special Networking Event

Evening Reception at the San Jose Museum of Art – Sponsored by Henkel This year's Special Networking Event will be a hosted reception at the San Jose Museum of Art. This year's event is generously sponsored by Henkel. Please join us at this hosted reception from 7:00 to 10:00 pm. For more details regarding the San Jose Museum of Art, please visit www.sjmusart.org. Tickets are $65 per person and can be purchased at the SID Registration Desk during Display Week.

Short Courses

Four 4-hour short courses, characterized by technical depth and covering the fundamentals of information displays, are scheduled for Sunday, May 31 (see page 9). PLEASE AVOID THE RUSH! Registration for the Short Courses begins at 8:00 am, Sunday morning, May 31. Registration will take place outside the Exhibit Hall in the main lobby of the San Jose Convention Center.

Display Technology Seminars

The Monday Seminar Series presents tutorials on diverse topics related to information display. Both newcomers and experienced professionals can benefit from the lectures provided. These tutorials focus on the technology and applications of information displays. The speakers are leaders in their fields and bring an international perspective to information display. The 90-minute lectures include ample time for audience participation. This year's new format consists of 15 lectures in a three-track parallel-session format on Monday, June 1 (see page 14).

Exhibition and Ribbon Cutting Ceremony

The SID Exhibition opens Tuesday morning, June 2, at 10:30 am and concludes at 2:00 pm on Thursday, June 4, in Exhibit Halls 1–3. A special Ribbon Cutting Ceremony will take place outside the exhibit hall to officially open the exhibition. This event will be presided over by SID President Amal Ghosh. Many of the leaders and innovators in the display industry will be represented (see page 193 for a listing of exhibitors and show hours).

Innovation Zone (I-Zone)

Making its return at Display Week 2015, the Innovation Zone (I-Zone) will provide a forum for live demonstrations of emerging information-display technologies in a designated area of the Exhibit Hall. The I-Zone, sponsored by E Ink, offers researchers an opportunity to demonstrate their prototypes or other hardware demo units for 2 days (Tuesday and Wednesday) free of charge, thus encouraging participation by small companies, startups, universities, government labs, and independent research labs (see inside back panel for a list of participants).

Exhibitors Forum

Exhibitors will be giving 15-minute presentations describing their products and services in a symposium-like setting. The forum will give attendees a more complete picture of what is being exhibited. The presentations are organized by subject and will be presented on a predetermined schedule on Tuesday through Thursday Wednesday (June 2–4) in Ballroom 210 (see page 195 for the complete schedule).

Business Track

***Business Conference*:** The Business Conference, organized by IHS DisplaySearch, will be held on Monday, June 1, featuring presentations from top executives of leading companies throughout the display supply chain. Registration includes a continental breakfast, lunch, refreshments, an evening networking reception, access to the online conference proceedings, and access to both the Symposium Keynote Session on Tuesday morning and the Exhibit Hall (see page 18 for full details).

Investors Conference: The Investors Conference will take place on Tuesday, June 2. Co-sponsored and organized by Cowen & Company, LLC, a securities and investment banking firm, this conference will feature presentations from leading public and private display companies, intended to appeal primarily to securities analysts, portfolio managers, investors, M&A specialists, and display-company executives. Registration includes a continental breakfast, lunch, refreshments, an evening networking reception, access to both the Symposium Keynote Session on Tuesday morning, the Exhibit Hall, and a copy of the Investors Conference Notes (see page 21 for full details).

Market Focus Conferences

This year's Market Focus Conferences, organized by IHS DisplaySearch, will be held on Wednesday and Thursday, June 3 and 4, and will cover two special topics: (1) ***Touch*** (Wednesday) and (2) ***Wearables–Flexible*** (Thursday). Each Market Focus Conference will concentrate on the critical market development issues facing each of these segments. Developed in collaboration with IHS DisplaySearch, each event will feature presentations and panel sessions from executives throughout the display supply chain (see page 23 for full details). The fee includes a continental breakfast, lunch, refreshments, access to the Exhibit Hall, the Symposium Keynote Session on Tuesday morning, and access to the online version of the presentation material.

Business Track Reception

This reception follows the Business Conference on Monday at the San Jose Convention Center, and will include a beer-tasting featuring the microbrews of a local San Jose brewery, The Strike Brewing Co. Business Conference attendees will be able to attend the reception directly after the conference and taste beer, drink cocktails, eat hors d'oeuvres, and have a chance to win fun raffle prizes. There is no extra cost for this reception, but please note a Display Week badge showing Business or Market Focus Conference attendance is required for this event. The reception will be on Monday, June 1 from 5:00 to 7:00 pm on the Almaden Terrace at the San Jose Convention Center.

GENERAL INFORMATION

Logistics
Display Week 2015 will be held May 31– June 5, 2015, in San Jose, California. Most of the Display Week events and activities will be held at the San Jose Convention Center. The Fairmont Hotel is this year's host hotel.

Sponsorship
Display Week 2015 is sponsored by the Society for Information Display located at 1475 S. Bascom Avenue, Suite 114, Campbell, CA 95008; telephone 408/879-3901, fax – 3833, e-mail: doug@sid.org.

Membership in SID
Payment of membership fee on-site entitles the attendee SID membership from May 31, 2015 through May 30, 2016. The membership fee applies to both new members and renewable memberships.

Book Orders
Additional conference publications will no longer be available through advance registration but they will be available for purchase at the SID Registration Desk booth located directly outside Exhibit Hall 1. If you are not attending Display Week and wish to purchase conference publications, please contact SID HQ at 408/879-3901, fax 408/879-3833, e-mail: doug@sid.org.

Conference Recordings
GES will be recording the audio and capturing all of the presentation slides for all Symposium Technical Sessions (Tuesday through Friday) and Monday Seminars for video streaming after the Display Week. The site will be activated approximately 6 weeks after Display Week. All attendess of the Symposium and Monday Seminars will have access to the video streaming.

Registration Desk Hours
The Display Week 2015 registration desk will be located directly outside Exhibit Hall 1 of the San Jose Convention Center. The registration hours are as follows:

Sunday, May 31:	8:00 am – 6:00 pm
Monday, June 1:	7:00 am – 6:00 pm
Tuesday, June 2:	7:00 am – 6:30 pm
Wednesday, June 3:	7:00 am – 5:00 pm
Thursday, June 4:	7:00 am – 2:00 pm
Friday, June 5:	7:00 am – 12:00 pm

Speakers Prep Room
Speakers may preview their presentations in Room 211B from 7:00 am to 7:00 pm on Monday, from 7:00 am to 6:00 pm Tuesday through Thursday, and from 7:00 am to 12:00 noon on Friday.

Explore Job Opportunities at Display Week 2015
SID will provide a forum to match attendees looking for jobs with job opportunities. Room 212A will be designated as SID's Recruitement Office where employers can list positions available and meet with conference attendees seeking employment. Also, individuals seeking employment may post a position-wanted notice. The job placement room will be open from 8:00 am to 4:00 pm, Tuesday through Thursday.

Spouses' Hospitality Suite
A Spouses' Hospitality Suite has been scheduled for all day Monday through Thursday in Room 213 of the Convention Center. Coffee and pastry will be served each morning at 8:00 am. Someone will be on hand Monday and Tuesday morning to assist anyone looking for things to do in and around San Jose.

Exhibit Hall Refreshments

Refreshments will be available for purchase in the Exhibit Hall on Tuesday through Thursday. Complimentary water will be available Tuesday through Thursday.

Cameras

The use of flash cameras and smartphone cameras are prohibited in the Symposium and Seminar sessions. Picture taking inside the Exhibit Hall is prohibited unless specific permission is obtained from appropriate booth personnel.

Internet Cafe

The Internet Cafe will be located in the Main Lobby of the Convention Center. It will feature six terminals with high-speed Internet access, allowing attendees and exhibitors to check their e-mail and surf the web – Sponsored by LG Display.

Networking Lounge

The Networking Lounge is a 20 x 90 ft. carpeted area consisting of chairs and tables where attendees can take a break to eat or sit and meet with other attendees. The lounge is located in the Main Lobby Sponsored by Amazon Lab 126.

Program Updates on the Web

To stay abreast of the latest program changes, visit the Display Week Web site at http://www.displayweek.org.

SID Web Site

The SID Web site (http://www.sid.org) has information on Society activities, including local chapters and all SID-sponsored conferences. A list of the sustaining members and links to their home pages is available. In addition, a collection of links to other Web display-related information has been assembled.

2015 SID HONORS AND AWARDS

Society for Information Display Honors and Awards

At this year's Symposium, the Society is pleased to honor the following individuals for their important contributions to the display profession and to the Society.

Karl Ferdinand Braun Prize

Junji Kido

For his outstanding contributions to the science and technology of OLEDs and pioneering contributions to commercializing white OLEDs for general lighting applications

Jan Rajchman Prize

Shohei Naemura

For his outstanding achievements in the chemical physics of liquid crystals and contributions to research on LCDs

Otto Schade Prize

Ingrid Heynderickx

For her outstanding contributions to the measurement, specification, and improvement of the image quality of electronic display technologies

Slottow-Owaki Prize

Jin Jang

For his major contributions to display education and active-matrix display developments including AMOLED displays, AMLCDs, and flexible displays

Lewis and Beatrice Winner Award

Allan Kmetz

For his exceptional and sustained service to the Society for Information Display

SID Fellows

The following awardees have been made Fellows of the SID:

Fuji Okumura

For his pioneering contributions to the research and development of LTPS-TFTs and SOG devices and significant contributions to the advancement of the display community

Ryuichi Murai

For his outstanding contributions to the research and development of PDPs, CRTs, flat CRTs, and OLED displays and nurturing and leadership in the PDP as well as other display communities

Anne Chiang

For her pioneering contributions to electrophoretic display technology and significant innovations in the development of polysilicon-TFT technology

John Wager

For his pioneering contributions to the development of oxide TFTs

Hidefumi Yoshida

For his many significant contributions to LCD technology, especially wide-viewing multi-domain vertical-alignment LCDs, including protrusion geometry, photo-alignment process, halftone technology, and fast-response architecture

Special Recognition Awards

Toshio Kamiya
For his outstanding contribution to the material science of amorphous-oxide semiconductors

Byeongkoo Kim
For his leading contributions to the research and development of AH-IPS technology for high-end displays including smartphones, tablets, notebooks, monitors, and automotive displays

Yasuhiro Koike and Akihiro Tagaya
For their leading contributions to the research of zero-birefringence polymers, highly birefringent polymers, and highly scattered optical-transmission polymers and their applications in LCDs

Byoungho Lee
For his leading contributions to three-dimensional display technologies based on integral imaging and holography

Jun Ho Song
For his invention and product development in simplifying the TFT process for LCD devices and the development of a 22-in. TFT-LCD TV in 1995 and integrated a-Si gate driving in TFT-LCD in 2005

Shunpei Yamazaki
For discovering CAAC-IGZO semiconductors, leading its practical application, and paving the way to next-generation displays by developing new information-display devices such as foldable or 8K × 4K displays

Presidential Citations

Norbert Fruehauf
For his outstanding service as General Chair of the 2014 SID International Symposium

Hoi-Sing Kwok
For his outstanding service as Program Chair of the 2014 SID International Symposium

Donggun Park
For his outstanding service as General Chair of the 2014 International Meeting on Information Display (IMID)

Ki-Woong Whang
For his outstanding service as General Co-Chair of the 2014 International Meeting on Information Display (IMID)

Jae Soo Yoo
For his outstanding service as Executive Chair of the 2014 International Meeting on Information Display (IMID)

Sung-Tae Shin
For his outstanding service as Program Chair of the 2014 International Meeting on Information Display (IMID)

Kazufumi Azuma
For his outstanding service as General Chair of the 2014 International Display Workshops (IDW).

Shinichi Komura
For his outstanding service as Executive Chair of the 2014 International Display Workshops (IDW)

Akiyoshi Mikami
For his outstanding service as Program Chair of the 2014 International Display Workshops (IDW)

Fan Luo
For leadership and service as Honors & Awards Committee Chair

Frank Yan
For his contributions towards starting up the Display Training School in China

Achin Bhowmik
For his outstanding work towards increasing corporate memberships

Silviu Pala
For his outstanding and sustained service organizing the Vehicle Displays Symposium

Birendra Bahadur
For long-standing service as Upper Mid-West Chapter Director

Joel Pollack
For his many years of service as Bay Area Chapter Director

Brian Berkeley
For his many contributions towards contracts negotiations

2014 *Journal of the SID* Best Paper Award

Shohei Katsuta, Emi Yamamoto, Yasushi Asaoka, Toru Kanno, Hideomi Yui, Tsuyoshi Kamada, Tsuyoshi Maeda, Yusuke Tsuda, and Katsumi Kondo, Sharp Corp., Chiba, Japan

"Optical Design and Roll-to-Roll Fabrication Process of Microstructure Film for Wide-Viewing LCDs"

2014 *Journal of the SID* Outstanding Student Paper Award

Jing Wang, Saijun Huang, Jun Liu, Xinkai Wu, Xindong Shi, Chaoping Chen, Zhicheng Ye, Jiangang Lu, Yikai Su, and Gufeng He

"High-Efficiency OLEDs Based on the Gradient Doping and Non-Linear Cross-Fading Doping in Transporting Layers"

SUNDAY SHORT COURSES

Society for Information Display

**Four 4-hour Short Courses
on
Information-Display Technology**

Short-Course Organizer/Chair
Yi-Pai Huang
National Chiao Tung University, Hsinchu, Taiwan

The Society for Information Display presents four 4-hour short courses on diverse topics related to information display. The tutorials are characterized by technical depth and small class size and are scheduled for the Sunday preceding the SID Symposium.

Full-color Tutorial Notes will be distributed to all participants and are included in the fee. Time will be provided for questions from the audience. The speakers are leaders in their respective fields and bring an international perspective to information display.

SUNDAY, MAY 31

SAN JOSE CONVENTION CENTER		
Time	**Room 210CG**	**Room 210DH**
9:00 – 1:00 pm	**S-1:** Fundamentals of AMOLED Displays	**S-2:** Fundamentals of Organic Devices for Flexible Displays and Electronics
LUNCH		
3:00 – 7:00 pm	**S-3:** Fundamentals and Applications of Oxide TFTs	**S-4:** Fundamentals of Color Science and the CIE Color Standards

SHORT COURSE S-1

9:00 am – 1:00 pm **San Jose Convention Center Room 210CG**

Moderator:
Hsing-Hung Hsieh, Polyera Corp., Hsinchu, Taiwan, ROC

S-1: Fundamentals of AMOLED Displays

Ho Kyoon Chung, Chair Professor
Sungkyunwan University, Gyeonggi-do, South korea

Jongwook Park, Professor
The Catholic University of Korea, Gyeonngi-do, South Korea

The commercial production of OLED TV and flexible OLED devices began in 2014 with great excitement. LG Display announced that they will produce 600,000 OLED TVs using a white OLED and oxide-TFT backplane in 2015. Also, plastic OLED technology has been applied to Samsung's Galaxy Note 4-Edge and smart watches. Professor Chung will review the technical challenges of large-sized OLED TV and flexible OLED devices and will discuss the future opportunities of OLED technology. Professor Park will address the basic structure of OLEDs, their operational principles, fluorescent and phosphorescent materials, fabrication methods, evaluation technologies, top-emission technologies, tandem technologies, *etc*. In addition, the current technical status of OLED materials and devices will also be discussed.

Instructor Bios:
Ho Kyoon Chung is currently Chair Professor at Sungkyunkwan University. He was previously a full-time Advisor and Executive Vice-President at Samsung SMD, which was dedicated to the R&D and manufacture of AMOLED products and mobile LCD modules. Prior to that, he was the Executive Vice-President and CTO of Samsung SDI and head of the Samsung SDI Corporate R&D Center from 2006 to 2008. Dr. Chung led the R&D for active-matrix OLEDs (AMOLEDs) since 2000 and is a world leader in bringing AMOLED technology into the commercial marketplace. Prior experience includes Managing Director of Memory Product Engineering and the Manufacturing Technology Center at Samsung Electronics, Semiconductor Business, from 1988 to 1999. Dr. Chung received his B.S. degree in electronics engineering in 1973 from Seoul National University, M.S. degree in 1977 from Case Western Reserve University, and Ph.D. in electrical engineering in 1981 from the University of Illinois at Urbana-Champaign.

Jongwook Park is Professor of Organic Chemistry in the Chemistry Department of the Catholic University of Korea. He received his Ph.D. degree from KAIST (Korea Advanced Institute of Science and Technology) in 1994. From 1995 to 1996, he worked as a research fellow under Prof. Alan MacDiarmid, Nobel Laureates of Chemistry in 2000, at the University of Pennsylvania. In 1995, he joined Samsung SDI, received the Ph.D. Project Award from Samsung SDI in 1996, and established his OLED team in 1997. His research interests are mainly focused on the synthesis and properties of π-conjugated materials for electronics as well as OLEDs. For his contributions in the development of new synthetic compounds for OLEDs, he was awarded the Excellent Paper award of the Korean Electronic Materials Society in 2001. He has authored 214 SCI papers and holds 43 patents in the field of organic semiconducting materials. He was a general director of the Korean Polymer Society, the Korean Union of Chemical Science and Technology Societies, and the Korean Society of Industrial and Engineering Chemistry for 7 years. He is an OLED committee member of SPIE in the U.S., the Korean Display Society, and the polymer division chairman of the Korean Society of Industrial and Engineering Chemistry. He was also chairman of eight large-scale projects of the Korean industry in relation to electronic materials. He received the Prime Minister Award from Korean government in 2012.

LUNCH BREAK **1:00–3:00**

SHORT COURSE S-2

9:00 am – 1:00 pm **San Diego Convention Center Room 210DH**

Moderator:
Bo-Ru (Paul) Yang, Sun Yat-Sun University, Guangdong, China

S-2: Fundamentals of Organic Transistors for Flexible Displays and Electronics

Hsiao-Wen Zan, Professor
National Chiao Tung University, Hsinchu, Taiwan, ROC

Yong-Young Noh, Associate Professor
Dongguk University, Seoul, Korea

This short course will firstly address the fundamentals (materials, device physics, and process) of organic transistors, including conventional field-effect transistors and various kinds of vertical-channel transistors. Then, with an emphasis on solution-processed organic transistors, key issues such as the control of hysteresis, bias-stress reliability, carrier mobility, and ambient stability will be discussed. Finally, recent progress on large-area solution process will be introduced.

Instructor Bios:
Hsiao-Wen Zan is a full professor in the Department of Photonics at National Chiao Tung University in Taiwan. She obtained her undergraduate degree from the Department of Electrical Engineering of National Taiwan University (1997) and her M.S. (1999) and Ph.D. (2003) degrees from the Institute of Electronics at National Chiao Tung University. She joined the Department of Photonics of National Chiao Tung University as an assistant professor soon after obtaining her Ph.D. degree. Since then, she has performed research on transistors and sensors based on organic and oxide-semiconductor materials. In 2008 and 2012, she became an associate professor and full professor, respectively. During the past decade, she has authored and/or co-authored more than 74 SCI papers and 22 invention patents. She received the Excellent Young Electrical Engineer Award from the Chinese Institute of Electrical Engineering in 2010 and was named as one of Taiwan's Promising Women in Science by the Wu-Chien Shiung Education Foundation in 2011. Since 2013, she has served as an Associate Editor for the *IEEE Sensors Journal* and is Chair of the IEEE Taipei Section Sensor Council. With a background in electronics, she has formed close collaboration with chemists and medical doctors when developing organic-based devices and biomedical sensors. Her research interest focuses on organic and oxide-semiconductor devices, with an emphasis on the development of low-temperature high-performance organic or organic/inorganic hybrid transistors, reliability analysis, photo sensors, and chemical/bio sensors for medical diagnostics.

Yong-Young Noh is an Associate Professor in the Department of Energy and Materials Engineering at Dongguk University in Seoul, Korea. He received his Ph.D. degree in 2005 from the Gwangju Institute of Science and Technology, Korea, and then worked at the Cavendish Laboratory in Cambridge, UK, as a postdoctoral associate from 2005 to 2007. Afterwards, he worked at the Electronics and Telecommunications Research Institute (ETRI), Korea, as a senior researcher from 2008 to 2009 and at Hanbat National University as an Assistant Professor from 2010 to 2012. Prof. Noh received the Merck Young Scientist Award (2013), the Korea President Award (2014), and the George E. Smith Award from the IEEE Electron Device Society (2014). He has expertise in materials, process, and device physics of organic and printed electronics for flexible electronics, especially printed OFETs, carbon-nanotube or oxide TFTs, and OLEDs. He has published more than 150 SCI papers and 40 patents.

LUNCH BREAK **1:00–3:00**

SHORT COURSE S-3

3:00 – 7:00 pm **San Jose Convention Center Room 210CG**

Moderator:
Dong-Kil Yim, Applied Materials, Santa Clara, CA, USA

S-3: Fundamentals and Applications of Oxide TFTs

Toshio Kamiya, Assistant Professor
Tokyo Institute of Technology, Tokyo, Japan

Amorphous-oxide semiconductors (AOSs) have large electron mobilities > 10 cm^2/(V-sec) and are used for thin-film transistors (TFTs) in high-resolution LCDs and large-sized OLED displays. This short course will first provide a review of the current applications of amorphous-oxide semiconductor displays and other applications. This will be followed by a discussion on how to grow device-quality AOS films and TFTs in relation to the atomic structure, defect structure, and impurity issues, which can be controlled by the deposition and annealing conditions. More fundamental aspects, the origin of the large mobility, and the material design of amorphous-oxide semiconductors will also be discussed.

Instructor Bio:
Toshio Kamiya began his research career as an Assistant Professor in the Department of Inorganic Materials at the Tokyo Institute of Technology, Tokyo, Japan, in 1991 and then moved to the Interdisciplinary Graduate School of Science and Engineering in 1996. He received his Dr(Eng) degree in materials science from the Tokyo Institute of Technology in 1996. He spent 2 years at the Microelectronics Research Centre, Cavendish Laboratory, at the University of Cambridge as a visiting scholar from 2000 to 2002. He became an Associate Professor in 2002 and a full professor in 2010 in the Materials and Structures Laboratory at the Tokyo Institute of Technology. His field of research includes exploration, materials design, and device applications of new functional inorganic materials. He has published about 350 scientific papers. He was awarded with the Tejima Research Award (Invention) in 2011, CerSJ Awards for academic achievements in ceramic science and technology, the Young Scientists' Prize by MEXT in 2007, and the Advanced Technology Award by the Fuji-Sankei group in 2005.

SHORT COURSE S-4

3:00 – 7:00 pm | **San Jose Convention Center Room 210DH**

Moderator:
Gabriel Marcu, Apple, Inc., Cupertino, CA, USA

S-4: Fundamentals of Color Science and the CIE Color Standards

James Larimer, Consultant
ImageMetrics LLC, Half Moon Bay CA, USA

Color standards are used to specify the colors of paints, fabrics, dyes, pigments, and colors captured and reproduced by cameras and displays and to gauge the quality of artificial light. All standards used today are traceable to the CIE 1931 XYZ Standard Observer and the Photopic Luminosity Function that preceded it. This short course will provide the foundation for reproducing color on displays and for the Monday Seminar on Device Color Management.

Instructor Bio:
James Larimer has over 40 years experience in the field of color vision and electronic displays. He has a Ph.D. in experimental psychology from Purdue University and was a Postdoctoral Fellow at the University of Michigan's Human Performance Center. He was a Professor of Psychology and Department Chair at Temple University, served as the Director of the Sensory Physiology and Perception Program at the National Science Foundation, and was a Senior Scientist at NASA's Ames Research Center. He is currently retired and serving as a consultant in the field of imaging and displays.

MONDAY SEMINARS

Society for Information Display Seminars on Information Display Technology

Seminar Organizer/Chair
Cheng Chen, *Apple, Inc., Cupertino, CA, USA*

Seminar Co-Organizer/Co-Chair
Takahiro Ishinabe, *Tohoku University, Tohoku, Japan*

The SID Seminar Series presents lectures on diverse topics related to information display. The seminars are tutorial in nature and an attempt is made to provide information at three levels. First and foremost, the technical foundations of the topic are treated in detail. Next, recent technical advances are discussed, and, finally, the current state of the art and projection of future trends are analyzed.

These seminars can benefit both newcomers and experienced professionals. Engineers, new to assignments in information display, find these seminars especially helpful in getting up to speed quickly. Experienced professionals attend to keep up with recent developments in fields closely related to their specialties. Managers attending the seminars obtain a broad perspective of the display field and a sense of its recent dynamics.

Attendees will receive an excellent set of notes, replete with references and illustrations. Time is provided for questions from the audience in each session. The speakers are leaders in their fields and bring an international perspective to information display.

MONDAY, JUNE 1

SAN JOSE CONVENTION CENTER

Time	Displays and Touch 101 Room LL20D	Display Technologies Room LL21EF	Display Applications Room LL20BC
8:30-10:00	**M-1** **Display Market Forecast – LCDs, OLEDs, e-Paper, and Touch: From Main Stream to Emerging Displays**	**M-2** **High-Dynamic-Range Imaging and Displays**	**M-3** **Head-Worn Displays for Augmented-Reality Applications**
BREAK (10:00 – 10:30)			
10:30-12:00	**M-4** **Recent Capacitive Touch Technologies**	**M-5** **GaN-Based LEDs for Energy-Efficient Displays**	**M-6** **Color Optimization for Displays with Color Management**
LUNCH (12:00 – 1:00)			
1:00-2:30	**M-7** **Display Metrology**	**M-8** **Quantum Dots and Other Nano-Materials**	**M-9** **CAAC Oxide Semiconductor and Its Application**
BREAK (2:30 – 3:00)			
3:00-4:30	**M-10** **Major Issues of OLED Displays: Challenges of Flexible OLED Displays and OLED TV**	**M-11** **Microscale LEDs for Multifunctional Display Systems**	**M-12** **Stereo 3D, Light Fields, and Perception**
BREAK (4:30 – 5:00)			
5:00-6:30	**M-13** **Electro-Optical Properties of IPS-LCDs**	**M-14** **OLEDs: Recent Advances and Their Applications**	**M-15** **Introduction to Oxide TFTs**

Track 1: Displays and Touch 101

SEMINARS M-1, M-4, M-7, M-10, & M-13

8:30 am – 6:30 pm — **San Jose Convention Center, Room LL20D**

M-1: Display Market Forecast – LCDs, OLEDs, e-Paper, and Touch: From Mainstream to Emerging Displays (8:30–10:00)

Jennifer Colegrove, CEO and Principal Analyst
Touch Display Research, Santa Clara, CA, USA

Global display-industry growth is slowing down, but there are hot trends in many areas. The market forecast for the overall display market from 2015 through 2020 will be presented. New opportunities in the display market – flexible and curved LCDs, quantum-dot displays, high-resolution displays, OLED displays, e-Paper displays, and embedded touch screens – will be discussed.

Moderator: *Tetsu Ogawa, Japan Display, Inc., Tokyo, Japan*

M-4: Recent Capacitive Touch Technologies (10:30–12:00)

Koji Noguchi, Group Manager
Japan Display, Inc., Tokyo, Japan

This seminar will focus on recent capacitive touch-panel technology. Topics to be covered include the basic principles of capacitive touch panels, a review of the latest On-Cell and In-Cell technology, the latest trends of touch functions, *etc*.

Moderator: *Vincent Tseng, Tianma Microelectronics, Shenzhen, China*

M-7: Display Metrology (1:00–2:30)

Ed Kelley, Consulting Physicist
KELTEK LLC, Boulder, CO, USA

Metrology is the science of measurement. The measurement pitfalls, mistakes people often make, limitations of equipment, and how to work around those limitations will be focused upon. The reflection and transmission terminology and measurement methods will be reviewed. A knowledge of photometry and colorimetry is required.

Moderator: *Lisa Zhao, Apple, Inc., Cupertino, CA, USA*

M-10: Major Issues of AMOLED Displays: Challenges of Flexible OLED Displays and OLED TV (3:00–4:30)

Jun Souk, Professor
Hanyang University, Seoul, Korea

This seminar will focus on the remaining issues of AMOLED displays. Topics include OLED lifetime, manufacturing issues of Flexible OLEDs and OLED TVs.

Moderator: *Yanli Zhang, Intel Corp., Santa Clara, CA, USA*

M-13: Electro-Optical Properties of IPS-LCDs (5:00–6:30)

Shinichi Komura, Group Manager, R&D
Japan Display, Inc., Chiba, Japan

In-plane-switching LCDs (IPS-LCDs) have been used for many applications ranging from small mobile devices to large TVs owing to their superior image quality. IPS-LCDs realize high contrast ratio and stable gray scale for a wide-viewing-angle range. The fundamental electro-optical properties of IPS-LCDs will be discussed.

Moderator: *S. J. Kim, LG Display Co., Ltd., Gyeonggi-do, South Korea*

Track 2: Display Technologies

SEMINARS M-2, M-5, M-8, M-11, & M-14

8:30 am – 6:30 pm | **San Jose Convention Center Room LL21EF**

M-2: High-Dynamic-Range Imaging and Displays (8:30–10:00)

Scott Daly and Timo Kunkel
Dolby Laboratories, Inc., Sunnyvale, CA, USA

This seminar will examine an entire high-dynamic-range (HDR) ecosystem, including image capture, video processing (including both human-assisted steps such as color grading and automated steps such as transform compression), display mapping, and display technology. New concepts arising from the capability of HDR such as utility of absolute light levels as opposed to relative light levels, specific allocation of a substantial range for highlights, interscene luminance-level variations, dimidiate histograms, *etc.*, will be discussed. The main emphasis will be focused on display and perception.

Moderator: *Ian Underwood, University of Edinburgh, Edinburgh, Scotland*

M-5: GaN-Based LEDs for Energy-Efficient Displays (10:30–12:00)

Steve P. DenBaars
University of California at Santa Barbara, Santa Barbara, CA, USA

Gallium-nitride (GaN) based semiconductor materials have been used to fabricate LEDs that have lead to the realization of high-efficiency LED backlights for TV and mobile displays. By using advanced light-extraction structures, advanced GaN blue-LED structures that exhibit external quantum efficiencies higher than 70% and 60% energy efficiencies have been fabricated. The fundamental physics of GaN emitters and the promise of all nitride-LED-based red-green-blue LEDs for flexible and transparent displays will be discussed.

Moderator: *Jacques Drolet, Apple, Inc., Cupertino, CA, USA*

M-8: Quantum Dots and Other Nano-Materials (1:00–2:30)

Vladimir Bulović, Dean for Innovation and Professor of EE
MIT School of Engineering, Cambridge, MA, USA

High luminescence efficiency and tunable saturated color of colloidal quantum dots (QDs) led to their commercialization in energy-efficient lighting and high–color-quality displays. Furthermore, electrically excited QD thin-film LEDs recently reached EQEs of >18% (IQEs of 90%), with a brightness of 50,000 cd/m^2 at only a few volts. These and other complementary nanoscale devices will be described.

Moderator: *Philip Chen, National Chiao Tung University, Taiwan, ROC*

M-11: Microscale LEDs for Multifunctional Display Systems (3:00–4:30)

John A. Rogers, Swanlund Chair Professor
University of Illinois at Urbana/Champaign, Urbana, IL, USA

This seminar summarizes progress over the last ten years on the development of microscale, high-performance LEDs and means for their rapid, deterministic assembly over large areas on substrates ranging from glass plates to plastic sheets. Applications in advanced, multifunctional displays will be highlighted.

Moderator: *Phil Bos, Liquid Crystal Institute, Kent State University, Kent, OH*

M-14: OLEDs: Recent Advances and Their Applications (5:00–6:30)

Franky So
University of Florida, Gainsville, FL, USA

The fundamental chemistry and physics related to the operation of organic light-emitting diodes will be presented. In addition to displays, non-display applications such as lighting and sensing will also be discussed.

Moderator: *Flora Li, Apple, Inc., Cupertino, CA, USA*

Track 3: Display Technology and Applications

SEMINARS M-3, M-6, M-9, M-12, & M-15

8:30 am – 6:30 pm **San Jose Convention Center Room LL20BC**

M-3: Head-Worn Displays for Augmented-Reality Applications (8:30–10:00)

Hong Hua, Associate Professor
University of Arizona, Tucson, AZ, USA

This seminar will provide a review on the historical developments of augmented-reality (AR) displays and the various optical technologies used for the development of lightweight AR displays, key fundamentals in designing wearable displays, and recent technological advancements. The potential impact of such technologies will be discussed.

Moderator: *Fenghua Li, Wavexing, Inc., Santa Clara, CA, USA*

M-6: Color Optimization for Displays with Color Management (10:30–12:00)

Gabriel Marcu, Senior Color Scientist
Apple, Inc., Cupertino, CA, USA

This seminar describes the most important aspects of color rendering on displays such as electro-optical transfer function, luminance, dynamic range (including HDR), contrast (static/dynamic), gray tracking, channel crosstalk, white point, color gamut and primaries, and response time. The seminar shows how to effectively apply these factors in display color management for maximizing the displayed color quality.

Moderator: *Karlheinz Blankenbach, Pforzheim University, Pforzheim, Germany*

M-9: CAAC Oxide Semiconductor and Its Application (1:00–2:30)

Yoshitaka Yamamoto
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

A c-axis-aligned crystalline oxide semiconductor (CAAC-OS) has a crystal structure without grain boundaries. Its application expands from several-tens-of-nanometer LSIs to large-sized displays. Flexible AMOLED technology is one of the most attractive technologies for next-generation display applications. This seminar will discuss CAAC-OS material and flexible OLED technology, combined with CAAC-OS FETs, transfer, and white OLEDs using a color filter.

Moderator: *Jun Qi, Apple, Inc., Cupertino, CA, USA*

M-12: Stereo 3D, Light Fields, and Perception (3:00–4:30)

Kurt Akeley
Lytro, Inc., Mountain View, CA, USA

Are stereo cinema and television necessarily passing fads? To better understand the long-term prospects of perceptually correct 3D display, current practice and possible futures in the context of light-field photography and human perception will be considered.

Moderator: *Yi-Pai Huang, National Chiao Tung University, Taiwan, ROC*

M-15: Introduction to Oxide TFTs (5:00–6:30)

John F. Wager,
Oregon State University, Corvalis, OR, USA

The objective of this seminar is to introduce display engineers and research scientists to the field of oxide thin-film transistors (TFTs). Topics addressed include: (i) Why oxides? (ii) Which oxides? (iii) Oxide-TFT advantages? (iv) Oxide-TFT disadvantages? (v) Oxide-TFT device physics? (vi) Oxide-TFT stability? (vii) How about CMOS?

Moderator: *Masayuki Inoue, Sharp Microelectronics Corporation of America, Camas, WA, USA*

MONDAY, JUNE 1

IHS/SID BUSINESS CONFERENCE
"Game Changers: Finding Ways to Increase Profitability"

Monday, June 1 / 7:00 am – 7:00 pm / San Jose Convention Center Room 230A

Businesses in the display industry face an unprecedented confluence of challenges, from the uncertain global economic outlook to complex supply chains and ever-changing end markets. Display Week's Business Conference investigates current and future issues and provides in-depth analysis and knowledge of the display industry necessary for successfully navigating this evolving sector. Industry leaders and IHS analysts will provide attendees insight into current market dynamics, technology and the trends to watch, as well as their impact on the supply chain.

Insightful presentations from industry leaders and IHS analysts alike will assess the current market dynamics, technology, and the market trends to watch, and their impact on the supply chain. In addition to presentations from industry leaders, the IHS Business Conference at SID Display Week will feature lively panel discussions and ample opportunities for networking.

Registration and Continental Breakfast **(7:00-8:00)**

Welcome from SID **(8:00–8:05)**
Amal Ghosh, *President, SID and Senior VP, eMagin Corp.*

Welcome from IHS **(8:05–8:10)**
Ian Weightman*, VP of Research and Operations, IHS*

Special Display Manufacturer Address **(8:10–8:30)**
Feng (Philip) Yuan**,** *Chief Strategy Marketing Officer and VP, BOE Technology Group*
"Innovations That Drive Value: Lessons from China"

David Hsieh**,** *Director, Analysis/Research, IHS* **(8:30–8:45)**
"Flat-Panel Displays: Is Low Cost the Only Path to Success?"

Session I **Panel Discussion**

IS GOOD ENOUGH, GOOD ENOUGH: CAN LCD PERSEVERE?

Monday, June 1 / 8:45 – 9:30 am / Room 230A

This session will be a panel discussion where companies will introduce their business models for emerging technologies such as OLED and Quantum Dot and BE asked debatable questions.

Panelists:
- ***Jason Hartlove,*** *CEO, Nanosys*
- ***Robert O'Brien****, Director, Marketing Intelligence, Corning Incorporated*
- ***Ho Kyoon Chung,*** *Professor, Sungkyunkwan University*
- ***Rono Mathieson,*** *VP of TV and Video Related Development, Sharp Laboratories of America*

Moderator:
David Hsieh*, Director, Analysis/Research, IHS*

BREAK **(9:30–10:00)**

Session II

A BETTER CONSUMER EXPERIENCE: DISPLAY CUSTOMERS POINT OF VIEW ON INCREASING PROFITABILITY

Monday, June 1 / 10:00 – 11:15 am / Room 230A

This session will focus on consumer-electronic company perspectives on the display industry.

Speakers:

- ***Achin Bhowmik***, *VP, Intel Corp.* **(10:00)**
- ***Erin Walline,*** *Director, of Engineering, User Experience & Design, Operations, & Client Solutions, Dell* **(10:15)**
- ***Jim Sanduski***, *President, Sharp Electronics* **(10:30)**
- ***Gang Xu,*** *Huawei* **(10:45)**

Panel Discussion **(11:00)**
Moderator:
Paul Gagnon, *Senior Manager, Analysis/Research, IHS*

Session III

FINANCIAL IMPLICATIONS THAT CAN LEAD TO SUCCESS

Monday, June 1 / 11:15 am – 12:15 pm / Room 230A

This session will bring together an analyst, an investor, and an economist to talk about segments in the display industry that are profitable and why.

Speakers:

- **Comparison of Profitability by the FPD Segment** **(11:15)**
  Paul Gagnon, *Senior Manager, Analysis/Research, IHS*
- **Slinking into the Future: An Economist's View of the Display Industry** **(11:30)**
  David Barnes, *Principal, Biz/Witz, LLC*
- **Why and Where Would Venture Capitalists Invest** **(11:45)**
  Ron D. Reich, *Managing Director, Corporate Development, Intel Corp.*

Panel Discussion **(12:00)**
Moderator:
Paul Gagnon, *Senior Manager, Analysis/Research, IHS*

LUNCH **(12:15–1:30)**

Session IVa

EMERGING TECHNOLOGIES AND APPLICATIONS TO INCREASE PROFIT POINT

Monday, June 1 / 1:30 – 3:10 pm / Room 230A

This two-part session will focus on emerging technologies across various applications segments that will shape the future of the display industry.

Speakers:

- ***Roman Maisch,*** *Senior VP, Merck* **(1:30)**
- ***Andrew Lee****, Global Business Director, Display Technologies, Dow Electronic Materials, The Dow Chemical Co.(licensing the Nanoco quantum-dot technology)* **(1:45)**
- ***Yoshinori Kobayashi,*** *Senior Executive Officer, President of AGC Electronics, Asahi Glass Co., Ltd.* **(2:00)**
- ***Fedja Kecman,*** *Marketing Manager for Tablets and Notebook Computers, 3M Display Materials & Systems* **(2:15)**
- ***Max McDaniel,*** *Senior Director, CMO, Display Group, Applied Materials* **(2:30)**

Q&A **(2:45)**
Moderator:
Paul Gagnon*, Senior Manager, Analysis/Research, IHS*

BREAK **(3:10–3:30)**

Session IVb

EMERGING TECHNOLOGIES AND APPLICATIONS TO INCREASE PROFIT POINT

Monday, June 1 / 3:30 – 5:00 pm / Room 230A

Speakers:

- ***Thomas Seder,*** *Chief Technologist, HMITBD, General Motors* **(3:30)**
- ***Roland Vlaicu****, VP of Consumer Imaging, Dolby Laboratories* **(3:45)**
- ***David Chu****, CEO, EverDisplay Optronics (EDO)* **(4:00)**
- ***Joe Kane****, CEO, Joe Kane Productions* **(4:15)**

Q&A **(4:30)**
Moderator:
Paul Gagnon*, Senior Manager, Analysis/Research, IHS*

CLOSING REMARKS **(4:50–5:00)**

NETWORKING COCKTAIL RECEPTION AND SPECIAL BEER-TASTING EVENT (Almaden Terrace) **(5:00–7:00)**

The Beer-Tasting Reception (originated by NPD DisplaySearch) is back by popular demand at Display Week 2015. For the fourth year in a row, you will have the opportunity to take part in the local brewery scene and taste its local flavors! Join all Business Conference attendees as we learn about and enjoy beer from Strike Brewing Company located in San Jose, California. Beer fans and home brewers can sample beer, drink cocktails, eat hors d'oeuvres and have a chance to win fun raffle prizes at this complimentary event. This event is complimentary to all Business Track attendees.

TUESDAY, JUNE 2

INVESTORS CONFERENCE

“Trendspotting in the Emerging Display Technology Ecosystem”
(Co-Organized by Cowen and Company)

Tuesday, June 2 / 8:00 am – 7:00 pm / San Jose Convention Center Room 230A

Registration **(8:00–8:20)**

SID Symposium Keynote Session (Room 220A) **(8:20–10:20)**

Welcoming Remarks **(10:25–10:30)**
Josh Epstein
Managing Director, Cowen and Company Investment Banking

Session I

QUANTUM DOTS: FROM THE LAB TO COMMERCIAL SUCCESS

Tuesday, June 2 / 10:30 – 11:30 am / Room 230A

- **QD Vision** (Private)
  Steve Ward, CEO
- **Nanosys** (Private)
  Jason Hartlove, CEO
- **Nanoco** (AIM: NANO)
  Michael Edelman, CEO

Session II

EVOLUTION OF THE IMMERSIVE EXPERIENCE

Tuesday, June 2 / 11:30 am – 12:30 pm / Room 230A

- **Immersion** (IMMR)
  Paul Norris, CEO
- **Prysm** (Private)
  Amit Jain, CEO
- **Tactus Technology** (Private)
  Craig Ciesla, CEO

Lunch and Plenary Presentation (Room 230A) **(12:30–1:00)**
“A Quick History from CRT of Yesterday to the Immersive Displays of Tomorrow”
Paul Gagnon, *Director, TV, IHS*

Session III

INNOVATIONS DRIVING WEARABLE DISPLAYS

Tuesday, June 2 / 1:00 – 1:45 pm / Room 230A

- **Kopin** (KOPN)
  John Fan, CEO
- **Vuzix** (VUZI)
  Paul Travers, CEO

Session IV

NEW INITIATIVES DRIVING DISPLAY PERFORMANCE

Tuesday, June 2 / 1:45 – 2:30 pm / Room 230A

- **CBRITE** (Private)
  Boo Nilsson, CEO
- **Glō** (Private)
  Fariba Danesh, CEO

Session V

ADVANCED TECHNOLOGIES IMPACTING THE DISPLAY ECOSYSTEM

Tuesday, June 2 / 2:30 – 4:00 pm / Room 230A

- **Cima NanoTech** (Private)
  Jon Brodd, CEO
- **Innova Dynamics** (Private)
  Daniel Button, CEO
- **Uni-Pixel** (UNXL)
  Jeff Hawthorne, CEO
- **VIA Optronics** (Private)
  Juergen Eichner, CEO

Session VI

THE OLED REVOLUTION IS NOW

Tuesday, June 2 / 4:00 – 4:50 pm / Room 230A

- **Universal Display Corp.** (OLED)
  Sidney Rosenblatt, Executive VP and CFO
- **Kateeva** (Private)
  Alain Harrus, CEO

Closing Presentation (Room 230A) **(4:50–5:20)**
"Deploying New Viewing Experiences for Consumer-Electronic Devices"
Mark Turner, *VP, Partnership Relations and Business Development, Technicolor*

Drinks & Displays (Almaden Terrace) **(5:20–7:00)**
Networking Reception with Presenters and Investors

WEDNESDAY, JUNE 3

MARKET FOCUS CONFERENCE
on
TOUCH

"The Changing Landscape of Traditional Touch Technologies and Applications

Wed., June 3 / 7:00 am – 5:00 pm / San Jose Convention Center Room 230A

Registration / Continental Breakfast **(7:00–8:00)**

Welcome from SID **(8:00–8:05)**
Amal Ghosh, *President, SID*
Senior VP, eMagin Corp.

Welcome from IHS **(8:05–8:10)**
Ben Keen
VP, Technology Market Intelligence, IHS

Special Display Manufacturer Address **(8:10–8:30)**
Yoshiharu Nakajima, *Senior General Manager, Display Systems R&D, Japan Display, Inc.*
"The Latest Direction of Pixel Eyes Development"

Calvin Hsieh, *Principal Analyst, IHS* **(8:30–9:00)**
"Touch Market Dynamics and Evolution and the Automotive Touch Market"

BREAK **(9:00–9:20)**

Session I

FINDING THE RIGHT TOUCH TECHNOLOGY

Wednesday, June 3 / 9:20 – 11:00 am / Room 230A

Traditional touch technologies are getting challenged by new emerging technologies. This session will uncover new solutions in materials, controller ICs, and in-cell and on-cell technologies.

Speakers:

- ***J-K. Zhang***, *Senior Director of Marketing, FocalTech* **(9:20)**
- ***Jimmy Lin,*** *Senior Product Line Manager, Synaptics* **(9:35)**
- ***Rob Frizzell***, *Marketing Director, Atmel* **(9:50)**
- ***Kelly Ingham***, *COO, Cima NanoTech* **(10:05)**
- ***Ikuo "Kurt" Kawamoto***, *Display & Touch Materials Specialist, Nitto Denko* **(10:20)**

Panel Discussion
Moderator: *David Hsieh, Senior Director, Displays, IHS*

Session II

EXISTING AND EMERGING TOUCH APPLICATIONS IN TRANSITION

Wednesday, June 3 / 11:00 am – 12:00 pm / Room 230A

This session will focus on traditional and emerging applications for touch including mobile, PCs, wearables, automotive, and signage

Speakers:

- ***Mark Hamilton***, *Executive VP, Operations, Sentons* **(11:00)**
- ***Dhwani Vyas***, *President and CEO, FlatFrog* **(11:15)**
- ***Makoto Enomoto***, *DNP Corporation USA* **(11:30)**

Panel Discussion **(11:45)**
Moderator: *David Hsieh, Senior Director, Displays, IHS*

LUNCH BREAK **(12:00–1:00)**

Special Touch Manufacturer Address **(1:15–1:30)**
Paul Chen, CTO, GIS Touch

Session III

THE BATTLE FOR ITO ALTERNATIVES

Wednesday, June 3 / 1:30 – 3:00 pm / Room 230A

This session will discuss the cost structures and options for ITO alternatives such as projected-capacitive and carbon-nanotube and metal-mesh materials.

Speakers:

- ***Hak Fei Poon***, *Founder and CTO, Nuovo Film* **(1:30)**
- ***Risto Vuohelainen,*** *CEO, Canatu* **(1:45)**
- ***Jagadish Kumaran,*** *Director of Product Management Cambrios* **(2:00)**
- ***Arjun Srinivas,*** *Co-Founder and Chief Strategy Officer, Innova Dynamics* **(2:15)**
- ***Zheng Cui***, *Director, Flexible Opto-Electronics Laboratory* **(2:30)**
  (jointly founded by O-Film and Suzhou Institute of Nanotech)

Panel Discussion **(2:45)**
Moderator: ***Rusty Stapp***, *Cambro Services*

BREAK **(3:00–3:15)**

Session IV

EXTENSIONS OF TOUCH

Wednesday, June 3 / 3:15 – 4:15 pm / Room 230A

This session will cover other user interface technologies that are available currently and in next-generation products such as gesture, voice, and feedback technologies.

Speakers:

- ***Micah Yairi,*** *CTO, Tactus Technology* **(3:15)**
- ***Chris Ullrich****, VP of User Experience, Immersion* **(3:30)**
- ***Francois Jeanneau****, CEO, Novasentis* **(3:45)**
- ***Ian Campbell****, COO, NextInput* **(4:00)**
- ***Nobutaka Ide****, VP, Marketing, Wacom Corp.* **(4:15)**

Panel Discussion **(4:30)**
Moderator*: *Rusty Stapp, *Cambro Services*

CLOSING REMARKS **(4:45–5:00)**

THURSDAY, JUNE 4

MARKET FOCUS CONFERENCE
on
WEARABLE–FLEXIBLE

"Challenges and Opportunities for New Form Factors and Applications"

Thursday, June 4 / 7:00 am – 5:00 pm / San Jose Convention Center Room 230A

Registration / Continental Breakfast **(7:00–8:00)**

Welcome from SID **(8:00–8:05)**
Amal Ghosh, *President, SID*
Senior VP, eMagin Corp.

Welcome from IHS **(8:05–8:15)**
Paul Gray, *Principal Analyst, IHS*

Special Wearable Address **(8:15–8:45)**
Sidney Chang, *Head of Business Development, Android Wear, Google*
"Android Wear Overview and Google's Wish List"

Special Wearable Address **(8:45–9:15)**
Margaret Kohin, *Senior VP, Business Development, eMagin Corp.*
"Bridging the Gap from Head-Mounted Displays for Avionics and Defense to Consumer Products"

BREAK **(9:15–9:35)**

Session I

WHAT ARE WEARABLES FOR ANYWAY?

Thursday, June 4 / 9:35 – 11:30 am / Room 230A

This session will include speakers from the head-mounted, smart-watch, and health and wellness industries giving presentations on the latest wearables applications.

Speakers:

- ***Jack Kent,*** *Senior Manager, Analysis and Research, IHS* **(9:35)**
- ***Chris Verplaetse,*** *Head of R&D Devices, Basis, an Intel Company* **(9:55)**
- ***Kevin McDermott,*** *Director of Strategic Marketing, Imagination Technologies* **(10:10)**
- ***Andrew Witte,*** *Founder and CTO, Pebble Technology* **(10:25)**
- ***Ernesto Martinez,*** *Head of Wearable Computing, Kopin Corp.* **(10:40)**

Panel Discussion **(10:55)**
Moderator*: *Jack Kent, *Senior Manager, Analysis and Research, IHS*

Session II

WEARABLE–FLEXIBLE MARKET OVERVIEW

Thursday, June 4 / 11:10 – 11:30 am / Room 230A

Speaker:

- ***Paul Gray,*** *Principal Analyst, IHS*

LUNCH **(11:30–12:45)**

Session III **Panel Discussion**

POWER: THE ELEPHANT IN THE ROOM

Thursday, June 4 / 12:45 – 2:00 pm / Room 230A

In this panel discussion, panelists will introduce their display battery technologies and energy harvesting solutions and answer hot-topic questions.

Panelists:

- ***Andy Crump****, West Coast Sales, Ascent Batteries*
- ***Giovanni Mancini****, Head of Global Marketing, E Ink*
- ***Dominic Pajak,*** *Senior Embedded Strategist, ARM*
- ***Tim Saxe,*** *CTO, QuickLogic*
- ***Sam Massih,*** *Director, Wearable Sensors, InvenSense*

Moderator: ***Paul Gray,*** *Principal Analyst, IHS*

BREAK **(2:00–2:20)**

Session IV **Panel Discussion**

SOFTWARE: DIVERSITY OR MONOCULTURE

Thursday, June 3 / 2:20 – 3:35 pm / Room 230A

In this panel discussion, panelists will uncover the challenges and opportunities faced by software and app developers.

Panelists:

- ***Matthew Claypotch****, Mozilla*
- ***Brian Hernacki****, Chief Architect, New Devices, Intel Corp.*
- ***Josh Schaeffer,*** *VP of Business Development, Runtastic*

Moderator: ***Jack Kent,*** *Analysis and Research, IHS*

ENABLING FRESH DESIGN IDEAS: DESIGNERS' DILEMMAS AND SOLUTIONS

Thursday, June 4 / 3:35 – 4:50 pm / Room 230A

In this panel discussion, panelists will focus on designers' dilemmas, including discussions on designing glass, backplanes, packaging (thin and flexible), and flexible materials.

Panelists:

- ***Terri M. Bassitt,*** *Product Marketing Manager, OLEDs, Futaba Corporation of America*
- ***Paul Cain,*** *Strategy Director, FlexEnable, Ltd.*
- ***Boh Ruffin,*** *Commercial Technology Manager, Corning Incorporated*
- ***Conor Madigan,*** *Co-Founder and President, Kateeva.*
- ***Michael Cowin,*** *Head of Strategic Marketing, SmartKem, Ltd.*

Moderator: ***Paul Gray,*** *Principal Analyst, IHS*

CLOSING REMARKS **(4:50–5:00)**

TUESDAY, JUNE 2

Session 1

ANNUAL SID BUSINESS MEETING

Tuesday, June 2 / 8:00 – 8:20 am / Room 220A

Presiding
Amal Ghosh, *President, Society for Information Display*
eMagin Corp., Hopewell Junction, NY, USA

Session 2

KEYNOTE SESSION

Tuesday, June 2 / 8:20 – 10:20 am / Room 220A

Opening Remarks (8:20–8:25)

Amal Ghosh, *President, Society for Information Display*
eMagin Corp., Hopewell Junction, NY, USA

Welcoming Remarks (8:25–8:30)

Shin-Tson Wu, *SID '15 General Chair*
University of Central Florida, Orlando, FL, USA

Seonki Kim, *SID '15 Technical Program Chair*
Samsung Display Co., Ltd., Gyeonggi-do, Korea

Keynote Addresses (8:30–10:20)

- Introduction to Keynotes **(8:30–8:35)**
  Shin-Tson Wu, *SID '15 General Chair*
  University of Central Florida, Orlando, FL, USA

2.1: On to the Era of Immersive Interactions (8:35–9:10)

Mr. Brian M. Krzanich, *CEO*
Intel Corp., Santa Clara, CA, USA

The relentless advances in computing technologies, utilizing the power of Moore's Law, will be described. How these advances, coupled with remarkable innovations in sensing and display technologies, are transforming computing, communications, and entertainment devices, systems and applications will be discussed. Over the past decades, human-device interactions have morphed from text inputs to graphical user interfaces. Efforts under way at Intel and in the industry to usher in a new era of interactivity, where devices can "see," "hear," "feel," and "understand," transforming our experiences with the content on displays of all form-factors to be more engaging and immersive, will be explained.

2.2: The Booming Display Industry in China (9:10–9:45)

Mr. Dongsheng Li
Chairman and CEO, TCL Corp., Shenzhen, China

As the supply chain becomes more and more integrated, China's display industry has been rapidly growing, and it’s end-products have become more diversified and are continually being advanced. How to ride the tide and win the marketplace by synergy will be discussed.

2.3: The Opportunities and Challenges Facing the Display Industry (9:45–10:20)

Dr. In Byeong Kang
Senior VP and CTO, LG Display Co., Ltd., Gyeonggi-do, South Korea

The IT environment is leaping into the next generation with faster and better technologies such as the Internet of Things, 5G mobile communications, *etc*. We are seeing new opportunities and potential for the display industry as a result of this change. The opportunities and challenges facing the display industry will be discussed. That being said, this will not be an easy challenge. But, it is our firm belief that if we work together as an industry, we could realize the dream of having major breakthroughs for displays in the near future.

BREAK (10:20-10:50)

WEARABLE DISPLAY SYSTEMS

Tuesday, June 2 / 10:50 – 11:50 am / Ballroom 220B

Chair:
B. Schowengerdt, *University of Washington, Seattle, WA, USA*

Co-Chair:
M. Brennesholtz, *Display Central, Pleasantville, NY, USA*

3.1: Achieving Inconspicuous Head-Mounted-Display Optics (10:50)

T. Wong, A. Ouderkirk
3M Company, St. Paul, MN, USA

Optical components for head-mounted displays using multi-layered optical film offer dramatic improvements in efficiency, aesthetic appearance, and optical image quality. Multi-layered optical film can be embedded in a conventional ophthalmic lens creating a more natural looking form with reduced weight.

3.2: *Distinguished Student Paper:* High-Image-Quality Wearable Displays with a Fast-Response Liquid Crystal (11:10)

Z. Luo, F. Peng, H. Chen, S-T. Wu
University of Central Florida, Orlando, FL, USA

M. Hu
Xi'an Modern Chemistry Research Institute, Xi'an, China

Two ultra-low-viscosity liquid crystals for high-image-quality wearable displays with a field-sequential-color LCOS scheme will be reported. A fast response time offers vivid color, high ambient contrast ratio, and reduced color breakup even at –20°C. Different LC modes and frame rates will also be discussed.

3.3: Single-Mirror IMOD Display for Practical Wearable Devices (11:30)

T. Chang, E. Chan, J. Hong, C. Kim, J. Ma, Y. Pan, R. Van Lier, B. Wen, L. Zhou, P. Mulabagal
Qualcomm MEMS Technologies, Inc., San Jose, CA, USA

The progress toward realizing commercially viable wearable displays that will enable always-on operation using single-mirror interferometric modulation (SMI) and a continuously tunable reflective color display technology based on interferometric modulation (IMOD) will be described.

LUNCH (11:50–2:00)

AUTHOR INTERVIEWS (5:00–6:00)

FLEXIBLE-DISPLAY MANUFACTURING

Tuesday, June 2 / 10:50 am – 12:10 pm / Ballroom 220C

Chair:
B. Bowden, *Corning Incorporated, Corning, NY, USA*

Co-Chair:
C. Kim, *Samsung Display Co., Ltd., Gyeonggi-do, South Korea*

4.1: *Distinguished Paper:* Apparatus for Manufacturing Flexible OLED Displays: Adoption of Transfer Technology (10:50)

S. Idojiri, M. Ohno, K. Takeshima, S. Yasumoto, M. Sato, N. Sakamoto, K. Okazaki
Advanced Film Device, Inc., Tochigi, Japan

K. Yokoyama, S. Eguchi, Y. Hirakata, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

A manufacturing process for flexible displays, adopting a transfer technology using tungsten separation layers, has been established. Separation with water was performed. The apparatus built for the manufacturing process will be described. This apparatus fabricated an 8K (7680 × 4320 effective pixels) flexible OLED display.

4.2: Study of ACF Bonding Technology in Flexible Display-Module Packages (11:10)

Y-H. Lai, W-T. Wang, K-L. Hwu, L-H. Chang
AU Optronics Corp., Hsinchu, Taiwan, ROC

Based on current results, soft conductive particles of ACF were developed and chosen in PI/glass substrate bonding. For film-type substrate bonding, especially in IC bonding, the design of the ACF is very important in avoiding the insufficient conductive particle deformation issue induced by the sink of plastic substrate. Here, a feasible and simple flexible substrate bonding technology to package driver IC, FPC, or COF for flexible AMOLED application will be presented.

4.3: Ultra-Thin LTPS TFT-LCD by Using Glass-on-Carrier Technology (11:30)

S-P. Chiao, T-C. Fan, C-H. Chan, C-H. Liao, Y-H. Lai, J-K. Lu, N. Sugiura
AU Optronics Corp., Hsinchu, Taiwan, ROC

A glass-on-carrier technology was developed and applied to low-temperature polysilicon (LTPS) TFT-LCDs. A newly optimized de-bonding layer, SiON, successfully provided easy peeling of the glass from the carrier even after the LTPS high-temperature process. Finally, an ultra-thin LTPS TFT-LCD having a total thickness of 0.915 mm was realized by the glass-on-carrier technology.

4.4: Dimension Control of CF Fabricated by Transfer Method **(11:50)**

T. Furukawa, S. Tokito
Yamagata University, Yamagata, Japan

The dimensional change before or after transfer by the transfer method has been controlled. The choice of peelable layer materials and adhesives are important in controlling the dimensional change. Based on these results, the color filter with ITO was fabricated by using this new transfer method. ‘

LUNCH **(12:10–2:00)**

AUTHOR INTERVIEWS **(5:00–6:00)**

IMAGE QUALITY OF DISPLAYS

Tuesday, June 2 / 10:50 am – 12:10 pm / Room LL20A

Chair:
S. Ohtsuka, *Kagoshima University, Kagoshima, Japan*

Co-Chair:
D. Hoffman, *Samsung Semiconductor, San Jose, CA, USA*

5.1: Influence of Pixel Density on the Image Quality of Smartphone Displays (10:50)

S. Kubota
Ergo Design Laboratory, Tokyo, Japan

Y. Hisatake, T. Kawamura
Japan Display, Inc., Tokyo, Japan

M. Takemoto
Seikei University, Tokyo, Japan

The influence of pixel density on the image quality of characters displayed on smartphone screens has been investigated. The image quality of characters increased steadily as the pixel density increased up to around 700 ppi, whereas the perception of jaggies for aliased artifacts had not yet been saturated at 800 ppi.

5.2: Simulation of Color-Breakup Perception Using Eye-Tracking Data (11:10)

M. Tada, K. Hirai, T. Horiuchi
Chiba University, Chiba, Japan

A simulator for color-breakup (CBU) perception due to saccades using eye-tracking data has been developed. Eye speed was measured concurrently with subjective evaluation of CBU. The simulated CBU images based on the eye-tracking measurements reproduced human perception with high fidelity.

5.3: Extending the Flicker Visibility Metric to a Range of Mean Luminance (11:30)

A. B. Watson
NASA Ames Research Center, Moffett Field, CA, USA

A. Ahumada
NASA Ames Research Center, Moffett Field, CA, USA
and
New York University, Abu Dhabi, UAE

A flicker visibility metric for displays at a high mean luminance that extends the metric to lower mean luminances is proposed. This extension relies on a linear relation among log sensitivity, critical fusion frequency, and log retinal illuminance. The extended flicker visibility metric is measured in just-noticeable differences (JNDs).

5.4: Subpixel Rendering for a High-Resolution OLED Display with Low-Resolution Photomasks **(11:50)**

H-C. Lin, P-L. Sun
National Taiwan University of Science and Technology, Taipei, Taiwan, ROC

C-H. Wen, S-P. Wang
ITRInstitute, Hsinchu, Taiwan, ROC

A suitable subpixel arrangement was investigated for OLED displays. If its resolution matches that of an active matrix, then quad RGGB fits the best. If it were 2/3 the resolution of the active matrix, a size-varied quad RGGB is preferable. And if it were half the resolution, a double-pixel quad RGGB is preferable. Spatial sharpening can increase the visual resolution and image quality.

LUNCH **(12:10–2:00)**

AUTHOR INTERVIEWS **(5:00–6:00)**

NOVEL DISPLAY APPLICATIONS I

Tuesday, June 2 / 10:50 am – 12:10 pm / Room LL20BC

Chair:
I. Underwood, *University of Edinburgh, Edinburgh, Scotland*

Co-Chair:
J-N. Perbet, *THALES Avionics, Le Haillan, France*

6.1: A New Application of a Touch-Screen Display for Data Transfer (10:50)

P. Coni, J-N. Perbet, L. Augros, J. C. Abadie, Y. Sontag
THALES Avionics, Bordeaux-Le Haillan, France

Touch screens are used as human-computer interfaces to transmit finger positions to a host computer. Data was transmitted to and from the touch screen with a dongle or fingertip on the touch screen. Simple software modifications of a touch-screen controller enable a data rate of up to 500 kbit/sec.

6.2: Hybrid-Type Temperature Sensors Using TFTs: Characteristic Comparison of n, p, and Pin-Type Transistors (11:10)

K. Kito, H. Hayashi, S. Kitajima, T. Matsuda, M. Kimura
Ryukoku University, Otsu, Japan

Hybrid-type temperature sensors combining TFTs, a capacitor, and a ring oscillator have been developed. The characterisics of those using n, p, and pin-type transistors were compared. For all types, temperature dependence of oscillation frequencies were confirmed, which indicates their applicability to temperature sensors.

6.3: Adaptable Light Beaming and Shaping with LED Matrix and Lens Array (11:30)

F. Wang, Y. Zhang, J. Wang, X. Li
Southeast University, Nanjing, China

A lighting system, which consists of a 32 × 32 × RGB LED matrix and an 8 × 8 Fresnel lens array, is proposed and demonstrated. It accomplishes a localized lighting with 4 × 4 addressable regions and projects color patterns for atmosphere heightening. Device parameters were studied and the power savings and lighting effect were optimized.

6.4: Local Tone Mapping Based Dynamic-Backlight Algorithm (11:50)

V. Chesnokov, M. Tusch, T. Steder, V. De Silva
Apical, Ltd., London, UK

A new method for dynamic backlight control based on Local Tone Mapping is introduced and compared to currently deployed Content-Adaptive Backlight-Controlling approaches. A methodology, based on user studies, for quantifying the tradeoff between perceptual image quality and power savings in CABC systems will be described.

LUNCH (12:10–2:00)

AUTHOR INTERVIEWS (5:00–6:00)

OLED DRIVING TECHNIQUES

Tuesday, June 2 / 10:50 am – 12:10 pm / Room LL20D

Chair:
W. Yao, *Apple, Inc., Cupertino, CA, USA*

Co-Chair:
D. McCartney, *Consultant, Silicon Valley, CA, USA*

7.1: *Invited Paper:* Novel OLED Display Technology for Large-Sized UHD OLED TVs **(10:50)**

H-J. Shin, S. Takasugi, K-M. Park, S-H. Choi, Y-S. Jeong, B-C. Song, H-S. Kim, C-H. Oh, B-C. Ahn
LG Display Co., Ltd., Gyeonggi-do, South Korea

55-, 65-, and 77-in. UHD OLED TVs, which include an IGZO-TFT backplane, an RGBW pixel structure with a white OLED, driving scheme, and a compensation method applied to the panel, will be described. Technologies to enhance image quality, panel reliability, and cost competitiveness of UHD OLED TV has been investigated.

7.2: A Pixel Structure Using Switching Error Reduction Method for High-Image-Quality AMOLED Displays **(11:10)**

N-H. Keum, K. Oh, S-K. Hong, O-K. Kwon
Hanyang University, Seoul, South Korea

An AMOLED pixel that reduces the switching error is proposed. The switching error is reduced by floating the storage capacitor before it is induced. As shown by the simulation results, the switching error and the emission current error are reduced by 91.4% and 77.5%, respectively.

7.3: Depletion-Mode Oxide-TFT Shift Register with Wide Operating Frequency Range for AMOLED Displays **(11:30)**

I. Han, E. Song, B. Kang, K. Oh, B. Kim, C. Oh, B. Ahn
LG Display Co., Ltd., Gyeonggi-do, South Korea

H. Nam
Kyung Hee University, Seoul, South Korea

A narrow-border AMOLED display gate-driver–in–panel (GIP) is proposed. The circuit with depletion-mode oxide TFTs was designed to reduce power consumption at low frequency and to improve motion-picture response time (MPRT) at high frequency. The GIP was integrated into a 15-in. (1366 × 768, 105 ppi) AMOLED panel.

7.4: A Slim Border Design for Wearable Displays: Using a Novel P-Type Shift Register and Optimal Layout Arrangement **(11:50)**

Y-S. Tsai, C-Y. Liu, C-C. Tseng, L-W. Shih
AU Optronics Corp., Hsinchu, Taiwan, ROC

Generally, a non-rectangular wearable AMOLED display border is larger than 2.0 mm. A novel P-type shift register with five TFTs and two capacitors (5T2C) is proposed. An optimal layout arrangement is also proposed to narrow the border size. A 1.4-in. circular AMOLED wearable display with a 1.6-mm border was demonstrated by these methods.

LUNCH **(12:10–2:00)**

AUTHOR INTERVIEWS **(5:00–6:00)**

QUANTUM-DOT MATERIALS

Tuesday, June 2 / 10:50 – 11:50 am / Room LL21EF

Chair:
S. Coe-Sullivan, *QD Vision, Inc., Redondo Beach, CA, USA*

Co-Chair:
T. Shiga, *University of Electro-Communications, Tokyo, Japan*

8.1: *Invited Paper:* Alignment of Quantum Rods (10:50)

M. Hasegawa, Y. Hirayama, S. Dertinger
Merck, Ltd., Japan, Kanagawa, Japan

Electrospinning and fine-pitch groove-structure aligned semiconductor quantum rods (QRs) parallel to the grooves will be described. QR-embedded electrospun polymer nanofiber sheets produce polarized fluorescence emission.

8.2: Semiconductor Quantum Rods for Display Applications (11:10)

E. Shaviv, D. Glozman, Y. Bonfil, S. Amir
Qlight Nanotech, Ltd., Jerusalem, Israel

U. Banin
Qlight Nanotech, Ltd., Jerusalem, Israel
and
Hebrew University of Jerusalem, Jerusalem, Israel

Semiconductor quantum rods offer new functionality for flat-panel displays because they exhibit tunable narrow emission in addition to polarized emission and lower self-absorption compared to that of other quantum materials. Quantum-rods-based films for backlighting, enabling wide color gamut and the design of an energy-efficient polarized backlight, has been developed.

8.3 *Distinguished Paper:* Next-Generation Display Technology: Quantum-Dot LEDs (11:30)

J. R. Manders, L. Qian, A. Titov, J. Hyvonen, J. Tokarz-Scott, P. Holloway
NanoPhotonica, Inc., Gainesville, FL, USA

J. Xue
University of Florida, Gainesville, FL, USA

P. H. Holloway
NanoPhotonica, Inc., Gainesville, FL, USA
and
University of Florida, Gainesville, FL, USA

Colloidal quantum-dot-based hybrid LEDs (QD-LEDs) that exhibit external quantum efficiencies >10% for all three fundamental colors (>18% for green), device lifetimes of >300 khours, extreme tuned color fidelity, and complete processing using only solutions have been demonstrated. The features make the QD-LED technology disruptive for displays and will lead to next-generation displays.

LUNCH (11:50–2:00)

AUTHOR INTERVIEWS (5:00–6:00)

IMAGING TECHNOLOGIES AND APPLICATIONS I

Tuesday, June 2 / 10:50 am – 12:10 pm / LL21D

Chair:
Achin Bhowmik, *Intel Corp., Santa Clara, CA, USA*

I1.1: *Invited Paper:* Light Field Imaging (10:50)

K. Akeley
Lytro, Inc., Mountain View, CA, USA

Commercial light-field imaging systems that support photography, depth analysis, and other applications are becoming available. The development of light-field photography over the past century will be summarized, and issues such as depth of field and final image resolution will be briefly described. Future photographic and imaging opportunities will be identified.

I1.2: *Invited Paper:* Switchable Liquid-Crystal Micro Lens Arrays for the Light-Field Camera Application (11:10)

H. Kwon, M. Ito, Y. Kizu, Y. Kizaki, M. Kobayashi, R. Ueno, K. Suzuki, H. Funaki, Y. Nakai
Toshiba Corp., Kawasaki, Japan

Two types of gradient-index liquid-crystal micro lens arrays (LC-MLAs) for light-field camera application is reported. The LC-MLAs enabled the capture of both compound eye images to be refocused on the various positions with its depth information and clear 2D images without reconstruction.

I1.3: *Invited Paper:* Immersive Applications Based on Depth-Imaging and 3D-Sensing Technology (11:30)

A. K. Bhowmik, S. BenHimane, D. Molyneaux, B. C. Lucas, H. P. Ho
Intel Corp., Santa Clara, CA, USA

G. Kutliroff, C. Rand
Intel Development Center, Israel

The recent developments in depth-imaging and 3D computer-vision technologies allow efficient and real-time acquisition, reconstruction, and understanding of the 3D environment, which enable an array of life-like and immersive augmented-reality applications. The key technologies spanning sensors, algorithms, and system integration will be detailed, new applications will be described, and emerging trends in this burgeoning field will be discussed.

I1.4: ***Invited Paper:* Indoor Scene Understanding from RGB-D Images** **(11:50)**

S. Gupta, J. Malik
University of California at Berkeley, Berkeley, CA, USA

R. Girshick
Microsoft Research, Reston, WA, USA

P. Arbeláez
Universidad de los Andes, Bogotá, Colombia

The objective of this work is to be able to align objects in an RGB-D image with 3D models from a library. The pipeline for this task involves detecting and segmenting objects and estimating coarse pose by using a convolutional neural network followed by the insertion of the rendered model in the scene.

LUNCH **(12:10–2:00)**

AUTHOR INTERVIEWS **(5:00–6:00)**

WEARABLE DISPLAYS: DIRECT VIEW

Tuesday, June 2 / 2:00 – 3:20 pm / Ballroom 220B

Chair:
R. Ma, *Universal Display Corp., Ewing, NJ, USA*

Co-Chair:
Y. Hong, *Seoul National University, Seoul, South Korea*

9.1: *Invited Paper:* Status and Outlook of Organic Electronic Materials for Flexible and Stretchable Displays (2:00)

Z. Bao
Stanford University, Stanford, CA, USA

M. He
Corning Incorporated, Corning, NY, USA

Organic materials are interesting alternatives to inorganic materials in applications where low cost, transparent, flexible, or even stretchable substrates and large-area format is required. The current status of organic electronic material performance and prospects for flexible and stretchable display applications will be presented.

9.2: A Novel Lamination Process for Flexible AMOLED Encapsulation (2:20)

T. Wang, S. Zhang, T. Sun, X-B. Du, J. Gao, W-F. Zhou, D-W. Wang
BOE Technology Group Co., Ltd., Beijing, China

An ultra-thin barrier film (UTBF) and a novel transfer lamination process assisted with a thermal release adhesive has been developed and applied to a 4.8-in. flexible AMOLED display to reduce the total thickness of the panel.

9.3: The First Flexible LCD Applied for Wearable Smart Device (2:40)

W-Y. Li, P-H. Chiu, T-H. Huang, J-K. Lu, Y-H. Lai, Y-S. Huang, C-T. Chuang, C-N. Yeh, N Sugiura
AU Optronics Corp., Hsinchu, Taiwan, ROC

Flexible substrate materials and the handling method are the key factors in making flexible LCDs. A 3.47-in. flexible LCD designed for wearable applications was successfully fabricated by using an optically clear fiber-reinforced-plastic (FRP) substrate and a film lamination followed by a mechanical peeling process.

9.4: Stretchable 45 × 80 RGB LED Display Using Meander Wiring Technology **(3:00)**

H. Ohmae, Y. Tomita, M. Kasahara
Panasonic Corp., Moriguchi, Japan

J. Schram, E. Smits, J. van den Brand
Holst Centre / TNO, Eindhoven, The Netherlands

F. Bossuyt, J. Vanfleteren, J. De Baets
imec – Ghent University, Gent, Belgium

A stretchable and foldable display using a 45 × 80 RGB LED passive-matrix display on a meandering circuitry embedded in a polyurethane film will be presented. The display has a 3-mm pitch, a stretchability up to 10%, and a brightness that exceeds 30 cd/m^2.

BREAK **(3:20–3:40)**

AUTHOR INTERVIEWS **(5:00–6:00)**

OLED ENCAPSULATION AND RELIABILITY

Tuesday, June 2 / 2:00 – 3:20 pm / Ballroom 220C

Chair:
I. Bita, *Apple, Inc., Cupertino, CA, USA*

Co-Chair:
D. Wang, *BOE Technology Group Co., Ltd., Beijing, China*

10.1: ***Invited Paper:*** **Roll-to-Roll Manufacturing of Functional Substrates and Encapsulation Films for Organic Electronics: Technologies and Challenges** **(2:00)**

J. Fahlteich, C. Steiner, T. Wanski, S. Mogck, D. Wynands, M. Top
Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology, Dresden, Germany

E. Kücükpinar-Niarchos
Fraunhofer Institute for Process Engineering and Packaging, Freising, Germany

S. Amberg-Schwab
Fraunhofer Institute for Silcate Research, Würzburg, Germany

C. Boeffel
Fraunhofer Institute for Applied Polymer Research, Potsdam-Golm, Germany

Roll-to-roll technologies for the manufacture of functional films as substrates and encapsulation for flexible OLED displays and lighting devices comprising ultra-high permeation barrier performance, a transparent electrode, and device-optimized optical properties will be reviewed. Flexible small-molecule OLED devices have been prepared in roll-to-roll. The current challenges for device encapsulation will be discussed.

10.2: **High-Performance Barrier Films for Flexible Organic Display and Lighting Applications** **(2:20)**

J. Kimmel
Nokia Technologies, Tampere, Finland

J. Nikkola, L. Räsänen, P. Willberg-Keyriläinen, H. Viljanen
VTT Technical Research Centre of Finland, Espoo, Finland

M. Paajanen
VTT Technical Research Centre of Finland, Tampere, Finland

Oxygen and moisture permeation barriers are essential in manufacturing flexible OLED displays. For this purpose, intrinsically flexible barrier films need to be developed. Sol-gel/atomic-layer-deposition (ALD) films on poly(ethylene naphthalate) substrates have been investigated. The results show improved surface morphology and promising barrier properties.

10.3: An Empirical Analysis of Effect Factors for High Reliability on AMOLED Displays (2:40)

H. Kim, C. Jung, J.-Y. Kwon, S. Kim
Yonsei University, Incheon, South Korea

The luminance degradation of AMOLED displays was simulated in order to determine the driving factors for achieving high reliability for 10,000 panels under increased stress time up to 100,000 hours. Aging and non-uniformity parameters between the TFTs and OLEDs were considered in generating a model to verify yield.

10.4: Non-Contact Current Measurements for AMOLED Backplanes Using Electron-Beam-Induced Plasma Probes (3:00)

N. Saleh, E. Sterling, D. Toet
Photon Dynamics, an Orbotech Co., San Jose, CA, USA

A proprietary non-contact atmospheric electron-beam-induced plasma probe technique for current-based electrical characterization of flat-panel-display backplanes has been demonstrated for the first time. Accurate I–V curves were measured and single-line-defect sensitivity was demonstrated. This technology is expected to greatly benefit AMOLED-display fabrication yields.

BREAK (3:20–3:40)

AUTHOR INTERVIEWS (5:00–6:00)

HUMAN FACTORS AND APPLICATIONS

Tuesday, June 2 / 2:00 – 3:20 pm / Room LL20A

Chair:
Y-P. Huang, *National Chiao Tung University, Hsinchu, Taiwan, ROC*

Co-Chair:
T. Shibata, *Tokyo University of Social Welfare, Gunma, Japan*

11.1: *Invited Paper:* Brain–Display Interaction and Its Biomedical Application Using Steady-State Visual Evoked Potentials (2:00)

F-C. Lin, Y-Y. Chien, J. K. Zao, Y-P. Huang, H-P. D. Shieh
National Chiao Tung University, Hsinchu, Taiwan, ROC

Y. Wang, T-P. Jung
University of California at San Diego, La Jolla, CA, USA

By applying steady-state visual evoked potentials (SSVEPs) on a display system, a novel brain–display interaction (BDI) system was developed. This study further proposed an imperceptible flickering visual stimulus to make an SSVEP-based BDI more practical and promising for biomedical applications such as glaucoma visual-field-loss diagnosis.

11.2: Usefulness of Stereoscopic 3D Images in Elementary-School Classes (2:20)

T. Shibata, Y. Ishihara
Tokyo University of Social Welfare, Gunma, Japan

K. Satou
Toyokawa Elementary School, Tokyo, Japan
and
Tohoku University, Miyagi, Japan

The advantages of stereoscopic 3D images in education were evaluated in an elementary schools' experimental class. The results from the worksheets filled out by students revealed that educational 3D material could help students focus on details and understand three-dimensional spaces or concavo–convex shapes.

11.3: Readability Performance and Subjective Appraisal of a Curved Monitor (2:40)

K. A. Jeong, N. Na, H-J. Suk
KAIST, Daejeon, South Korea

A comparison of the usability of a curved and flat panel in terms of the readability performance and subjective judgment of preference was performed. A bendable 27-in. monitor panel was facilitated in an experiment. As a result, participants read faster on curved panels and preferred curved panels.

11.4: Study on the Saccadic-Eye-Movement Metric of Visual Fatigue Induced by 3D Displays (3:00)

B. Zou, Y. Liu, Y. Wang
Beijing Insitute of Technology, Beijing, China

The effects of 3D visual fatigue on the dynamics of saccadic eye movements will be examined. Thirteen subjects participated in a random dot stereogram (RDS) based task. The peak velocity-magnitude relationship of saccadic eye movements decreases after the experiment, and no significant differences were observed in the other saccadic parameters.

BREAK (3:20–3:40)

AUTHOR INTERVIEWS (5:00–6:00)

NOVEL DISPLAY APPLICATIONS II

Tuesday, June 2 / 2:00 – 3:00 pm / Room LL20BC

Chair:
G. Jones, *Nanoquantum Corp., Newcastle, WA, USA*

Co-Chair:
B-J. Pong, *ITRI, Hsinchu, Taiwan, ROC*

12.1: *Invited Paper:* An Overview of Vision Realistic Rendering and Vision-Correcting Displays (2:00)

B. A. Barsky
University of Caifornia at Berkeley, Berkeley, CA, USA

An overview of the optical research on vision-correcting displays will be presented. Exemplary potential applications utilizing measurements taken of actual eyes of individuals will be discussed. This technique's potential for improving the images of monitors, tablets, handheld devices, and head-up displays will also be discussed.

12.2: Flame-Resistant and Heat-Resistant Lithium-Ion Battery Used to Operate Heat-Resistant OLED (2:20)

J. Ishikawa, T. Oguni, K. Narita, A. Hitotsuyanagi, M. Yamakaji, J. Momo, T. Hirohashi, Y. Yoshitani, H. Nowatari, T. Takahashi, T. Suzuki, S. Seo, M. Takahashi, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

A flame- and heat-resistant lithium-ion battery has been developed using an ionic liquid electrolyte. This battery has been stably discharged at 100°C as well as at 0°C. A heat-resistant OLED has been stably operated at 100°C and 0°C using this battery as a power source.

12.3: WITHDRAWN

12.4: A Liquid-Crystal Biosensor for Liver Diseases (2:40)

S. He, J. Fang, S-T. Wu
University of Central Florida, Orlando, FL, USA

The urinary concentration level of bile acids is a useful indicator for the diagnosis of several liver diseases. A sensor platform is presented based on the anchoring transition of nematic liquid crystals (LCs) at the surfactant-laden LC/aqueous interfaces for the detection of bile acids in urinary solution.

BREAK (3:00–3:40)

AUTHOR INTERVIEWS (5:00–6:00)

ADVANCED DISPLAYS AND IMAGING

Tuesday, June 2 / 2:00 – 3:20 pm / Room LL20D

Chair:
H. Okumura, *Toshiba Corp., Kanagawa, Japan*

Co-Chair:
A. Bhowmik, *Intel Corp., Santa Clara, CA, USA*

13.1: WITHDRAWN

13.2: 360° Multi-Faced Tracking and Interaction Using a Panoramic Camera **(2:00)**

C. Su, Q. Zhong, C. Yu, H. Li, X. Liu
Zhejiang University, Hangzhou, China

A 360° multi-faced tracking and interaction method using a panoramic camera has been implemented, which can detect and track multiple users around a general display to achieve a better interaction experience. In the experiment, the panoramic face-tracking method was applied to a 360° 3D display system for verification.

13.3: Efficient Direct Light-Field Rendering for Autostereoscopic 3D Displays **(2:20)**

Y. J. Jeong
Samsung Electronics, Suwon, South Korea
and
University of Southern California, Los Angeles, CA, USA

H. S. Chang, Y. H. Cho, D. Nam
Samsung Electronics, Suwon, South Korea

C-C. J. Kuo
University of Southern California, Los Angeles, CA, USA

Direct light-field rendering, a novel multiview rendering process which can compose the display light-ray image without prior reconstruction of all of the multiview images, is proposed. The algorithm is of remarkably low complexity, consisting of solving linear systems of two variables.

13.4 An Electro-Optical Transfer Function with Improved Uniformity of Palette Color Distribution in Absolute Color Space **(2:40)**

S. Wen
Yuan Ze University, Chungli, Taiwan, ROC

A gamma function (electro-optical transfer function) is proposed for uniformity improvement of palette color distribution in CIE u'v' color space. It was found that the uniformity can be significantly improved by the use of a high-gamma value.

13.5L: ***Late-News Paper:* A Simple Pixel Circuit for Ultra-High-Resolution Active Matrix OLED-on-Silicon (OLEDoS) Microdisplays with Highly Uniform Luminance** **(3:00)**

S-W. Hong, B-C. Kwak, J-S. Na, S-K. Hong, O-K. Kwon
Hanyang University, Seoul, South Korea

A simple pixel circuit with a area of 3 μm × 9 μm is proposed for a high-resolution OLED-on-silicon (OLEDoS) microdisplay with highly uniform luminance. The proposed pixel circuit achieves a wide input data voltage range and suppresses the emission current deviation due to the threshold-voltage variation of the driving transistor.

BREAK **(3:10–3:40)**

AUTHOR INTERVIEWS **(5:00–6:00)**

PHOTOLUMINESCENT QUANTUM DOTS

Tuesday, June 2 / 2:00 – 3:00 pm / Room LL21EF

Chair:
J. Van Derlofske, *3M Co., Saint Paul, MN, USA*

Co-Chair:
L. Weber, *PLEXIE, New Paltz, NY, USA*

14.1: *Invited Paper:* Heavy-Metal-Free Quantum Dots for Display Applications (2:00)

N. L. Pickett, J. A. Harris, N. C. Gresty
Nanoco Technologies, Ltd., Manchester, UK

Due to their superior color quality, quantum-dot-containing displays have started to appear in the consumer marketplace. However, cadmium presents a serious threat to the environment and human health. An LCD backlight unit comprised of heavy-metal-free quantum dots, offering a consumer-friendly alternative to cadmium-based quantum-dot displays, will be reported.

14.2: *Invited Paper:* Cadmium- and Indium-Based Quantum-Dot Materials (2:20)

S. Coe-Sullivan
QD Vision, Inc., Lexington, MA, USA

Quantum dots (QDs) deliver exceptional color for LCD backlighting-unit (LCD-BLU) applications. The two most prevalent material sets, cadmium-based QDs and indium-based QDs, from both performance and environmental health and safety perspectives, will be compared and contrasted.

14.3: Quantum Dots: Optimizing LCD Systems to Achieve Rec. 2020 Color Performance (2:40)

J. Chen, S. Gensler, J. Hartlove, J. Yurek, E. Lee
Nanosys, Inc., Milpitas, CA, USA

J. Thielen, J. Van Derlofske, J. Hillis, G. Benoit, J. Tibbits, A. Lathrop
3M Co., St. Paul, MN, USA

Quantum dots are being adopted in today's LCDs, providing wide color gamut with high power efficiency. Optimized quantum-dot-enabled LCD systems are capable of delivering ultra-wide color gamuts that cover 90–95% of the Rec. 2020 specification, perceptually achieving the future color standard of UHD TV broadcasting.

BREAK (3:00–3:40)

AUTHOR INTERVIEWS (5:00–6:00)

IMAGING TECHNOLOGIES AND APPLICATIONS II

Tuesday, June 2 / 2:00 – 3:20 pm / LL21D

Chair:
Achin Bhowmik, *Intel Corp., Santa Clara, CA, USA*

I2.1: *Invited Paper:* On the Duality of Compressive Light-Field Imaging and Display (2:00)

G. Wetzstein
Stanford University, Palo Alto, CA, USA

Light-field cameras and displays are being treated distinctly in the literature. Despite significant differences in the signal-processing tools employed, there is a natural duality between compressive cameras and displays. An intuitive interpretation of the optical systems and optimization schemes of modern compressive light-field imaging systems has been has been derived.

I2.2: *Invited Paper:* Image Systems Simulation (2:20)

J. Farrell
Stanford University, Palo Alto, CA, USA

A computational software environment for modeling the complete image-processing pipeline of an imaging system, including the spectral and spatial properties of scenes, image formation, sensor capture, and display rendering will be described. The extension of the software environment to model human optics and retinal image processing will be discussed.

I2.3: *Invited Paper:* Computational Diffractive Sensing and Imaging: Using Optics for Computing and Computing for Optics (2:40)

D. G. Stork, P. R. Gill
Rambus Labs, Sunnyvale, CA, USA

Computational diffractive sensors and imagers eschew coventional lenses and curved mirrors and rely instead upon application-specific diffraction gratings affixed to CMOS image sensors. The non-conventional optical signals were processed to yield an image or some measurement of the visual scene (visual motion, point localization, barcode payload, face presence, *etc*.).

I2.4: *Invited Paper:* Rethinking the Imaging Pipeline for Energy-Efficient Privacy-Preserving Continuous Mobile Vision (3:00)

R. LiKamWa, Y. Hou, P. Y. Washington, L. Zhong
Rice University, Houston, TX, USA

Current mobile imaging chains are ill-suited for wearable vision analytics due to their high power consumption and privacy concerns. An in-imager analog vision processor that exports a low-bandwidth irreversibly encoded signal, generating vision features before analog-to-digital conversion, is proposed.

BREAK (3:20–3:40)

AUTHOR INTERVIEWS (5:00–6:00)

APPLIED VISION AND APPLICATIONS OF WEARABLE DISPLAYS

Tuesday, June 2 / 3:40 – 5:10 pm / Ballroom 220B

Chair:
J. Kimmel, *Nokia Technologies, Tampere, Finland*

Co-Chair:
J. Mulligan, *NASA Ames Research Center, Moffett Field, CA, USA*

15.1: Data Glasses for Improved User Interaction in 3D (3:40)

R. Herold, F. Weidenmüller, M. Penzel, M. Ebert
University of Applied Sciences Zwickau, Zwickau, Germany

Conventional data glasses that show stereoscopic 3D suffer from the problem that the virtual image is at a fixed distance causing vergence-accommodation mismatch in the viewer. An approach to overcome this limitation that combines integrated eye tracking with liquid lenses will be described.

15.2: High-Luminance See-Through Eyewear Display with Novel Volume Hologram Waveguide Technology (4:00)

T. Oku, K. Akutsu, M. Kuwahara, T. Yoshida, E. Kato, K. Aiki, I. Matsumura, S. Nakano, A. Machida, H. Mukawa
Sony Corp., Atsugi, Japan

High luminance (~1000 nits) and good uniformity have been achieved together in a transparent optical-waveguide-based eyewear display that employs a volume hologram to achieve out-coupling and a double-faced hologram for in-coupling in which the holograms on the faces are optimized for different wavelengths.

15.3: Optimal Monitor Gamma for Transparent Displays (4:20)

Y. Kwak, H. Ha, S. Lee
Ulsan National Institute of Science and Technology, Ulsan, South Korea

H. Kim, Y-J. Seo, B. Yang
Samsung Display Co., Ltd., Gyeonggi-do, South Korea

The preferred gamma value of a transparent OLED display was investigated in a group of human subjects. Transparency was simulated by displaying an image of the background under a range of real room-lighting levels. It was found that, as the luminance of the black point of the display increases, the preferred gamma value of the display decreases.

15.4: Weight Optimization of Near-to-Eye Light-Field Displays Based on the Human Visual System (4:40)

J. Ding, Q. Zhong, M. Liu, H. Li, X. Liu
Zhejiang University, Hangzhou, China

The central vision parameters of the human eye were utilized to design an optical weight matrix which indicates perceptual significance of the rays, making optimization results closer to ground truth. In this design, multiple LCD layers were employed to optimize near-to-eye display imaging, allowing both vertical and horizontLateal parallax.

15.5L: *Late-News Paper*: SVGA Full-Color Bidirectional OLED Microdisplay (5:00)

P. Wartenberg, B. Richter, S. Brenner, M. Thomschke, K. Fehse, J. Baumgarten, U. Vogel
Fraunhofer Institute for Organic Electronics, Dresden, Germany

A new bidirectional OLED microdisplay with increased SVGA resolution will be described. A bidirectional microdisplay means that the active area comprises an OLED display with an additional nested image sensor. The latest results from the labs as well as from the first results in the field of capturing an eye scene will be derscribed.

AUTHOR INTERVIEWS (5:00–6:00)

OLED DEPOSITION AND PATTERNING

Tuesday, June 2 / 3:40 – 5:00 pm / Ballroom 220C

Chair:
G. Gibson, *FAS Holdings Group, Dallas, TX, USA*

Co-Chair:
A. Hornell, *EuroLCDs SIA, Falum, Sweden*

16.1: *Invited Paper:* Measurement Methods for Quality Control of Coating Uniformity in Solution-Processed OLED Displays (3:40)

I. Parker, A. Johnson, K. Frischknecht, M. Stainer
DuPont Displays, Santa Barbara, CA, USA

Techniques and metrics for measuring and quantifying the uniformity of organic films used in solution-based OLED fabrication will be described. Measurements of the uniformity of the physical parameters (such as thickness and topographic profile, *etc*.) will be described as well as the uniformity in the final luminance of the display.

16.2: *Invited Paper:* Electroforming Technology for Manufacturing Thin Metal Masks with Very Small Apertures for OLED Display Manufacturing (4:00)

S. N. Kumar, R. John, S. Lauer, W. Little
Advantech US, Inc., Pittsburgh, PA, USA

B. Daul
Allen Woods and Associates, Arlington Heights, IL, USA

The power of electroforming to faithfully capture and replicate metal features down to the atomic scale has been elegantly exploited to consistently produce OLED deposition masks with high yields. By using a unique combination of photolithography and electroforming, large-area 10–15-μm-thick nickel masks with apertures as small as 15 μm have been fabricated. This manufacturing technology is targeted to provide OLED masks for future generations of ultra-high-resolution display manufacturing.

16.3: True-Color 640-ppi OLED Arrays Patterned by CA i-line Photolithography (4:20)

P. E. Malinowski, T. H. Ke, T-Y. Chang, P. Gokhale, S. Steudel
imec, Leuven, Belgium

A. Nakamura, D. Janssen
FUJIFILM Electronic Materials N.V., Zwijndrecht, Belgium

Y. Kamochi, I. Koyama, Y. Iwai
FUJIFILM Corp., Shizuoka, Japan

P. Heremans
imec, Leuven, Belgium
and
Holst Centre, Eindhoven, The Netherlands

Side-by-side patterning of red, green, and blue OLEDs has been demonstrated. To achieve 640-ppi arrays with a 20-μm subpixel pitch, a chemically amplified i-line photoresist system with submicron resolution was used. These results show the feasibility of obtaining full-color displays with ultra-high resolution.

16.4: Fully R2R-Processed Flexible OLEDs for Lighting (4:40)

T. Minakata, M. Tanamura, Y. Mitamura, M. Imashiro, A. Horiguchi, A. Sugimoto, M. Yamashita, K. Ujiiye, S. Sunahiro, Y. Yada, N. Ibaraki, H. Tomiyasu
CEREBA, Ibaraki, Japan

Flexible OLEDs on continuous plastic film have been fabricated using full R2R processes, including depositions of gas-barrier layers, electrodes, layered-organic semiconductors, and lamination encapsulation. The OLEDs exhibit excellent stability and performance comparable to that of OLEDs on glass. The correlation between the barrier performance and OLED stability has been confirmed.

AUTHOR INTERVIEWS (5:00–6:00)

COLOR APPEARANCE OF DISPLAYS

Tuesday, June 2 / 3:40 – 5:00 pm / Room LL20A

Chair:
M. Ayama, *Utsunomiya University, Utsunomiya, Japan*

Co-Chair:
J. Gille, *Qualcomm, Santa Clara, CA, USA*

17.1: *Invited Paper:* Closing in on Rec. 2020: How Close Is Close Enough? (3:40)

J. Hillis, J. Thielen, J. van Derlofske, J. Tibbits, G. Benoit
3M Co., St. Paul, MN, USA

How close do color primaries have to be to the ITU Rec. 2020 recommendations to qualify as meeting this standard? To address this question, color-discrimination thresholds for scenes rendered with simulated primary shifts were measured, and statistics of natural scenes were examined. Tolerance guidelines, based on the investigation, were formed.

17.2: KANSEI Evaluation of Color Images Presented in Color Gamuts of Different Blue Primaries (4:00)

M. Ayama, T. Fuseda, T. Hamano, T. Ishikawa
Utsunomiya University, Utsunomiya, Japan

To investigate the best blue primary for color displays from a KANSEI-evaluation point of view, an evaluation experiment using the semantic differential method was carried out using four monochromatic blue primaries. As a result, a 470-nm primary showed the best performance among them. Results were compared with color-naming data.

17.3: D-CIELab: A Color Metric for Dichromatic Observers (4:20)

H. Jiang, B. A. Wandell, J. E. Farrell
Stanford University, Stanford, CA, USA

A color metric for dichromatic subjects is proposed. D-CIELab maps the two cone-type absorptions in dichromats to the three cone-type absorptions in trichromats, and then applies the traditional CIELab color metric. The accuracy by predicting color discrimination thresholds for three types of dichromatic observers was evaluated.

17.4: Image-Quality Assessment of Large UHD LCDs Using Quantum-Dot and RGBW Technologies (4:40)

C-W. Hsu, J-Y. Huang, H-S. Chen, P-L. Sun
National Taiwan University of Science and Technology, Taipei, Taiwan, ROC

R. Luo
University of Leeds, Harrogate, UK

State-of-the-art RGBW and quantum-dot LCD technologies were evaluated both objectively and subjectively. Results show that the new technologies improve the image quality of LCDs in several ways. The known drawbacks of RGBW LCDs can be overcome by a color-recovery algorithm; uneven gamut expansion in quantum-dot LCDs is acceptable to observers.

AUTHOR INTERVIEWS (5:00–6:00)

APPLICATIONS OF FLEXIBLE-DISPLAY TECHNOLOGY

Tuesday, June 2 / 3:40 – 5:00 pm / Room LL20BC

Chair:
J. Jang, *Kyung Hee University, Seoul, South Korea*

Co-Chair:
L. Palmateer, *Rovi Corp., San Francisco, CA, USA*

18.1: *Invited Paper:* Flexibility Improvement of Foldable AMOLED with Touch Panel (3:40)

C-C. Lee, J-C. Ho, G. Chen, M-H. Yeh, J. Chen
ITRI, Hsinchu, Taiwan, ROC

Flexible Universal Plane (FlexUP) technology using a polyimide substrate and a novel debonding method was demonstrated with LTPS TFTs and OLEDs for foldable AMOLED displays. Several approaches were carried out to overcome issues of failure in the folding region. AMOLEDs with touch-panel modules at a folding radius of 5 mm will be discussed.

18.2 *Invited Paper:* Flexible eWriter Technology and Applications (4:00)

A. Khan, E. Montbach
Kent Displays, Inc., Kent, OH, USA

Reflective cholesteric-LCD-based flexible eWriters are redefining the writing space in the digital world. Flexible eWriters have been rapidly penetrating the consumer marketplace and now are poised to add new and unique applications in consumer, education, healthcare, and other fields. These applications and eWriter technology will be discussed in detail.

18.3: An 8.67-in. Foldable OLED Display with an In-cell Touch Sensor (4:20)

K. Watanabe, Y. Iwaki, Y. Uchida, D. Nakamura, H. Ikeda, H. Miyake, Y. Hirakata, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

M. Katayama, T. Cho
Advanced Film Device, Inc., Tochigi, Japan

An 8.67-in. foldable OLED display with an in-cell touch sensor, where metal-mesh sensor electrodes were formed in a counter substrate of the display, has been fabricated. The OLED display with a radius of curvature of 5 mm demonstrates normal operation after one-million folding operations.

18.4: A 13.3-in. 8K × 4K 664-ppi Foldable OLED Display Using Crystalline-Oxide-Semiconductor FETs (4:40)

K. Takahashi, T. Sato, R. Yamamoto, H. Shishido, T. Isa, S. Eguchi, H. Miyake, Y. Hirakata, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

R. Sato, H. Matsumoto, N. Yamazaki
Advanced Film Device, Inc., Tochigi, Japan

A prototype 13.3-in. 8K × 4K 664-ppi foldable AMOLED display has been developed. The C-axis-aligned crystalline In-Ga-Zn-O (CAAC-IGZO) FETs with 1.5-μm design were used in the backplane with each pixel consisting of 3 FETs and 1 capacitor. External circuits were used to control the pixel current.

AUTHOR INTERVIEWS (5:00–6:00)

IMAGE PROCESSING FOR DISPLAY ENHANCEMENT

Tuesday, June 2 / 3:40 – 4:40 pm / Room LL20D

Chair:
S. W. Lee, *Kyung Hee University, Seoul, South Korea*

Co-Chair:
Y. H. Tai, *National Chiao Tung University, Hsinchu, Taiwan, ROC*

19.1: OLED Power-Reduction Algorithm Using Gray-Level Mapping Conversion (3:40)

Y. D. Ahn, S-J. Kang
Dong-A University, Busan, South Korea

A new OLED power-reduction algorithm will be presented. It computes the optimal power-reduction level by modifying the gray-level mapping curve between input and output signals based on the image-quality metric. Therefore, it does not need any circuit modification or additional circuits for the power reduction.

19.2: *Distinguished Student Paper:* Compensation of OLED I–V Drift for Suppressing Image Sticking in a Digital AMOLED Display Module (4:00)

P. Volkert, C. Xu
Saarland University, Saarbruecken, Germany

A novel method for compensating image-sticking artifacts in a digitally driven AMOLED display will be presented. It analyzes the non-uniform pixel current distribution. With a specific algorithm, the input image data are accordingly manipulated so that image sticking is effectively suppressed. First evaluation results confirm the feasibility of compensation of OLED I–V drift. With this, digitally driven AMOLED displays may reach a lifetime similar to that of conventional analog technology.

19.3: MOVED TO P.185

19.4: Denoising for Polarizer-Free Imaging of a Liquid-Crystal Lens (4:20)

C. Cui, R. Bao, S. Yu, H. Mai, M. Ye
SuperD Co., Ltd., Shenzhen, China

Polarizer-free imaging (PFI) methods have been proposed to address the problem of polarizer dependency of a liquid-crystal (LC) lens. PFI can generate images with high contrast, but will also raise the image noise. A denoising method specially designed for the images generated by PFI, namely PFI denoising, will be presented. The salient noises and image textures can be accurately detected. Different denoising filters are then applied to different image regions. Good performance of PFI denoising was demonstrated by experimental results.

AUTHOR INTERVIEWS (5:00–6:00)

ELECTROLUMINESCENT QUANTUM DOTS

Tuesday, June 2 / 3:40 - 5:00 pm / Room LL21EF

Chair:
M. Nakamoto, *Shizuoka University, Hamamatsu, Japan*

Co-Chair:
Y. S. Kim, *Hongik University, Seoul, South Korea*

20.1: ***Invited Paper:* Red and Green Quantum-Dot-Based LEDs Demonstrating Excellent Color Coordinates (3:40)**

P. Kathirgamanathan, L. Bushby, M. Kumaraverl, S. Ravichandran, S. Surendrakumar,
Brunel University London, Uxbridge, UK

Two red LED devices using quantum-dot emissive layers demonstrating maximum current efficiencies of 1.7 and 3.4 cd/A were achieved with LiQ and ZnO as the electron-injecting layer, respectively, while a green device achieved 2.4 cd/A. All devices displayed excellent color coordinates and lifetimes up to 1000 hours at 200 cd/m^2.

20.2: Ultra-Bright Highly Efficient Low-Roll-Off Inverted Quantum-Dot Light-Emitting Devices (4:00)

Y. Dong
QD Vision, Inc., Lexington, MA, USA
and
University of Central Florida, Orlando, FL, USA

J-M. Caruge, Z. Zhou, C. Hamilton, J. Ho, M. Stevenson, G. Liu, P. T. Kazlas, J. Steckel, S. Coe-Sullivan
QD Vision, Inc., Lexington, MA, USA

Z. Popovic
QD Vision, Inc., Lexington, MA, USA
and
McMaster University, Hamilton, Ontario, Canada

V. Bulovic, M. Bawendi
Massachusetts Institute of Technology, Cambridge, MA, USA

A low-roll-off inverted quantum-dot-based red-light-emitting device (QLED) using solution-processed zinc-oxide nanoparticles and cesium carbonate films as the electron-injection and hole-blocking layers, respectively, is reported. A record luminance of 165,000 cd/m^2 was obtained at a current density of 1000 mA/cm^2 with a low driving voltage of 5.8 V with CIE coordinates of (0.69, 0.31).

20.3: Optimizing the Balance of Holes and Electrons in Inverted Quantum-Dot LEDs by Inserting an Electron-Transporting Barrier Layer **(4:20)**

Y. Jiang, H. Tang, H-S. Kwok
Hong Kong University of Science & Technology, Kowloon, Hong Kong

S. Chen
Hong Kong University of Science & Technology, Kowloon, Hong Kong
and
South University of Science and Technology of China, Shenzhen, China

The hole–electron balance of quantum-dot LEDs (QDLEDs) was tuned to enhance its efficiency. This hole–electron balance optimization was realized by inserting a thin barrier layer in the electron-transport layer. Although the current density was slightly sacrificed by the barrier layer, the charge balance was improved, resulting in a 123% efficiency enhancement.

20.4: *Distinguished Student Paper:* Quantum-Dot LEDs with Charge-Generation Layers **(4:40)**

H-M. Kim, J-G. Kim, J-E. Lee, J. Jang
Kyung Hee University, Seoul, South Korea

Inverted quantum-dot LEDs (QLEDs) were demonstrated by using solution-processed charge-generation layers (CGLs). The CGL-based green, yellow, and red QLEDs demonstrated a current efficiency of 22.1, 14.5, and 6.1 cd/A, respectively. Also, it can be applied to various substrates which have different work functions.

AUTHOR INTERVIEWS **(5:00–6:00)**

IMAGING TECHNOLOGIES AND APPLICATIONS III

Tuesday, June 2 / 3:40 – 5:00 pm / LL21D

Chair:
A. Bhowmik, *Intel Corp., Santa Clara, CA, USA*

I3.1: *Invited Paper:* The Importance of Focus Cues in 3D Displays (3:40)

M. Banks
University of California at Berkeley, Berkeley, CA, USA

Stereoscopic displays present different images to each eye and thereby create a compelling three-dimensional (3D) sensation. In a series of experiments, how focus cues affect 3D shape perception, visual performance, and, most importantly, visual comfort have been investigated. Guidelines for minimizing these adverse effects are offered, and foreseeable display technologies that may eventually eliminate them altogether will be described.

I3.2: *Invited Paper:* A Multiview 3D Holochat System (4:00)

S. Y. Hu, J. Baldwin
Antimatter Research Inc., Palo Alto, CA, USA

A. Niederberger, D. Fattal
LEIA, Inc., Menlo Park, CA, USA

A lightweight holographic video chat system composed of a multi-camera system streaming live content onto a LEIA 64-view full-parallax 3D display will be presented. The system auto-calibrates the camera views to a simple target and is suitable for real-time communication over a peer-to-peer network. The zoom level and focal (zero-disparity) plane location of the system can be adjusted in the software, and the depth of field can be adjusted by simple modification of the camera baseline.

I3.3: *Invited Paper:* Immersive Virtual Reality on the Desktop: System Integration of a Stereoscopic Display and Image-Based Tracking System (4:20)

D. Chavez
zSpace, Inc., Sunnyvale, CA, USA

Essential elements of a virtual-reality system include a stereoscopic display that can deliver high-quality projections based on user head position, as well as some form of interaction. The delivery of a convincing and comfortable virtual-reality experience requires a minimal level of fidelity in tracking and display technology, which has only recently been achievable. The demands of the imaging system in the realization of a virtual-reality system will be discussed in the context of overall system comfort, performance, and value.

I3.4: *Invited Paper:* Delivering High-Dynamic-Range Video to Consumer Devices (4:40)

J. L. Helman
MovieLabs, San Francisco, CA, USA

The implementation of high dynamic range in the coming generation of studio home-entertainment video formats and the technical considerations that led to the ad option of a perceptually tuned electro-optical transfer function for high-dynamic-range mastering and distribution will be discussed. The value of display-referred systems based on reference rendering versus historical scene-referred systems based on relative luminance and camera characterization will explained.

AUTHOR INTERVIEWS (5:00–6:00)

Session 21 **Display Manufacturing**

OXIDE-TFT MANUFACTURING

Wednesday, June 3 / 9:00 – 10:20 am / Ballroom 220B

Chair:
T. Arai, *JOLED, Inc., Kanagawa, Japan*

Co-Chair:
T. Xiao, *CBRITE, Inc., Goleta, CA, USA*

21.1: *Invited Paper:* High-Throughput MOTFT with Organic Etch Stopper and SiN_x Gate Insulator (9:00)

G. Yu, C-L. Shieh, T. Xiao, K. Lee, F. Foong, G. Wang, J. Musolf, Z. Chen, F. Chang, K. Ottosson, J-W. Park, J. Chen, C-Y. Li
CBRITE, Inc., Goleta, CA, USA

It is highly desirable to develop an oxide-TFT process that requires minimal equipment upgrade and capital investment to the existing a-Si TFT fabs. High-performance oxide TFTs with SiN_x GI and organic etch stoppers meeting TFT-LCD and AMOLED specifications have been developed using the same mask counts as with the BCE process.

21.2: Highly Reliable Oxide TFT with Novel Oxide Passivation Layers by All-Printing Processes (9:20)

S. Matsumoto, R. Saotome, Y. Hirano, Y. Sone, S. Arae, M. Kusayanagi, Y. Nakamura, N. Ueda, K. Yamada
Ricoh Co., Ltd., Yokohama, Japan

Highly reliable oxide-TFT arrays have been developed by using an all-printed maskless process from gate to passivation layers with 100-ppi RGB resolution. The threshold-voltage shifts under positive and negative bias temperature stress at 50°C after 100,000 sec were less than 0.8 and 0.3 V, respectively.

21.3: A Novel 5-Mask Etch Stopper Pixel Structure with a Short-Channel Oxide-Semiconductor TFT (9:40)

J-Y. Yang, S-H. Jung, C-S. Woo, J-Y. Lee, M. Jun, I-B. Kang
LG Display Co., Ltd., Gyeonggi-do, South Korea

J-H. Park
Korea University, Seoul, South Korea

A new 5-mask etch-stopper (ES) pixel structure with a 5-μm channel length, which eliminates two mask steps compared to the conventional 7-mask process, is introduced. Excellent characteristics for the 5-μm channel-length TFTs were obtained, and a 9.7-in. QXGA resolution panel was realized by using the new structure.

21.4: Deposition Conditions and HRTEM Characterization of CAAC IGZO (10:00)

D. M. Lynch, B. Zhu, B. D. A. Levin, D. A. Muller, D. G. Ast, M. O. Thompson
Cornell University, Ithaca, NY, USA

R. G. Greene
Corning Incorporated, Corning, NY, USA

CAAC IGZO promises improved TFT device stability and off-current. Conditions for RF sputter deposition of CAAC were quantified by using X-ray diffraction and high-resolution TEM. Formation occurs over a broad range of deposition parameters with a grain alignment of ±9°. At higher deposition temperatures, alignment is gradually lost as polycrystalline films are developed.

BREAK (10:20–10:40)

AUTHOR INTERVIEWS (5:00–6:00)

OLED MATERIALS I

Wednesday, June 3 / 9:00 – 10:20 am / Ballroom 220C

Chair:
S. Zimmermann, *Novaled AG, Dresden, Germany*

Co-Chair:
Y. Kijima, *JOLED, Inc., Kanagawa, Japan*

22.1: *Invited Paper:* New Fluorescent Blue-Host Materials for Achieving Low Voltage in OLEDs (9:00)

K. Okinaka, T. Ikeda, M. Mitsuya, H. Saito, H. Ito, M. Kawamura, H. Kuma
Idemitsu Kosan Co., Ltd., Chiba, Japan

New fluorescent blue-host materials for low-voltage OLEDs were developed. A new blue-host molecular structure was designed to improve both the electron and hole mobility and optimize the ionization potential. An EQE of 9.5% and a lifetime (LT95) of 420 hours with a low voltage of 3.2 V at 10 mA/cm^2 was achieved.

22.2: *Invited Paper:* New HBL Development for High Efficiency and Long Lifetime of Blue OLED Device (9:20)

T. H. Kim, H. C. Park, C. J. Lee, Y. B. Kim, H. M. Kim
Doosan Corp., Gyeonggi-do, South Korea

There are several methods to achieve high-efficiency blue OLED devices. One activity involved the development and control of the electron-related layer. DS-ET1 material showed a high efficiency (>10%) and long lifetime compared to when it was not used between the emitting and electron-transport layer.

22.3: CbzTAZ Hosts in Blue Organic Light-Emitting Devices Demonstrate a High Current Efficiency of More than 50 cd/A (9:40)

T-L. Chiu, S-R. Chen
Yuan Ze University, Taoyuan, Taiwan, ROC

Y-S. Hsieh, M-K. Leung, P-S. Wang, J-H. Lee
National Taiwan University, Taipei, Taiwan, ROC

H-C. Ho
ITRI, Hsinchu, Taiwan, ROC

Two novel bipolar carbzol-triazole derivatives were synthesized by conjugating hole-transport moiety carbazole (Cbz) with electron-transport moiety triazole (TAZ) to achieve bipolar molecules. As hosts inside a blue phosphorescence OLED with blue-emitter FIrpic, high current efficiencies of 52.1 and 52.2 cd/A and an EQE of 24.4 and 24%, respectively, were demonstrated.

22.4: Synthesis of Host Materials for Blue Phosphorescent OLEDs with High Efficiency and Low Driving Voltage **(10:00)**

S. Y. Byeon, S. H. Hwang, O. Y. Kim
Dankook University, Yongin, South Korea

J. Y. Lee
Sungkyunkwan University, Gyeonggi-do, South Korea

Blue host materials for PHOLEDs were synthesized with carbazole as a donor moiety and α-carboline as an accepter moiety to assign bipolar property. The carbazole-carboline core was modified with benzonitrile, phenyl, and carbazole to control charge-transport properties. EQEs of 23.4%, 19.6%, and 17.4% were obtained using the new host materials.

BREAK **(10:20–10:40)**

AUTHOR INTERVIEWS **(5:00–6:00)**

e-PAPER

Wednesday, June 3 / 9:00 – 10:20 am / Room LL20A

Chair:
C-Y. Chen, *Jiangsu Hecheng Display Technology, Nanjing, China*

Co-Chair:
M. Omodani, *Tokai University, Hiratsuka, Japan*

23.1: *Invited Paper:* Colloidal Dispersion Materials for Electrophoretic Displays and Beyond (9:00)

M. Goulding, N. Smith, L. Farrand, C. Topping, S. Norman, A. Sauter, G. Cooper
Merck Chemicals, Ltd., Southampton, UK

H. S. Jin, J. Y. Lee
Merck Advanced Technologies, Gyeonngi-do, South Korea

Electrophoretic-based technology is a leading option for black-and-white reflective display media, notably for e-Readers. There is great future potential to extend electrophoretic and other colloidal-dispersion-based displays into a range of new application fields, such as digital signage, wearable displays, and “smart windows.” These new applications require novel particle and fluid concepts which present many materials design challenges, especially bright color, image stability, and ultra-low power consumption. The state of the art and new materials for a range of pixel architectures will be discussed.

23.2: Predicting the Viewing-Direction Performance of e-Paper Displays with a Front Light under Ambient Lighting Conditions (9:20)

D. Hertel
E Ink Corp., Billerica, MA, USA

J. Penczek
Luminex Technologies, Boulder, CO, USA

Integrated lighting units (ILU) extend the usage of reflective e-Paper displays (EPD) into low-light environments. IEC-standard methodology for predicting ambient viewing-direction performance from display measurements and illumination models was applied to EPD with operating ILU, showing consistent performance over the full range of viewing directions and illumination conditions.

23.3: Flexible Semitransparent eWriter Displays (9:40)

C. Braganza, E. Montbach, A. Khan, J. W. Doane
Kent Displays, Inc., Kent, OH, USA

Flexible semi-transparent cholesteric liquid-crystal eWriters have been developed. It was found that the absorption of the opaque layer used to enhance the contrast of the display does not need to be high in order to allow for a new use of the eWriter as a tracing device, among other uses.

23.4L: ***Late-News Paper:*** **Stretchable and Flexible Electrophoretic Image Display** **(10:00)**

T. Sawada, T. Abe, S. Yoshioka
Panasonic Corp., Osaka, Japan

T. Kitamura, T. Nakamura, N. Kobayashi
Chiba University, Chiba, Japan

A stretchable and flexible electrophoretic image display device using stretchable resin polymer film with a carbon-nanotube conductive layer has been demonstrated. The film offers good electrical insulation, high heat resistance, low elasticity, and good elastic recovery.

BREAK **(10:20–10:40)**

AUTHOR INTERVIEWS **(5:00–6:00)**

3D LIGHT-FIELD DISPLAYS AND IMAGING

Wednesday, June 3 / 9:00 – 10:20 am / Room LL20BC

Chair:
N. Balram, *Ricoh Innovations Corp., Menlo Park, CA, USA*

Co-Chair:
K. Käläntär, *Global Optical Solutions, Tokyo, Japan*

24.1: ***Invited Paper:*** **Design Principles for Light-Field Image Capture and Display (9:00)**

K. Berkner, I. Tošić, W. Wu, L. Meng, N. Bedard, N. Balram
Ricoh Innovations Corp., Menlo Park, CA, USA

The high-dimensional design space of light-field systems imposes new challenges for end-to-end system design and evaluation. The design principles for task-specific light-field camera systems will be discussed and extended to the design of personal light-field displays.

24.2: Real-Time Rendering 360° Floating Light-Field 3D Display (9:20)

C. Su, Q. Zhong, L. Xu, H. Li, X. Liu
Zhejiang University, Hangzhou, China

By using a light-field reconstruction technique, the real-time rendering of a floating colorful three-dimensional image has been implemented. A high-frame-rate projector, rotating transmitted directional diffuser, and high-speed data processing and transmission module were utilized to create the light field of animated 3D scenes with higher light-use efficiency.

24.3: Adaptive Optimization of Rendering for Multi-Projector-Type Light-Field Display (9:40)

Q. Zhong, H. Li, X. Liu, B. Chen, L. Xu
Zhejiang University, Hangzhou, China

Adaptive optimization of the rendering process for a multi-projection-type light-field display is proposed to smoothen the distortion of the scene far away from the screen while maintaining the sharpness of the scene near the screen. This enhances the overall display quality of the scene for a large depth range.

24.4: ***Distinguished Student Paper:*** **Floating 3D Image for High-Resolution Portable Device Using Integral Photography Theory (10:00)**

C-W. Shih, J-H. Wang, C-H. Ting, Y-P. Huang
National Chiao Tung University, Hsinchu, Taiwan, ROC

A floating 3D image was created and displayed at an oblique viewing angle on a high-resolution smartphone display, using integral photography theory. The repeated image overlapping problem was solved by adjusting the receiving angle.

BREAK (10:20–10:40)

AUTHOR INTERVIEWS (5:00–6:00)

LASER-PHOSPHOR LIGHT SOURCES FOR PROJECTORS

Wednesday, June 3 / 9:00 – 10:20 am / Room LL20D

Chair:
D. Eccles, *Rockwell Collins, Salt Lake City, UT, USA*

Co-Chair:
F. J. Kahn, *Kahn International, Inc., Palo Alto, CA, USA*

25.1: The Progress in International Safety Standards for Laser-Illuminated Projection Systems (9:00)

G. Niven
Necsel, Milpitas, CA, USA

P. Ludé
RealD, Beverly Hills, CA, USA

J. Daem
Barco, Kuurne, Belgium

H. Hoffman
LIPA, San Jose, CA, USA

International safety standards for lasers are detailed in the International Electrotechnical Commission (IEC) under the IEC 60825-1:2014 standard. In May 2014, an update to this standard was released and excluded coverage of finished products which contain an embedded laser used as a broadband light source, such as laser-illuminated projector systems (LIP Systems). The tests, conditions, and adoption into regulation of the new edition will be presented from the perspective of the Laser Illuminated Projection Association (LIPA).

25.2: High-Brightness Solid-State Light Source for 4K Ultra-Short-Throw Projector (9:20)

Y. Maeda, Y. Imai, M. Ishige, I. Kobayashi, K. Murakami, T. Mochizuki, T. Nomura, H. Kikuchi
Sony Corp., Kanagawa, Japan

A solid-state light source composed of a blue laser diode and a reflective phosphor wheel has achieved 40,000 lm. The efficiency has been increased by reducing the effects of temperature quenching and brightness saturation and by optimizing the conditions of the fluorescent material. The result is more brightness than has been conventionally achieved.

25.3: A Miniature Laser-Driven Visible-Light Source (9:40)

N. Abu-Ageel
Ain University of Science and Technology, Al Ain, UAE

A. Abu-Ageel
Michigan State University, East Lansing, MI, USA

A compact light source uses low-cost commercially available lasers to generate visible light for étendue-limited applications. A phosphor-based optical cavity converts 405/445-nm laser light into speckle-free red, green, blue, or white light at a selected étendue. Theoretical and experimental results will be reported.

25.4: Laser-Excited Phosphor/Dye in Liquid for High-Power Digital Projectors (10:00)

K. Li
Wavien, Inc., Valencia, CA, USA

A blue-emitting laser diode excites a phosphor suspended in a dye containing circulating liquid. The liquid provides effective heat sinking. This combination could enable very high projector outputs, over 30,000 lm for standard digital cinema and 60,000 lm for 3D digital cinema.

BREAK (10:20–10:40)

AUTHOR INTERVIEWS (5:00–6:00)

MICRO LED DISPLAYS AND ELECTROLUMINESCENCE

Wednesday, June 3 / 9:00 – 10:00 am / Room LL21EF

Chair:
P. Kathirgamanathan, *Brunel University London, Uxbridge, UK*

Co-Chair:
Q. Yan, *Sichuan COC Display Devices Co., Ltd., Chengdu, China*

26.1: *Invited Paper:* Quantum Photonic Imager (QPI): A Novel Display Technology that Enables More than 3D Applications (9:00)

H. S. El-Ghoroury, C-L. Chuang, Z Y. Alpaslan
Ostendo Technologies, Inc., Carlsbad, CA, USA

A quantum photonic imager (QPI) is a new generation of spatial light modulator (SLM) that combines the light source and light modulation at the pixel level, thus eliminating the waste in most existing SLMs where light is separately generated and modulated. The QPI architecture and its 3D application and beyond will be explained.

26.2: *Invited Paper:* High-Brightness Emissive Microdisplay by Integration of III-V LEDs with Thin-Film Silicon Transistors (9:20)

B. R. Tull, Z. Basaran, D. Gidony, V. W. Lee
Lumiode, Inc., New York, NY, USA

A. B. Limanov, J. S. Im, I. Kymissis
Columbia University, New York, NY, USA

As augmented-reality and wearable technology increase in popularity, there is a demand for truly see-through displays. For highly transparent optical systems, a high-brightness display is required in order to achieve high-quality images. Thin-film poly-Si transistors were integrated with conventional III-V LED materials to meet the brightness and efficiency demands.

26.3: High-Resolution Laser-Etched Circuitry for ACEL Lamps (9:40)

J. Silver, P. G. Harris, G. Fern
Brunel University, Uxbridge, Middlesex, UK

W. Perrie, Y. Jin
Liverpool University, Liverpool, UK

Laser ablation has been used to etch electrode circuitry onto low-cost aluminium-coated polymer sheets for ACEL lamps. It is possible to etch lines of only 20 µm in width at high speed using this approach. Interdigitated electrode ACELs have been produced, and their performance has been characterized.

BREAK (10:00–10:40)

AUTHOR INTERVIEWS (5:00–6:00)

ADVANCED MANUFACTURING TECHNOLOGIES

Wednesday, June 3 / 10:40 am – 12:10 pm / Ballroom 220B

Chair:
J. Winkler, *PLANSEE SE, Reutte, Austria*

Co-Chair:
W. L. Liau, *AU Optronics Corp., Hsinchu, Taiwan, ROC*

27.1: *Invited Paper:* Opening the Door to New LCD Applications via Polymer Walls (10:40)

N. Greinert, C. Schoenefeld, P. Suess, M. Bremer, M. Klasen-Memmer, J. Canisius
Merck KGaA, Darmstadt, Germany

By using certain combinations of liquid-crystal mixtures and polymer precursors, polymer walls can be created within the LC layer of a display via the photolithographic process. As a result, the polymer walls enhance the functionality of the display in respect to applications such as freeform, curved, or unbreakable.

27.2 : The Fabrication of Novel PSVA Pixel Structure by GTM Technology (11:00)

Z. Deng, F. Zhao, C.-Y. Chiu, Y. Wu, Q. Gan, C-Y. Lee, C-C. Lo
Shenzhen China Star Optoelectronics Technology Co., Ltd., Guangdong, China

A. Lien
TCL Corporate Research, Guangdong, China

A new polymer-stabilized vertical-alignment (PSVA) pixel structure has been fabricated by using gray-tone mask (GTM) technology where one mask can be reduced, thus simplifying the process. The influence of process parameters on groove depth has been studied in this work.

27.3: Development of Highly Durable Achromatic Polarizer with High Heat and Moisture Resistance (11:20)

N. Mochizuki
Nippon Kayaku Co., Ltd., Tokyo, Japan

T. Ishinabe, H. Fujikake
Tohoku University, Sendai, Japan

D. Fujiwara, D. Nakamura, N. Koma
Polatechno Co., Ltd., Joetsu, Japan

A monochrome-type LCD with high paper-white reflectance was realized by developing novel polarizers with dichromatic azo pigments. These polarizers exhibit no wavelength dependency and high environmental stability.

27.4: Selective Laser-Annealing System for LTPS-TFT Panels (11:40)

S. Sugimoto, T. Kiguchi, M. Hatanaka, M. Mizumura, K. Kajiyama
V Technology Co., Ltd., Kanagawa, Japan

J. Kido
Yamagata University, Yamagata, Japan

A new laser-annealing system for LTPS process was developed, which can selectively anneal only the TFT channel area by irradiating a-Si with a laser beam using a microlens located at the TFT array and a highly accurate optical exposure alignment system. Process throughput is increased, stitching issues overcome, and substrate sizes larger than G6 are accessible.

27.5L: *Late-News Paper:* Hybrid Printing of High-Resolution Metal Mesh as a Transparent Conductor for Touch Panels and OLED Displays (12:00)

Z. Cui
Chinese Academy of Sciences, Suzhou, China

Y. Gao
Nanchang O-Film Display Technology Co., Ltd., Nanchang, China

A hybrid printing technique has been developed to manufacture high-resolution metal mesh as flexible transparent conductors. The metal mesh is made by embedding nanosilver inks into trenches. A much finer metal mesh (<3 μm) with much higher conductivity (<1 Ω/sq.) has been achieved while still maintaining high transparency (>88%). The transparent conductor sheets can be roll-to-roll printed and has been successfully implemented in high-volume manufacturing of touch panels (half-million per month) as well as adapted to making flexible OLED displays.

LUNCH (12:10–2:00)

AUTHOR INTERVIEWS (5:00–6:00)

OLED MATERIALS II

Wednesday, June 3 / 10:40 am – 12:00 pm / Ballroom 220C

Chair:
Y. Kijima, *JOLED, Inc., Kanagawa, Japan*

Co-Chair:
C. H. (Fred) Chen, *Guangdong Aglaia Optoelectronic Materials Co., Ltd., Foshan, China*

28.1: *Invited Paper:* Triplet-Energy Control of PAHs by Heteroatom Incorporation for Development of Efficient Materials for PHOLEDs (10:40)

T. Hatakeyama, S. Nakatsuka, H. Hirai, K. Nakajima
Kwansei Gakuin University, Hyogo, Japan
and
Japan Science and Technology Agency, Tokyo, Japan

T. Ikuta, K. Shiren, J. Ni
JNC Petrochemical Corp., Chiba, Japan

S. Hashimoto, M. Nakamura
Kyoto University, Kyoto, Japan

The triplet-energy control of polycyclic aromatic hydrocarbons (PAHs) was achieved by replacing the CC unit with a BN unit. The PAH containing the BN unit, 4b-aza-12b-boradibenzo[g,p]chrysene, demonstrated a large ET value and ambipolar carrier-transport abilities and enables the fabrication of phosphorescent OLEDs with high performance.

28.2: *Invited Paper:* Reverse Intersystem Crossing from High-Lying Triplet Energy Levels to an Excited Singlet: A "Hot Excition" Path for OLEDs (11:00)

D. Hu, Y. Ma
South China University of Technology, Guangzhou, China

L. Yao, B. Yang
Jilin University, Changchun, China

The photophysical process of reverse intersystem crossing (RISC) from upper triplet levels to singlet manifold was innovatively utilized to enhance the efficiency of fluorescent OLEDs (FOLEDs) by simultaneously harvesting singlet and triplet excitons. Efforts are being devoted to developing materials with high photoluminescence efficiency and effective RISC.

28.3: *Invited Paper:* Progress on Phosphorescent OLED Materials (11:20)

B. Balaganesan, H. L. Huang, H. M. Guo, P. W. Hsu, C. C. Yao, H. L. Lu
eRay Optoelectronics Technology Co., Ltd., Taoyuan, Taiwan, ROC

Development of host materials, with triplet energies >2.5 eV, to sensitize red phosphorescent dopants will be presented. The phosphorescent hosts such as PH4 and PH5 exhibited lifetimes (LT70) of 40,000 and 66,000 hours at an initial luminance of 1000 cd/m^2, with efficiencies as high as 28.5 cd/A at a driving voltage of 4.2 V.

28.4: ***Invited Paper:* Development of Tetradentate Pt Complexes for Efficient, Stable, and High-Color-Purity Blue OLEDs** **(11:40)**

T. Fleetham, G. Li, Z-Q. Zhu, J. Li
Arizona State University, Tempe, AZ, USA

The development of blue OLEDs employing tetradentate platinum complexes will be discussed along with the development of a wide range of efficient blue-emitting Pt complexes enabling OLEDs with a record purity blue emission of (0.14, 0.08), an external quantum efficiency exceeding 25%, and blue OLEDs with operational lifetimes of over 2000 hours.

LUNCH **(12:00–2:00)**

AUTHOR INTERVIEWS **(5:00–6:00)**

TFTs AND CIRCUITS FOR FLEXIBLE DEVICES

Wednesday, June 3 / 10:40 am – 12:00 pm / Room LL20A

Chair:
R. Ishihara, *Delft University of Technology, Delft, The Netherlands*

Co-Chair:
S. H. Park, *KAIST, Daejeon, South Korea*

29.1: Solution-Processed Poly-Si TFTs at Paper-Compatible Temperatures (10:40)

M. Trifunovic, J. Zhang, M. van der Zwan, R. Ishihara
Delft University of Technology, Delft, The Netherlands

For the first time, CMOS poly-Si TFTs were produced at a maximum temperature of 150ºC using liquid silicon ink and an excimer-laser annealing process. The low-temperature process allowed formation of the poly-Si layer on inexpensive paper substrates. This could lead to new applications such as biodegradable UHF RFID tags with a sensor for the Internet of Things, which can be mass-produced at very low costs by a roll-to-roll manufacturing process.

29.2: Silicon-Ink-Based Poly-Si CMOS TFT Fabricated on 300-mm Stainless-Steel-Foil Substrates (11:00)

M. Takashima, A. Chandra, J. Li, A. Kamath
Thin Film Electronics, Inc., San Jose, CA, USA

Laser-crystallized CMOS TFTs were fabricated on thin 300-mm stainless-steel substrates using silicon ink. Logic circuit devices with PECVD-equivalent TFT characteristics using semiconductor-grade inks are routinely fabricated using this process. This technology is foundational to low-cost high-volume RF display and integrated sensor system circuits on thin large-area flexible and durable substrates.

29.3: High-Resolution Flexible AMOLED with Integrated Gate Driver Using Bulk-Accumulation a-IGZO TFTs (11:20)

D. Geng, H. M. Kim, M. Mativenga, Y. F. Chen, J. Jang
Kyung Hee University, Seoul, South Korea

A high-resolution flexible AMOLED display with a 40-μm-pitch integrated gate driver has been demonstrated on plastic. The gate driver employs bulk-accumulation a-IGZO TFTs and for a V_{DD} = 20 V, operates under a mechanical bending radius of 2 mm with a clock frequency of 250 kHz, corresponding to a pulse width of 2 μsec.

29.4: Flexible AMOLED Display with Integrated Gate Driver Operating at an Operation Speed Compatible with a 4K × 2K Display **(11:40)**

S. Steudel, K. Myny, S. Schols, P. Vicca, T. H. Ke, S. Smout, M. Willegems, M. Ameys
imec, Leuven, Belgium

B. Cobb, A. Kumar, J.-L. van der Steen, G. Gelinck
TNO/Holst Centre, Eindhoven, The Netherlands

M. Nag, A. Bhoolokam, J. Genoe, P. Heremans
imec, Leuven, Belgium
and
KU Leuven, Leuven, Belgium

K. Obata, M. Murata
Panasonic Corp., Moriguchi, Japan

A QVGA top-emitting AMOLED display with 250-ppi resolution using a self-aligned IGZO TFT backplane on polyimide with a full barrier will be presented. The backplane process flow is based on a 7-layer lihotolithography process. An integrated gate driver was driven at an operation speed equivalent to that of a 4K × 2K display.

LUNCH **(12:00–2:00)**

AUTHOR INTERVIEWS **(5:00–6:00)**

3D APPLICATIONS

Wednesday, June 3 / 10:40 am – 12:00 pm / Room LL20BC

Chair:
S. Jones, *Nulumina Corp., Bellevue, WA, USA*

Co-Chair:
A. Abileah, *Adi-Display Consulting, LLC, Portland, OR, USA*

30.1: Review of Dynamic Holography in Materials for Large-Sized Holographic 3D Video Displays (10:40)

H. Gao, J. Liu, Y. Yu, C. Zeng, Q. Yao, P. Liu, H. Zheng
Shanghai University, Shanghai, China

Results on dynamic holography and real-time holographic 3D video displays in super-fast liquid crystals have been obtained. Some of the latest holographic 3D display developments will be presented. These achievements might become good candidates to realize large-sized, high-resolution, and color 3D holographic video displays.

30.2: Color Holographic Projection Based on Liquid Lens (11:00)

D. Wang, F.-Z. Li, Q.-H.Wang, X. Zhou
Sichuan University, Chengdu, China

Based on a liquid lens, color holographic projection is proposed. Color reconstruction was realized by using a time-division method. By controlling the focal length of the liquid lens, three-color reconstructed images can be displayed in the same position without chromatic aberration.

30.3: Design Parameters for a Curved Barrier-Type Autostereoscopic Display (11:20)

W-C. Lin, Y-T. Cheng, H. Y. Lin
National Taiwan University, Taipei, Taiwan, ROC

K-C. Huang
ITRI, Hsinchu, Taiwan, ROC

The design for planar to flexible barrier-type autostereoscopic displays shows the curvature radius R of the display and the aperture ratios of the barrier and pixel are the only parameters to change the viewing zone. For a threshold R value, the aperature ratios have different effects on 3D performance.

30.4: Multi-Plane Holographic Display with a Uniform 3D Gerchberg–Saxton Algorithm (11:40)

P. Zhou, Y. Li, C. P. Chen, X. Li, W. Hu, N. Rong, Y. Yuan, S. Liu, Y. Su
Shanghai Jiao Tong University, Shanghai, China

A modified 3D Gerchberg–Saxton (GS) algorithm for phase-only holograms in holographic displays is proposed. Numerical and experimental results compared with the conventional 3D GS algorithm show that the image-quality difference in the proposed method was reduced by four orders of magnitude, while the average image quality increased by 28.7%.

LUNCH (12:00–2:00)

AUTHOR INTERVIEWS (5:00–6:00)

DISRUPTIVE LCD MATERIALS

Wednesday, June 3 / 10:40 am – 12:00 pm / Room LL20D

Chair:
S. C. (Alan) Lien, *TCL Group, Shenzhen, Guangdong, China*

Co-Chair:
Y. Saitoh, *FUJIFILM Corp., Kanagawa, Japan*

31.1: Evolution of Cellulose Triacetate (TAC) Films for LCDs: Novel Technologies for High Hardness, Durability, and Dimensional Stability (10:40)

R. Suzuki, M. Nagura, Y. Sasada, N. Fukagawa, K. Kawato, Y. Ito
FUJIFILM Corp., Kanagawa, Japan

Two types of cellulose triacetate (TAC) polarizer protection films have been successfully developed by utilizing TAC's unique features. A high-hardness and high-durability 25-μm TAC film and a high-dimensional-stability TAC film solve problems caused by the reduction in the thickness of polarizers and reduce warpage of panels in IPS-LCD TVs, respectively.

31.2: Low-Dielectric-Constant Materials for High-Performance LCDs (11:00)

H. Chen, F. Peng, S.-T. Wu
University of Central Florida, Orlando, FL, USA

M. Hu, J. Li, Z. An
Xi'an Modern Chemistry Research Institute, Xi'an, China

M-C. Li, S-L. Lee, W-C. Tsai
AU Optronics Corp., Hsinchu, Taiwan, ROC

A small $|\Delta\varepsilon|$ LC mixture exhibits ultra-low viscosity, low activation energy, and high transmittance at a reasonably low voltage. Its response time remains at 45 msec even at –20°C. These materials are attractive for fringe-field-switching-based mobile displays, IPS-based 4K × 2K TVs, and MTN-based wearable LCoS projection displays.

31.3: New Approach to Developing Liquid-Crystal Materials for Idling Stop Driving on Reflective Displays (11:20)

Y. Niikura, D. Kubota, R. Hatsumi, Y. Hirakata, H. Miyake, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

A. Nakamura, Y. Chubachi, M. Katayama
Advanced Film Device, Inc., Tochigi, Japan

By using a temporal modulation transfer function, the luminance change during the low-frequency driving of LCDs, which is not perceived as flickers by humans, was examined. A novel liquid-crystal mixture that doubles the rewrite interval (relative to the conventional mixture) and realizes an eye-friendly display panel has been developed.

31.4: Properties of Nano-Phase-Separated Liquid Crystals (NPS LCs) with Fast Response Time (11:40)

T. Fujisawa, K. Jang, F. Kodera, M. Gushiken, G. Sudou, H. Hasebe, H. Takatsu
DIC Corp., Ina, Japan

A nano-phase-separated LC, which is composed of a polymer/liquid-crystal composite, realizes a faster response time than polymer-sustained vertical-aligned liquid crystals (PSA). A decay time of less than 1 msec was achieved for a driving voltage of 22 V.

LUNCH (12:00–2:00)

AUTHOR INTERVIEWS (5:00–6:00)

FRONT LIGHTING AND REFLECTIVE DISPLAYS

Wednesday, June 3 / 10:40 am – 12:00 pm / Room LL21EF

Chair:
K. Käläntär, *Global Optical Solutions, Tokyo, Japan*

Co-Chair:
K. Gahagan, *Corning Incorporated, Corning, NY, USA*

32.1: Front Light for Electrophoretic Display Applications (10:40)

H-T. Huang, Y-N. Pao, I-J. Chen
E Ink Holdings, Inc., Hsinchu, Taiwan, ROC

An optical design for a front light to enhance the performance of color e-Paper is proposed. The optical simulation results indicate that the stripe-type color-filter arrangement can achieve high color saturation. A method to control the micro-pattern configuration and distribution on the front-light guiding plate (LGP) was also developed.

32.2: A Study on the Front Light Guide Used in Color Reflective LCDs (11:00)

X. Wang, G. Qin, J. Tan, M. Zhu, Z. Yang, J. Yao
BOE Technology Group Co., Ltd., Beijing, China

A solution to the use of a common front light-guide plate with a color reflective LCDs will be presented. A front-light-guided high-contract-ratio color reflective LCD can be achieved by matching the anisotropic diffusing film to the light-guide plate.

32.3: Enhancing Interferometric Display Color View Angle Performance Using a Fiber-Array Film (11:20)

J. Ma, B. Hong, J. Hong, T. Chang
Qualcomm MEMS Technologies, Inc., San Jose, CA, USA

The viewing-angle-dependent color shift is a fundamental phenomenon and potential issue for all interferometric displays. A solution to reduce the color shift using a fiber array fabricated on a polycarbonate film by nano-embossing will be presented. The FDTD simulation, fabrication, and experimental results will be shown.

32.4L: *Late-News Paper:* Frontlighting Reflective Display with Enhanced Image Using an Optical Noise-Filtering Multi-Layered Light-Guide Plate (11:40)

K. Käläntär
Japan Global Optical Solutions, Tokyo, Japan

A multilayered frontlighting unit (FLU) with optical noise filtering and image-enhancing functions to illuminate reflective displays, such as reflective LCDs, EPDs, and MEMS displays, was studied.

LUNCH (12:00–2:00)

AUTHOR INTERVIEWS (5:00–6:00)

NOVEL DEVICES

Wednesday, June 3 / 3:30 – 5:10 pm / Ballroom 220B

Chair:
K. Omata, *Konica Minolta, Tokyo, Japan*

Co-Chair:
M. Hack, *Universal Display Corp., Ewing, NJ, USA*

33.1: *Invited Paper:* A Novel Vertical-Type Light-Emitting Transistor and Panel Design on a-Si Backplane for High-Resolution TV Application (3:30)

T. Hirai, M. Bown, K. Ueno
CSIRO Manufacturing Flagship, Clayton, Australia

A novel vertical-type light-emitting transistor (VLT) having a combination of a metal-oxide transistor and organic light-emitting diode (OLED) has been developed. An ON/OFF ratio of 3.7 and a gain of 16.7 for the first VLT device has been obtained. Furthermore, a design for a 42-in. 4K VLT panel on a conventional a-Si backplane with a high-speed feedback compensation circuit will be reported.

33.2: Neuron MOS Devices Using TFTs (3:50)

M. Kimura, K. Shimada, T. Matsuda
Ryukoku University, Otsu, Japan

Neuron MOS devices using TFTs have been developed. They possess floating and multiple input-gate terminals capacitively connected. The neuron MOS transistors, a neuron inverter, which can be a variable threshold voltage inverter, and an almighty logic circuit were evaluated. The neuron MOS devices have great potential for artificial neural networks.

33.3: *Invited Paper:* Electronic Properties of Highly Oriented Nano-Crystalline Semiconducting Polymers (4:10)

A. J. Heeger, C. Luo, B. B-Y. Hsu, B. H. Lee
University of California, Santa Barbara, CA, USA

A general strategy is presented to self-assemble unidirectional alignment and efficient charge transport for semiconducting polymer films deposited on textured Si/SiO_2 substrates. By employing sandwich casting in a tilted tunnel system, capillary action was utilized, generated by functionalized spacers, to self-assemble semiconducting polymers along uniaxial nano-grooves on the substrate. The strength of capillary action can be tailored by different surface treatments of the glass spacers. Mobilities in excess of 50 cm^2/V-sec have been obtained. The details of the Directed Self-Assembly will be described, and the high-mobility data will be discussed in terms of initial band structure calculations.

33.4: Flexible IGZO TFTs with a Disruptive Photo-Patternable and Thermally Stable Organic Gate Insulator **(4:30)**

H-H. Hsieh, S-I. Lin, C-W. Chou, W-Y. Hung, C-C. Hsiao
Polyera Taiwan Corp., Hsinchu, Taiwan, ROC

W. C. Sheets, S. J. Kang, Y. Xia, S. Bull, A. Facchetti
Polyera Corp., Skokie, IL, USA

A new photo-patternable and thermally stable organic gate insulator has been developed specifically for IGZO TFTs. Combined with an optimized device platform, flexible IGZO TFTs show groundbreaking performance such as high mobilities, negligible hysteresis, and good thermal and bias-temperature stress stability. A 5-in. flexible AMOLED display that utilizes these technologies has been fabricated.

33.5: Fabrication of an All-Screen-Printed Oxide-Semiconductor TFT Active-Matrix Backplane **(4:50)**

K. Fukada, Y. Maeda, X. Y. Liu, S. Inoue
Japan Advanced Institute of Science and Technology, Ishikawa, Japan

A. Matoba
Industrial Research Institute of Ishikawa, Ishikawa, Japan

S. Takagi
Tokyo Process Service Co., Ltd., Tokyo, Japan

T. Shimoda
Japan Advanced Institute of Science and Technology, Ishikawa, Japan
and
JST-ERATO, Tokyo, Japan

An oxide-semiconductor TFT active-matrix backplane was fabricated by screen printing. The new layout to successfully fabricate an all-screen-printed TFT was utilized. The applications of this screen-printing method include not only the printing of electrodes for assemblies but also multilayer patterning of large-sized electronic devices.

AUTHOR INTERVIEWS **(5:00–6:00)**

DISRUPTIVE OLED MATERIALS

Wednesday, June 3 / 3:30 – 4:50 pm / Ballroom 220C

Chair:
S. Coe-Sullivan, *QD Vision, Inc., Redondo Beach, CA, USA*

Co-Chair:
S. Zimmermann, *Novaled AG, Dresden, Germany*

34.1: ***Invited Paper:*** **Effect of Singlet-Triplet Recycling in the Charge-Transfer-State Manifold and Molecular Geometry on Thermally Activated Delayed Fluorescence** **(3:30)**

F. B. Dias, D. Graves, V. Jankus, A. P. Monkman
Durham University, Durham, UK

Detailed photophysical measurements of the TADF process in charge-transfer molecules show triplets with 100%-efficiency harvesting, but also complex heterogeneity in samples. By using a CT molecule with a rigid geometry, the heterogeneity was removed and simple OLEDs with an EQE >19% from a material with a PLQY of 30% were demonstrated.

34.2: ***Invited Paper:*** **Highly Efficient and Stable OLEDs Using Hosts with Thermally Activated Delayed Fluorescence** **(3:50)**

L. Duan
Tsinghua University, Beijing, China

It was demonstrated that materials with thermally activated delayed fluorescence (TADF) are ideal host materials for OLEDs. TADF-sensitized fluorescent OLEDs exhibit a maximum power efficiency of up to 45 lm/W. Moreover, TADF-sensitized phosphorescent OLEDs show high efficiency, low voltage, and long lifetime even at low phosphor concentrations of <3 wt.%.

34.3: **Emitting Materials for Thermally Activated Delayed Fluorescent OLEDs Using Benzofurocarbazole and Benzothienocarbazole as Donor Moieties** **(4:10)**

D. R. Lee, C. W. Lee, O. Y. Kim, S. H. Hwang
Dankook University, Yongin, South Korea

J. Y. Lee
Sungkyunkwan University, Suwon, South Korea

Activated Delayed-Fluorescent (ADF) emitters were synthesized and fabricated as OLEDs. The HOMO and LUMO distribution of the emitters were well separated, and small singlet-triplet energy gaps of 0.13 and 0.17 eV were measured, respectively. BFCzPN and BTCzPN showed 12.4 and 11.8% of maximum quantum efficiency as TADF emitters.

34.4: ***Invited Paper:* Combinatorial Design of OLED Emitting Materials** **(4:30)**

A. Aspuru-Guzik, R. Adams, J. Aguilera-Iparraguirre, R. Gómez-Bombarelli
Harvard University, Cambridge, MA, USA

M. Baldo
MIT, Cambridge, MA, USA

The first results from a combinatorial design effort focused on new OLED emitters that exploit thermally activated delayed fluorescence will be reported. By using quantum chemistry and machine learning techniques to prune a pool of over 200,000 combinations of donor and acceptor subgroups, new dyes that are state of the art, yet entirely computationally derived, were demonstrated.

AUTHOR INTERVIEWS **(5:00–6:00)**

PROJECTION OPTICS

Wednesday, June 3 / 3:30 – 4:50 pm / Room LL20A

Chair:
J. Vieth, *Christie Digital Systems, Kitchener, Ontario, Canada*

Co-Chair:
M. H. Wu, *Hamamatsu Corp., Bridgewater, NJ, USA*

35.1: *Distinguished Paper:* Auto-Calibration for Screen Correction and Point Cloud Generation (3:30)

J. Deglint, A. Cameron, C. Scharfenberger, A. Wong, D. Clausi
University of Waterloo, Waterloo, Ontario, Canada

M. Lamm
Christie Digital Systems Canada, Inc., Kitchener, Ontario, Canada

The alignment and adjustment of projectors to display images on arbitrary irregular surfaces such as structures and buildings has been a difficult task. This automatic calibration technique, using projected Gray-code-structured light patterns captured by camera to acquire a 3D model and perform screen correction saves time and effort.

35.2: Design of Hybrid Refractive/Reflective Projection Optics for Family Theatre (3:50)

Z. Zhuang, P. Surman, X. W. Sun
Nanyang Technological University, Singapore

F. Yu
Zhejiang University, Hangzhou, China

An ultra-short-throw projector having wide field of view, low *f*-number, and reduced distortion is proposed using a set of refractive lenses together with an odd polynomial mirror. The performance parameters of this optical system will be described with a proposal for a portable LED projector.

35.3: Resolution Enhancement Based on Shifted Superposition (4:10)

E. Barshan, C. Scharfenberger, P. Fieguth
University of Waterloo, Waterloo, Ontario, Canada

M. Lamm
Christie Digital Systems Canada, Inc., Kitchner, Ontario, Canada

To overcome the limitations of low-native-resolution projection devices to project high-resolution content, a system has been developed to derive a set of optimum, spatially shifted, low-resolution images that are superimposed using an opto-mechanical image shifter. The effectiveness and efficiency of the technique is evaluated using a variety of metrics

35.4: A High Contrast Ratio and Compact-Sized Prism for DLP Projection System **(4:30)**

Y-C. Huang, J-W. Pan, C-W. Chiang, P-C. Lin
National Chiao Tung University, Tainan, Taiwan, ROC

K.-D. Chang
ITRI, Hsinchu, Taiwan, ROC

A new light separator for enhancing contrast ratio and maintaining the optical efficiency of DLP projection is proposed. This light separator is to direct the uncontrolled light away from the image system a by total-internal-reflection (TIR) surface which significantly improves the image quality. The theory behind this light separator and examples of measured results will be presented.

AUTHOR INTERVIEWS **(5:00–6:00)**

HOLOGRAPHIC 3D DISPLAYS

Wednesday, June 3 / 3:30 – 5:00 pm / Room LL20BC

Chair:
W. Hendrick, *Rockwell Collins Optronics, Carlsbad, CA, USA*

Co-Chair:
K. Käläntär, *Global Optical Solutions, Tokyo, Japan*

36.1: Binocular Holographic Display Using the Pupil Space Division Method (3:30)

J. An, G. Sung, S. Kim, H. Song, J. Seo, H. Kim, W. Seo, C-S. Choi, H-S. Lee, U-I. Chung
Samsung Electronics Co., Gyeonggi-do, South Korea

E. Moon, H. Kim
Korea University, Sejong, South Korea

A binocular holographic display with an amplitude-only spatial light modulator (SLM) has been demonstrated. Instead of frame or pixel division for assigning the left and right images, the pupil was spatially divided by modulating the phase of a computer-generated hologram, enabling a higher frame-rate 3D scene.

36.2: Speckle Suppression in a Scaled Holographic Display from a Single-Phase-Only Computer-Generated Hologram (3:50)

C. Chang, J. Xia, Q. Li, W. Lei
Southeast University, Nanjing, China

A method to suppress the speckle noise in a scaled phase-only holographic display is proposed. Both amplitude and phase distribution on the image plane were optimized. The experimental results show a prominent effect in the reconstruction with speckle suppression compared to the conventional iterative-based method.

36.3: Flat-Panel Coherent Backlight for Holographic Displays with Improved Diffraction Efficiency (4:10)

W. Hu, C. P. Chen, Y. Li, Z. He, X. Li, P. Zhou, J. Lu, Y. Su
Shanghai Jiao Tong University, Shanghai, China

A novel compact coherent backlight, an important component of holographic 3D displays, will be presented. The feasibility of this structure was experimentally verified by reconstructing 3D images with a spatial light modulator, and diffraction efficiency of ~4.3% was obtained.

36.4: *Invited Paper:* Real-Time Light Amplification by Using Photorefractive Ferroelectric Liquid-Crystal Mixtures (4:30)

T. Sasaki
Tokyo University of Science, Tokyo, Japan

Recent progress made on the amplification of light signals using photorefractive ferroelectric liquid crystals will be presented. The photorefractive effect is a phenomenon that is applicable to a wide range of devices related to diffractive optics including 3D displays and optical amplification.

36.5L: ***Late-News Paper:*** **Multi-Projection 3D Display with Dual-Projection System Using Uniaxial Crystal** **(4:50)**

C.-K. Lee, S.-G. Park, J. Jeong, B. Lee
Seoul National University, Seoul, South Korea

A multi-projection 3D display that utilizes a dual-projection system with a uniaxial crystal is proposed. The exit pupil of the projector was duplicated in the uniaxial crystal according to its polarization. Polarization of the image was modulated by using a polarizing rotator along the time sequence. A four-view multi-projection 3D display that provides a super multi-view condition was realized with two projectors.

AUTHOR INTERVIEWS **(5:00–6:00)**

BLUE-PHASE LCDs

Wednesday, June 3 / 3:30 – 4:50 pm / Room LL20D

Chair:
M. Wittek, *Merck KGaA, Darmstadt, Germany*

Co-Chair:
S-T. Wu, *University of Central Florida, Orlando, FL, USA*

37.1: ***Distinguished Paper:* A Novel Blue-Phase LCD Applying Wall Electrode and High-Driving-Voltage Circuit** **(3:30)**

C-Y. Tsai, F-C. Yu, Y-F. Lan, P-J. Huang, S-Y. Lin, Y-T. Chen, T-I. Tsao, C-T. Hsieh, B-S. Tseng, C-W. Kuo, C-H. Lin, C-C. Kuo, C-H. Chen, H-Y. Hsieh, C-T. Chuang, N. Sugiura
AU Optronics Corp., Hsinchu, Taiwan, ROC

C-L. Lin, M-H. Cheng
National Cheng Kung University, Tainan, Taiwan, ROC

A novel polymer-stabilized blue-phase LCD (BPLCD) using an optimized BPLC material, wall electrode, and driving circuit has been demonstrated. A prototype BPLCD panel was fabricated, and its performance evaluated. This BPLCD exhibits 2× better electro-optic properties while keeping a superior reliability.

37.2: High-Performance Blue-Phase Liquid Crystals Stabilized by Linear Photopolymers **(3:50)**

D. Xu, J. Yuan, S.-T. Wu
University of Central Florida, Orlando, FL, USA

M. Schadt
MS High-Tech Consulting, Seltisberg, Switzerland

An IPS BPLC stabilized by linear photo-polymerization (LPP) was experimentally demonstrated. The LPP-process helps reduce response time and suppress hysteresis. By optimizing device structure, the operation voltage was reduced to 7.4 V and the peak electric field was 10x lower. As a result, the electrostriction effect can be eliminated.

37.3: Polymer-Stabilized Blue-Phase Liquid Crystal Cured with a Visible Laser **(4:10)**

Y. Yuan, Y. Li, C. P. Chen, N. Rong, W. Li, X. Li, W. Hu, P. Zhou, J. Lu, Y. Su
Shanghai Jiao Tong University, Shanghai, China

A polymer-stabilized blue-phase liquid crystal (PS-BPLC) cured by visible laser light in an in-plane-switching (IPS) cell will be reported. Its electro-optic properties will be compared with those of conventional PS-BPLC cured by UV light. In addition, a PS-BPLC grating was fabricated by using visible-laser holography.

37.4L: ***Late-News Paper:*** **High-Contrast Flexible Blue-Phase LCD with Polymer Walls** **(4:30)**

T. Ishinabe, H. Sakai, H. Fujikake
Tohoku University, Sendai, Japan

A high-contrast flexible blue-phase LCD with polymer walls has been developed by using UV irradiation through a photomask. It was verified that both polymer walls and BP stabilization can be achieved only one time by UV irradiation, and the polymer walls can suppress the distortion of the LC layer in the bending state.

AUTHOR INTERVIEWS **(5:00–6:00)**

OLED LIGHTING

Wednesday, June 3 / 3:30 – 4:30 pm / Room LL21EF

Chair:
J. H. Kwon, *Kyung Hee University, Seoul, South Korea*

Co-Chair:
F. So, *University of Florida, Gainesville, FL, USA*

38.1: Efficiency Enhancement of OLEDs on Flexible Substrates with Patterned Inverted Cone Structure (3:30)

Y-J. Wang, S-H. Ouyang
Shanghai Jiao Tong University, Shanghai, China

J-G. Lu
Shanghai Jiao Tong University, Shanghai, China
and
South China University of Technology, Guangzhou, China

H-P. D. Shieh
Shanghai Jiao Tong University, Shanghai, China
and
National Chiao Tung University, Hsinchu, Taiwan, ROC

A patterned-inverted-cone (PIC) structure on flexible substrates, produced by a focused femtosecond laser, has been demonstrated, resulting in out-coupling efficiency enhancement of OLEDs. A green OLED with a PIC structure on a flexible substrate exhibited a current efficiency enhancement by a factor of 2.12 at 10 mA/cm^2 without altering the emission spectrum compared to that of conventional flexible OLEDs. The PIC structure is compatible with the current device fabrication process and is applicable to full-color OLED displays and lighting.

38.2: *Distinguished Student Paper:* High-Efficiency Three-Stack Tandem White OLEDs (3:50)

Y. H. Son, J. M. Lee, B. Y. Kang, J. H. Kwon
Kyung Hee University, Seoul, South Korea

Three-stack tandem white OLEDs with an efficiency of 51 lm/W at 1000 nits without out-coupling, a driving voltage of 7.4 V, and a lifetime of 37,000 hours at 3000 nits are reported. With internal and external out-coupling in this device, an efficiency of 100 lm/W was achieved.

38.3: Simulations, Measurements, and Optimization of OLEDs with a Scattering Layer **(4:10)**

S. Altazin, C. Reynaud, U. M. Mayer, L. Penninck, B. Ruhstaller
Fluxim AG, Winterthur, Switzerland

T. Lanz, K. Lapagna, R. Knaack, C. Kirsch, K. P. Pernstich
Zurich University of Applied Sciences, Winterthur, Switzerland

S. Harkema, D. Hermes
Holst Centre, Eindhoven, The Netherlands

A multi-scale optical model for OLEDs containing scattering layers will be presented. This model describes the radiation of embedded oscillating dipoles and scattering from spherical particles. After validation with experiments with a top-emitting white OLED, it will be shown how this tool can be used for optimization with specific targets.

AUTHOR INTERVIEWS **(5:00–6:00)**

Session 39 **Active-Matrix Devices**

ADVANCED TFTs

Thursday, June 4 / 9:00 – 10:20 am / Ballroom 220B

Chair:
H. J. Kim, *Yonsei University, Seoul, South Korea*

Co-Chair:
J. Song, *Samsung Display Co., Ltd., Gyeonggi-do, South Korea*

39.1: *Invited Paper:* Printed Inorganic Transistors Based on Transparent Oxides (9:00)

V. Subramanian, J. Jang, W. Scheideler, S. Swisher
University of California, Berkeley, CA, USA

Printed transparent transistors based on various oxides will be reviewed. The synthesis and formulation of nanoparticle and sol-gel precursor inks for printing of transparent conductors, semiconductors, and dielectrics will be discussed, and it will be shown how these inks can be integrated by using ink-jet and gravure printing processes.

39.2: *Invited Paper:* Recent Progress of Oxide-Semiconductor-Based P-Channel TFTs (9:20)

K. Nomura
Qualcomm Technologies, Inc., San Jose, CA, USA

Oxide semiconductors are emerging as next-generation display materials because of their superior electrical characteristics and wide capability of processing. The development of high-performance p-channel oxide TFTs is one of the key issues to be resolved for wider adoption in industry. The recent progress of oxide-based p-channel TFTs will be reviewed.

39.3: *Invited Paper:* Novel Perspective of Nano-Material: Exploiting Graphene for Display Application (9:40)

Y. Jeong, D. C. Lee, J. Kang, S. H. Cho, S. S. Choi, J. Kim, C-H. Kim, G. S. Chae, I. B. Kang
LG Display Co., Ltd., Gyeonggi-do, South Korea

H-M. Kim, J-G. Kim, J. Jang
Kyung Hee University, Seoul, South Korea

Graphene nano-material was exploited for possible commercial display applications in terms of the transparent electrode layer. The device demonstrated better performances than ever reported based on this newly developed material and process methods. The device feasibility of a graphene transparent electrode in conjunction with the work function control will be reported.

39.4L: ***Late-News Paper:* Vertical Organic Transistors (V-OFETs) for Truly Flexible AMOLED Displays** **(10:00)**

M. Furno, H. Kleemann, G. Schwartz, J. Blochwitz-Nimoth
Novaled GmbH, Dresden, Germany

Vertical organic field-effect transistors (V-OFETs) capable of driving very high currents as needed for high-brightness AMOLED displays will be reported. The integration of V-OFETs as drive transistors into flexible backplanes on plastic substrates obtaining a ~4× brightness enhancement compared to that of reference AMOLED displays will be described.

BREAK **(10:20–10:40)**

AUTHOR INTERVIEWS **(4:30–5:30)**

OLED DEVICES I

Thursday, June 4 / 9:00 – 10:20 am / Ballroom 220C

Chair:
M. Weaver, *Universal Display Corp., Ewing, NJ, USA*

Co-Chair:
D. Kondakov, *DuPont Displays, Wilmington, DE, USA*

40.1L: ***Late-News Paper:*** **A Novel RGB Color-Patterning Method for OLED: Joule-Heating-Induced Color Patterning (JICP)** **(9:00)**

W-E. Hong, H-J. Lee, J-S. Ro, I-G. Jang, D-J. Park
EnSilTech Corp., Seoul, South Korea
and
Hongik University, Seoul, South Korea

Y-K. Kim, H-W. Lee, S-E. Lee,
Hongik University, Seoul, South Korea

B. Lassiter, D. Haas
Applied Materials, Santa Clara, CA, USA

A novel RGB color-patterning method, referred to as Joule-Heating-Induced Color Patterning (JICP) where sublimation of small organic molecules was induced by applying an electric pulse to a pre-patterned conductive layer on a donor glass, is reported. The JICP process has a potential for high-resolution patterning and for patterning large-sized panels.

40.2: **Efficiency Enhancement in Phosphorescent and Fluorescent OLEDs Utilizing Energy Transfer from Exciplex to Emitter** **(9:20)**

S. Seo, T. Takahashi, H. Nowatari, S. Hosoumi, T. Ishisone, T. Watabe, S.Mitsumori, N. Ohsawa, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

The effectiveness of energy transfer from an exciplex to emitter in both phosphorescent and fluorescent OLEDs will be discussed. This energy transfer enhances the efficiency, lowers the drive voltage, and extends the lifetime. The increase in the quantum efficiency of a fluorescent OLED using this mechanism has also been analyzed.

40.3: **Optimization of Host-Dopant System for Realizing Efficient Thermally Activated Delayed Fluorescence OLEDs** **(9:40)**

Y. R. Cho, S. J. Cha, M. C. Suh
Kyung Hee University, Seoul, South Korea

A promising method to realize highly efficient fluorescent OLEDs via thermally activated delayed fluorescence (TADF) mechanism will be described. The resultant TADF OLEDs with an optimized host-dopant system showed comparable device performance and surpassed the limits of conventional fluorescent OLEDs.

40.4: High-Efficiency Blue Phosphorescent OLEDs with >57 cd/A, >50 lm/W, and >25% External Quantum Efficiency **(10:00)**

Y-H. Lan, J-J. Huang, M-K. Leung, J-H. Lee
National Taiwan University, Taipei, Taiwan, ROC

Y-T. Chuang, T-L. Chiu
Yuan Ze University, Chungli, Taiwan, ROC

C-F. Lin
National United University, Miaoli, Taiwan, ROC

Blue phosphorescent OLEDs (BPhOLEDs) were successfully fabricated by using a new imidazole-based host doped with bis [2-(4′,6′-difluoro)phenylpyrid-inato-N,C2′]iridium(III) picolinate with 57.24 cd/A, 50.42 lm/W, and a 25.67% external quantum efficiency.

BREAK **(10:20–10:40)**

AUTHOR INTERVIEWS **(4:30–5:30)**

PLENARY TALK: VEHICLE DISPLAYS AND TRENDS

Thursday, June 4 / 8:30 – 9:00 am / Room LL20A

PL.1: *Plenary Talk*: Evolution of Automotive Displays and HMI: Past, Present, and Future (8:30)

Peter N. Knoll, Bosch, Gerlingen, Germany

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

Session 41 Vehicle Displays and Trends

AUTOMOTIVE DISPLAY APPLICATIONS AND SYSTEMS

Thursday, June 4 / 9:00 – 10:20 am / Room LL20A

Chair:
M. Larry, *Ford Motor Co., Macomb, MI, USA*

Co-Chair:
R. Rao, *Harlan International, Palo Alto, CA, USA*

41.1: Development of RGBW LCD with Edge-Lit 2D Local-Dimming System for Automotive Applications (9:00)

N. Takasaki, T. Harada, A. Sakaigawa, K. Sako, M. Mifune, Y. Shiraishi
Japan Display, Inc., Tokyo, Japan

A 10-in. RGBW LCD with an edge-lit 2D local-dimming backlight system for automotive applications has been developed. This prototype system exhibits a reduction in power consumption of 41.5% compared to that of a conventional RGB display without a local-dimming backlight. The performance and evaluation results will be described.

41.2: High-Reliability Integrated Gate Driver Circuit in a Panel for Automotive Displays (9:20)

D. Shim, J-M. Choi, H-U. Jang, S.-J. Nam, D-K. Kim, S-J. Yoo, T-H. Kim, J-Y. Lee, M-C. Jun, I-B. Kang
LG Display Co., Ltd., Gyeonggi-do, South Korea

Automotive displays require high reliability for long-term usage and a wide operation temperature range. A new a-Si:H integrated gate driver circuit, where the self-compensation transistors are intentionally added to stabilize the bias conditions at the extreme environment, is proposed. This improves the reliability of the automotive display.

41.3: *Invited Paper:* Megatrends Driving Automotive Displays and Associated Mega Issues (9:40)

P. M. Russo
GEO Semiconductor, Inc., San Jose, CA, USA

The accelerating growth in the use of advanced electronic safety, convenience, and semi-autonomous driving systems in automobiles will generate massive amounts of information that must be conveyed to drivers. Displays are evolving rapidly to provide this information in safe and efficient ways. Automotive displays will increasingly resemble airplane cockpits. From reconfigurable large-area high-resolution LCDs to HUD systems offering increasing content while the drivers' eyes remain focused on the road, new classes of displays will become the norm to allow drivers to easily absorb the critical information being generated. Challenges associated with these display transitions will also be discussed.

41.4: *Invited Paper:* Future Car HMI Innovations (10:00)

I. P. Park
Harman International, Stamford, CT, USA

R. Rao, S. Marti
Harman International, Palo Alto, CA, USA

There will be more and more computers in cars: built-in, brought-in, worn, etc. These computers want to interact with us (and we with them). If not designed and engineered appropriately, the user interfaces between us and these computers will become more complex — and more distracting. What is needed is careful attention to the interaction methods, or HMI. Changes to the HMI cannot be just incremental but have to be dramatic. Recent developments that can be game-changing for in-car HMI will be covered.

BREAK (10:20–10:40)

AUTHOR INTERVIEWS (4:30–5:30)

CURVED AND HIGH-RESOLUTION DISPLAY METROLOGY

Thursday, June 4 / 9:00 - 10:20 am / Room LL20BC

Chair:
S. Atwood, *Azonix Corp., Webster, MA, USA*

Co-Chair:
F. Rochow, *Adviser, Berlin, Germany*

42.1: Comparison of Key Optical Measurements of Curved to Flat LCD TVs and Their Impact on Image Quality **(9:00)**

K. Blankenbach, A. Marsal, A. Sycev
Pforzheim University, Pforzheim, Germany

Results of several optical measurements comparing key metrics of curved and flat LCD TVs will be presented. Results show improved performance of viewing-angle-dependent metrics but potential reductions in areas associated with reflection and inherent panel construction. The authors recommend further study and future development of new metrology methods.

42.2: Stress-Induced Substrate Mura in Curved LCDs **(9:20)**

K. H. Vepakomma, T. Ishikawa, R. G. Greene
Corning Incorporated, Corning, NY, USA

Curving flat substrates creates retardance proportional to the square of the thickness, approximately three times the typical maximum value of flat substrates. These stress patterns have distinctive interactions with dark-state VA and IPS LC modes. Curved substrate stress birefringence can create unique circular polarized edge mura through liquid crystal and substrate interactions.

42.3: Light-Leakage Study on Curved ADS-Mode LCDs **(9:40)**

J. You, W. Zhao, C. Jung, G. Qin, K. Kim, Y. Yang, Z. Wu, X. Wang
BOE Technology Group Co., Ltd., Beijing, China

The phenomena of increased light leakage in curved ADS-mode LCDs will be exaimed. The mechanism was found to be non-uniform optical retardation in the upper and lower glass layers caused by residual stress buildup. Both a simulation model and experimental results to confirm the hypothesis will be presented.

42.4: How to Perform Viewing-Angle Measurements on Curved Displays **(10:00)**

P. Boher, T. Leroux, T. Bignon, V. Collomb-Patton
ELDIM, Herouville, France

P. Blanc
Laboratoires d'Essai de la FNAC, Massy, France

The impact of the radius of curvature on the emissive properties of curved displays has been investigated. The resulting distortion on viewing-angle properties has been computed and compared to experimental results obtained on a curved TV with a BEF film. If the spot-size/curvature ratio is below 0.5%, the impact was negligible.

BREAK **(10:20–10:40)**

AUTHOR INTERVIEWS **(4:30–5:30)**

FFS/IPS I

Thursday, June 4 / 9:00 - 10:20 am / Room LL20D

Chair:
H. C. Choi, *LG Display Co., Ltd., Gyeonggi-do, South Korea*

Co-Chair:
K. C. Shin, *Samsung Display Co., Ltd., Gyeonggi-do, South Korea*

43.1: *Invited Paper:* UB-FFS: New Materials for Advanced Mobile Applications (9:00)

M. Engel, G. Bernatz, A. Götz, H. Hirschmann, S.-K. Lee
Merck KGaA, Darmstadt, Germany

The refined display technology, namely FFS, is a trend in mobile-display applications. Ultra-brightness FFS (UB-FFS) is at the brink of wide-spread commercialization. It can provide a transmittance improvement of more than 15%. The LC plays a key role here. The recent progress for two key challenging points, fast switching speed and high reliability, will be discussed.

43.2: New Fast-Response-Time In-Plane-Switching Liquid-Crystal Mode (9:20)

T. Matsushima, K. Okazaki, Y. Yang, K. Takizawa
Japan Display, Inc., Kanagawa, Japan

A fast-response-time in-plane-switching (IPS) LCD that has a three times faster response time with comparable optical performance than that for conventional IPS-mode LCDs has been developed. The analytical consideration of the elastic-energy function under an electric field will be discussed.

43.3: Fast-Response Fringe-Field-Switching LCD with Patterned Common Electrode (9:40)

D. Xu, H. Chen, S-T. Wu
University of Central Florida, Orlando, FL, USA

M-C. Li, S-L. Lee, W-C. Tsai
AU Optronics Corp., Hsinchu, Taiwan, ROC

A fast-response and wide-view fringe-field-switching (FFS) LCD using patterned common electrodes is proposed. By applying a restoring pulse voltage on common electrodes, the LC decay process was expedited. The GTG decay time can be reduced by more than 6 times. This new mode also preserves the wide-viewing characteristics as the conventional FFS mode.

43.4: *Distinguished Student Paper:* A Fast-Response A-Film-Enhanced Fringe-Field-Switching LCD (10:00)

H. Chen, Z. Luo, D. Xu, F. Peng, S-T. Wu
University of Central Florida, Orlando, FL, USA

M-C. Li, S-L. Lee, W-C. Tsai
AU Optronics Corp., Hsinchu, Taiwan, ROC

A new A-film-enhanced fringe-field-switching (A-FFS) LCD whose required $d\Delta n$ value is only 50% of that of conventional FFS has been developed. Fast response time can be achieved by decreasing the cell gap, while keeping the transmittance over 90%, is proposed. The parameters which may degrade the contrast ratio will be addressed.

BREAK (10:20–10:40)

AUTHOR INTERVIEWS (4:30–5:30)

ADVANCED LIGHT SOURCES, COMPONENTS, AND SYSTEMS I

Thursday June 4 / 9:00 – 10:20 am / Room LL21EF

Chair:
M. Lu, *Acuity Brands Lighting, Berkeley, CA, USA*

Co-Chair:
D. Aurelien, *Soraa, Inc., Goleta, CA, USA*

44.1: *Invited Paper:* OLED Lighting for General Lighting Applications (9:00)

S. Jang
LG Chem, Cheongjoo, South Korea

Y. Lee, M. Park
LG Chem, Daejeon, South Korea

The efficacy of a large-area white-OLED lighting panel reached 100 lm/W in a three-stack tandem structure. The device has an expected lifetime, LT70, of 40,000 hours at a luminance of 3000 cd/m^2. The pixellation method was adapted to eliminate the possibility of abrupt failure while used in the field.

44.2: *Invited Paper:* Current and Future Projection of Edge-Lit LED Panel Adoption in Lighting (9:20)

B. A. Shriver
Global Lighting Technologies, Brecksville, OH, USA

Edge-lit light guides utilizing highly efficient LEDs are becoming widely adopted within the lighting industry due to their ability to manipulate and distribute the light from LED light sources in the direction and distribution desired by the lighting engineer.

44.3: Display Technologies for LED Lighting. Part I: Optical Components (9:40)

W. F. Edmonds, J. Wheatley, K. J. L. Geisler, D. G. Freier, R. L. Brott
3M Co., St. Paul, MN, USA

3M Optical Films deliver brightness, energy performance, and color enhancement to LCDs. Transforming thin films to three-dimensional components result in improved efficiency and light control for both reflective and refractive optics.

44.4: Display Technologies for LED Lighting. Part II: Scalable Optical Architectures Enabled by Modular Film-Based Components (10:00)

W. F. Edmonds, J. Wheatley, K. J. L. Geisler, D. G. Freier, R. L. Brott
3M Co., Saint Paul, MN, USA

A novel luminaire architecture based on LCD light-management technologies will be described. Results from prototype lighting systems which demonstrate directional control capabilities comparable to lensed LED arrays with large uniformly emitting surfaces more typical of traditional Lambertian fixtures will be discussed in detail.

BREAK (10:20–10:40)

AUTHOR INTERVIEWS (4:30–5:30)

HIGH-PERFORMANCE OXIDE TFTs I

Thursday, June 4 / 10:40 – 11:40 am / Ballroom 220B

Chair:
H-H. Hsieh, *Polyera Taiwan Corp., Hsinchu, Taiwan, ROC*

Co-Chair:
R. Stewart, *Sourland Mountain Associates, Hillsborough, NJ, USA*

45.1: *Invited Paper:* Future Possibilities of Crystalline Oxide Semiconductor, Especially C-Axis-Aligned Crystalline IGZO (10:40)

S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

T. Matsuo
Sharp Corp., Nara, Japan

Through detailed analyses, the structure of c-axis-aligned crystalline (CAAC) IGZO, which is a dense, stable, crystal morphology, was found to differ from single-crystal and amorphous structures. The use of CAAC-IGZO field-effect transistors was expanded to large-scale integrated circuits and new displays; for example, an 81-in. 8K × 4K display.

45.2: Effects of RF Sputtering Parameters and Film Composition on C-Axis-Aligned Crystalline (CAAC) IGZO Films (11:00)

B. Zhu, D. M. Lynch, C-Y. Chung, D. G. Ast, M. O. Thompson
Cornell University, Ithaca, NY, USA

R. G. Greene
Corning Incorporated, Corning, NY, USA

Processing conditions for RF sputter deposition of c-axis-aligned crystalline (CAAC) IGZO have been studied by using a DOE approach. Deposition temperature, oxygen fraction in sputter gas, and Zn composition were identified as the key parameters correlating with alignment quality. Optimal deposition conditions were identified and correlated with a nucleation/growth model.

45.3: *Invited Paper:* High-Performance Nanocrystalline ZnO_xN_y for Imaging and Display Applications (11:20)

E. Lee, T. Shin, A. Benayad, H. Lee, D-S. Ko, H. Kim, G-S. Park
Samsung Electronics Co., Gyeonggi-do, South Korea

S. Jeon
Korea University, Sejong, South Korea

A versatile ZnO_xN_y, applicable to a wide range of imaging/display devices, will be presented. A well-optimized ZnO_xN_y material exhibits high mobility exceeding 100 cm^2/V-sec, a bandgap energy of 1.3 eV, and a multiphase nanocrystalline microstructure. Accordingly, the performance of ZnO_xN_y-based device can meet the requisite of future electronic/photonic device elements.

45.4: WITHDRAWN

LUNCH (11:40–1:30)

AUTHOR INTERVIEWS (4:30–5:30)

OLED DEVICES II

Thursday, June 4 / 10:40 am – 12:00 pm / Ballroom 220C

Chair:
E. Forsythe, *Army Research Laboratory, Adelphi, MD, USA*

Co-Chair:
D. Kondakov, *DuPont, Wilmington, DE, USA*

46.1: *Invited Paper:* Recent Progress of Light-Emitting Diodes Based on Colloidal Quantum Dots (10:40)

C. Lee, M. Park, K. Char, S. Lee
Seoul National University, Seoul, South Korea

J. Kwak
Dong-A University, Busan, South Korea

W. K. Bae
Korea Institute of Science and Technology, Seoul, South Korea

Very efficient red, green, blue, and white LEDs based on colloidal quantum dots (QLEDs) using an inverted device architecture is reported. Recent research progress of QLEDs will be reviewed and issues for realizing full-color QLED displays will be discussed.

46.2: Novel Laminated OLEDs with a Multi-Layered Graphene Top Anode (11:00)

H. Lee, J. T. Lim, N. S. Cho, B-H. Kwon, H. Cho, J-H. Han, B-G. Yu, J-I. Lee
ETRI, Daejeon, South Korea

S. C. Lim
Sungkyunkwan University, Suwon, South Korea

A novel OLED fabrication method using a multilayered graphene (MLG) film and a lamination technique will be reported. A transparent OLED with a MLG top electrode that exhibits a higher transmittance and lower reflectance than a transparent OLED of a conventional thin metal cathode has been developed.

46.3: Anchoring Energy of PEDOT:PSS Alignment Layer for High-Order Parameter and Polarized Luminescence of Organic Dyes (11:20)

A. Stankevich, V. Bezruchenko, A. Muravsky, A. Murauski, V. Agabekov
Institute of Chemistry of New Materials of National Academy of Sciences of Belarus F. Skoriny, Minsk, Belarus

Azimuthal anchoring energy of a PEDOT:PSS alignment layer has been investigated, and its influence on the order parameter of wet-coated films was studied. Azimuthal anchoring energy affects both the dichroic ratio and contrast ratio of the polarized emission of wet-coated uniaxial films. The process of high-anchoring PEDOT:PSS alignment layer is suggested.

46.4: Effects of Electron-Injection Layer on Storage and Operational Stability of Air-Stable OLEDs **(11:40)**

H. Fukagawa, T. Tsuzuki, T. Shimizu, T. Yamamoto
NHK Science & Technology Research Laboratories, Tokyo, Japan

K. Morii, M. Hasegawa, S. Gouda
Nippon Shokubai Co., Ltd., Osaka, Japan

Air-stable OLEDs are necessary for expanding the availability of OLEDs. The configuration of the electron-injection layer suitable for air-stable OLEDs has been examined. A highly operationally stable inverted OLED was demonstrated employing a newly developed EIL which does not require chemical n-doping of the electron injection from the bottom cathode.

LUNCH **(12:00–1:30)**

AUTHOR INTERVIEWS **(4:30–5:30)**

NEXT-GENERATION AUTOMOTIVE DISPLAY TECHNOLOGIES I: HUDS

Thursday, June 4 / 10:40 am – 12:00 pm / Room LL20A

Chair:
R. Rao, *Harman International, Palo Alto, CA, USA*

Co-Chair:
M. Suzuki, *SKC Haas Display Films, Tokyo, Japan*

47.1: ***Invited Paper:*** **Practical Application of TI DLP® Technology in the Next-Generation Head-Up Display System** **(10:40)**

G. Pettitt, J. Ferri, J. Thompson
Texas Instruments DLP® Products, Plano, TX, USA

Next-generation automotive head-up displays (HUDs) could fundamentally change how OEMs utilize the HUD. A significantly larger virtual display area and vastly improved image quality are two of the many benefits. Along with the benefits come a unique set of challenges, which can be addressed by incorporating TI DLP® solutions. Options for these challenges, including the comparison of different solid-state illumination sources, have been explored, and practical solutions for developers will be offered.

47.2: ***Invited Paper:*** **Laser-Scanning Head-Up Display for Better Driving Assistance** **(11:00)**

K. Nakamaura, K. Saisho
Ricoh Co., Ltd., Yokohama, Japan

As advanced driving-assistance systems pervade automobiles, drivers are exposed to more information than ever before. Head-up displays are expected to provide the necessary contents depending on necessity and urgency. The promises and challenges of the technology will be discussed.

47.3: ***Invited Paper:*** **World-Fixed Augmented-Reality HUD for Smart Notifications** **(11:20)**

M. Biswas, S. Xu
Qualcomm Technologies, Inc., San Diego, CA, USA

A head-up display (HUD) system that displays perspective-correct surrounding information for driver safety will be presented. In the implementation, contrast-enhanced ego lane information on the HUD is displayed during driving conditions with poor visibility. The use of HUD for augmented-reality (AR) needs an accurate model of the picture-generation process for proper visualization of the 3D content that is perspective accurate from the user view point. The system uses multiple computer-vision techniques for the accurate visualization.

47.4: A Novel Full-Windshield Head-Up Display Technology (11:40)

T. X. Sun
Sun Innovations, Inc., Fremont CA USA

A full-windshield head-up display (FWD) system for automotive applications has been developed. This revolutionary display device is based on a projection-based fluorescent display (PFD) technology which is a new concept of forming full-color and emissive images on an optical clear and fluorescent substrate by projecting light at multiple UV/blue wavebands. With the FWD, information such as GPS navigation signs, on-road obstacles detected by a night-vision camera, warnings from on-board sensors, as well as many other types of mission-critical information can be graphically displayed anywhere on the windshield without any limitation of view angles. FWD will also enable advanced augmented-reality applications over the entire windshield.

LUNCH (12:00–1:30)

AUTHOR INTERVIEWS (4:30–5:30)

DISPLAY STANDARDS AND THEIR APPLICATION TO TRANSPARENT DISPLAYS

Thursday, June 4 / 10:40 am – 12:20 pm / Room LL20BC

Chair:
T. Fiske, *Consultant, Campbell, CA, USA*

Co-Chair:
M. Salmimaa, *Nokia Research Center, Tampere, Finland*

48.1: *Invited Paper:* Recent Advances in the Standardization of Display Metrology and Light Measurement (10:40)

M. E. Becker
Instrument Systems GmbH, Munich, Germany

An introduction to recent activities and achievements of three international standardization organizations – ISO, IEC, and CIE – relevant to display metrology and light measurement will be provided. The current status will be described in detail and future plans and schedules presented.

48.2: *Invited Paper:* Recent Developments in IEC TC 110, Electronic Display Devices: Reflecting Market Interests (11:00)

K. Hyodo
Konica Minolta, Inc., Hachioji, Japan

B. Wang
Southeast University, Nanjing, China

Y. Shibahara
Fujifilm Co., Tokyo, Japan

S. Uehara
Toshiba Corp., Kawasaki, Japan

Until recently, IEC TC 110 focused on technologies such as how a display could be distinguished from others. As new display technologies appeared, IEC TC 110 realizes that focus needs to be placed on market interest also. Therefore, specialized groups for strategic decisions and to handle common fundamental optical measuring methods were established.

48.3: Optical Measurement Method for Transparent LCDs (11:20)

X-L. Ma, Z-Y. Zhang, H-C. Choi, Y-S. Im
BOE Technology Group Co., Ltd., Beijing, China

Optical measurement methods of transparent LCDs have been studied, and three new definitions are introduced to quantify the transparent effect of transparent LCDs (TLCDs). Three types of TLCDs have been measured, and the results agree with experimental observation.

48.4: General Metrology Framework for Determining the Ambient Optical Performance of Flat-Panel Displays **(11:40)**

J. Penczek
University of Colorado, Boulder, CO, USA
and
National Institute of Standards and Technology, Boulder, CO, USA

E. F. Kelley
KELTEK, LLC, Longmont, CO, USA

P. A. Boynton
National Institute of Standards and Technology, Gaithersburg, MD, USA

A framework which allows a generalized treatment of display ambient characteristics will be described. The proposed methodology incorporates both display reflection and transmission properties. A transparent LCD was used as an example to demonstrate the utility of this framework.

48.5: Optical Measuring Methods for Transparent Displays **(12:00)**

J. Penczek
University of Colorado, Boulder, CO, USA
and
National Institute of Standards and Technology, Boulder, CO, USA

E. F. Kelley
KELTEK, LLC, Longmont, CO, USA

P. A. Boynton
National Institute of Standards and Technology Gaithersburg, MD, USA

A set of optical transmission measurements which can be used to determine the optical performance of transparent displays under arbitrary ambient lighting environments will be described. The methodology measures the transmission coefficients in order to determine the on-screen photometric and colorimetric characteristics of transmissive, emissive, and reflective displays.

LUNCH **(12:20–1:30)**

AUTHOR INTERVIEWS **(4:30–5:30)**

FFS/IPS II

Thursday, June 4 / 10:40 am – 12:00 pm / Room LL20D

Chair:
T. Ishinabe, *Tohoku University, Sendai, Japan*

Co-Chair:
J. H. Kim, *Hanyang University, Seoul, South Korea*

49.1: *Invited Paper:* n-FFS vs. p-FFS: Who Wins? (10:40)

H. Chen, Y. Gao, S-T. Wu
University of Central Florida, Orlando, FL, USA

Both negative and positive dielectric-anisotropy liquid crystals have been used in fringe-field-switching (FFS) display devices. The electro-optic performances of single-domain p-FFS and two-domain n-FFS were compared from device and material viewpoints. Quantum-dot backlight-enhanced FFS shows vivid colors with negligible color shift, higher transmittance, and better sunlight readability.

49.2: Image-Sticking Reduction of Fringe-Field-Switching LCDs (11:00)

D. Xu, F. Peng, H. Chen, J. Yuan, S-T. Wu
University of Central Florida, Orlando, FL, USA

M-C. Li, S-L. Lee, W-C. Tsai
AU Optronics Corp., Hsinchu, Taiwan, ROC

A kinetic model to characterize the image sticking under non-uniform electric field in fringe-field-switching (FFS) LCDs, considering material and device parameters, is proposed. In addition, the voltage and temperature effects of image sticking of FFS cells employing positive and negative LCs and approaches for reducing the image sticking will be discussed.

49.3: Analysis of Press Mura in Fringe-Field-Switching LCD (11:20)

Y-L. Yeh, H-Y. Cheng, C-R. Huang, Y-C. Chen, P-C. Liao, W-H. Hsu
AU Optronics Technology Center, Hsinchu, Taiwan, ROC

The formation mechanism of press mura in 2-domain FFS-LCDs was investigated. The LC directors were analyzed by comparing the brightness with that for a rotated polarizer and 3D simulation. The relationship of press mura and pixel edge designs will be discussed. The press-mura phenomenon of a negative LC will also be reported.

49.4: A High-Transmittance IPS LC Mode Using a New Self-Aligned Structure (11:40)

S-H. Lee, H. Park, C. Lee, J-D. Lee, J-Y. Yang, M. Jun, I-B. Kang, S-D. Yeo
LG Display Co., Ltd., Gyeonggi-do, South Korea

High-transmittance LCDs have been developed by using a new self-aligned structure for the IPS LC mode. The transmittance of these new IPS LCDs is 14% higher than that of AH-IPS LCDs in both the simulated and experimental results.

LUNCH (12:00–1:30)

AUTHOR INTERVIEWS (4:30–5:30)

EFFECT OF LIGHTING ON HEALTH AND PERCEPTION

Thursday, June 4 / 10:40 am – 12:00 pm / Room LL21EF

Chair:
J. Larimer, *ImageMetrics LLC, Half Moon Bay, CA, USA*

Co-Chair:
I. Heynderickx, *Eindhoven University of Technology, Eindhoven, The Netherlands*

50.1: *Invited Paper:* The Importance of Melanopsin Activation in Perception, Health, and Lighting Design (10:40)

D. Cao, P. A. Barrionuevo
University of Illinois at Chicago, Chicago, IL, USA

The important role of melanopsin-containing intrinsically photosensitive retinal ganglion cells (ipRGCs) in several subconscious non-image-forming light responses will be briefly described. Then, a five-primary photostimulating method that can independently control melanopsin activation will be described. Finally, one study that assessed the contributions of melanopsin activation to contrast sensitivity will be reported.

50.2: *Invited Paper:* Stroboscopic Effect of LED Lighting (11:20)

L. Wang, Y. Tu, L. Liu
Southeast University, Nanjing, China

M. Perz
Philips Research Europe, Eindhoven, The Netherlands

I. Vogels, I. Heynderickx
Eindhoven University of Technology, Eindhoven, The Netherlands

The stroboscopic effect is one of the main visible artifacts of temporally modulated light, which exists even at high frequencies. Various impacts on the visibility of stroboscopic effect will be discussed. A measure which can efficiently predict the visibility of stroboscopic effect based on the analysis of driven wave is introduced.

50.3: *Invited Paper:* Perceptual Accuracy in the Visualization of Lighting Scenes (11:40)

M. J. Murdoch, M. G. M. Stokkermans, M. Lambooij
Philips Research Europe, Eindhoven, The Netherlands

Complex solid-state lighting systems demand accurate 3D visualization for the design, development, and control. In the creation of visualizations, choices in modeling, light simulation, tone-mapping, and display affect the perceptual accuracy. A series of experiments has uncovered these effects and led to a robust and honest visualization pipeline for indoor lighting scenes.

50.4: Relationship between Short-Term and Long-Term Assessment of Glare **(12:00)**

Y. Chen, Y. Tu, J. Zhang, F. Lu, L. Liu, L. Wang
Southeast University, Nanjing, China

S. Peng
Philips Research China, Shanghai, China

I. Heynderickx
Eindhoven University of Technology, Eindhoven, The Netherlands
and
Philips Research Laboratories, Eindhoven, The Netherlands

Two experiments were performed to investigate the relationship between short- and long-term exposure on perceived discomfort glare. The results indicated that glare reported after long-term exposure was equal or slightly lower than what was assessed after short-term exposure, reducing the need for longer-term experiments.

LUNCH **(12:20–1:30)**

AUTHOR INTERVIEWS **(4:30–5:30)**

HIGH-PERFORMANCE OXIDE TFTs II

Thursday, June 4 / 1:30 – 2:50 pm / Ballroom 220B

Chair:
K. Sarma, *Honeywell, Inc., Phoenix, AZ, USA*

Co-Chair:
T. Nishibe, *Japan Display, Inc., Tokyo, Japan*

51.1: Amorphous Indium-Gallium-Zinc-Tin-Oxide TFTs with High Mobility and Reliability (1:30)

T. Sun, L-Q. Shi, C-Y. Su, W-H. Li, X-W. Lv, H-J. Zhang, Y-H. Meng, W. Shi, S-M. Ge, C-Y. Tseng, Y-F. Wang, C-C. Lo
Shenzhen China Star Optoelectronics Technology Co., Ltd., Guangdong, China

A. Lien
TCL Corporate Research, Guangdong, China

A high-mobility amorphous indium-gallium-zinc-tin-oxide (a-IGZTO) TFT has been demonstrated. The new TFT achieved a large field-effect mobility of ~24.7 cm^2/V-sec, which had a reliability comparable to that of an a-IGZO TFT. Furthermore, a 4K × 2K AMOLED TV addressed by a-IGZTO TFTs demonstrated good performance.

51.2: Development of a High-Mobility Zinc-Oxynitride TFT for AMOLED Displays (1:50)

L. Yan, M. Wang, L. Zhang, D. Wang, F. Liu, G. Yuan, G. Wang
BOE Technology Group Co., Ltd., Beijing, China

Etch-stopped-structured TFTs with zinc oxynitride (ZnON) as the active layer were developed, and a saturation mobility of over 50 cm^2/V-sec was achieved. The ZnON TFTs show superior I–V performance and uniformity. A 14-in. WOLED panel driven by ZnON TFTs was demonstrated, and the reliability of these panels was evaluated under high- and low-temperature operating conditions.

51.3: A Mobility-Enhancing Method Adopting a Multi-Active-Layer Structure in TFTs (2:10)

M-Y. Tsai, T-C. Chang, A-K. Chu, T-Y. Hsieh, P-Y. Liao, B-W. Chen, H-C. Huang, D-S. Gan
National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC

C-E. Chen, H-M. Chen
National Chiao Tung University, Hsinchu, Taiwan, ROC

Y-X. Yang, K-K. Chen, T-H. Shih, H-H. Lu
AU Optronics Corp., Hsinchu, Taiwan, ROC

Three-layered oxide TFTs showed a better mobility of 46.5 cm^2/V-sec than any other single layer. The middle layer has a higher carrier concentration, while the bottom and top layers have lower ones. In this way, the main channel current flows through the middle layer, and this avoidance of the gate insulator/active layer and active layer/passivation interface leads to higher mobility.

51.4: ***Invited Paper:* High-Performance Flexible TFTs from Oxide/Carbon Heterostructures** **(2:30)**

Y. Liu, Y. Huang, X. Duan
Unversity of California, Los Angeles, CA, USA

L. Liao
Wuhan University, Wuhan, China

Transparent oxide has attracted increasing interest as a new TFT material but is limited by relatively low electronic performance and poor mechanical flexibility. The use of an oxide/carbon nanotube composite and oxide/graphene vertical heterostructures to achieve TFTs with greatly improved electronic characteristics and unprecedented mechanical flexibility will be discussed.

BREAK **(2:50–3:10)**

AUTHOR INTERVIEWS **(4:30–5:30)**

OLED DEVICES III

Thursday, June 4 / 1:30 – 2:50 pm / Ballroom 220C

Chair:
D. Kondakov, *DuPont, Wilmington, DE, USA*

Co-Chair:
C. C. Lee, *BOE Technology Group Co., Beijing, China*

52.1: Analysis of Self-Heating and Negative Capacitance in Organic Semiconductor Devices (1:30)

E. Knapp
Zurich University of Applied Sciences, Winterthur, Switzerland

B. Ruhstaller
Fluxim AG, Winterthur, Switzerland

Numerical modeling for charge transport in organic semiconductor devices that accounts for self-heating will be presented. In admittance spectroscopy, this model reproduces negative capacitance in bipolar, and, more importantly, in single-carrier devices. It was shown that self-heating is crucial not only in large-area OLEDs, but also in small-area devices.

52.2: Non-Destructive Analyses of Operational Degradation of OLED Devices (1:50)

T. Miyamae, N. Takada, H. Okumoto
AIST, Ibaraki, Japan
and
CEREBA, Ibaraki, Japan

T. Yoshioka, S. Miyaguchi, H. Ohata, T. Tsutsui
CEREBA, Ibaraki, Japan

M. Yahiro, C. Adachi
ISIT, Fukuoka, Japan
and
Kyusyu University, Fukuoka, Japan

Y. Tsutsui
ISIT, Fukuoka, Japn

Non-destructive analyses were conducted on the intrinsic degradation of OLEDs. After long-term operation, sum-frequency spectroscopy reveals changes in the molecular orientation. Furthermore, change in the mobility of the OLEDs can be evaluated from impedance spectroscopy. Carrier trap behavior was also investigated via thermally stimulated current spectroscopy.

52.3: Exciton Management in Non-Doped Ultra-Thin Emissive Layers Based OLED (2:10)

T. Tan, S. Ouyang, Y. Xie, D. Wang, D. Zhu, X. Xu,
H. H. Fong
Shanghai Jiao Tong University, Shanghai, China

An ultrathin non-doped emissive-layer-based OLED is a promising novel structure which has many merits. However, the single-peak space distribution of exciton hampered its application in fabricating balanced multiple-color light-emitting OLEDs. By using a thin TAPC interlayer which acts as a hole-trapping quantum well, exciton redistribution was realized.

52.4L: *Late-News Paper:* Transmissive One-Sided-Emission OLED Panel Using Alignment-Free Cathode Patterning **(2:30)**

D. Kato, H. Kakizoe, T. Sugizaki, T. Sawabe, K. Sugi, A. Amano, T. Ono, Y. Shinjo, Y. Nakai
Toshiba Corp., Kanagawa, Japan

A simple technique to fabricate a transmissive one-sided-emission OLED panel is proposed. By using this technique, a non-luminescent and non-transparent area can be reduced by using an alignment-free cathode patterning. As a result, the luminescence of the fabricated panel was improved by 1.28 fold and maintained high transmittance.

BREAK **(2:50–3:10)**

AUTHOR INTERVIEWS **(4:30–5:30)**

TOUCH, INTERACTIVITY, AND HUMAN-MACHINE INTERFACE

Thursday, June 4 / 1:30 – 2:50 pm / Room LL20A

Chair:
T. Seder, *General Motors, Dearborn, MI, USA*

Co-Chair:
A. Tagaya, *Keio University, Japan*

53.1: A 10.0-in. 1080 × 2880 Capacitive Curved-Faced In-Cell Touch Panel for Automotive Use (1:30)

T. Kasai, K. Yoshida, M. Ishikawa, F. Goto, H. Mizuhashi, H. Kurasawa, K. Takizawa, Y. Nakajima, T. Ito, H. Kaneko
Japan Display, Inc., Tokyo, Japan

A 10.0-in. 1080 × 2880 capacitive curved-faced prototype LCD for automotive use, which has integrated in-cell touch panel technology, will be described. A sufficient signal-to-noise ratio of 100–160 was achieved with this display despite the 1.1-mm-thick cover glass.

53.2: Visual Search and Attention: What Eye-Tracking Reveals about Visual Performance in the Curved Display (1:50)

K. Choi, H. Bae, S-W. Ju, H-J. Suk
KAIST, Daejeon, South Korea

For flat and curved displays, the subjective impressions of quality were measured, and the eye gaze to a variety of video content was tracked. There was a subjective preference for curved displays, but eye-gaze analysis revealed no statistically significant differences in number or duration of eye fixations.

53.3: *Invited Paper:* Creating a Compelling Touch Experience (2:10)

C. Sampanes, I. Segalman, N. Olien
Immersion Corp., San Jose, CA, USA

Car infotainment systems now offer a larger variety and a more complex set of use cases than ever before. Haptics have the potential to improve safety, utility, and user experience of these touch-based systems. Some of the design issues will be covered, and how to create compelling haptic experiences will be discussed.

53.4: Metal-Mesh Design for High-ppi LCD Application (2:30)

C-C. Chen, C-Y. Chen, S-Y. Huang
Gerneral Interface Solution, Ltd., Miaoli, Taiwan, ROC

Metal-mesh technology offers low RC loading in touch panels and curved touch LCDs, as well as low cost. For high-resolution displays (>530 ppi), moire patterns due to interference with the TFT-LCD can be a significant problem. Methods to solve the visibility issue of moire patterns for touch displays, including curved touch LCDs, will be described.

BREAK (2:50–3:10)

AUTHOR INTERVIEWS (4:30–5:30)

TRANSPARENT DISPLAY SYSTEMS

Thursday, June 4 / 1:30 – 2:50 pm / Room LL20BC

Chair:
Bill Cummings, *BYDU Technology Services, Clinton, WA, USA*

Co-Chair:
Jean-Pierre Guillou, *Apple, Inc., Cupertino, CA, USA*

54.1: *Distinguished Paper:* A Switched Emissive Transparent Display with Controllable Per-Pixel Opacity (1:30)

Q. Smithwick
Disney Research, Glendale, CA, USA

A transparent display for spatial augmented-reality applications has been developed. It employs rapid synchronized switching of a transparent display and backlight between content with luminous backlight and masks with an unlit backlight. A 144-fps transparent LCD panel was used with a transparent backlight and a smart glass screen.

54.2 : A Novel Flat-Type Transparent LCD (1:50)

C-W. Kuo, Y-Y. Liao, B-S. Tseng, C-H. Lin, Y-H. Lai, C-T. Chuang, C-N. Yeh, N. Sugiura
AU Optronics Corp., Hsinchu, Taiwan, ROC

A novel transparent light guide has been developed. Concave microstructures with partially random distribution were designed to reflect incident light and prevent moiré issues. A 12.1-in. LCD was combined with this light guide to demonstrate the transparent tablet scenario.

54.3: PSCT for Switchable Transparent LCD (2:10)

A. Moheghi, D-K. Yang
Kent State University, Kent, OH, USA

M. Kashima, Q. Qin, Y. Dong
BOE Technology Group Co., Beijing, China

A switchable diffuser for transparent LCDs has been developed. It can be switched between a transparent state and a milky scattering state by applying voltages. A transparent advanced super-dimension switch display with a PSCT, which has excellent viewing angle, has also been developed.

54.4: Smart-Window Devices for Black Screen of OLEDs (2:30)

D. C. Choe, G. W. Kim, R. Lampande, J. H. Kwon
Kyung Hee University, Seoul, South Korea

A smart-window OLED device made by combining a transparent OLED and a new black-screen electrochromic device (ECD) is reported. The smart window has high transmission, high contrast, a fast response time, and a long lifetime.

BREAK (2:50–3:10)

AUTHOR INTERVIEWS (4:30–5:30)

LC BEYOND DISPLAYS

Thursday, June 4 / 1:30 - 2:30 pm / Room LL20D

Chair:
P. Chen, *National Chiao Tung University, Hsinchu, Taiwan, ROC*

Co-Chair:
X-Y. Huang, *Ebulent Technologies Corp., Dublin, CA, USA*

55.1: *Invited Paper:* Liquid Crystals for Smart Antennas and Other Microwave Applications (1:30)

M. Wittek, C. Fritzsch, J. Canisius
Merck KGaA, Darmstadt, Germany

Liquid crystals exhibit high tuning ranges and relatively low-dielectric losses for microwave components, operated at frequency ranges from 10 up to 100 GHz. Broad nematic phase ranging from as low as –40°C up to 120°C and relatively high polarity ensure acceptable driving voltages in smart antenna and other microwave components.

55.2: *Invited Paper:* Rethinking Wireless Communications: Advanced Antenna Design Using LCD Technology (1:50)

R. A. Stevenson, A. H. Bily, D. Cure, M. Sazegar, N. Kundtz
Kymeta Corp., Redmond, WA, USA

For mobile satellite communications, applications such as the connected automobile, a scanning antenna is required. A novel electronically scanned antenna technology achieved through the use of high-birefringence liquid crystals has been developed. This technology is positioned for mass production by leveraging the existing manufacturing capabilities of the LCD industry.

55.3: A Low-Voltage and Fast-Response Infrared Spatial Light Modulator (2:10)

F. Peng, D. Xu, H. Chen, S.-T. Wu
University of Central Florida, Orlando, FL, USA

A low-voltage fast-response polymer-network liquid-crystal (PNLC) infrared phase modulator is reported. By optimizing the UV curing temperature and LC host, low operation voltage (V = 22.8 V) at 1.55 µm and a response time of 1 msec have been achieved. It is useful for adaptive optics, adaptive lens, and laser-beam steering.

BREAK (2:30–3:10)

AUTHOR INTERVIEWS (4:30–5:30)

ADVANCED LIGHTING APPLICATIONS

Thursday, June 4 / 1:30 – 2:50 pm / Room LL21EF

Chair:
I. Heynderickx, *Eindhoven University of Technology, Eindhoven, The Netherlands*

Co-Chair:
P.-C. Hung, *Konica Minolta Sensing, Ramsey, NJ, USA*

56.1: ***Invited Paper:*** **Creating an Effective Lighting Environment with Task, Surround, and Ambient Lighting** **(1:30)**

P. Y. Ngai
Acuity Brands Lighting, Berkeley, CA, USA

A study on creating an effective lighting environment by employing three different layers of lighting – Task, Surround, and Ambient lighting – was conducted. Results show that the visual quality of the lit space is enhanced by the addition of surround lighting.

56.2: ***Invited Paper:*** **Progress in Color-Rendition Measures for Lighting** **(1:50)**

A. David
Soraa, Inc., Fremont, CA, USA

A method to evaluate the color rendition of light sources, which improves upon the well-known color-rendering index, will be presented. The method combines two metrics (for color fidelity and gamut) and employs an optimized set of reflectance test samples. It is the basis of the upcoming IES Color Rendition Metric.

56.3: ***Invited Paper:*** **New Color-Rendering Standards and Implications for Displays that Provide Illumination: The Promise and Peril of Solid-State Lighting** **(2:10)**

L. A. Whitehead
University of British Columbia, Vancouver, British Columbia, Canada

As displays become larger and more efficient, they may provide illumination as well as imagery. This will require reconciling a conflict between color gamut and color rendering. Standards for color rendering are also evolving, and this should be taken into account in the optimization of displays serving these two purposes.

56.4: **Forward-Looking Light Sensor Utilization for Automatic Luminance Control** **(2:30)**

P. Weindorf
Visteon Corp., Van Buren Township, MI, USA

A mathematical framework is proposed for an automotive automatic luminance control system that automatically adjusts the display luminance as a function of incident ambient light and forward field-of-view intensities from logarithmic light sensors.

BREAK **(2:50–3:10)**

AUTHOR INTERVIEWS **(4:30–5:30)**

OXIDE AND LTPS TFTs

Thursday, June 4 / 3:10 – 4:30 pm / Ballroom 220B

Chair:
James Chang, *Apple, Inc., Cupertino, CA, USA*

Co-Chair:
N. Fruehauf, *University of Stuttgart, Stuttgart, Germany*

57.1: ***Invited Paper:*** **High-Performance Poly-Si TFTs Using Pressure-Induced Nucleation Technology** **(3:10)**

M.-K. Kang
Samsung Electronics Co., Ltd., Gyeonggi-do, South Korea

S. J. Kim
Samsung Display Co., Ltd., Gyeonggi-do, South Korea
and
Yonsei University, Seoul, South Korea

H. J. Kim
Yonsei University, Seoul, South Korea

A simple method to improve the performance of polycrystalline Si (poly-Si) thin-film transistors (TFTs) via pressure-induced nucleation (PIN) is proposed. The TFTs formed using the PIN process exhibited a high field-effect mobility greater than 160 cm^2/V-sec, which was achieved using only six laser exposures.

57.2: **Electrical Characterization of BCE-TFTs with an a-IGZTO Oxide Semiconductor Compatible with Cu and Al Interconnections** **(3:30)**

M. Ochi, S. Morita, Y. Takanashi, H. Tao, H. Goto, T. Kugimiya
Kobe Steel, Ltd., Kobe, Japan

M. Kanamaru
Kobelco Research Institute, Inc., Takasago, Japan

An In-Ga-Zn-Sn-O (IGZTO) oxide semiconductor, which is highly resistive to etchants, used as the channel material has been developed. IGZTO TFTs were realized by back-channel etching using not only a conventional PAN etchant for Al interconnections but also a H_2O_2-based etchant for Cu interconnections.

57.3: ***Distinguished Paper:*** **New Pixel Circuits for Controlling Threshold Voltage by Back-Gate Bias Voltage Using Crystalline-Oxide-Semiconductor FETs** **(3:50)**

M. Kaneyasu, K. Toyotaka, H. Shishido, T. Isa, S. Eguchi, H. Miyake, Y. Hirakata, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

M. Dobashi, C. Fujiwara
Advanced Film Device, Inc., Tochigi, Japan

A threshold-voltage compensation pixel circuit using back-gate bias voltage has been devised. Variations in threshold voltage can be reduced to 10% while improving the saturation characteristics of a driving transistor. A 5.29-in. quad-VGA OLED display that uses this pixel circuit was fabricated.

57.4: *Invited Paper:* Device Physics of Amorphous-Oxide TFTs **(4:10)**

A. Dodabalapur, B. Cobb, B. Kim, S. Kim
University of Texas at Austin, Austin, TX, USA

L. Schulz
Sichuan University, Chengdu, China

C. Lee
Intel Corp., Portland, OR, USA

The charge transport below and above threshold, techniques to reduce trap densities and device architectures for state-of-the art amorphous-metal-oxide transistors processed from solution will be reviewed. The semiconductors that will be discussed include amorphous zinc-tin-oxide as well as other systems.

AUTHOR INTERVIEWS **(4:30–5:30)**

OLED DISPLAYS I

Thursday, June 4 / 3:10 – 4:30 pm / Ballroom 220C

Chair:
T. Ali, *eMagin Corp., Hopewell Junction, NY, USA*

Co-Chair:
C. H. (Fred) Chen, *Guangdong Aglaia Optoelectronic Materials Co., Ltd., Foshan, China*

58.1: A Study of Adaptive Temporal Aperture Control for OLED Displays with Motion Vector (3:10)

T. Usui, H. Sato, Y. Takano, K. Ishii, T. Yamamoto
NHK Science & Technology Research Laboratories, Tokyo, Japan

To achieve longer lifetime and better motion image quality, adaptive temporal aperture control was previously proposed. However, image-quality degradation resulted due to the difference in temporal apertures in a frame. Hence, three methods to suppress this degradation were developed and the image quality for these three methods was evaluated.

58.2: High-Performance Large-Sized OLED TV with UHD Resolution (3:30)

Y-H. Chen, C-A. Huang, T-W. Chen, Y-S. Lin, Y-J. Hsiao, C-Y. Lu, C-M. Chao, Y-P. Kuo, C-C. Nen, F-W. Chang, H. S. Lin, H-H. Lu, L-H. Chang, Y-H. Lin
AU Optronics Corp., Hsinchu, Taiwan, ROC

By combining stable array processes and cutting-edge OLED processes, a high-performance 65-in. UHD TV with excellent visual quality was successfully fabricated. The architecture of the OLED TV and its merits will be briefly explained.

58.3: A Novel Highly Transparent 6-in. AMOLED Display Consisting of IGZO TFTs (3:50)

C-T. Lee, Y-Y. Huang, C-C. Tsai, S-F. Liu, C-C. Kuo, C-H. Chiu, C-H. Huang, E-C. Liu, S-C. Huang, C-L. Chen, C-T. Liang, J-S. Huang
Chunghwa Picture Tubes, Ltd., Taoyuan, Taiwan, ROC

AMOLED panel cathodes and anodes use transparent materials along with IGZO TFTs. A high-transparent 6-in. AMOLED display with IGZO TFTs has been demonstrated, and the module transparency is about 23% transmittance, which results in transparent and thinner portable devices.

58.4: A 31-in. 4K × 2K WRGB AMOLED TV with a High-Stability IGZO Backplane **(4:10)**

W-H. Li, W. Shi, L-Q. Shi, X-W. Lv, H-J. Zhang, C-Y. Su, C-Y. Tseng, X-J. Li, C-C. Liu, T-P. Wu, X-L. Wu, K-Y. Ko, Y-C. Wu, Y-F. Wang, C-C. Lo, A. Lien
Shenzhen China Star Optoelectronics Technology Co., Ltd., Guangdong, China

A 31-in. UHD AMOLED TV was developed by using high-stability a-IGZO TFTs with an etching-stop-layer on a Gen 4.5 glass substrate with an IGZO (1:1:1) target, and TFT stability was studied. Bottom-emission WOLED technology was adopted and the color-filter–on–array method was applied to increase the aperture ratio.

AUTHOR INTERVIEWS **(4:30–5:30)**

NEXT-GENERATION AUTOMOTIVE DISPLAY TECHNOLOGIES II: FLEXIBLE, CURVED, COATINGS

Thursday, June 4 / 3:10 – 4:10 pm / Room LL20A

Chair:
P. Drzaic, *Apple, Inc., Cupertino, CA, USA*

Co-Chair:
T. Tsujimura, *Konica Minolta, Inc., Tokyo, Japan*

59.1: *Invited Paper:* Flexible Flat-Panel-Display Designs with Gate Driver Circuits Integrated within the Pixel Area (3:10)

H. Yoshida, K. Tanaka, T. Noma, T. Nishiyama, R. Yonebayashi, Y. Nasu, T. Ishida, M. Murata, Y. Nakanishi, S. Kadowaki, H. Watanabe, T. Tomotoshi, R. Yuki, M. Kanehiro
Sharp Corp., Nara, Japan

A new stylish TFT-LCD has been developed, where gate-driver monolithic circuits were placed in the pixel area. Because there are no electronic circuits in the frame area, a narrow border and round corners or a multi-concave shape can be simultaneously realized.

59.2: Highly Stable and Transparent Oxide TFTs for Rollable Displays (3:30)

M. Mativenga, X. Li, J. Um, D. Geng, S. Jin, J. Jang
Kyung Hee University, Seoul, South Korea

Highly stable oxide-TFT circuits with a visible-light transmittance of ~70% and rollable to cylinders with a radius of 2 mm were demonstrated on solution-processed colorless polyimide. Carrier glass and a special de-bonding layer were used during fabrication. Stable TFT and circuit performance were achieved under positive-bias and mechanical bending stress.

59.3: Functional Transparent Coatings for Displays (3:50)

S. Lu
PPG Industries, Inc., Allison Park, PA, USA

Optical functional coatings have been spray deposited onto a pre-treated glass surface followed by a low-temperature curing at 150°C. Such coatings exhibit excellent steel-wool wear durability and a low coefficient of friction. The coating has gloss values between 50 and 100, pencil hardness > 8H, and exhibits no sparkling.

AUTHOR INTERVIEWS (4:30–5:30)

CAPACITIVE TOUCH

Thursday, June 4 / 3:10 – 4:10 pm / Room LL20BC

Chair:
J. Han, *Microsoft, Redmond, WA, USA*

Co-Chair:
J. Zhong, *Apple, Inc., Cupertino, CA, USA*

60.1: ***Distinguished Paper:*** **A Capacitive Touch Panel for Simultaneous Detection of Non-Conductive and Conductive Objects** **(3:10)**

C. Brown, A. Kay
Sharp Laboratories of Europe, Oxford, UK

Y. Sugita, K. Kida
Sharp Corp., Nara, Japan

A mutual-capacitance touch panel with a novel electrode pattern and the use of recognition algorithms for the simultaneous detection of conductive and non-conductive objects will be presented. A prototype of the novel touch panel was fabricated by using standard techniques and was integrated with a standard touch-panel controller to demonstrate its improved usability.

60.2: ***Invited Paper:*** **Advanced In-Cell Touch Technology for Large-Sized LCDs** **(3:30)**

C. Kim, D. S. Lee, J. H. Kim, H. B. Kim, S. R. Shin,
J. H. Jung, I. H. Song, C. S. Jang, K. S. Kwon, S. H. Kim,
G. T. Kim, J. H. Yoon, B-Y. Lee, B. K. Kim, I-B. Kang,
LG Display Co., Ltd., Gyeonggi-do, South Korea

A new in-cell touch sensor integrated on a TFT substrate is proposed. The proposed touch sensor perceives the self-capacitance formed between the touching of an object and the sensing electrode, which has a common electrode structure of a AH-IPS panel. This new sensor structure demonstrates a signal-to-noise ratio (SNR) of more than 50 dB and a multi-touch function without a loss in transmittance. Finally, a 15.6-in. FHD in-cell touch panel has been developed for a notebook PC and a 7-in. WVGA touch panel for automotive applications that supports glove touch has also been development.

60.3L: ***Late-News Paper:*** **Algorithm for Recognizing Pinch Gestures on Surface-Capacitive Touch Screens** **(3:50)**

J. Yanase, K. Takatori, H. Asada
NLT Technologies, Ltd., Kawasaki, Japan

The pinch gestures for scaling an image were recognized successfully on a surface-capacitive touch screen that has a single-touch function only without increasing manufacturing cost. An algorithm recognizing the pinch gestures has been developed, which calculates the distance between two touching points without detecting each position of the two points.

AUTHOR INTERVIEWS **(4:30–5:30)**

LIQUID-CRYSTAL LENSES

Thursday, June 4 / 3:10 – 4:10 pm / Room LL20D

Chair:
P. Bos, *Kent State University, Kent, OH, USA*

Co-Chair:
H-S. Kwok, *Hong Kong University of Science & Technology, Kowloon, Hong Kong*

61.1: Variable-Lens-Pitch LC GRIN Lens for Adapting a 3D Viewing Angle (3:10)

A. Takagi, S. Uehara, M. Kashiwagi, Y. Kizu, M. Baba
Toshiba Corp., Kawasaki, Japan

An electrode design is proposed for adjustable pitch GRIN lenses for autostereoscopic displays. The design allows for to two viewing modes, a wider-viewing-angle mode for multi-users, and a narrower one for personal use. A 15-in. 2D/3D display has been successfully developed.

61.2: Dependence of the Optical Power of an LC Lens on Cell Gap (3:30)

R. Bao, H. Mai, G. Zhang, M. Ye
SuperD Co., Ltd., Shenzhen, China

The optical power and RMS aberrations of an LC lens based on hole-patterned electrodes with different cell gaps has been studied. By increasing the cell gap, the LC lens exhibits a similar relationship between the optical power and the driving voltage, and the RMS aberrations increases with optical power. The maximum optical power of the LC lens within an aberration level of 0.07 and the corresponding driving voltage is found to be nearly proportional to the cell gap.

61.3: Ultra-Compact Non-Mechanical Zoom Lens for Enhanced Machine Vision and Computer Input Applications (3:50)

K. Gao, H-H. Cheng, C. McGinty, P. Bos
Kent State University, Kent, OH, USA

A. Bhowmik
Intel Corp., Santa Clara, CA, USA

A new design for an ultra-compact non-mechanical zoom lens in use with a camera for an enhanced computer input device will be presented. The device is based on polarization-dependent Pancharatnam phase lenses and a polarization rotator. A demonstration device has been shown to have a 4× zoom ratio and a 6.5-mm length.

AUTHOR INTERVIEWS (4:30–5:30)

ADVANCED LIGHT SOURCES, COMPONENTS, AND SYSTEMS II

Thursday, June 4 / 3:10 – 4:30 pm / Room LL21EF

Chair:
Bob Horner, *IES, New York, NY, USA*

Co-Chair:
M. Lu, *Acuity Brands Lighting, Berkeley, CA, USA*

62.1: *Invited Paper:* Application-Specific Spectral Power Distributions of White Light (3:10)

P-C. Hung
Konica Minolta Laboratory USA, Inc., San Mateo, CA, USA

K. Papamichael
University of California at Davis, Davis, CA, USA

The potential of today's LED technologies to approximate the spectral power distribution (SPD) aimed to optimize specific performance goals were investigated. The numerically optimal SPDs were compared to actual SPDs produced by a 16-channel LED light source aimed at optimizing the performance for six different applications.

62.2: *Invited Paper:* LED Life Versus LED System Life (3:30)

N. Narendran, Y-W. Liu
Rensselaer Polytechnic Institute, Troy, NY, USA

The useful life of an LED is presently determined by the IESNA LM80-08 lumen maintenance standard. Even though an LED system has many components, the current industry practice rates LED system lifetime based on a single component, namely, the LED. An accelerated life test and the results for LED components and systems to illustrate the difference in lifetimes and to emphasize the need for a standardized LED system life test will be described.

62.3: Speckle Contrast Reduction in a Blue-LD Pumped Micro-Vibrated Reflective Phosphor Paper for Lighting-Source Applications (3:50)

S-Y. Tu, H. Y. Lin
National Taiwan University, Taipei, Taiwan, ROC

T-X. Lee
National Taiwan University of Science and Technology, Taipei, Taiwan, ROC

Efficient speckle-reduction techniques have been demonstrated by using both micro-vibrated and mixing light methods for solid-state backlighting source applications. A micro-vibrated-reflective phosphor paper is used for speckle suppression and white-light generation. A mixing speckle contrast (SC) is defined, and the almost speckle-free results have been achieved.

62.4: PFS, $K_2SiF_6:Mn^{4+}$: A Red-Line-Emitting LED Phosphor Behind GE's TriGain Technology Platform (4:10)

J. Murphy, F. Garcia-Santamaria, A. A. Setlur, S. Sista
GE Global Research Center, Niskayuna, NY, USA

The red-line emission of a PFS phosphor centered at 631 nm results in phosphor converted LED package efficacy improvements of >10% relative to packages using conventional Eu^{2+}-doped nitride broad-band red-emitting phosphors. Improvements in absorption, quantum efficiency, and stability under high humidity and high light flux will be presented that have resulted in the commercialization of this material under GE TriGain™ technology.

AUTHOR INTERVIEWS (4:30–5:30)

POSTER SESSION

Thursday, June 4 / 5:00 – 8:00 pm / Ballroom 220A

Active-Matrix Devices

P.1: Current-Supplying Driving Method of Active-Matrix Ionic Polymer-Metal Composites for Stereoscopic Displays

S. Sawada, H. Okazaki, M. Okumura, T. Matsuda, M. Kimura
Ryukoku University, Otsu, Japan

H. Tanaka, T. Matsumoto
Seiko Epson Corp., Nagano, Japan

A current-supplying driving method for active-matrix ionic polymer-metal composites for stereoscopic displays has been developed. Poly-Si TFTs were fabricated using ELC, whereas IPMC was fabricated using an ionic polymer and vacuum evaporation of gold electrodes. The pixel circuit consisted of two pairs of three transistors to supply sufficient alternating current.

P.2: A Novel Way of LTPS Model Extraction with Hysteresis and Transient Current Analysis

C-H. Kuo, Y-S. Tsai, C-C. Tseng, C-W. Lau, C-Y. Liu
AU Optronics Corp., Hsinchu,T aiwan, ROC

H. Wang, L. Huang, S. Lin, Y-P. Wei, P-T. Liu
Legend Design Technology, Inc., Santa Clara, CA, USA

Time-sampling measurements were used to build a time-dependent LTPS TFT current model. The device model that considers bias and time-dependent threshold-voltage (V_{th}) shift and mobility degradation was implemented by using Mentor Graphics' ELDO and GUDM for simulating a pixel circuit as an indicator of panel performance.

P.3: A New LTPS Pixel Circuit for Compensating the Variation of TFT Characteristics and Alleviating OLED Degradation

W-C. Hsu, P-C. Wu, K-R. Jen, C-Y. Lee, H-S. Lin,
L-H. Chang, Y-H. Lin
AU Optronics Corp., Hsinchu, Taiwan, ROC

A pixel compensation circuit that utilizes six LTPS TFTs and one capacitor for AMOLED displays by using a voltage-programmed method has been developed. The proposed pixel circuit can compensate for the threshold-voltage variation of the TFTs and extend OLED lifetime, showing improved compensation performance.

P.4: Feasibility Study of a Dual-Gate Photosensitive TFT for Fingerprint-Sensor-Integrated Active-Matrix Display

H. Jeong
Carnegie-Mellon University, Pittsburgh, PA, USA
and
Sun Yat-Sen University, Guangdong, China

M. Won, W. Shi, J. A. Weldon, X. Li
Carnegie-Mellon University, Pittsburgh, PA, USA

K. Wang
Sun Yat-Sen University, Guangzhou, China

By placing a transparent conductive ITO layer atop a display driver TFT, a dual-gate photosensitive TFT is formed to integrate a fingerprint-sensing function in a display pixel. An analytical model is proposed to elaborate its working principles in achieving both fingerprint-imaging and display-driving functions.

P.5: Oxide Semiconductor/Polypropylene Carbonate Paste for a TFT Using Screen Printing

A. Matoba, Y. Yonezawa
Industrial Research Institute of Ishikawa, Ishikawa, Japan

K. Fukada, Y. Maeda, X. Y. Liu, S. Inoue, T. Shimoda
Japan Advanced Institute of Science and Techonology, Ishikawa, Japan

K. Nishioka, N. Fujimoto, M. Suzuki
Sumitomo Seika Chemicals Co., Ltd., Osaka, Japan

S. Takagi
Tokyo Process Service Co., Ltd., Tokyo Japan

An oxide-semiconductor paste utilized to fabricate a TFT by screen printing has been developed. Polypropylene carbonate was used as a binder to control the viscosity of the paste. The channel layer patterned by screen printing exhibited the desired semiconductor characteristics.

P.6: Impact of Buffer Layers on the Self-Aligned Top-Gate a-IGZO TFT Characteristics

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M. Murata
Panasonic Corp., Moriguchi, Japan

By studying the buffer layer by using various deposition methods such as PECVD, PVD, and ALD on self-alignment top-gate a-IGZO TFTs, the optimized TFT characteristic were found. An optimized layer was integrated into a TFT backplane on polyimide (PI) foil, and a QQVGA AMOLED display was demonstrated.

P.7: Improvement of PBTS Stability in Self-Aligned Coplanar a-IGZO TFTs

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The PBTS instability of top-gate coplanar amorphous InGaZnO TFTs was improved by optimizing the buffer and gate insulator layers. The interface trap density was obtained from photonic capacitance-voltage measurements and correlated with PBTS characteristics. Inter-diffusion at the gate-insulator interface lessens electron trap defects, which brings improvement in PBTS from ΔV_{th} of 4.2 to 0.5 V.

P.8: Investigation the Degradation Behaviors for Bottom/Top Gate Sweep under Negative-Bias Illumination Stress in Dual-Gate InGaZnO TFTs

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Y-X. Yang, K-K. Chen, T-H. Shih, H H. Lu
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It was found that the degradation behavior is completely different in the bottom and top gate sweep, regardless of the bottom gate or top gate stress. The different locations of these hole-trapping regions cause the respective degradation behavior in the bottom/top gate sweep.

P.9: Improved Electrical Stability of Double-Gate a-IGZO TFTs

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S. Zhang
Peking University, Beijing, China
and
Peking University, Shenzhen, China

The electrical stability of double-gate a-IGZO TFTs has been investigated. The double-gate devices exhibit a much smaller Vth shift than that of single-gate devices under gate bias stress. The improved electrical stability comes from not only the lowered vertical electric field but also more effective moisture resistance due to the shield of double-gate electrodes.

P.10: Comparative Studies of ZnON and ZnO TFTs Fabricated by DC Reactive Sputtering Method

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H-S. Kim
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DC reactive sputtered ZnO and ZnON TFTs were fabricated in order to investigate the role of the nitrogen element in the ZnO matrix. The physical structure and chemical-bonding was analyzed by X-ray diffraction, absorption and photoelectron spectroscopy, respectively. Consequently, nitrogen incorporation in DC reactive spurring can suppress the crystal growth and enhance electron mobility due to Zn-N bonding.

P.11: Channel-Etched CAAC-OS FETs Using Multi-Layered IGZO

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The improvement in the reliability of a channel-etched field-effect transistor (FET) using the buried channel effect was achieved by stacking In-Ga-Zn-O (IGZO) films with different compositions. In addition, an LCD that uses an IGZO multi-layered c-axis-aligned crystal FET for the backplane was fabricated.

P.12: A Study on the Characteristics of Crystalline Indium-Gallium-Zinc-Oxide TFTs

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H. S. Shin, J. Bae
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IGZO thin films were crystallized by annealing to achieve high device performance. The electrical properties and reliability under various stress conditions of crystalline-IGZO (c-IGZO) TFTs were investigated and compared to that of conventional amorphous-IGZO (a-IGZO). In addition, the effects of IGZO thickness on the electrical properties of c-IGZO were also studied.

P.13: The Relationship between Crystallinity and Device Characteristics of In-Sn-Zn-Oxide

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Nano-scale structures of In-Ga-Zn-O (IGZO) films and amounts of H_2O desorption from the film have been investigated, and their influence on the characteristics of field-effect transistors (FETs) will be discussed. It is suggested that IGZO films with high crystallinity and a small amount of H_2O desorption are favorable for uniform FET characteristics.

P.14: A Narrow-Bezel FFS-Mode WQHD LCD with a Modified ESL-Type a-IGZO TFT

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A 4.9-in. narrow-bezel FFS-mode WQHD (2560 × 1440) LCD was developed by using modified ESL-type a-IGZO TFTs. Those displays were manufactured on Gen 4 original equipment for a-Si TFTs. The Ion/Ioff of the modified ESL-type TFTs is 10^8.

P.15: Self-Aligned Top-Gate Zinc-Oxide TFTs Fabricated by Reactive Sputtering of a Metallic Zinc Target

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By optimizing deposition conditions by reactive sputtering of a metallic zinc target, high-performance TFTs with a field-effect mobility of 37.5 cm^2/V-sec and an I_{on}/I_{off} ratio of 3.8 × 10^8 was obtained. ZnO TFTs using a phosphorus-doped source/drain shows good thermal instability.

P.16: Research on Dual-Layer Channel ITO/MZO TFTs Fabricated on Glass at Low Temperature

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and
Peking University, Beijing, China

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Peking University, Beijing, China

S. Zhang
Peking University, Shenzhen, China

High-performance dual-layer channel ITO/MZO TFTs have been successfully fabricated on a glass substrate at low temperature. The dual-layer channel is composed of ITO and MZO layers. The use of the a-ITO layer brought about enhanced subthreshold swing, enhanced saturation mobility, and decreased threshold voltage compared to that of MZO TFTs.

P.17: High-Mobility ITZO BCE-Type TFTs for AMOLED Applications

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BCE-type oxide-semiconductor TFTs with high mobility and high photoreliability have been developed by using ITZO as the channel material. The mobility was over 25 cm^2/V-sec, and the threshold-voltage shifts of BITS were successfully reduced to 0.4 V. Furthermore, a 13.3-in. top-emission AMOLED has been fabricated.

P.18: Extraction and Simulation with Time-Dependent V_{th}-Shift Model for an IGZO Panel

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S. Lin, C-W. Wang, L. Huang, Y-P. Wei
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P-T. Liu
National Chiao Tung University, Hsinchu, Taiwan, ROC

The impact of stress effect on the performance of an IGZO panel will be discussed. Instead of observing the threshold-voltage (V_{th}) shift, the time dependency of serial ID-VG test is included in building an accurate V_{th}-shift model, enabling simulations of IGZO TFT current change under fixed bias for circuit optimization.

P.19: Effect of Strain on the Characteristics of Amorphous In-Ga-Zn-O TFTs Fabricated on Engineered Aluminum Substrates

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K. N. Shah, T. L. Levendusky
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The effect of strain induced by bending on the characteristics of a-IGZO TFTs fabricated on conformal aluminum substrates will be reported. The successful demonstration of IGZO TFTs on aluminum substrates presented in this study points to the promise of aluminum substrates for use in future flexible display and electronics applications.

P.20: The Effect of Oxide-TFT Design on Voltage-Threshold Shift

X. Wang, X. Yao, W. Qin, H. Zhang, L. Xiao, Y. Um, K. Peng, Y. Im, J. Jun
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The threshold-voltage (V_{th}) instability of oxide TFTs is the biggest challenge for production. Test results show that an optimized device design can also reduce the V_{th} shift. The influence of the TFT shape on the V_{th} shift and the mechanism of this influence will be explained.

P.21: Effects of Low-Hydrogen Dielectric Film on a-IGZO TFT Properties

X. Liu, L. Yan, G. Yuan, L. Chen, J. Cheng, C. Jiang, X. Kong, J. Chen, W. Liu, W. Shen, W. Gang
BOE Technology Group Co., Ltd., Beijing, China

Low-hydrogen dielectric film deposition was used in PECVD. The properties of IGZO bottom-gate TFTs using this dielectric were investigated. The overall properties for low-hydrogen dielectric recipe IGZO TFTs maintain the field of the oxide backplane, and the PBTS and NBTS was reduced to 0.481 and –0.269 V, respectively.

P.22: High-Performance a-IGZO TFT Backplanes with Cu Gate and Source/Drain Electrodes for AMOLED Displays

X. Zhu, C. Jiang, G. Yuan, W. Liu, X. Li, L. Xin, M. Wang, G. Wang
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The fabrication process for Cu-gate TFTs has been developed and the TFT performance is good enough for driving large-sized AMOLED displays. The TFT process, uniformity, and reliability will be discussed. 14-V and 55-V UHD AMOLED displays will be described and have been demonstrated by using this process.

P.23: Simulation Calibration Procedure of Leakage Current in TFTs

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The procedure to calibrate TCAD simulation data, based on both measurement data and the probability effects, will be described. By using a density-of-states model and a band-to-band tunneling model in the Silvaco Atlas device simulator, insight into the TFTs and more accurate simulations can be obtained.

P.24: Optimization of the Fabrication Process for Bridged-Grain Metal-Induced Crystallization TFTs

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Bridged-grain metal-induced crystallization of poly-Si TFTs typically requires about 10 hours. Increasing the amount of nickel can reduce the time for the crystallization process. The effect of the amount of nickel and the electrical performance of the resulting BG MIC TFTs will be explained. The optimization of the number and width of the Bridged-grain lines on the electrical properties of the TFTs were also investigated.

P.25: Enhancement in Positive-Bias-Stress Stability of In-Ga-ZnO TFTs with Vertically Graded-Oxygen-Vacancy Active Layer

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J. S. Choi
Hongik University, Seoul, South Korea

A simple method to deposit the vertically graded oxygen-vacancy active layer is proposed. The threshold voltage shift of optimized VGA TFTs were drastically improved under the positive-bias-stress condition.

P.26: High-Capacity Memory Using Oxide-Based Schottky Diode and Unipolar Resistive Array

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G-T. Zheng
National Tsing Hua University, Hsinchu, Taiwan, ROC

An Al-doped zinc-tin-oxide-based Schottky diode and resistive switching memory have been demonstrated. Due to post-deposition annealing, the forward current of the proposed Schottky diode was improved. Integration of a one diode and one resistor (1D1R) configuration through SPICE simulation has been achieved. Furthermore, the read margin analysis of the array size was carried out, and a 1-kbit array can be realized with the anti-crosstalk properties of the AZTO-based 1D1R devices.

P.151L: *Late-News Poster:* Printing Pixel Circuits on a LED Array for AMLED Displays

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An active-matrix LED module integrated with carbon-nanotube control circuits was fully printed. The high performance of super-pure single-chirality carbon-nanotube TFTs provides super-bright and low-power-consumption technologies for indoor and outdoor augmented reality that are highly desirable for civil and military display applications.

P.152L: *Late-News Poster:* Simple Method for Low-Temperature-Processed In-Ga-Zn-O TFTs by Using the Vertical Diffusion Technique

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and
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S. Yoon, Y. J. Tak, H. J. Kim
Yonsei University, Seoul, Republic of Korea

A novel and simple strategy for fabricating solution-processed IGZO TFTs at low annealing temperatures via a vertical diffusion technique is proposed. This technique enables a significant reduction in processing temperatures (< 300°C) by maintaining its electrical performance and is useful in the fabrication of flexible/transparent oxide TFTs.

P.153L: *Late-News Poster:* Interface-Location-Controlled Dual-Stacked Solution-Processed In-Ga-Zn-O TFTs for Improved Electrical Performances

J. W. Na, Y.-G. Kim, H. J. Kim
Yonsei University, Seoul, South Korea

Indium-gallium-zinc (IGZO) TFTs using dual-stacked active layers of different molarities to improve their electrical performance were fabricated. By controlling the molarities, IGZO TFTs exhibit enhanced field-effect mobility and PBS stability.

P.154L: *Late-News Poster:* Stability Enhancement of Oxide TFTs by Blue Laser Annealing

S. Jin, S. Lee, E. Lee, M. Mativenga, J. Jang
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A highly stable a-IGZO TFT with the conventional back-channel-etch structure has been achieved by using blue (445-nm) laser annealing (BLA). After application of negative bias and light-illumination stress, TFTs irradiated by a blue laser exhibited a smaller negative threshold-voltage shift compared to those without laser irradiation.

P.155L: *Late-News Poster:* Low-Temperature Activation of In-Ga-Zn-O TFTs Using High-Pressure Annealing

W-G. Kim, Y. J. Tak, T. S. Jung, S. P. Park, H. Lee, J. W. Park, H. J. Kim
Yonsei University, Seoul, South Korea

The effects of high-pressure annealing as a source of activation energy to form the a-IGZO channel layer at 100°C has been investigated. Thermal activation under oxygen pressure was used to facilitate the formation of a channel layer as well as to improve positive-bias-stress stability.

Applications

P.27: Diffractive Color Splitter for High-Efficiency LCDs

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Absorptive color filters in LCDs reject more than 70% of their incident light. A high-efficiency diffractive color splitter was designed, fabricated, and characterized that is able to redirect light into the red, green, and blue color subpixels and thereby improve light transmission through the LCD.

P.28: Contrast Enhancement for an Imaging System Using Electrically Tunable Liquid-Crystal Lens

S. Yu, R. Bao, C. Cui, M. Ye
SuperD Co., Ltd., Shenzhen, China

A method of improving the image quality of an optical system using a liquid-crystal lens is proposed and has been demonstrated by experiments. Because image magnification is invariant with liquid-crystal-lens imaging, image processing using focused and defocused images can be performed to enhance the contrast of the focused image.

P.29: A Polymer/Fullerene-Based Material in Near-Infrared Photodetector Applications

H-T. Hsiao, Y-H. Liang, H-I. Peng, C-H. Tu, C-Y. Liu, M-F. Chiang
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A semiconducting polymer with alternating diketopyrrolopyrrole and terthiophene units (PDPP3T), a band gap of 1.3 eV, and high hole mobility was used to create a near-infrared absorbing organic photosensor with photo and dark currents of 4.6 $\mu A/cm^2$ and 2.1 nA/cm^2 at –1 V. The device yields a good linear photocurrent response.

P.30: A Study on the Viewing Zone of Curved Barrier-Type Autostereoscopic Displays

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This analysis introduces a display curvature functionality to derive the designed eye position and viewing zone for flexible displays. Parameters to avoid forward shifts of the designed eye position have been determined .

P.156L: ***Late-News Poster:*** **Optical Tubes Using High-Refractive-Index Resin and Their Application to New Concept Lighting Designs**

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Fluorescent lamp-type lighting that uses a light pipe with a high-refractive-index optical resin with less LEDs than that for conventional LED lighting is proposed. In order to increase the efficiency of FL-type lighting, a technique to form a Fresnel lens in the light-emitting part and a designed edge-type lighting structure using an optical pipe, which enables a high optical efficiency with less LEDs, is introduced. A simulation using this lighting design was performed, and data indicating that this lighting design seems to produce an improved efficiency twice that for current 45-W fluorescent lamps was obtained.

Applied Vision / Human Factors

P.31: Will Curved Displays Become Mainstream in Electronics? Appraisal for Aesthetic and Usability Aspects of Various Curves and Sizes

N. Na, K. A. Jeong, S-W. Ju, K. Choi, H-J. Suk
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The optimal curvature of displays differs based on the screen size. A subjective evaluation with 80 participants reported that a 2000-mm radius of curvature is most preferred for 55-in. displays and a radius between 2000 and 3000 mm is preferred for 65-and 75-in. TVs.

P.32: Impact of 3D Visualization Conditions on the Contrast Sensitivity Function

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L. Platiša, W. Philips
Ghent University, Ghent, Belgium

The contrast sensitivity function is well known for 2D images, but it has not been measured for stimuli outside the display plane. Variations in contrast sensitivity for Gabor stimuli that had depth behind the display and that were inclined in depth with respect to the display were explored.

P.33: A Comprehensive Evaluation of Visual Fatigue When Viewing Small Autostereoscopic Displays

D. Wang, X. Yang, Y. Xie, Z. Wang
Chinese Academy of Sciences, Beijing, China

A comprehensive evaluation method, which combines both subjective and objective assessments for a mobile autostereoscopic display, is proposed. Eighteen subjects were evolved in viewing the same video under both 2D and 3D conditions. The change in visual fatigue on viewing the mobile display was analyzed.

P.34: Curved OLED Display to Effectively Enhance Natural3D

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Natural3D is a natural stereoscopic effect produced by high-resolution images without parallax. Optimal display curvature that enhances natural3D was found for displays of different sizes. Statistical tests indicated that the tiredness was reduced. The measurement of focal distance showed that a high-contrast OLED display enhances natural3D.

P.35: The Prospect Assessment of 65-in.+ TVs Based on the Size of Mainstream Living Rooms in China

F. Jiang, L. Zhou, K. Liu, X. He, X. Liu, Z. Li
BOE Technology Group Co., Ltd., Beijing, China

The prospect of 65-in.+ high-resolution TVs was assessed by analyzing the sizes of mainstream living rooms in China. Quantitative data analysis shows that 65–77-in. high-resolution TVs, which can fit into typical apartment-building elevators, are well suited for wall decoration and provide an excellent visual experience.

P.36 : Subjective Size of News Presenation Shrinking with Recent Enlargement of Display Size in Japan

Y. Kumagai, K. Nagata, K. Kihara, S. Ohtsuka
Kagoshima University, Kagoshima, Japan

Subjective and objective sizes of news presentations on Japan's ground-wave digital television news programs in 2011 were compared to those of 2014. The results show that (1) the average subjective size decreased but not the objective size and (2) the most significant transition was observed in weather-forecast programs.

P.157L: *Late-News Poster:* Subjective Assessment of Simulated Curved Displays for UHD TV in a Large-Sized and Wide-Viewing-Angle Environment

S. Ohtsuka, C. Imabayashi, Y. Kumagai, K. Nagata, K. Kihara
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The visibility of flat and curved simulated displays with 8K resolution has been compared. The results show that (1) curved displays were preferred over flat ones and (2) the preferred viewing distance varied only slightly with display type. The visual effects of geometrical distortions will also be discussed.

P.37: A 5-Gbps/lane Intra-Panel Interface for UHD TFT-LCD Application

Y-C. Kang, L-W. Chang, Y-C. Wu, W-T. Chen, C-P. Ho, C-H. Yang
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A high-speed intra-panel interface which applies point-to-point topology, phase-locked-loop (PLL) type clock data recovery (CDR), and a dc self-adjusting data encoder will be presented. The preliminary measurement result on an Altera stratix5 FPGA platform shows that the maximum data rate can be operated up to 5 Gbps/lane.

P.38: A Narrow-Gate Driver Circuit with a-Si TFTs for a 8-in. WQXGA TFT-LCD Panel

C.-D. Tu, Y.-C. Chen, C.-H. Huang, K.-W. Hong, H.-S. Chang, C.-H. Kuo
AU Optronics Corp., Hsinchu, Taiwan, ROC

An 8-in. WQXGA TFT-LCD prototype with a bi-directional integrated gate driver circuit by using a-Si:H TFTs which can stabilize the floating of gate line has been fabricated. The border size of the proposed gate driver circuit is below 1 mm. High-temperature operation within 300 hours without failure shows the useful stabilization of the proposed circuit.

P.39: High-Speed and Power-Savings Interface for High-Resolution and Low-Power Display Panel

H.-E. Liu, C.-J. Su, C.-K. Cheng, W.-K. Liu
ILI Technology Corp., Jhubei, Taiwan, ROC

An 8-bit 1446-channel source driver IC for 2K-resolution applications will be presented. The source IC adopts the point-to-point interface with an embedded clock. Fine-grained control has been developed for the interface to operate with very low power consumption. The source driver is implemented in a 0.15-μm 1.8/13.5-V high-voltage process. The maximum data rate with a 1.8-V supply voltage is up to 2.25 Gbps.

P.40: Development and Evaluation: Image-Processing Algorithms for Reducing Image Sticking

C-C. Chang, J-F. Huang, C-H. Chang, C-M. Hsu, H-S. Lin, L-H. Chang, Y. Lin
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Life-engine managing algorithms are introduced. The algorithms reduce image sticking in multiple ways. The simulation method for reproducing image sticking and the benchmark method of ranking the efficiency between algorithms were also developed. According to simulation, the image orbit dominates the strength of curing image sticking in algorithms.

P.41: A New a-IGZO TFT Gate Driver Circuit with Threshold-Voltage-Shift Recovery Driving Scheme

C-L. Lin, C-E. Wu, C-E. Lee
National Cheng Kung University, Tainan, Taiwan, ROC

An a-IGZO TFT integrated gate driver with a 33% ac driving structure and a new driving scheme for recovering threshold-voltage shift (V_{th}) will be presented. Simulation results illustrate that the proposed circuit can be successfully operated with a-IGZO TFTs, and the power consumption was improved to 274.56 μW.

P.42: Moved to Paper 41.2

P.43: New Pixel Circuit to Improve Current Uniformity for High-Resolution AMOLED Displays

C-L. Lin, P-C. Lai, M-Y. Deng
National Cheng Kung University, Tainan, Taiwan, ROC

A pixel circuit based on LTPS-TFTs that compensate for V_{th} and mobility variations of TFTs utilizing a parallel addressing scheme for high-resolution AMOLED displays will be presented. Simulated current error rates were all lower than 2.1% for 0.5-V V_{th} variations and lower than 2.5% for 30% mobility variations of the TFTs.

P.44: New Pixel Circuit with Simple Driving Scheme for AMOLED Displays

C-L. Lin, P-S. Chen, P-S. Shieh
National Cheng Kung University, Tainan, Taiwan, ROC

A new pixel circuit with four LTPS TFTs and one capacitor for AMOLED displays will be presented. The proposed pixel circuit is capable of compensation for V_{th} variations of driving TFTs with only one scan signal in one step. Furthermore, the OLEDs were reverse biased in the programming step to avoid flicker phenomenon.

P.45: Simple Low-Noise Gate-Driver Circuit for Slim-Border and High-Resolution Applications

C-L. Lin, M-H. Cheng, Y-W. Du, P-C. Lai
National Cheng Kung University, Tainan, Taiwan, ROC

A novel compact gate-driver circuit is proposed for slim-border and high-resolution applications. The input TFT has multi-functions to simplify the circuit structure. The pull-up TFT charges and discharges the row line so that the circuit area is further decreased. Importantly, the inverse-coupling method assures the stability of the output waveform.

P.46: Row-Division Driving Scheme for AMOLED Displays

C. Leng, X. He, H-M. Lam, X. Meng, C. Wang, S. Zhang
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Y-C. Wu, K-Y. Ko
China Star Optoelectronics Technology Co., Ltd., Guangdong, China

A novel row-division (RD) driving scheme together with a new AMOLED pixel circuit with only three transistors and one capacitor is proposed. The RD method can effectively increase the OLED emission time compared with the simultaneous emission method while retaining the prevalent simple pixel structure.

P.47: Algorithm for Regional Mura Reduction by Using Gamma-Curve Transformation in LCD Panels

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A. Lien
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When LCDs become ultra-high resolution, the reduction of mura becomes more significant in the Tcon design in terms of cost reduction and improvement in display quality. An algorithm for mura reduction is proposed and was demonstrated in HD displays. For hardware integration, a data-compression method to save non-volatile-memory space will be discussed.

P.48: A Simple Low-Temperature Workable a-Si:H TFT Integrated Gate Driver on Array

C. Liao, Z. Hu, J. Li, W. Li, S. Cao, S. Zhang
Peking University, Shenzhen, China

A simple a-Si TFT integrated gate driver on array, which can work at low temperatures, is proposed and has been studied. The circuit features a capacitor-coupling gate bias at the TFT for suppressing the feed-through effect. The bias allows the circuit output to be well-formed waveform even at low temperatures.

P.49: The Sequential V_{com} Swing Circuit for Contrast Improvement

K. Kim, W. K. Sang, J. M. Choi, O. S. Yoo, Y. S. Cho, H. U. Jang, J-S. Lee, J-Y. Lee, M-C. Jun, S-D. Yeo
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V_{com} swing technology reduces power consumption by lowering the operating voltage. It can minimize the reduction in the aperture ratio through sequential driving and the new PXL structure. A 32-in. HD-resolution panel in a R&D line was fabricated. Contrast and transmittance, the same performance as from the 32-in. HD production, was confirmed.

P.50: Integrated Gate-Driver Circuit Employing IGZO TFTs for AMOLED Compensative Pixel Driving

K. Cao, Q. Li, C. Song, B. Zhang, Y. Li, S. Meng, J. Yin, C. Gai, L. Wang, Y. Wang, H. Xie, Z. Wu, G. Wang
BOE Technology Group Co., Ltd., Beijing, China

Novel integrated gate-driver circuit architectures for AMOLED pixel compensation purposes will be presented. An inner feedback technique was adopted in a GOA circuit for leakage current cutting of depletion-mode IGZO TFTs. Simulation results show that it successfully works with a maximum ±3-V threshold-voltage shift. These GOA circuits can be used for internal or external threshold-voltage compensation for AMOLED panels.

P.51: A Compact a-IGZO TFT-Based Digital-to-Analog Converter for Flexible Displays

X. Li, D. Geng, M. Mativenga, J. Jang
Kyung Hee University, Seoul, South Korea

A 4-bit a-IGZO TFT-based cyclic digital-to-analog converter (DAC) has been demonstrated on plastic substrates. The DAC has a 130-μm width and is compact enough to fit in the space of one data line. It exhibits good linearity, while being bent to a radius of 2 mm, making it suitable for flexible displays.

P.52: High-Gain Source Followers Driven by Corbino Oxide TFTs for Integrated Display Data Drivers

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R. K. Mruthyunjaya, G. N. Heiler, T. J. Tredwell
Carestream Health, Inc., Rochester, NY, USA

A high-gain source-follower OLED pixel circuit utilizing oxide TFTs with a Corbino (circular) structure, is reported. Given the infinite output resistance exhibited by Corbino TFTs in the outer-drain condition (*i.e.*, when the outer electrode is biased as the drain), the Corbino TFT-based source follower provides higher gain in operation than its rectangular TFT-based counterparts.

P.158L: *Late-News Poster:* Development of a Silicon Process with Device Mobility >500 cm^2/V-sec Suitable for a Large-Area-Display Backplane Using Embedded Single-Crystal-Silicon Particles

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D. R. Dykaar
DifTek Lasers, Inc., Waterloo, Ontario, Canada

A device mobility >500 cm^2/V-sec in a scalable process suitable for electronic backplanes for large-area OLED displays is reported. Ceramic substrates as large as 4 × 4 in. were fabricated utilizing planarized regions of single crystal silicon (SCS).

P.185: A Novel Rendering Algorithm with Adaptive Weighting Factors

S-Y. Su, S-W. Cheng, H-F. Lin, H. Chuke, Y-C. Chu, S-T. Huang, R-L. Dong, C-Y. Lo
AU Optronics Corp., Hsinchu, Taiwan, ROC

Subpixel-rendering (SPR) technology is a method used to improve visual resolution by utilizing the subpixel arrangement and a rendering algorithm. A novel rendering algorithm to improve image sharpness will be described. The algorithm dynamically references the adjacent image data, including saturation (S) and luminance (V). Then, the sequence for rendering the image data is calculated by using S, V, and pre-determined weighting factors P. The weighting factors for most subpixel arrangements are optimized by minimizing the root-mean-square error (RMSE) from the original image data. The algorithm was applied to an 8-in. 424-ppi LCD. The proposed method reduces both the color fringing artifact and blurring in subpixel-rendered images and has the same resolution perception compared with that for a conventional RGB stripe.

Display Manufacturing

P.53: Study on the Interface between Passivation and Insulator Layers in TFT with Organic Process

N. Zhao, Q. Shen, G. Shi, X. Xu, Y. Wang, J. Song, J. Han, Y. Yin, D. Chen, C. Che, C. Li
BOE Technology Group Co., Ltd., Anhui, China

A phenomenon called flexible printed circuit (FPC) peel off, caused by interference between the passivation layer and gate insulator layer in TFTs during the organic curing process, is introduced. The relationship between this phenomenon and the TFT array process was investigated, and the interface characteristics through N_2 plasma and N_2 flow skip in the passivation deposition step were improved. An optimized VIA hole design, which can achieve a favorable FPC bonding condition, was developed.

P.54: WCS Material Development of the FIT M+ Structure to Reduce Power Consumption of Large-Sized UHD TVs

C. Park, E. Kim, W. Byun, M. Nam, S. Yu, J. Park, S. Shin
LG Display Co., Ltd., Paju, South Korea

M+ technology has been developed to reduce the power consumption of large-sized UHD TV. Various white+ structures were researched and developed. The most advanced construction is a FIT M+ structure. This structure was mass produced, and an FIT M+ TV model was developed.

P.55: Process Development of Integrated V_{com} and PAS Using Wet-Etching Bias Control for UHD AH-IPS TFT-LCDs

H. Kwack, E. Kim, C. Park, M. Nam, S. Yu, J. Park, S. Shin
LG Display Co., Ltd., Paju, South Korea

In order to reduce the number of mask steps in the TFT-LCD manufacturing process, a new structure and process has been developed. This technique involves patterning the bottom layer by using the upper layer's pattern. The bottom layer is made of Vcom ITO and the upper Layer is a passivation layer.

P.56: High-Resolution OLED Panel Fabricated by Ink-Jet-Printing Process

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AU Optronics Corp., Hsinchu, Taiwan, ROC

Ink-jet printing is expected to be an emerging manufacturing method for large-sized displays. A 200-ppi OLED panel was successfully fabricated by using ink-jet printing . Research shows that the ink-jet-printing approach not only can be used for large-sized displays but also for small–to–medium-sized displays and to achieve a resolution exceeding 200 ppi.

P.57: OLED Lighting Devices Fabricated by Flexography Printing Consisting of Silver Nanowire and a Conducting Polymer

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J. Inoue
Dexerials Corp., Miyagi, Japan

Non-ITO transparent electrodes with a stacking structure composed of silver nanowire and transparent conducting polymer have been developed by using flexography printing. In addition, OLED devices were successfully fabricated on the newly developed transparent electrodes.

P.58: Highly Stable Organic TFT Array Fabricated on Gorilla Glass Substrates Using Direct Photolithography

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Shanghai Jiao Tong University, Shanghai, China

W-Y. Lee, Z. Bao
Stanford University, Stanford, CA, USA

J. R. Matthews, W. Niu, K. L. Simonton, T. E. Myers, R. A. Bellman, M. He
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Photolithography was applied to pattern a PTDC16DPPTDC17FT4-based organic TFT (OTFT) array on an ion-exchanged NAS glass substrate with pattern features down to 10 μm. High stability and excellent uniformity of bottom-contact OTFT devices using a photo-patternable polymer gate insulator over 2 in. × 2 in. glass substrates has been demonstrated.

P.59: A 6-in. Full-Color AMOLED with Improved Bonding Strength of Laser Frit Encapsulations

Y-W. Chiu, S-F. Liu, J-Y. Chiou, Y-W. Liu, M-H. Lai, C-Y. Huang, Y-F. Niu
Chunghwa Picture Tubes, Ltd., Taoyuan, Taiwan, ROC

Although laser seal-frit encapsulation has the ability to protect OLEDs from moisture and oxygen oxidation, the bonding strength is too weak and can easily result in peeling of the top and bottom substrates. The bonding strength and production yield can be improved by optimizing the TFT-array structure and process.

P.60: High-Edge-Strength Glass for Mobile Devices

H. Ikeda, K. Kinoshita, M. Fukada, K. Kawamoto, T. Murata, K. Choju, M. Ohji, H. Yamazaki
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T2X-2 has been recently developed. T2X-2 is characterized by the world's highest compressive stress. The high compressive stress of T2X-2 realizes 30% higher resistance to edge impact damage. The improvement contributes to the reduction in the breakage of glass for mobile devices.

P.61 WITHDRAWN

P.62: Silicone Adhesive Providing Protection, Waterproofing, and Reworkability for Precision Assembly of Electronic Devices

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S. H. Kim
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G. S. Lee
Dow Corning Korea, Jincheon, South Korea

The performance of the silicone hot-melt bonding solution for device fabrication will be described. Inherent attributes of traditional silicones including water repellency, chemical resistance, and durability were augmented with automated precision hot-melt delivery and instant room-temperature adhesion to provide ingress and impact protection while allowing manufacturers the rework ability.

P.63: Effect of Glass-Substrate Characteristics on Pattern Tolerance in Inverted-Staggered-Type TFT-Array Fabrication

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Asahi Glass Co., Ltd., Tokyo, Japan

The effect of glass properties on warpage caused during gate-metal deposition and gate-insulator deposition was investigated through numerical simulation. It was found that the thermal-expansion coefficient of the glass substrate as well as Young's modulus needs to be taken into account in order to reduce the warpage.

P.64: Influence of Laser Sealing Process on the Frit Hermetical Performance

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The rough surface of frit after laser scanning can lead to a defect called frit mura, which was proven to decrease the adhesive strength of an OLED device. Thus, the optimal double laser-scanning process will be described to improve frit mura.

P.65: Advanced Processing of ITO and IZO Thin Films on Flexible Glass

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T. Gebel
DTF Technology GmbH, Dresden, Germany

100-µm-thick flexible glass was deposited with transparent conductive ITO and IZO at room temperature using in-line magnetron sputtering and was further refined by dynamic flash lamp annealing (FLA). After flashing the films, an improved transmittance and a reduced sheet resistance of the films were achieved.

P.66: Crystallized Thin Film Using a Carbon-Nanotube Electron Beam (C-Beam) for High-Performance TFTs

H. R. Lee, S. W. Lee, J. S. Kang, J. H. Hong, C. Shikili, K. C. Park
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Carbon-nanotube (CNT) emitters grown by the RAP process was used as the source of electrons to crystallize an a-Si thin films to nano-crystallized silicon thin films in the triode system. The high crystallinity of silicon has been confirmed and the grain-size distribution of the silicon is about 5–20 nm.

P.159L: ***Late-News Poster:*** **A Tungsten-Oxide Buffer Layer on Silver Nanowires for Electrically Stable, Flexible, Transparent Hybrid Electrodes Using Solution Process**

S-G. Jung, H. J. Lee, J. H. Hwang, Y. S. Shim, K. N. Kim, C. H. Park, Y. W. Park, B. K. Ju
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A hybrid AgNW/WO_3 transparent electrode shows strong mechanical and chemical stability for a flexible transparent electrode. This hybrid electrodes can be used effectively in next-generation flexible electrical devices. Also, the process used to make electrodes is a simple solution process that can reduce the cost of fabrication.

Display Measurement

P.67: Viewing Angle and Imaging Multispectral Characterization of OLED Displays

P. Boher, T. Leroux, V. Collomb-Patton, T. Bignon
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OLED displays exhibit luminance fluctuations and color shifts that the human eye can be sensitive to. By using viewing-angle and imaging multispectral measurements, it was shown that color shifts are generally related to the multilayered structure of each subpixel. Interference fringes result in angular variations and thickness variations in surface non-uniformities.

P.68: An Efficient Simulation Algorithm for Analysis of Moiré Patterns in Display Systems

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S-J. Byun, J. Lee, S. Y. Byun
INSIDEOPTICS Co., Ltd., Seoul, South Korea

A fast computational method for the simulation and analysis of moiré patterns is proposed. It includes complex, large-scale displays, and reflecting surfaces under the illumination of an external ambient light source. All based on convolution with superposition of the intensity profile and the point spread function.

P.69: Compensation of View Profile for More-Reliable Cross-Talk Value of a Multi-View 3D Display

S. Hwang, J. Yoon, K. Kang
Samsung Electronics Co., Ltd., Suwon, South Korea

A method to improve the reliability of cross-talk values of a naked-eye multi-view 3D display is proposed. The limited measurement area of viewing-angle measuring equipments and the difference in the configuration of RGB color pixels which frame the area result in different luminances and create errors in the cross-talk value.

P.70: Novel Sparkling Quantification Method on TFT-LCD

Y.-H. Chiang, T.-W. Hsu, S.-C. Lin, C.-H. Liao, J.-J. Su
AU Optronics Corp., Hsinchu, Taiwan, ROC

Sparkle in LCDs is an observable phenomena caused by optical interference between surface treatments and pixel geometry. The authors propose a novel measurement technique that shows high correlation to human observations. This measurement can predict the observable sparkle on high-resolution displays with various surface treatments and complex pixel structures.

P.160L: ***Late-News Poster:*** **Viewing-Angle Analysis of Integral-Imaging Displays**

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A new method to determine the viewing angle of an integral-imaging display is proposed. The viewing angle is equal to an angle between the farthest edges of the collecting rays on the integrated point. This method is useful in determining the viewing angle of other three-dimensional displays.

P.161L: ***Late-News Poster:*** **Evaluation of Image Quality through the Transparent Displays**

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W-D. Jeng, O-Y. Mang
National Chiao Tung University, Hsinchu,Taiwan, ROC

When an object is viewed behind a transparent display, image blur could be detected. This phenomenon was evaluated by measuring the diffraction width and modulation transfer function (MTF). By optimizing the pixel layout, the diffraction width of the object image can be decreased to 54% in the x direction and 48% in y direction. The MTF also showed that the image quality could be improved by modifying the structure of the transparent display.

Display Systems

P.71: A 3D/2D Convertible Integral-Imaging Display with High Optical Efficiency

H. Deng, Q-H. Wang, D-H. Li, C-G. Luo
Sichuan University, Chengdu, China

A high-optical-efficiency 3D/2D convertible integral-imaging display is proposed. 3D mode is realized by using a pinhole array on a polarizer to generate a point-light-source array. 3D/2D switching is achieved by electrically controlling the polarization switcher. A reflective polarizer and a diffuser were used to recycle polarized light. Experimental results demonstrate high optical efficiency.

P.72: Non-Unified Elemental-Image-Array Generation Method for Moiré-Reduced Integral-Imaging System

Z-L. Xiong, J. Chen, H. Deng, Q-H. Wang
Sichuan University, Chengdu, China

A selective pixel-sampling algorithm is proposed for the generation of a non-unified integral-imaging elemental image array with reduced moiré patterns. Experiments show that the proposed method can increase the three-dimensional resolution and substantially reduce rendering cost in the generation of an ultra-high-definition elemental image array.

P.73: Lenticular-Lens Parameter Estimation Using a Single Image for Crosstalk Reduction of a Three-Dimensional Multi-View Display

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I. S. Kweon
KAIST, Daejeon, South Korea

A method to estimate the parameters of a lenticular-lens array is proposed. A single stripe-patterned display image was used to estimate the slanted angle and pitch of a lenticular lens. The lens parameters can be derived from an observed pattern parameters on a captured image. Experimental results using a simulated dataset show estimated errors for rotational angle and pitch of 0.0077° and 0.0002 mm, respectively. The proposed method is robust to image noise and reduces crosstalk when applied to a conventional multi-view display.

P.74: View-Map Redesign Method for Optical Error Compensation by 3D Panel

M-S. Park, H-J. Kim, K-A. Chin, K-T. Kim, J-H. Park, K-M. Lim
LG Display Co., Ltd., Gyeonggi-do, South Korea

A method to correct lenticular lens misalignment on an image panel for a lenticular-lens-based multi-view displays is introduced. The method is composed of two processes. The first is to determine whether an alignment error happens during the process of lens lamination on an image panel by observing the assembly from an optimum viewing distance (OVD). The second process is to redesign the view map of the image panel. A significant reduction in 3D crosstalk is demonstrated by applying the suggested view-map correction method.

P.75: Autostereoscopic 3D Projection Display with Low Crosstalk

J-L. Liang, Q. Wang, S-F. Zang, W-X. Zhao, Q-H. Wang
Sichuan University, Chengdu, China

An autostereoscopic 3D display based on a parallax barrier and a lenticular sheet is proposed. It is an effective approach to realizing large-sized 3D images. A 50-in. prototype which demonstrates good stereoscopic images with low crosstalk has been developed.

P.76: Autostereoscopic 2D/3D Switchable Display with Electrode-Driven Liquid-Crystal Lens

K. Wu, N. Wu, W. Wei, J. Lin, T. Wang, C. Zhou, Y. Im, J. Jun
BOE Technology Group Co., Ltd., Beijing, China

An autostereoscopic display with 2D/3D switching capability has been developed by using an electrode-driven liquid-crystal (ELC) lens. Tilt ITO electrodes, a resin layer that decreases the transverse electric field, and Axostep testing equipment to fine tune the retardation was applied. An autostereoscopic prototype with low crosstalk, insignificant moiré, and high brightness that is suitable for mass production was fabricated.

P.77: Increased Power Saving by Combining Global and Local Dimming for Edge-LED LCDs

M. Schmidt, D. Schäfer, C. Xu
Saarland University, Saarbrücken, Germany

Global dimming is widespread and delivers significant power savings at modest hardware cost. An amended hardware-efficient global dimming approach combined with the use of local dimming is proposed to improve visual quality and achieve significant additional power savings.

P.78: A Novel Autostereoscopic Display without Moiré

L. Niu, J. Li, J. Ma, Z. Ling, T. Wu, S. Huo, Q. Yao, J. Huang
Shanghai Tianma Microelectronics Co., Ltd, Shanghai, China

Based on Fourier analysis, the theoretical conditions for a moiré-free 3D display have been deduced. A novel high-resolution 3D display has been developed by using the proposed pixel rendering. Measurement results of the 3D display, including the moiré-free performance, will be presented.

P.79: Maximizing the 2D Viewing Field of a Computational Two-layer Light-Field 3D Display

S. Wang, M. Sun, P. Surman, J. Yuan, X. W. Sun
Nanyang Technological University, Singapore

A method to extend the field of view of a compressive light-field display with maximum viewing-angle optimization is proposed. This method improves the overall visual effect of a compressive light-field display and provides a relative desirable improvement, especially for the performance of the non-target light-field display region.

P.80: The Use of Multiple Orthographic Image Interleaving to Generate a Tilted Elemental Image Array at an Arbitrary Angle Directly

J. Chen, Z.-L. Xiong, C.-G. Luo, Q.-H. Wang
Sichuan University, Chengdu China

Multiple orthographic image interleaving, a computer-generated integral-imaging method used to generate a tilted elemental image array (EIA) at an arbitrary angle, is proposed. Experiments to generate tilted EIAs with different angles were performed, and different integral-imaging 3D display systems to reconstruct 3D images were demonstrated.

P.162L: *Late-News Poster:* Intelligent Backlight Technology Developments for Uniformity, Privacy, and 3D Operation

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M. G. Robinson, B. Ihas, R. Ramsey
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New research results for intelligent backlights which uses a directional light guide and an imaging micro-structured reflector illuminated by an addressable LED array will be described. New modes of light-field control, including multiple implementations of privacy operation and advanced autostereoscopic 3D modes, will be presented along with performance and image optimization data.

P.163L: *Late-News Poster:* The Influence of Spatial-Light-Modulator Parameters on the Quality of 3D Holographic Reconstructed Images

Y. Zhang, J. Liu, X. Ma, J. Han, Y. Wang
Beijing Institute of Technology, Beijing, China

The influence of the pixel shape of a spatial light modulator on the image quality of an reconstructed 3D object has been analyzed. Comparisons of the pixel pitch and fill factor for different pixel shapes have been made showing that the circular pixel can improve image quality.

Emissive Displays

P.81: Non-Quasi-Static Measurement in Random-Network Carbon-Nanotube TFTs for Next-Generation Displays

H. Shin, S-Y. Park, C. Lee
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T-J. Ha
Kwangwoon University, Seoul, South Korea

Single-walled carbon-nanotube (SWCNT) based field-effect transistors (FETs) have been investigated by using transient analysis, and its non-quasi-static (NQS) characteristics have been compared with steady-state characteristics. The results provide additional information on the understanding of the charge-transport mechanisms in SWCNT-FETs for active-matrix backplanes.

P.82: Doubling the Light-Outcoupling Efficiency of Quantum-Dot LEDs

R. Zhu, Z. Luo, S-T. Wu
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A dipole model was used to analyze the light outcoupling and angular distribution of quantum-dot QLEDs. It was confirmed that the light-outcoupling efficiency can be doubled by combining a high-refractive-index glass substrate with macro extractors. The electroluminescent spectra analysis at different angles shows the QLED experiences a small color shift.

P.83: Oxygen Annealing Effect on the Enhancement of Green Emission from ZnO-Nanorod Recrystallized Growth from Sputtered ZnO Thin Film

C. Li, S. Hou
Kochi University of Technology, Kochi, Japan

ZnO nanorods were fabricated from sputtered ZnO thin film. The amount of oxygen vacancies were successfully introduced into the ZnO nanorods by oxygen annealing during the post-treatment procedure. The strong CL luminance from the ZnO nanorods was 185 cd/m^2 under an excitation of 500 V and 10 μA/cm^2.

P.84: A Low-Cost, High-Throughput Synthesis Procedure of Pure-Green Core-Multishell Quantum Dots by Using the Modified Tri-n-Octylphosphine-Assisted SILAR Method

J. Hao, W. Chen, J. Qin, K. Wang
South University of Science and Technology of China, Shenzhen, China

Pure-green core-multishell quantum dots synthesized by the modified tri-n-octylphosphine-assisted SILAR method will be reported. In this low-cost high-throughput procedure, the tri-n-octylphosphine-assisted extraction process was used to obtain quantum dots with high luminescence efficiency (>90%).

P.85: Quantum-Dots-Enhanced Vivid-Color Liquid Displays

Z. Luo, S. Xu, Y. Gao, Y.-H. Lee, Y. Liu, S.-T. Wu
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Two types of electrowetting displays with a patterned quantum-dot array achieve highly saturated colors. These polarizer-free liquid displays offer high transmittance, wide viewing, modest response time and contrast ratio, and vivid colors. They are promising candidates for e-Book and mobile-display applications.

P.164L: *Late-News Poster:* Enhancing the Light-Outcoupling Efficiency of Quantum-Dot LEDs with Periodic Microstructures

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J. Li, J. Wang, J. Zhou
Sun Yat-Sun University, Guangzhou, China

A periodic SiN_x/SiO_2 microstructure for effectively extracting light from quantum-dot LEDs (QLEDs) is proposed. The FDTD simulation results show that the direct emitting efficiency can be doubled while keeping an indistinguishable color shift. This approach can also be applied to optimize the performances of green and blue QLEDs.

e-Paper and Flexible Displays

P.86: High-Reliability Flexible OLED Display with Side-Seal ALD Film

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A flexible OLED display, fabricated by using transfer technology and provided with high-quality passivation layers, demonstrates high reliability without being sealed with thick films that reduce productivity. The display survived 500 hours of preservation testing at 65°C and 95% RH. To prevent moisture from entering the sides of the panel, the entire flexible display is coated with an aluminum-oxide film using atomic layer deposition.

P.87: Applying Low-Temperature Thin-Film Encapsulation to a 6-in. IGZO Flexible AMOLED

M-H. Lai, S-F. Liu, C-Y. Huang, J-Y. Chiou, Y-W. Chiu, Y-W. Liu, Y-F. Niu
Chunghwa Picture Tubes, Ltd., Taoyuan, Taiwan, ROC

Applying a high-performance thin-film barrier to OLED products conventionally requires a high-temperature process which would damage the OLED device. A low-temperature encapsulation process was applied to a 6-in. VGA IGZO AMOLED display where the OLED passed the 60°C/90% RH over 500 hours environmental test. The water-vapor transmission rate (WVTR) is about 10^{-5} g/m^2-day.

P.88: Enhancement of Electro-Optic Properties of Optically Isotropic Liquid-Crystal Device for Flexible Displays

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J. H. Lee, B. K. Kim
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Polymer-dispersed nano-sized liquid-crystal (LC) composite, which is an optically isotropic liquid crystal (OILC), has been investigated for application to flexible LCDs. In the device, LC droplets with a diameter of 268 nm were dispersed in a polymer matrix, resulting in many advantages such as free touch mura, high contrast ratio, rubbing free, and wide viewing angle. However, its high operating voltage and low transmittance need to be overcome. A novel method to improve the transmittance and reduce the operating voltage by controlling the ratio of LC to polymer in the mixture will be presented.

P.165L: *Late-News Poster:* Measuring the Optical Performance of Flexible Displays under Hemispherical Diffuse Illumination

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Luminex Technologies, Boulder, CO, USA

Hemispherical diffuse illumination is a common ambient lighting environment. Unique issues related to measuring the ambient performance of curved displays under hemispherical diffuse illumination will be highlighted, and methods to address them proposed. Flexible e-paper displays (EPD) were measured in flat and cylindrical forms.

IES Lighting Track

P.89: Effects of Nano-TiO_2 Particles on Conversion Efficiency of Quantum-Dots Light-Converting Nanocomposites

W. Chen, J. Hao, J. Qin, K. Wang
South University of Science and Technology of China, Shenzhen, China

High-quality pure-color quantum dots (QDs) were synthesized and employed to fabricate QD light-converting film (QDF). The advanced QD film with embedded nano-TiO_2 particles demonstrated excellent luminescence with a light power-conversion efficiency (CE) of 66.48%, which is higher than that of conventional QDF (54%).

P.90: Phosphor-Converted White LED with High Angular CCT Uniformity by Adding Scattering Particles

W-S. Liao, S-Y. Chan, Y-C. Peng, H-Y. Lin
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C-S. Jao
ITRI, Hsinchu, Taiwan, ROC

The common white LED light, which uses a blue LED to excite yellow phosphor has poor angular correlated-color-temperature (CCT) uniformity and is reported harmful to the eye after long exposure. How to reduce the poor angular uniformity by adding scattering particles into the colloid will be discussed.

P.91: Enabling a Low Circadian Rhythm to Impact Lighting on Basis of Candle Light Giving OLEDs

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S-H. Chen, S-H. Shih, S-C. Lin
National Tsing-Hua University, Hsinchu, Taiwan, ROC
and
WiseChip Semiconductor, Inc., Chu-Nan, Taiwan, ROC

Long exposure to blue-enriched white light has been confirmed to cause public-health issues, including retina damage, circadian disruption, breast cancer, and artwork discoloration. To minimize blue hazards and maximize visual comfort, a "candle light" emitting OLED with a high-CRI and a high-SRI at around 1,900K with high-band low-color-temperature blackbody-radiation complementary emitters have been devised.

P.166L: *Late-News Poster:* Clock Data Recovery for Short-Distance Visible-Light Communications

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Clock data recovery (CDR) that enhances the BER performance for audio applications for short-distance visible-light communications (VLC) will be presented. The entire system and algorithms were implemented with FPGA boards, and the BER performance was measured to be less than 10^{-8} for a 35-cm separation of the transmitter and receiver.

Liquid-Crystal Technology

Alignment

P.92: Orientational Ordering of Nematic Liquid-Crystal Aligned with a Directly Spinnable Carbon-Nanotube Web

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The orientational ordering of liquid crystal aligned with a carbon nanotube (CNT) web has been studied and the temperature dependence and order parameter of a rubbed sample were found to be nearly the same as that of a polyimide sample. The CNT web sample showed good electro-optical modulation of the retardation and a smaller residual dc than that of the polyimide sample.

P.93: Highly Reliable Mobile LCD Using AlO_x Deposited by Atomic Layer Deposition for Side-Sealing Structure

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Approximately 110 nm of AlO_x was deposited outside the conventional LCD perimeter seal using atomic layer deposition (ALD). This structure prevents the entry of external moisture as evidenced by the dramatic increase in the stability of the voltage-holding ratio. An LCD with this type of structure can have long-term high reliability as a low-frequency driving LCD.

P.94: Fast-Response-Time Liquid Crystal Using a Nanofiber and Polyimide Alignment Mixture

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CSIRO Materials Science and Engineering, Clayton, Victoria, Australia

The electro-optical properties of nematic liquid-crystal samples aligned with nonofiber (NF) polyimide (PI) mixtures were studied. The sample coated with a NF-PI mixture showed a faster fall time than the pure PI sample. The elastic constant and order parameter of the NF-PI samples were also larger than the pure PI sample.

P.95: Anchoring-Energy Enhancement and Pre-Tilt-Angle Control of Liquid-Crystal Alignment on Polymerized Surfaces

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P-C. Liao, C-C. Lin, T-L. Ting, W-H. Hsu, J-J. Su
AU Optronics Corp., Hsinchu, Taiwan, ROC

The effect of polymerized surfaces on the anchoring energy and pre-tilt angle of liquid-crystal alignment has been investigated. An ultraviolet light-illuminated cell initiates polymerization and produces submicron-sized polymer protrusions. Experimental evidence reveals the relationship between the curing conditions and the resulting pre-tilt angle and anchoring energy of the cells.

Blue-Phase LCs

P.96: Blue-Phase Dual-View LCD Based on Patterned Electrodes

P. Tang, J-P. Cui, H-X. Fan, Q-H. Wang
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A blue-phase dual-view LCD based on patterned electrodes has been designed. By combining the patterned electrodes with a directional backlight system, transmittance increases while the crosstalk ratio is suppressed to 1.17%. Moreover, the resolution density and brightness would triple by using the field-sequential-color approach.

P.97: An Ultra-Low-Voltage Blue-Phase LCD for Mobile Applications

J. Yuan, D. Xu, S-T. Wu
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An ultra-low-voltage (<5 V) two-domain blue-phase LCD (BPLCD) for mobile applications will be presented. Compared to fringe-field switching, the BPLCD shows superior performance in response time, integrated transmittance, viewing angle, and color shift. It also enables a color-sequential display with tripled optical efficiency and resolution.

P.167L: *Late-News Poster:* Enhanced Stability, Hysteresis, and Dark State of Polymer-Stabilized Blue-Phase III

M. S. Kim, L-C. Chien
Kent State University, Kent, OH, USA

A polymer-stabilized blue-phase (PSBP) III mode device exhibiting broad blue-phase III temperature, an enhanced dark-state level by one order of magnitude, and less hysteresis than that of PSBP I has been demonstrated. How the extended temperature range of over 80K is achieved with a selection of reactive monomers will be described. The random polymer morphology of PSBP III implies no preferential orientation or structure. This enabling PSBP III mode device exhibits fast switching of electric-field-induced birefringence and high contrast ratio than those of a PSBP I mode device because of strong interactions between the amorphous blue-phase structure and polymerized polymer networks.

Display Modeling

P.98: A New Blue-Pixel Design for Improving the Side-View Performance

C-T. Kang, L-X. Chen, Y. Zhang
Shenzhen China Star Optoelectronics Technology Co., Ltd., Shenzhen, China

A new low-color-shift (LCS) design for LCDs with a normal pixel structure is proposed. The viewing-angle performance and washout phenomenon have been improved by utilizing spatial blue-pixel signal conversion. The results and details of spatial LCS will be discussed.

P.99: Increasing the Rewriting Speed of Optically Rewritable e-Paper by an Electric Field

J. Sun, W. Zhang, V. Chigrinov, H-S. Kwok
Hong Kong University of Science and Technology, Kowloon, Hong Kong

A new method to increase the rewriting speed of ORW e-Paper has been developed. The rewriting time was increased by 4 times by applying an electric field across the liquid-crystal cell and decreasing the effective rotational viscosity.

P.100: Novel Method of Curved-Display Cell-Gap Measurement

W-S. Kao, W. Sung, K-H. Chen, Y. Cheng
AU Optronics Corp., Hsinchu, Taiwan, ROC

A method to correctly measure the cell gap when the panel is curved has been developed. Through hardware design and the use of modified calculation model, the accuracy and reproducibility were improved. The difference in behavior in curved and flat displays could be understood via this proposed measurement method.

P.101: Temperature-Dependent Behavioral Model of Twisted-Nematic Pixel in AMLCDs

J-M. Kim, S-W. Lee
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A behavioral circuit model to predict the optical characteristics of an active-matrix liquid-crystal display (AMLCD) is proposed. It was applied for various ambient temperatures to verify the model's universality dependence. The simulation results for the transient optical responses show excellent matches with measurement regardless of the type of LCDs.

FFS/IPS

P.102: Drive Scheme for Fast Gray-to-Gray Response in a Fringe-Field-Switching Liquid-Crystal Cell

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D-M. Shin
Hongik University, Seoul, South Korea

A drive scheme for fast gray-to-gray response in fringe-field-switching (FFS) liquid-crystal cells is proposed. Experiments demonstrate gray-to-gray switching of homogeneously aligned liquid crystals that is 11 times faster than in conventional FFS cells, with little change in the transmittance.

P.103: Improvement of Dark-State Light Leakage in ADS-Mode LCDs

J. You, Q. Jia, Y. Yang, K. Kim, Y. Zhang, G. Qin, T. Suzuki, G. Hui, J. Yao
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The light leakage has been improved from a level of 2.4 to 1.2 in ADS-mode LCDs. Due to LCD panel internal friction between post spacers and array substrate, the glass substrate shows some retardation, resulting in light leakage. Optimization of LC retardation successfully reduced light leakage.

P.104: A Novel Fringe-Field-Switching Mode with High Picture Quality

L-M. Jiang, Z-F. Su, Y-M. Liu, X. Guan, S. Chung
InfoVision Optoelectronics (Kunshan) Co., Ltd,. Kunshan, China

A LCD mode with homogenous alignment and fringe-field-switching (FFS) electrodes is proposed to improve optical performance. Simulations of the positive FFS mode for various spacings of the in-plane switching electrodes to minimize color washout and improve picture quality was carried out.

P.105: Field-Induced Diffraction in Polymer-Stabilized In-Plane-Switching Liquid Crystals with Vertical Alignment

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S. H. Lee
Chonbuk National University, Jeonbuk, South Korea

Electrical switchable diffraction grating has been demonstrated. Periodical modulation of field-induced refractive index provided by the specifically designed in-plane-switching (IPS) liquid-crystal device having vertical alignment enables a distinct voltage-dependent diffraction patterns.

P.106: A Novel Simulation Method for In-Plane Switching-Mode Panel by Considering Light-Scattering Behavior

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A. Yuuki, T. Fujino, T. Satake
Mitsubishi Electric Corp., Hyogo, Japan

Newly developed light-scattering simulation clarified the optical behavior of an IPS-mode panel quantitatively. This simulation also enables viewing-angle dependence of the luminance of the black state. A 10.2-in. IPS-mode TFT-LCD with a wide viewing angle has been developed by using the newly developed simulation method.

P.107: Investigation on the Flexoelectric Effect of LC in the Localized Area of FFS Pixel Structure

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Due to the pixel-size consideration, the finger design of an FFS-mode LCD pixel may be different in the local area. The flicker phenomenon and flexoelectric effect of LC in the localized area of a FFS-mode pixel will be discussed.

P.108: Eye-Tracking IPS 3D Display with a Liquid-Crystal Barrier

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Y. Maeda, T. Ochiai, T. Takahashi, S. Komura
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A new IPS electrode structure was designed for an eye-tracking 3D display. With an active barrier in the developed device, 3D wide-viewing-angle characteristics, low crosstalk, and a smooth moving barrier have been obtained in a 3D eye-tracking system.

P.109: Fast Flexoelectro-Optic Liquid-Crystal Device Operating at Room Temperature

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K-J. Kim, J-I. Hwang, J-H. Baek, M. Jun
LG Display Display Co., Ltd., Gyeonggi-do, South Korea

A uniform lying helix LC device with a large flexoelastic coefficient, fast flexoelectric switching, and operating at room temperature will be presented. A liquid-crystal (LC) mixture for the flexoelecro-optic LC mode made from constituents with smaller and larger flexoelectric coefficients and different temperature ranges of LC the phases will be described.

P.168L: *Late-News Poster:* Maximization of Electro-Optic Performances in the Fringe-Field-Switching Liquid-Crystal Mode Using a Liquid Crystal with Negative Dielectric Anisotropy

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G. Murali, Y. J. Lim, S. H. Lee
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and
Kent State University, Kent, OH, USA

P. J. Bos
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The fringe-field-switching (FFS) mode that uses liquid crystals (LCs) with negative dielectric anisotropy was used in high-resolution FFS-LCDs owing to their high transmittance although response times become slower and operating voltages (V_{op}) become higher than those using positive dielectric anisotrophy LC. In addition, the reduction in the cell gap to improve response time will result in a decrease in V_{op}. The FFS mode with an electrode width of 1 μm and a distance between electrodes of 1.5 μm is proposed. For such an electrode structure, V_{op} decreases with decreasing cell gap to 2 μm so that a proper operating voltage, a high LC light efficiency of 90%, and a fast response time of less than 10 msec can be achieved, thus maximizing the electro-optic performance of the FFS mode.

P.169L: ***Late-News Poster:* Electro-Optic Variation in AH-IPS Liquid-Crystal Mode by Controlling the Flexoelectric Effect of Liquid Crystal**

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M-K. Park, J-T. Kim, A. Ranjkesh, H-R. Kim
Kyungpook National University, Daegu, South Korea

J-H. Baek, J-H. Lee, H. Choi
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Electro-optic variation by controlling the flexoelectric effect of liquid crystal in an advanced high-performance in-plane-switching LC mode using a high-speed camera was investigated. To verify the coupling direction between the electric field and the flexoelectric effect, the electro-optic variation was evaluated by doping bent-core liquid crystals in the hybrid aligned nematic LC mode.

P.170L: ***Late-News Poster:* Viewing-Angle-Enhancement Technology with Polymer-Stabilized In-Plane-Switching-Mode LCD**

T. R. Lee, J. H. Baek, W. Y. Choi, M. Jun, J. J. Kim, M. K. Kim
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The polymer-stabilized effect on the in-plane-switching (IPS) liquid-crystal (LC) mode was investigated. The polymer-stabilized IPS LC mode exhibits a very-low-pretilt-angle property caused by additional new layer formation between the bulk LC and the alignment layer. Theoretically, low-pretilt-angle formation at the IPS LC mode is very helpful in improving the viewing-angle properties in the black state. But, up until now, it is almost impossible to realize a low-pretilt-angle IPS LC mode by using the usual rubbing process. With this low-pretilt-angle effect, polymer-stabilized IPS technology was confirmed to have very good viewing-angle properties in the black state.

New Display Components

P.110: **Negative Dispersion of Birefringence in Smectic-Liquid-Crystal Polymer Composite**

S. Yang, H. Lee, J-H. Lee
Chonbuk National University, Jeonbuk, South Korea

A negative-dispersion (ND) retarder that uses self-organization of smectic LC and polymer composite is reported. A smectic-LC absorbing short-wavelength UV was mixed with reactive monomers absorbing long-wavelength UV. The constituent molecules have an intrinsically positive-dispersion (PD) property. The composite shows a gradual transition in birefringence from PD to ND as monomer concentration increases.

P.111: ***Distinguished Student Paper:* An LCD with OLED-Like Luminance Distribution**

Y. Gao, Z. Luo, R. Zhu, Q. Hong, S-T. Wu
University of Central Florida, Orlando, FL, USA

M-C. Li, S-L. Lee, W-C. Tsai
AU Optronics Corp., Hsinchu, Taiwan, ROC

A single-domain LCD with a collimated backlight and a free-form optics-engineered diffuser is reported. This novel LCD exhibits a similar luminance distribution to OLED displays while maintaining high transmittance, high contrast ratio over the entire 80° viewing cone, indistinguishable color shift, low ambient reflection, and negligible gray-scale distortion.

P.112: A Wavelength Converter Based on Electrowetting

L-X. Yao, C. Liu, M-H. Wang, Q-H. Wang
Sichuan University, Chengdu, China

A wavelength converter, which is an expanded application of an electrowetting liquid prism actuated in the microsystem, has been demonstrated. Three different colors can be obtained from a non-transparent cap's light hole. The device shows a reasonable switching time.

P.184L: *Late-News Poster:* Fluoro-Polymer Coating to Protect Electronic Materials

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Digital signage, electronic paper, and even health-care devices are being impacted by emerging display technologies. These electronic devices require protection from harsh environmental conditions. Developments in fluoro-polymer thin films (less than 5 μm) suitable for protecting electronic devices from harsh environments, while maintaining long-term performance, will be introduced.

Photo Alignment

P.113: Improvement in the Surface Anchoring Energy of the Photo-Alignment Layer in a LCD Using the Two-Band UV-Exposure Method

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J-H. Kim
Han-Yang University, Seoul, South Korea

A photo-alignment method with a strong surface anchoring energy has been demonstrated by applying a two-band UV exposure method on a photosensitive PI layer embedded with reactive mesogens (RMs). The interconnection between a RM polymer and a photo-alignment layer was enhanced through high-band UV exposure on the long-pass UV filter over 340 nm, and then the alignment of the LCs was established through low-band linear-polarized UV exposure at 254 nm. The surface-anchoring energy and response time of the proposed photo-alignment method has been measured. The response time was reduced by approximately 22.3%.

P.114: The Application of Photo Alignment on Fringe-Field-Switching Cells

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Y. J. Song, C. C. Hsieh, C-C. Lo, C. Y. Lee, S-C. Lien
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H. Hasebe, H. Takatsu
DIC Corp., Saitama, Japan

A photo-alignment technique used in the preparation of fringe-field-switching (FFS) mode cells will be presented. The azimuthal anchoring energy (AAE) of photo alignment is controllable by tuning the UV-exposure condition, and the value of AAE is shown to be as strong as that of the rubbing method. The electro-optical properties of FFS cells were optimized with different electrode configurations to provide a high contrast ratio. The high stability to voltage and thermal stress tests confirm that photo alignment is suitable for FFS/IPS applications.

P.115: New Photo-Alignment Material: Azimuthal Anchoring Energy Decreases at Very-High Photo-Induced Order Parameters

A. Muravsky, V. Mikulich, A. Murauski, V. Bezruchenko
NAS Belarus, Minsk, Belarus

New azo-dye photo-alignment material with extremely high values of the photo-induced anisotropy (order parameter S~0.85, dichroic ratio DR~17.5) has been developed. Experiments reveal a decrease in the azimuthal anchoring energy for highly oriented azo-dye layers, contradicting regular expectations. A high-quality patterned λ/4 retarder based on reactive mesogens with an ~3-μm pattern disclination width has been obtained.

P.116: The Investigation of In-Plane-Switching Liquid-Crystal Photo-Alignment Technology for Large-Sized Panel

Y-J. Song, C-C. Hsieh, Y-C. Zhao, R-T. Zhao, X. Li, C-Y. Chiu, C-Y. Lee, C-C. Lo
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A. Lien
TCL Corporate Research, Guangdong, China

A new photo-alignment material for fringe-field-switching (FFS) and in-plane-switching (IPS) LCDs will be presented. It realizes the alignment by irradiating linearly polarized light at a wavelength of 365 nm. An excellent dark state and image-sticking property can be achieved by optimizing its photo-alignment conditions.

P.117: The Transmittance Study of the Photo-Alignment FFS LC Mode

Y-C. Zhao, C-C. Hsieh, Y-J. Song, X. Li, R-T. Zhao, C-Y. Lee, C-C. Lo
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A. Lien
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A photo-alignment material for fringe-field-switching (FFS) LCDs has been investigated using 254-nm linearly polarized light. The transmittance decreases with increasing alignment angle. The transmittance is also affected by the L/S width of the ITO electrode. A higher transmittance can also be achieved by using this negative LC.

P.118: Low-Voltage Drive Tunable Liquid-Crystal Lens Using Photo-Alignment Method

C-X. Zhao, F. Fan, L-Y. Shi, V. Chigrinov, H-S. Kwok
Hong Kong University of Science and Technology, Kowloon, Hong Kong

A method to prepare a liquid-crystal (LC) lens using photo-alignment technology was developed. It was fabricated by adjusting the pretilt angle from 1º to 89º using this photo-alignment layer. Such a lens will be very useful in many modern optical and photonic applications.

Reflective Displays

P.119: Full-Color Reflective Display Using Cholesteric Heliconical Structure

J. Xiang, O. D. Lavrentovich
Kent State University, Kent, OH, USA

A full-color reflective display based on the cholesteric liquid crystal with heliconical structure has been developed. The AC electric field was applied parallel to the heliconical axis to vary the period of the structure and thus the color of selective light reflection and transparency of the display.

P.120: Temperature Dependence of Dynamic Holographic Displays Using Doped Liquid Crystals

X. Li, P. Zhou, Y. Li, C. P. Chen, X. Jiang, W. Hu, N. Rong, Y. Yuan, S. Liu, Y. Su
Shanghai Jiao Tong University, Shanghai, China

The temperature dependence of diffraction efficiency and response time in two holographic systems using doped liquid crystals (LC) has been investigated. For dye-doped LC, the response time is generally insensitive to temperature variation, but the diffraction efficiency is temperature sensitive. However, with QD-doped LC, both characteristics are insensitive to temperature at around room temperature.

P.121: Angular-Insensitive Color Filters Based on Compact Multilayered Film for Reflective Displays and Decorations

C. Yang, W. Shen, Y. Zhang, X. Liu
Zhejiang University, Hangzhou, China

A compact multilayered film structure for wide-viewing-angle color filtering is proposed and was verified by theoretical calculations and experiment results. The introduction of amorphous silicon greatly reduces the angular sensitivity of the filters. This method has the potential for applications in displays and colorful decorations.

P.122: Liquid Optical Switch Based on Total Reflection

C. Liu, D. Wang, L-X. Yao, L. Li, Q-H. Wang
Sichuan University, Chengdu, China

A liquid optical switch based on total reflection has been demonstrated. In one state, the interface between two liquids is such that the condition of total reflection is met and light is not transmitted. In another state, when applying a voltage to the device, the shape of the liquid interface is modified so that the condition of total reflection is not met and light is transmitted. And advantage is that the device can attain nearly 100% intensity attenuation.

P.123: *Distinguished Poster:* Field-Sequential-Color Displays Based on Reflective Electrically Suppressed Helix Ferroelectric Liquid Crystal

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A reflective field-sequential-color display based on the electrically suppressed helix ferroelectric liquid-crystal mode has been demonstrated. The ultra-fast response time enables this display cell to be driven at a high frequency with low voltage. This device can be used in projection displays and microdisplays.

P.183L: ***Late-News Poster:*** **Design of Light-Diffusion Film with a Bent Structure for Reflective Displays**

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T. Ishinabe, H. Fujikake
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A novel technique to control the bent structure of light-diffusion film by using additives has been developed. The film obtained by combining a two-step UV-irradiation technique has a wide diffusion range and contributes to improve the utilization angle of the ambient light of the reflective display.

OLEDs

P.124: Excimer Formation in Organic Emitter Films Associated with a Molecular Orientation Promoted by Steric Hinderance

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B. Kim
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Yamagata University, Yamagata, Japan

White emission with two sharp strong peaks – a molecular emission peak at 455 nm and an excimer emission peak at 591 nm – was obtained by introducing a terphenyl group into a highly twisted core chromophore, which promoted a molecular orientation in the film state suitable for excimer formation.

P.125: Maskless RGB Color Patterning via Dye Diffusion for Vacuum-Deposited Small-Molecule OLED Displays

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K. Kajiyama
V-Technology Co., Ltd., Yokohama, Japan

Small-molecule RGB OLEDs were fabricated on one substrate by selectively doping dyes into the host through thermal diffusion via physical contact. The suggested maskless OLED color-patterning technique overcomes challenging issues in the conventional shadow-masking technique.

P.126: Stable Measurement of 10^{-6} $gm^{-2}day^{-1}$ Water-Vapor Transmission Rate in Barrier Materials by Intermittent Accumulation and Release by a Cold Trap

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T. Kanno
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H. Yoshida
AIST NMIJ, Tsukuba, Japan

T. Shimada
Hokkaido University, Sapporo, Japan

An ultra-sensitive and stable instrument for water-vapor transmission-rate evaluation has been reported. Water vapor permeated through the gas barrier was condensed by cold trap and measured by mass spectrometer. Intermittent absorption and release operation of the cold trap enables the measurement to be immune to gradual change in background H_2O.

P.127: Highly Efficient Light-Extraction Technologies Applicable to Transparent OLED Lighting Using a Corrugated Substrate

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OLED devices with enhanced out-coupling efficiency using corrugated substrates which have nanostructures imprinted from self-assembled block-copolymer pattern have been demonstrated. As a result of optimizing transparent OLED lighting, the developed substrate is transparent with 0.1% of haze and has achieved 1.79 times out-coupling efficiency by using a shortened pattern pitch.

P.128: High-Efficiency Hybrid Buffer Layer in Inverted Top-Emitting OLEDs

C. H. Park, H. J. Lee, J. H. Hwang, K. N. Kim, Y. S. Shim, S-G. Jung, B. H. Bae, C. H. Park, D. J. Lee, Y. W. Park, B-K. Ju
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A hybrid buffer layer with superior plasma protection and high injection efficiency has been developed. HAT-CN enhances the hole-injection efficiency and MoO_3 protects the organic layers that are under the electrode from plasma damage during deposition by sputtering. This hybrid buffer layer improves the electric characteristics of inverted top-emitting OLEDs.

P.129: Comprehensive Analysis of Luminous Decay Curves for Accelerated Lifetime Testing of OLEDs

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Chemical Materials Evaluation and Research Base (CEREBA), Ibaraki, Japan

Luminous degradation curves, as a stretched-exponential decay function, used to develop a lifetime prediction method, were analyzed. By using the proposed method, the lifetimes of several OLED devices were evaluated on the basis of limited data sets obtained in a short test time.

P.130: Highly Conductive Graphene and PEDOT:PSS Hybrid Film with the Treatment by Hydroiodic Acid for Indium-Tin-Oxide-Free Flexible OLEDs

X. Wu, J. Liu, Y. Wang, Z. Min, M. Yang, G. He
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A simple dipping treatment with hydriodic acid (HI) at low temperature to fabricate highly conductive, transparent, uniform, and flexible graphene oxide (GO) and poly (3,4-ethylenedioxythiophene):poly(styrene sulfonate) (PEDOT:PSS) hybrid film is proposed. Using the optimized hybrid film as the anode, a fascinating flexible OLED (FOLED) has been demonstrated.

P.131: Synthesis and Device Application of a Dibenzothiophene Derivative as Thermally Activated Delayed Fluorescence Material for Green Fluorescence OLEDs

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J. Y. Lee
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The dibenzothiophene derivative, 2,8-bis(9,9-dimethylacridin-10(9H)-yl)dibenzothiophene 5,5-dioxide, was synthesized as a thermally activated delayed fluorescence material for green fluorescence OLEDs. The dibenzothiophene derivative had a donor-acceptor structure for thermally activated delayed fluorescent emission and a high maximum quantum efficiency of 14.3% was achieved in green devices.

P.132: Solution-Processable Optical Nanohybrid Films for Displays and Lighting

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Nanograde, Ltd., Stäfa, Switzerland

Novel solution-processable optical nanohybrid materials which are based on oxide nanoparticles have been developed. Their use for dielectric mirrors, index-matched scattering layers, and charge-transport layers with haze have been demonstrated, and corresponding light-extraction concepts for OLED devices will been discussed.

P.133: Optimized Anodes for Flexible Large-Area OLEDs

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A. Richter
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The use of slot-die coated silver-nanowire films as OLED anodes have been developed. The influence of the coating parameter ‘shuttle velocity’ and ‘coating gap’ on the anisotropy behavior of the single-layer properties of transmittance and sheet resistance was examined. The influence on OLED characteristics has been explored.

P.134: Synthesis of Host Material for Blue Phosphorescent OLEDs Derived from Bicarbazole Backbone Structure

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Dankook University, Yongin, South Korea

J. Y. Lee
Sungkyunkwan University, Suwon, South Korea

4,4'-(9,9'-[2,3'-bicarbazole]-9,9'-diyl) bis(N,N-di-p-tolylaniline)(44BBDT) was synthesized between 9H,9'H-2,3'-bicarbazole and 4-bromo-N,N-di-p-tolylaniline as a host material in blue phosphorescent. The 44BBDT was applied as the host material of the blue triplet emitter derived from phenylimidazole ligand and the 44BBDT device showed a maximum external quantum efficiency of 17.8% with a low driving voltage.

P.135: Recombination-Zone Monitoring of the Blue Phosphorescent OLEDs During Lifetime Testing

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Sungkyunkwan University, Suwon, South Korea

C. H. Noh, S. H. Kim
Samsung Advanced Institute of Technology (SAIT), Gyeonggi-do, South Korea

The recombination-zone shift during lifetime measurement in phosphorescent blue OLED devices with a sensing layer was studied. It was found that the recombination zone shifted to the electron-transport layer side according to the luminance decrease of the device via direct monitoring of the recombination zone shift.

P.136: New Materials for OLEDs Displaying Thermally Activated Delayed Fluorescence

J. L. O'Connell, J. M. Macdonald, A. D. Scully, M. A. Skidmore, A. J. Wilson, M. Bown, K. Ueno
CSIRO Manufacturing Flagship, Clayton, Australia

Several examples of a new class of materials that exhibit thermally activated delayed fluorescence were designed and synthesized. The device architectures for these materials were optimized, and the effect of differing host materials upon transient lifetimes of the delayed electroluminescence and the external quantum efficiencies of the devices were examined.

P.137: Improved Light Extraction of OLEDs Using Embedded Nanoscale Vacuum Line Layer

Y. S. Shim, H. J. Lee, J. H. Hwang, K. N. Kim, C. H. Park, S-G. Jung, B. H. Bae, D. J. Lee, C. H. Park, Y. W. Park, B-K. Ju
Korea University, Seoul, South Korea

OLEDs with improved light extraction were fabricated by embedding a nanoscale vacuum line layer (nVLL). The nVLL increases the optical efficiency both by inserting extremely low refractive-index materials between the substrate and anode, and also by the photonic crystal effect from a nano-periodic structure.

P.138: Metal-Oxide Thin Films for Hole-Injection Layers of OLEDs

J. Park, D. Kim, Y. Fu, H. K. Chung, H. Chae
Sungkyunkwan University (SKKU), Suwon, South Korea

In order to replace PEDOT:PSS, solution-processed metal-oxide thin films were developed as hole-injection layers of OLEDs. The device performance of MoO_x and VO_x is similar to that of PEDOT. Specially, the current efficiency of s-MoO_x layers was better than that for the e-MoO_x layers by reducing the OLED current density.

P.139: Improved Power Efficiency of OLEDs Using Solution-Processed CuSCN Hole-Injection Layer

J. Sohn, Y. Kwon, C. Lee
Seoul National University, Seoul, South Korea

Solution-processed copper thiocyanate (CuSCN), a wide-bandgap p-type semiconductor material, effectively operating as a hole-injection layer in OLEDs with solution process, is introduced. The electrical and optical characteristics of CuSCN has been investigated.

P.140: Novel ¼-Wave Plate Film for OLED Panels

K. Osato, T. Kobayashi
ZEON Corp., Toyama, Japan

A novel ¼-wave-plate film (QWP) for OLED displays is introduced. This QWP film has a combination of positive and negative intrinsic properties, which results in high on- and off-axis contrast as well as low reflective color shift. This will be evaluated versus conventional films used in OLED panels.

P.141: New High-T_g Hole Transporters: High Performance at High Luminance for Phosphorescent OLEDs

P. Kathirgamanathan, S. Surendrakumar, S. Ravichandran
Brunel University London, Uxbridge, UK

M. Kumaraverl
Power OLEDs, Ltd., Manchester, UK

M. Ryo
Takoma Technology and Company, Ltd., Chungcheongnam-do, South Korea

J. Kim, H-M. Kim, J. Jang
Kyung Hee University, Seoul, South Korea

Details of a new hole transporter with a high T_g of 122°C and a high triplet energy (3.1 e.V.), which demonstrates 30% improvement on current efficiency and up to 50% improvement on the power efficiency compared to α-NPB at 10000 cd/m^2 in green phosphorescent OLEDs without sacrificing the lifetime, will be reported.

P.171L: *Late-News Poster:* The Control of Optical Properties by Back-Cavity Effect in OLEDs with Multi-Cathode Structure

A. Mikami, S. Doi
Kanazawa Institute of Technology, Nonoichi, Japan

The angular dependence of the emission intensity can be successfully controlled by using the back-cavity effect in a multi-cathode structure. It is useful for this technique to optimize optical properties, without sacrificing an electrical property. In addition, surface plasmon loss is significant in the cathode suppressed as a result of optical coupling between the waveguide mode and long-range surface plasmon mode. Approximately 60% of optical power can be utilized as external mode.

P.172L: *Late-News Poster:* Enhanced Efficiency and Low Haze in OLEDs by Nanoscale Corrugation

J. H. Hwang, H. J. Lee, Y. S. Shim, C. H. Park, S.-G. Jung, K. N. Kim, Y. W. Park, B.-K. Ju
Korea University, Seoul, South Korea

OLEDs with a nanoscale corrugation for light extraction (NCLE) enhanced the current efficiency and power efficiency. The haze of the nanoscale corrugation for light extraction (NCLE) is comparable to that of bare glass. Furthermore, the OLEDs with NCLE exhibited angle-stable electroluminescence (EL).

P.173L: *Late-News Poster:* Simple Light-Extraction Technology for Flexible OLEDs

B. H. Bae, H. J. Lee, J. H. Hwang, K. N. Kim, Y. S. Shim, C. H. Park, S. G. Jung, C. H. Park, D. J. Lee, Y. W. Park, B. K. Ju
Korea University, Seoul, South Korea

Light extraction in flexible OLEDs (FOLEDs) by using a nano-sized random pattern (nRP) has been demonstrated. Simply fabricated nRP on flexible substrates reduced the optical loss through the scattering effect. Compared to a conventional device, FOLEDs with an nRP showed improved power (+36.36%), current (+25.64%) efficiency at a luminance of 4000 cd/cm^2, and improved external quantum efficiency (+22.26%) at a current density of 100 mA/cm^2.

P.174L: *Late-News Poster:* Optimizing High-Efficiency OLEDs Structure Based on Thermally Activated Delayed Fluorescence Emitter

C. H. Park, H. J. Lee, J. H. Huang, K. N. Kim, Y. S. Shim, C. H. Park, S. G. Jung, B. H. Bae, D. J. Lee, Y. W. Park, B.-K. Ju
Korea University, Seoul, South Korea

Thermally activated delayed fluorescence (TADF) OLEDs having enhanced efficiency will be reported. TADF OLEDs were optimized by controlling the HTL and ETL materials and thickness. An enhanced power efficiency, current efficiency, and external quantum efficiency were achieved.

P.175L: ***Late-News Poster:*** **High-Efficiency Light Extraction from Top-Emitting OLEDs Employing Mask-Free Plasma-Etched Stochastic Polymer Surface**

W-Y. Park, Y. Kwon, C. Lee, K-W. Whang
Seoul National University, Seoul, South Korea

A high-efficiency light-extraction method for top-emitting OLEDs (TEOLEDs) employing a mask-free plasma-etched stochastic polymer surface is proposed. The increase in light outcoupling from the TEOLEDs results in efficiency enhancement up to 1.55 fold relative to that of conventional devices.

P.176L: ***Late-News Poster:*** **Deposition and Structuring Processes of a Newly Developed Transparent Amorphous-Oxide Semiconductor for the Electron Transport and Injection Layers of AMOLEDs**

N. Nakamura,
Tokyo Institute of Technology, Yokohama, Japan
and
Asahi Glass Co., Ltd., Yokohama, Japan

T. Watanabe, N. Miyakawa
Asahi Glass Co., Ltd., Yokohama, Japan

J. Kim, S. Fujitsu
Tokyo Institute of Technology, Yokohama, Japan

S. Watanabe
Asahi Glass Co., Ltd., Yokohama, Japan
and
Japan Science and Technology Agency, Kawaguchi, Japan

E. Matsuzaki, Y. Toda, H. Hosono
Tokyo Institute of Technology, Yokohama, Japan
and
Japan Science and Technology Agency, Kawaguchi, Japan

Processes for new transparent amorphous-oxide semiconductors (TAOS) as the ETL and EIL have been developed. They are compatible with the current deposition and structuring processes and enable the fabrication of inverted OLEDs. New TAOS materials make it possible to apply a thicker ETL, impacting the yield and reducing the cost by omitting the resin banks.

P.177L: ***Late-News Poster:*** **Highly Efficient Inverted OLEDs Using a New Transparent Amorphous-Oxide Semiconductor**

J. Kim, T. Kamiya
Tokyo Institute of Technology, Yokohama, Japan

S. Watanabe
Asahi Glass Co., Ltd., Yokohama, Japan
and
Japan Science and Technology Agency, Kawaguchi, Japan

E. Matsuzaki, Y. Toda, H. Hosono
Tokyo Institute of Technology, Yokohama, Japan
and
Japan Science and Technology Agency, Kawaguchi, Japan

N. Nakamura
Tokyo Institute of Technology, Yokohama, Japan
and
Asahi Glass Co., Ltd., Yokohama, Japan

N. Miyakawa
Asahi Glass Co., Ltd., Yokohama, Japan

A highly efficient inverted OLED was fabricated by using a newly developed transparent amorphous-oxide semiconductor (TAOS) as the electron-transport layer. This new TAOS has high mobility (~1 cm^2/V-sec), low work function (~3.5 eV), sufficient chemical stability, and high transparency and can form a ohmic contact with conventional electrodes (ITO, Al, *etc*.).

P.178L: ***Late-News Poster:*** **New Silyl-Substituted Phosphorescent Materials for OLEDs**

J-S. Lin, J-L. Liou, C-N. Ku, M-H. Chang, M-R. Tseng
ITRI, Hsinchu, Taiwan, ROC

A new sky-blue phosphorescent material with a silyl-substituted ligand has been developed. The double-emission-layers (DELs) concept was utilized to fabricate a blue PHOLED device. The DELs comprise two different host materials with a higher triplet excited state. The high-efficienct blue OLED, which has up to 47.3 lm/W at a practical brightness of 1000 cd/m^2, was successfully improved.

P.179L: ***Late-News Poster:*** **13.3-in. WQHD AMOLED Notebook Utilizing High-Mobility BCE-Type TFTs**

L. Xin, F. Liu, S-H. Tseng, C-Y. Wu, D. Wang, L. Yan, M. Wang, G. Yuan, G. Wang
BOE Technology Group Co., Ltd., Beijing, China

A 13.3-in. WQHD AMOLED notebook utilizing BCE-type ITZO TFTs will be presented. The ITZO TFTs exhibit high mobility and high photostability. The field-effect mobility was over 25 cm^2/V-sec and the threshold-voltage shifts under BITS were reduced to 0.4 V.

Projection

P.142: A Method to Compensate Chromatic Aberration in Holography by Using Fourier-Transform Principle

C. Wang, D. Wang, D-H. Wang, Q-H. Wang
Sichuan University, Chengdu, China

A method for compensating chromatic aberration using a Fourier transform is proposed. The size of the reconstructed image is adjusted to compensate for the magnification of the chromatic aberration; the center positions of the reconstructed images are adjusted using the shift principle to solve the problem of coincidence of the reconstructed images.

P.143: 4D Floating Holographic-Like Image Display

K. Li
Wavien, Inc., Valencia, CA, USA

A floating holographic-like image display has been demonstrated with four dimensions in which the image moves as the object moves in space or move by a zoom lens system. A single-panel system has also been demonstrated in which one portion of the display is relocated to float in front of another portion.

P.144: See-Through Projection Screen and Display System

Z-Y. Su, C-H. Chen, P-H. Yao, W-H. Yang, W-C. Chao, J-J. Lin
National Tsing Hua University, Hsinchu, Taiwan, ROC

D. Wu
KangDeXin Composite Material Corp., Hsinchu, Taiwan, ROC
and
Phansco Corp., Hsinchu, Taiwan, ROC
and
Chiefway Optronics Corp., Taipei, Taiwan, ROC

A projection screen with a scattering dot pattern covering only a part of the screen area has been proposed for see-through display applications. Alternatively, a microstructure can be used for controlling the diverging angle while maintaining the efficiency. A prototype of the scattering film and microprism film has been developed, and the desired performance demonstrated.

P.180L: *Late-News Poster:* Speckle Contrast Reduction with Multi-Projection Units for a MEMS Scanning Laser Projector

S-Y. Tu, H. Y. Lin
National Taiwan University, Taipei, Japan

An efficient speckle-reduction technique by using static multi-projection units for a MEMS-scanning laser projector has been demonstrated. For a green image, the speckle contrast (SC) could be reduced from 23.3% to 13.1%. The speckle and safety issues were overcome simultaneously for high luminous output. A mixing SC was defined for white-light generation.

P.181L: ***Late-News Poster:* Color-Sequential Front-Lit LCOS for Wearable Displays**

K-Y. Chen, Y-W. Li, K-H. Fan-Chiang, H-C. Kuo, H-C. Tsai
Himax Display, Inc., Tainan, Taiwan, ROC

A color-sequential front-lit (CS-FL) LCoS optical design is compact and light weight for wearable displays. It achieves a wide color gamut of 120% sRGB, fine <5-µm pixel pitch, 17,000 nits for outdoor viewing with 116 nits/mW, a 188 simulated contrast, and the color luminance uniformity improved by 11% over that of the previous designs.

Touch and Interactivity

P.145: Optimization of Molybdenum Oxides for Low-Reflectance Thin Films Using Numerical Simulation

H. Köstenbauer, D. Lorenz, J. Winkler
PLANSEE SE, Reutte, Austria

W. Theiss
W. Theiss Hard- and Software, Aachen, Germany

Mo-oxide thin films were investigated for low-reflectance applications. Numerical simulation was used to optimize the optical properties of the thin films. Reflectance could be considerably reduced to values of 6% at 550 nm, maintaining a colorless black film.

P.146: Skin-Resistance Measurement of a Static Capacitive Touch Panel

Y. Morimoto, R. Yoneda, R. Hattori
Kyushu University Fukuoka Japan

A mutual capacitive touch system based on frequency sweeping is presented which can additionally sense the skin resistance of the finger, enabling new applications in user identification and bioelectrical sensing.

P.150L: ***Late-News Poster:* Exploration of Coating and Alignment Methods for Making High-Performance Transparent Conductive Films with Silver Nanowire Networks**

B-R. Yang
Sun Yat-Sen University, Guangzhou, China
and
SYSU-CMU Shunde International Joint Research Institute, Foshan, China

G-S. Liu, S-J. Han, W. Cao
Sun Yat-Sen University, Guangzhou, China

H-J. Chen
SYSU-CMU Shunde International Joint Research Institute, Foshan, China

J. Lu
Shanghai Jiao Tong University, Shanghai, China

H-P. D. Shieh
National Chiao Tung University, Hsinchu, Taiwan, ROC

A new method of aligning silver nanowires (AgNW) is proposed to improve sheet resistance by maintaining the optical transmittance level. The new method is based on a crossed-aligned structure, resulting in a three-fold reduction in sheet resistance.

Wearables

P.147: Organic TFTs Using Solution and Photolithography Process

C-H. Tu, Y-H. Liang, H-T. Hsiao, H-I. Peng, C-Y. Liu, M-F. Chiang, Y-C. Lin
AU Optronics Corp., Hsinchu, Taiwan, ROC

The organic TFTs (OTFTs) were fabricated and investigated. Solution and photography technology were used for organic thin-film formation and patterning. Also, the process temperatures were kept below 120°C for low-temperature process development. Furthermore, the performances of OTFTs were investigated in this study, including electrical characteristics and reliability.

P.148: Polymer LEDs Using the Dip-Coating Method on Flexible Fiber Substrates for Wearable Displays

S. Kwon, W. Kim, H. C. Kim, S. Choi, K. C. Choi
KAIST, Daejeon, South Korea

B-C. Park, S-H. Kang
Kolon Glotech, Inc.. Gyeonggi-do, South Korea

Polymer light-emitting diodes (PLEDs) using a dip-coating method on a flat glass, a flat polyethylene terephthalate (PET) substrate, and a cylindrically shaped fiber substrate has been demonstrated. This result enables the fabrication of low-cost easy-fabrication flexible fiber-based PLEDs by roll-to-roll manufacturing and realizes a the true fiber-based wearable display.

P.149: Oxide TFTs on the Fabric Substrates for Wearable Displays

J. Park, E. Kim, W. J. Jang, S-H. K. Park, K. C. Choi
KAIST, Daejeon, South Korea

B-C. Park, S-H. Kang
Kolon Glotech, Inc., Gyeonggi-do, South Korea

Transition-metal-oxide TFTs were fabricated on fabric substrates for wearable displays. Atomic layer deposition (ALD) was employed to reduce process temperature. The TFT fabricated on the fabric substrate shows the following performances: μFE = 0.6 cm^2/V-sec, on/off ratio = 9.07×102, sub-threshold swing = 1.725/decade, and V_{th} = –1.57 V.

P.182L: *Late-News Poster:* A True Circular Flexible AMOLED Display for Wearable Applications

K-R. Jen, L-F. Lin, Y-C. Chen, P-Y. Wang, Y-C. Huang, K-H. Lin, C-H. Yang, F-Y. Huang, C-L. Wang, J-H. Lin, W-H. Lee, C-Y. Yu, W-T. Wang, M-C. Hsu, C-H. Tu, Y-M. Chang, M-H. Tu, L-H. Chang, Y-H. Lin
AU Optronics Corp., Hsinchu, Taiwan, ROC

A 1.25-in. circular plastic-based AMOLED display has been developed for wearable applications. By locating gate drivers in the active area and bending the plastic substrate outside the active area of the panel, a display with a true circular shape and slim border was successfully realized.

Session 63 — **Oxide and LTPS TFTs / Active-Matrix Devices**

HIGH-RESOLUTION DISPLAYS

Friday, June 5 / 9:00 – 10:20 am / Ballroom 220B

Chair:
M. Wong, *Hong Kong University of Science & Technology, Kowloon, Hong Kong*

Co-Chair:
K. Takatori, *NLT Technologies, Ltd., Kawasaki, Japan*

63.1: An Ultra-High-Density 736-ppi LCD Using an InGaZnO Platform (9:00)

N. Ueda, S. Uchida, Y. Ogawa, K. Okada, A. Oda, S. Katoh, K. Yamamoto, K. Yamamoto, T. Matsuo, H. Kawamori
Sharp Corp., Osaka, Japan

A 736-ppi (WQXGA) LCD with a pixel density reaching 4K has been developed for smartphones by using oxide semiconductors. By utilizing the highly scalable channel etched-type InGaZnO-TFTs and a novel transparent contact structure, an aperture ratio of more than 50% was achieved by using patterning dimensions of a manufactured backplane.

63.2: A 2K × 4K 550-ppi In-Cell-Touch TFT-LCD Using 1.5-μm-Channel-Width LTPS-TFTs (9:20)

T. Nakamura, M. Tada, K. Mochizuki, T. Tsunashima, H. Hayashi, Y. Aoki, Y. Tanaka, D. Suzuki, H. Kimura
Japan Display, Inc., Chiba, Japan

A 2K × 4K 550-ppi LTPS TFT-LCD has been developed. The reduced channel width and thinner insulator for the storage capacitance allow for high display qualities in terms of reducing the vertical cross-talk and flicker. RGBW pixel technology and additional 30-Hz frame-rate drive can offer lower power with higher display qualities.

63.3: Fabrication of 8K × 4K Organic EL Panel Using High-Mobility IGZO Material (9:40)

K. Okazaki, H. Kanemura, D. Kurosaki, Y. Shima, J. Koezuka
Advanced Film Device, Inc., Tochigi, Japan

S. Kawashima, M. Shiokawa, H. Miyake, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Atsugi, Japan

A 13.3-in. 8K × 4K OLED display that uses an oxide semiconductor with high-mobility IGZO material has been fabricated. It was found that the use of such a material can decrease the size and power consumption of a gate driver. Furthermore, a stack of such oxide-semiconductor layers can increase process stability.

63.4: High-Performance 4K × 2K 65-in. TV with BCE-Type TFTs **(10:00)**

B-L. Yeh, C-N. Lin
AU Optronics Corp., Hsinchu, Taiwan, ROC

A 4K × 2K 65-in. TV with oxide TFTs has been investigated. The abnormal sub-threshold leakage current at high temperature results from the bulk active layer and the GI/active-layer interface. It is specific to devices with color materials as a passivation layer under NBIS.

BREAK **(10:20–10:40)**

AUTHOR INTERVIEWS **(12:00–1:00)**

OLED DISPLAYS II: CURVED AND HIGH-RESOLUTION

Friday, June 5 / 9:00 – 10:20 am / Ballroom 220C

Chair:
Y. Lin, *AU Optronics Corp., Hsinchu, Taiwan, ROC*

Co-Chair:
C. Chu, *Samsung Display Co., Ltd., Gyeonggi-do, South Korea*

64.1: Thin and Slim Design of a 65-in.UHD OLED TV (9:00)

K. Miwa, S.-M. Baik, C. Park, J.-H. Park, H.-S. Shin, S.-H. Kim, K.-H. Park, R. Tani, W.-J. Nam, J.-M. Kim, J.-K. Park, P.-Y. Kim, C.-H. Oh, B.-C. Ahn
LG Display Co., Ltd., Gyeonggi-do, South Korea

The curved slim design of a 65-in. UHD OLED TV will be reviewed. Reverse-bonding technology enables a slim bezel design. The metal-composite back-plate holds a curved module and dissipates heat effectively. Printed-circuit boards were placed at the bottom of the module to realize the ultra-thin-edge design of a 65-in. OLED TV.

64.2: Panel and Circuit Designs for the World's First 65-in. UHD OLED TV (9:20)

R. Tani, J-S. Yoon, S-I. Yun, W-J. Nam, S. Takasugi, J-M. Kim, J-K. Park, S-Y. Kwon, P-Y. Kim, C-H. Oh, B-C. Ahn
LG Display Co., Ltd., Gyeonggi-do, South Korea

The world's first 65-in. UHD OLED TV with a frame frequency of 120 Hz using coplanar-type IGZO TFTs has been developed. Novel panel designs and circuits to achieve high frame frequency and TFT reliability will be discussed.

64.3: Development of a 55-in. UHD AMOLED TV (9:40)

Z. Wu, G. Yuan, H. Xie, K. Cao, Y. Li, S. Zeng, Y. Zhou, F. Yang, J. Cheng, H. Shi, L. Ye, J. Yu, G. Wang
BOE Technology Group Co., Ltd., Beijing, China

Mass-production feasibility of a 55-in. UHD AMOLED TV on a Gen 8.5 fab line using an IGZO backplane and tandem white OLEDs with a color-filter array will be presented. Pixel compensation and external optical compensation was implemented to achieve good display uniformity.

64.4L: *Late-News Paper:* A Symmetric Panel Stacking Design for Achieving a 3-mm Rolling Radius in Plastic-Based AMOLED Displays (10:00)

M-T. Lee, C-L. Wang, C-S. Chan, C-C. Fu, C-C. Chen, K-H. Lin, W-C. Huang, C-H. Tsai, Z-X. Weng, C-C. Chan, Y-L. Lin, T-Y. Huang, P-Y. Lin, H-H. Lu, Y-H. Lin
AU Optronics Corp., Hsinchu, Taiwan, ROC

A 5-in. plastic-based AMOLED panel with an optimal structure and optical design has been fabricated. The panel was designed to coincide the OLED/TFT layer with the neutral plane and limit the largest strain at the outmost part to be less than 1%. Its performance remained prominent after being repeatedly rolled at a 3-mm radius.

BREAK (10:20–10:40)

AUTHOR INTERVIEWS (12:00–1:00)

FLEXIBLE DISPLAY TECHNOLOGY

Friday, June 5 / 9:00 – 10:20 am / Room LL20A

Chair:
J. Chen, *DTC/ITRI, Chutung, Taiwan, ROC*

Co-Chair:
C. Liu, *AU Optronics Corp., Hsinchu, Taiwan, ROC*

65.1: *Invited Paper:* World's First Large-Sized 18-in. Flexible OLED Display and the Key Technologies (9:00)

J. Yoon, H. Kwon, M. Lee, Y-Y. Yu, N. Cheong, S. Min, J. Choi, H. Im, K. Lee, J. Jo, H. Kim, H. Choi,Y. Lee, C. Yoo, S. Kuk, M. Cho, S. Kwon, W. Park, S. Yoon, I. Kang, S. Yeo
LG Display Co., Ltd., Gyeonggi-do, South Korea

The world's first 18-in. flexible OLED display has been fabricated, which is bendable up to a bending radius of 30 mm. The key technologies in fabricating a large-sized flexible OLED display will be discussed. The process flow and panel characteristics will be elaborated upon.

65.2: *Invited Paper:* Bias-Stress-Induced Charge Trapping at Flexible Polymer Gate Dielectric in Organic TFTs (9:20)

B. Kang, H. H. Choi, K. Cho
Pohang University of Science and Technology, Pohang, South Korea

Charge-trapping mechanisms at the polymer gate dielectric will be presented. The penetration of water molecules into the polymer chain ends having large free volume causes the bias-stress instability of organic TFTs with polymer gate dielectrics.

65.3: Development of Flexible Displays Using Back-Channel-Etched ITZO TFTs and Air-Stable Inverted OLEDs (9:40)

M. Nakata, G. Motomura, Y. Nakajima, T. Takei, H. Tsuji, H. Fukagawa, T. Shimizu, T. Tsuzuki, Y. Fujisaki, N. Shimidzu, T. Yamamoto
NHK Science & Technology Research Laboratories, Tokyo, Japan

Flexible displays using back-channel-etched In-Sn-Zn-O (ITZO) TFTs and air-stable inverted OLEDs were developed. The TFTs with a solution-processed passivation layer exhibited a high mobility (31.4 cm^2/V-sec) and good stability. ITZO was also used as an electron-injection layer in the OLEDs instead of air-sensitive materials.

65.4: Organic-TFT-Driven Backplane for Flexible Electrophoretic Display (10:00)

W-C. Tang, C-H. Hsu, K-Y. Lin, P-W. Chen, Y-L. Hsu, Y-L. Wang, K-Y. Chang, Y-S. Chang, C-C. Tsai
E Ink Holding, Inc., Hsinchu, Taiwan, ROC

A solution-based flexible organic-TFT backplane on polymer film has been developed and processed. The OTFT device shows a mobility of 1.5 cm^2/V-sec, V_{th} at 2 V, and an SS smaller than 1. The optical performance of this EPD module remains unchanged after bending.

BREAK (10:20–10:40)

AUTHOR INTERVIEWS (12:00–1:00)

STEREOSCOPIC 3D DISPLAYS

Friday, June 5 / 9:00 – 10:20 am / Room LL20BC

Chair:
F. Okumura, *NEC Corp., Kawasaki, Japan*

Co-Chair:
H. P. Shieh, *National Chiao Tung University, Hsinchu, Taiwan, ROC*

66.1: Feasibility of 3D Cinema with Uncompromised Performance (9:00)

G. D. Sharp, S. Gilman, M. Schuck, E. Deis, E. Arend
RealD, Inc., Boulder, CO, USA

The final word cannot be written on the value of 3D cinema until patrons experience stereo images with uncompromised 2D quality. Tradeoffs exist, and as lasers enable better 2D, there is a threat that this situation will persist. The feasibility for 3D technologies to address proposed new standards for 2D will be discussed.

66.2: A Tracked Automultiscopic 3D Tabletop (9:20)

Q. Smithwick
Disney Research, Glendale, CA, USA

M. Honeck
Walt Disney Imagineering, Glendale, CA, USA

A 42-in. autostereoscopic tabletop created using a lenticular display with viewer tracking and multiscopic viewpoint reprojection overcomes the inherent horizontal-parallax-only perspectives, limited field of view, and repeated viewing zones. A viewer observes a full-parallax large autostereoscopic tabletop over a wide field of view (120°) without the need for 3D glasses.

66.3: Smooth-Motion-Parallax Autostereoscopic 3D Display Using Linear Blending of Viewing Zones (9:40)

M. Date, H. Takada
Nippon Telegraph and Telephone Corp., Yokosuka, Japan

T. Kawakami, M. Sasai
Tohoku University, Sendai, Japan

A new autostereoscopic 3D display is proposed. By using only a small number of projectors, it produces smooth and exact motion parallax by applying the visual effects of dual-edge perception in a depth-fused 3D (DFD) display. It provides a breakthrough in overcoming the trade-off between 3D image reality and the number of video sources.

66.4: *Invited Paper:* Circularly Polarized 3D Monitors Attract Attention Again for Medical Applications (10:00)

T. Tanabe, T. Sato, K. Fukaishi, Y. Kakubari
Arisawa Manufacturing Co., Ltd., Niigata, Japan

3D monitors with circularly polarized 3D filters on glass substrates have been attracting attention once again in the medical field. The new technology using circularly polarized 3D and market trends will be discussed.

BREAK (10:20–10:40)

AUTHOR INTERVIEWS (12:00–1:00)

PHOTO ALIGNMENT

Friday, June 5 / 9:00 – 10:20 am / Room LL20D

Chair:
C. Chen, *Apple, Inc., Cupertino, CA, USA*

Co-Chair:
M. Sousa, *3M Co., Saint Paul, MN, USA*

67.1: Reactive-Mesogen-Stabilized Azodye Alignment for High-Contrast Displays (9:00)

V. Finnemeyer, D. Bryant, P. Bos
Kent State University, Kent, OH, USA

Azodye alignment has shown to be nearly ideal for high-contrast multidomain displays. It exhibits high anchoring energy, good microscopic uniformity, low processing temperature, low cost, and allows for simple patterning. A uniform, azodye alignment that provides a very-high-contrast-ratio device with improved stability has been demonstrated.

67.2: Fabrication of a Zero-Pretilt Liquid-Crystal Cell Using UV-Curable Polymer (9:20)

S-W. Oh, J-H. Park, T-H. Yoon
Pusan National University, Busan, South Korea

A fabrication method for zero-pretilt-angle nematic liquid crystal using UV-curable polymer mixed with polyimide films is proposed. Zero pretilt angle can be obtained by UV curing of reactive mesogen monomers mixed with planar-alignment material while a vertical electric field was applied to a liquid-crystal cell assembled after the rubbing process. It was demonstrated that the pretilt angle of a nematic liquid-crystal cell can be decreased to 0.082° by using the proposed method.

67.3: Photo-Stable Azo-Dye Photoalignment Polymer Surface for In-Plane-Switching LCDs (9:40)

M-C. Tseng, C-Y. Lee, A. K. Srivastava, V. G. Chigrinov, H-S. Kwok
Hong Kong University of Science and Technology, Kowloon, Hong Kong

O. V. Yaroshchuk
National Academy of Sciences of Ukraine, Kyiv, Ukraine

A photo-stable azo-dye photoalignment surface for liquid crystal is proposed and has been demonstrated. The alignment surface has a structure consisting of stacking a thin photo-polymerisable liquid-crystal polymer on top of an azo-dye photoalignment layer. The liquid-crystal polymer acts as a passivation layer for the azo-dye alignment layer. The alignment direction of the azo dye cannot be rewritten once the liquid-crystal polymer is polymerized. Hence, the synthetic alignment surface is robust, highly reproducible, and has excellent stability. In addition, measurement results show the alignment properties of this synthetic alignment surface are comparable to conventional polyimide. As a result, the proposed alignment layer is suitable for in-plane-switching LCDs which require high anchoring energy and very small residual direct current.

67.4L: ***Late-News Paper:*** **Electrically Suppressed Helix Ferroelectric Liquid Crystals: A Better Alternative for IPS Displays** **(10:00)**

A. K. Srivastava, M-C. Ken, V. G. Chigrinov, H. S. Kwok
Hong Kong University of Science and Technology, Kowloon, Hong Kong

Recently, in-plane switching (IPS) has been heavily exploited in particular for high-resolution mobile displays. The IPS displays offer good optical quality; however, the complex fabrication and manufacturing cost offers several limitations for their application. On the other hand, electrically suppressed helix ferroelectric liquid crystals (ESHFLCs), because of their intrinsic in-plane switching, offer better solutions with simpler and cheaper fabrication for high-resolution displays. ESHFLCs with fast response time (~10 μsec) and high contrast ratio (~ 10K:1) with low driving voltage (2-5 V/μm) has been achieved through photoalignment technology with acceptable shock stability and without natural diffraction. ESHFLCs provide good optical quality with simpler fabrication procedures and, therefore, could secure application for high-resolution displays.

BREAK **(10:20–10:40)**

AUTHOR INTERVIEWS **(12:00–1:00)**

TOUCH SYSTEMS AND MATERIALS

Friday, June 5 / 9:00 – 10:00 am / Room LL21EF

Chair:
W. Den Boer, *Guardian Industries, Carleton, MI, USA*

Co-Chair:
R. Mauch, *Schott AG, Mainz, Germany*

68.1: *Invited Paper:* Panel-Structure Evolution of In-Cell Capacitive-Touch Sensor (9:00)

J. Ma, Q. Yao, F. Lu, C. Ma, L. Wang, X. Zhou, L. Du, Z. Huang
Shanghai Tianma Microelectronics Co., Ltd., Shanghai, China

An in-cell LCD module with integrated self-capacitance touch sensor will be presented. Efforts to mitigate the interference between the display and touch-sensor structure will also bediscussed.

68.2: Study of the Optimized Design for High-Resistance Black Matrix at In-Cell Touch Structure (9:20)

Y. Na, C. H. Park, D. Kang, Y. Choi, S. Jeon
LG Display Co., Ltd, Gyeonggi-do, South Korea

An in-cell touch structure requires the inclusion of a high-resistance black matrix (BM) to enhance touch performance. The high-resistance BM must have at least 10^{13} Ω-cm, and there should be little variation caused by thermal stress. The variations of the BM electric properties were analyzed by thermal stress in post-bake.

68.3: Curved Mobile-Phone Cover with Carbon NanoBud Touch (9:40)

C. Bhat, C. Chen
Lite-On Technology Corp., Taipei, Taiwan, ROC

D. P. Brown, B. F. Mikladal, L. O. Súilleabháin, E. L. Soininen, D. Tian, I. Varjos, X. Zhan
Canatu, Helsinki, Finland

A touch-integrated cover lens for a mobile application has been developed using Carbon NanoBud material. The edge-curved cover lens with a touch function is of a high optical quality and light weight. Additionally, it is of an unbreakable and hard-coated all-plastic design. It has a cost-effective manufacturing process by using a film insert molding approach.

BREAK (10:00–10:40)

AUTHOR INTERVIEWS (12:00–1:00)

OXIDE-TFT RELIABILITY

Friday, June 5 / 10:40 – 11:40 am / Ballroom 220B

Chair:
Y. Yamamoto, *Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan*

Co-Chair:
H. J. Kim, *Yonsei University, Seoul, South Korea*

69.1: *Invited Paper:* The Advantages of the Self-Aligned Top-Gate Oxide-TFT Technology for AMOLED Displays **(10:40)**

T. Arai
JOLED, Inc., Kanagawa, Japan

In recent years, a great deal of effort has been devoted to developing oxide TFTs for active-matrix displays. Especially, oxide TFTs are expected to take some space away from LTPS TFTs to drive the AMOLED displays because of their low cost, high uniformity, and capability for large-sized display manufacturing. A self-aligned top-gate TFT is proposed for the oxide TFT, and a method to improve the stability in terms of the bias temperature stress will be discussed.

69.2: *Distinguished Paper:* Highly Reliable a-IGZO TFTs with Self-Aligned Coplanar Structure for Large-Sized Ultrahigh-Definition OLED TV **(11:00)**

C. Ha, H-J. Lee, J-W. Kwon, S-Y. Seok, C-I. Ryoo, K-Y. Yun, B-C. Kim, W-S. Shin, S-Y. Cha
LG Display Co., Ltd., Gyeonggi-do, South Korea

Metallized active films were employed as source/drain regions. By applying a light-shield layer, it was made possible to suppress the photo-induced threshold-voltage shift and obtain excellent output characteristics. The maximum difference of the threshold voltages of a-IGZO TFTs on Gen 8.5 glass is approximately 0.57 V. Also, a-IGZO TFTs reveal good reliability, showing a threshold voltage shift of 0.07 V and 0.03 V after 1 hour of PBTS and 10 hours of current stress, respectively.

69.3: a-IGZO TFT Reliability Improvement by Using a Dual-Gate Structure **(11:20)**

K-J. Chang, W-T. Chen, W-C. Chang, W-P. Chen, C-C. Nien, T-H. Shih, H-H. Lu, Y-H. Lin
AU Optronics Corp., Hsinchu, Taiwan, ROC

PBTS, NBTS, and NBIS stabilities of dual-gate a-IGZO TFTs were investigated by applying different top-gate voltages. These dual-gate devices show better PBTS/NBTS stress stability than conventional bottom-gate TFT devices. Additionally, these dual-gate devices also exhibit better NBIS than conventional bottom-gate TFT devices.

AUTHOR INTERVIEWS **(12:00–1:00)**

OLED DISPLAYS III

Friday, June 5 / 10:40 am – 12:00 pm / Ballroom 220C

Chair:
C. C. Lee, *BOE Technology Group Co., Ltd., Beijing, China*

Co-Chair:
Y. Lin, *AU Optronics Corp., Hsinchu, Taiwan, ROC*

70.1: High-Resolution OLED Display with the World's Lowest Level of Power Consumption Using Blue/Yellow Tandem Structure and RGBY Subpixels (10:40)

R. Yamaoka, T. Sasaki, R. Kataishi, N. Miyairi, K. Kusunoki, M. Kaneyasu, H. Miyake, N. Ohsawa, S. Seo, Y. Hirakata, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

K. Ono, T. Cho, H. Mori
Advanced Film Device, Inc., Tochigi, Japan

A top-emitting OLED with a microcavity structure combined with a blue/yellow tandem structure has been developed. A high-resolution AMOLED display having the lowest level of power consumption by using the tandem OLED with red, green, blue, and yellow subpixels has been fabricated.

70.2: An 81-in. 8K × 4K OLED Kawara-Type Multidisplay that Provides a Seamless, Continuous Image (11:00)

D. Nakamura, H. Ikeda, N. Sugisawa, Y. Yanagisawa, S. Eguchi, S. Kawashima, M. Shiokawa, H. Miyake, Y. Hirakata, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

S. Idojiri, A. Ishii, M. Yokoyama
Advanced Film Device, Inc., Tochigi, Japan

A Kawara-type multidisplay providing a seamless, continuous image was fabricated by precisely arranging 13.5-in. OLED flexible panels with transparent edges on two adjacent sides. By using 36 panels, an 81-in. 8K × 4K OLED Kawara-type multidisplay, the world's largest display, has been fabricated.

70.3: Low-Power-Consumption and Wide-Color-Gamut AMOLED Display with Four Primary Colors (11:20)

C-C. Chen, M-T. Lee, S-F. Wu, H-Y. Yang, S-M. Shen, Y-H. Lin
AU Optronics Corp., Hsinchu, Taiwan, ROC

A four-primary-color (RGBY) 1280 × 720 AMOLED display has been developed with a high NTSC ratio of 110% as well as low power consumption, which is 16% lower than that of a conventional three-color AMOLED panel for the same panel size of 4.65 in. and same pixel density of 317 ppi.

70.4: A 2.78-in 1058-ppi Ultra-High-Resolution OLED Display Using CAAC-OS FETs **(11:40)**

K. Yokoyama, S. Hirasa, N. Miyairi, Y. Jimbo, K. Toyotaka, M. Kaneyasu, H. Miyake, Y. Hirakata, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

M. Nakada, T. Sato, N. Goto
Advanced Film Device, Inc., Tochigi, Japan

The highest-density white-tandem top-emission color-filter structured OLED device with a backplane using CAAC-OS FETs over a glass substrate employing the 1.5-µm-rule, a 2.78-in. 1058-ppi OLED using TFTs over a glass substrate, has been fabricated. Additionally, a high-color-reproducibility (NTSC, CIE 1931) color gamut of 88% at 300 cd/m^2) has been obtained.

AUTHOR INTERVIEWS **(12:00–1:00)**

FLEXIBLE ENCAPSULATION

Friday, June 5 / 10:40 – 11:40 am / Room LL20A

Chair:
K. C. Choi, *KAIST, Daejeon, South Korea*

Co-Chair:
B-R. Yang, *Sun Yat-Sen University, Guangzhou, China*

71.1: High-Throughput and Scalable Spatial Atomic Layer Deposition of Al_2O_3 as a Moisture Barrier for aFlexible OLED Display (10:40)

H. Choi
LIG ADP Co., Ltd., Seongnam, South Korea
and
Hanyang University, Seoul, South Korea

S. Shin, Y. Choi, H. Jeon
Hanyang University, Seoul, South Korea

Y. Choi, J. Kim, S. Kim, H. Kim, J. Park, S. C. Chung, K. Oh
LIG ADP Co., Ltd., Seongnam, South Korea

The high-moisture permeation-barrier properties of Al_2O_3 films deposited by a newly developed high-throughput (> 70 Å/min) spatial ALD with Gen 2 substrate size (370 × 470 mm^2) is reported. The WVTR of a flexible substrate could achieve ~10^{-5} g/m^2-day under a tritium test.

71.2: Mechanical Characteristics of Flexible AMOLED Displays (11:00)

J-F. Chen, C-H. Tu, P-Y. Lin, M-C. Hsu, C-S. Huang, K-L. Hwu, H-H. Lu, L-H. Chang, Y-H. Lin
AU Optronics Corp., Hsinchu, Taiwan, ROC

The mechanical reliability of flexible AMOLEDs were experimentally investigated to build the feasible design concept of flexible products in the future.

71.3: Quantification of Water Penetration and Degradation through Adhesives Applicable to Flexible OLED Design **(11:20)**

Y. Ohzu, H. Takahagi, A. Uehigashi, H. Kubota, A. Sugimoto, H. Ohata, A. Suzuki, M. Tanamura, T. Minakata, M. Kimura, N. Ibaraki, H. Tomiyasu, T. Tsutsui
Chemical Materials Evaluation and Research Base (CEREBA), Ibaraki, Japan

S. Hara
Chemical Materials Evaluation and Research Base (CEREBA), Ibaraki, Japan
and
National Institute of Advanced Industrial Science and Technology (AIST), Ibaraki, Japan

H. Murata
Japan Advanced Institute of Science and Technology (JAIST), Ishikawa, Japan

A reliable evaluation method applicable to flexible OLEDs has been developed to quantify water penetration from an adhesive edge face. The adhesive's apparent water-diffusion coefficient obtained by this method provides the water penetration time and elucidates the pathway. Moreover, the proposed method can predict the start time of degradation.

AUTHOR INTERVIEWS **(12:00–1:00)**

CURVED AND HIGH-RESOLUTION LARGE DISPLAYS

Friday, June 5 / 10:40 am – 12:10 pm / Room LL20BC

Chair:
W. Chen, *Apple, Inc., Cupertino, CA, USA*

Co-Chair:
B. Berkeley, *Independent, San Jose, CA, USA*

72.1: World's First 55-in. 120-Hz-Driven 8K × 4K IPS-LCDs with Wider Color Gamut (10:40)

R. Oke, T. Nakai, J. Maruyama, D. Kajita, K. Miyazaki, M. Ishii, H. Matsukawa
Panasonic Liquid Crystal Display Co., Ltd., Hyogo, Japan

Unique pixel-driving technology, Next-APD, has been applied to 55-in.-diagonal 8K × 4K panels resulting in the first high-resolution and high-quality 8K × 4K display. This display is suitable for applications such as medical, broadcast, and industrial displays.

72.2: Development and Analysis of Technical Challenges in the World's Largest (110-in.) Curved LCD (11:00)

K. Hsiao, G. Tang, G. Yu, Z. Zhang, X. Xu, P. Zhang, C. Lv, A. Lien
Shenzhen China Star Optoelectronics Technology Co., Ltd., Shenzhen, China

A 110-in. curved LCD, the world's largest, has been successfully developed. Simulation was used to estimate shift between the color filter and TFT glass. Topology optimization was used to improve design of the back cover's aluminum extrusion skeleton and reduce product weight. Optical optimization of the LED with a lens was utilized to reduce product thickness.

72.3: The Mechanical Reliability of Glass Displays in Bending (11:20)

G. S. Glaesemann, K. H. Vepakomma
Corning Incorpoated, Corning, NY, USA

Glass-based displays have historically been shielded from stress events through well-constructed device frames. Today displays are increasingly being subjected to stress events where the mechanical reliability of the glass is of concern. One form of stress is that resulting from a loss of protection. A second form of stress is where the display is intentionally bent into a permanently deformed state. Televisions and monitors with curved displays are a good example of this later form of stress. A key mechanical failure mode for glass under long-term stress is delayed failure from the well-known phenomenon of subcritical crack growth. Flaws under sufficient stress can grow subcritically and fail prematurely. A practical reliability strategy for applications where display glass is intended to be bent for long periods of time will be discussed.

72.4: Development of a Laser Optical System for a 4K Laser-Backlit LCD TV (11:40)

N. Okimoto, S. Maeda, E. Niikura
Mitsubishi Electric Corp., Kyoto, Japan

T. Sawanaka, H. Kida
Mitsubishi Electric Corp., Kyoto, Japan

A laser-backlit LCD TV using red laser diodes and cyan LEDs has been developed. The laser diodes have a smaller divergence angle than that of an LED. Therefore, in the backlight, an optical system suitable to the characteristics of the laser light with a simple configuration has been developed.

72.5L: *Late-News Paper:* Development of a Novel Wide-Color-Gamut 8K 120-Hz LCD Complying with ITU-R BT.2020 (12:00)

T. Kumakura, S. Yoshida, A. Tomiyoshi, T. Fujine, Y. Yoshida
Sharp Corp., Nara, Japan

An 8K display with a 120-Hz frame rate, 12 bits for each RGB, has been successfully developed. This display has a wider color gamut, and the input interface uses a single optical-fiber cable of 256 Gbps for transmitting 8K/120-Hz video.

AUTHOR INTERVIEWS (12:10–1:00)

ULTRA-LOW-POWER LCDs

Friday, June 5 / 10:40 – 12:00 pm / Room LL20D

Chair:
G. Xu, *Hewlett-Packard Co., Sunnyvale, CA, USA*

Co-Chair:
A. Mochizuki, *I-CORE Technology, LLC, Louisville, CO, USA*

73.1: A Novel Pixel Structure for High Transmittance and High-Image-Quality LCDs (10:40)

J-D. Lee, J-B. Lee, S-J. Cho, J-Y. Yang, M. Jun, I. B. Kang, S-D. Yeo
LG Display Co., Ltd., Gyeonggi-do, South Korea

A newly designed two-pixel and two-domain FFS-LCD trapezoidal pixel structure, called TPS form, has been created. This provides 14% higher transmittance and better image quality than that of the conventional AHS-IPS structure.

73.2: A Novel TFT Pixel and Driving Scheme of an Electrically Suppressed Helix FLC for Active-Matrix Flat-Panel Displays (11:00)

T. K. Ho, M. C. Tseng, A. Srivastava, W. Zhou, L. Lu, V. G. Chigrinov, M. Wong, H.-S. Kwok
Hong Kong University of Science and Technology, Kowloon, Hong Kong

A novel pixel design for the electrically suppressed helix (ESH) FLC mode is proposed. This design has a 3T1C structure, which is compact enough to preserve high aperture ratio. This structure successfully demonstrates a TFT-compatible AMFLC pixel architecture possessing continuous gray scale. This is essential in obtaining high-quality LCDs, in particular, for field-sequential-color and high-resolution direct-view FPDs.

73.3: Elimination of Image Flicker in an FFS Panel under Low-Frequency Driving (11:20)

J-W. Kim, T-H. Choi, T-H. Yoon
Pusan National University, Busan, South Korea

E-J. Choi
Kumoh National Institute of Technology, Gyungbuk, South Korea

J-H. Lee
Chonbuk National University, Jeonju, South Korea

An elimination method of image flicker in a fringe-field-switching LCD will be discussed. Doping a small amount of bent-core liquid-crystal (BLC) molecules having the opposite sign of the flexo-electric polarization of the liquid-crystal material effectively compensates the local flexo-electric polarization. The optimized doping ratio of 2.0 wt.% could balance the transmittance of the LCD pan, resulting in elimination of flickering.

73.4: Reflective LCD with High Reflectivity and Color Reproductivity for Reduced Eye Strain **(11:40)**

D. Kubota, Y. Niikura, R. Hatsumi, T. Ishitani, Y. Hirakata, H. Miyake, S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

A. Nakamura, Y. Chubachi, M. Katayama
Advanced Film Device, Inc., Tochigi, Japan

Prototypes of a 6.05-in. reflective LCD with 212 ppi has been fabricated by CAAC-IGZO with ECB mode. A reflectivity of 34.5% and an NTSC of 40.8% have been achieved for an eye-friendly e-Book reader. For still images, the refresh rate can be lowered to 1/60 Hz.

AUTHOR INTERVIEWS **(12:00–1:00)**

TOUCH APPLICATIONS

Friday, June 5 / 10:40 – 11:40 am / Room LL21EF

Chair:
D. Lee, *LG Display Co., Ltd., Gyeonggi-do, South Korea*

Co-Chair:
B. Senior, *Canatu Oy, Morgan Hill, CA, USA*

74.1L: *Late-News Paper:* Force-Sensing Touch Screens (10:40)

H. Li, P. Maniar
New Degree Technology (NDT), Shenzhen, China

Breakthrough force-sensing capacitive touch screens havel been developed. The screen-printed force-sensing module is attached directly under the display, thus allowing high sensitivity, fine spatial resolution, and scalability to larger display sizes. This is in contrast to present force-sensing displays with capacitive plates or force-sensing resistors on the display periphery.

74.2: A Novel Three-Dimensional User-Interface Technology (11:00)

R. Gruhlke, B. Aryan, H.-J. Seo, Y. Zhou, J. Wyrwas, K. Alam, E. Gousev
Qualcomm Technologies, Santa Clara, CA. USA

A novel user interface that provides three-dimension interactivity was developed, which combines a special planar light guide with periphery arrays of lasers and detectors.

74.3: WITHDRAWN

74.4: *Invited Paper:* What Lies Beyond Multitouch? (11:20)

C. Harrison
Qeexo Co., San Jose, CA, USA
and
Carnegie Mellon University, Pittsburgh, PA

Seven years ago, multitouch devices went mainstream and changed the industry and our lives. In that time, mobile devices have gotten much more capable, yet the core user experience has evolved little. Contemporary touch gestures rely on poking screens with different numbers of fingers: one-finger tap, two-finger pinch, three-finger swipe, and so on. These are often labeled as "natural" interactions, yet the only place these gestures are performed is on a touch-screen device. The "fat finger" is blamed for much of the touch-interface woes – if a zipper or pen were too small to use, it would simply called "bad design." Fortunately, fingers and hands are amazing, and with good technology and design, touch interaction can be elevated to new heights. The era of multi-touch is coming to a close and the eve of an exciting new age of "rich-touch" devices and experiences is here.

AUTHOR INTERVIEWS (12:00–1:00)

DISPLAY WEEK 2015 EXHIBITORS

Exhibit Halls 1–3

Tuesday: 10:30 am – 6:30 pm
Wednesday: 9:00 am – 5:00 pm
Thursday: 9:00 am – 2:00 pm

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ZEON Corp.

EXHIBITORS' FORUM PRESENTATION SCHEDULE

TUESDAY, JUNE 2

Session F1 **Exhibitors' Forum**

DISPLAY MANUFACTURING AND COMPONENTS

Tuesday, June 2 / 10:45 am – 12:15 pm / Executive Ballroom 210

Moderator: *Joerg Winkler, Plansee SE*

F1.1: Wearable Electronics and Textile Electronic Integration: Forecasts 2015-2025 (10:45)

H. Zervos
IDTechEx Inc., Cambridge, MA, USA
Booth 946

This presentation will focus on a detailed study of the activities of over 1200 organizations (not only consumer-electronics companies, apparel companies, and healthcare companies, but also research and academic institutes) actively developing wearable devices. Their activities, areas of focus, growth areas, as well as particular challenges in commercialization will be described. Textile electronics will also be discussed, concluding with forecasts for the next decade.

F1.2: Cu-Alloy Sputtering Targets for Metal-Mesh Material (11:00)

Y. Yoshida
Daido Steel (America), Inc., Victoria, British Columbia, Canada
Booth 1919

Cu mesh is one of the promising alternatives to ITO for large-format capacitive touch displays for its low resistivity and low cost. However, some issues of adhesion, corrosion, and reflectance still exist. New Cu alloys that satisfy these critical requirements and opened the possibilities for applications such as mobile PC, electronic blackboards, as well as next-generation flexible displays and circuits have been developed.

F1.3: High-Impact Absorbent Acrylic Foam and Silicon OCA Technology (11:15)

K. Kato
Iwatani Corp., Tokyo, Japan
Booth 1240

Iwatani Corporation provides high-performance film and industrial tape products specialized for electronic devices. Our Acrylic Foam, ISR-ACF series, has high Impact-absorbing performance, and our Silicon OCA has high optical property suitable for mobile devices. With its innovative technologies and superb analysis, our products allow for different design concepts for customers to develop freely.

F1.4: VIZ-BOND®: Novel Optical Bonding Technology for Flat and Curved Surfaces (11:30)

J. Bartlett
Optical Filters USA LLC, Meadville, PA, USA
Booth 915

VIZ-BOND® is a novel display bonding system with unique advantages over alternative technologies. It uses semi-automated dispensing and very low viscosity adhesive to produce reliable optical bonds without requiring individual tooling. VIZ-BOND® is scalable for high-volume production, may be reworked, and can be incorporated into both flat and complex curved geometries.

F1.5: Innovative Adhesive-Tape Solutions for Displays (11:45)

R. Schreiber
tesa SE, Hamburg, Germany
Booth 846

tesa SE is one of the world's leading manufacturers of self-adhesive products. Our solutions for displays include optically clear adhesives used for bonding of displays and touch panels. Our newest innovations are barrier adhesive tapes for OLED encapsulation bonding, particularly suitable for flexible-panel production.

F1.6: Temporary Bonding Adhesives (12:00)

P. Malanaphy
Henkel Corp., Rocky Hill, CT, USA
Booth 534

Learn about Henkel's High Temperature Debondable Adhesive, aimed at offering solutions where sheets of flexible substrates on a carrier need to hold during the deposition process or temporarily bond precut glasses to a carrier in a piece-type deposition process.

LUNCH (12:15–2:00)

TOUCH TECHNOLOGY

Tuesday, June 2 / 2:00 – 4:15 pm / Executive Ballroom 210

Moderator: *Bill Cummings, BYDU Technology Services*

F2.1: New Generation of CNB Films: Unmatched Optical Performance Combined to Ultra-Flexibility (2:00)

B. Senior, Canatu Oy, Helsinki, Finland
Booth 447

SID award-winning Canatu and its CNB™ films for touch applications offer unmatched properties and design possibilities. Ultra-flexible and stretchable, it is now available down to 23-µm substrate thickness and with recently perfected optics. How thin touch can now be, and at present, a one-plastic-solution touch with windows integration, a curved mobile phone lens cover with touch, and a Film Insert Mold solution for touch on 3D surfaces will be. discussed.

F2.2: Water, Conductive Liquids, and Gloves: A Challenge for PCAP Systems (2:15)

A. Trica
Data Modul AG, Munich, Germany
Booth 1340

During the last several years, PCAP touch systems have become very popular in medical, industrial, and automotive applications. Therefore, it is almost common knowledge that water, gloves, and especially any type of conductive liquid make it difficult for a PCAP system to track touch points. A short introduction to the technical background will be presented, and the challenges a PCAP touch controller IC faces during the presence of liquids or gloves on the screen will be explained.

F2.3: Custom Touch-System Solutions for Commercial Markets (2:30)

M. Robrecht
Dawar Technologies, Inc., Pittsburgh, PA, USA
Booth 743

Dawar Technologies will present its new Projected Capacitive Touch sensor offerings along with its new control electronics debuting at Display Week 2015 along with new value-added integration services including optical bonding to displays that simplify the supply chain and reduce costs.

F2.4: Selecting Touch Technology for Industrial Applications: When to Choose Resistive Versus Capacitive (2:45)

B. DeVisser
Fujitsu Components America, Inc., Bellevue, WA, USA
Booth 1625

Going beyond ITO. The market drivers for Carbon NanoBud® (CNB™) based touch sensors that provide high-display-contrast enhancing properties will be discussed. Consumer electronics and automotive-industry long-awaited design freedom that enable high performance for complex flexible and 3D-shaped touch-enabled electronics devices will be described.

F2.5: Capacitive Touch Panel for Automotive Applications **(3:00)**

D. Feeney
Goworld Display USA, Ltd., Bellevue, WA, USA
Booth 242

Goworld is a market leader in projected-capacitance touch panels, specializing in the unique demands of the automotive industry. Special technologies include anti-glare, anti-reflection, anti-fingerprint, and shatter-proof designs. High-yield low-cost optical bonding is readily available, along with thick glove operation and impact resistance to 12 pounds.

BREAK **(3:15–3:30)**

F2.6: Futaba **(3:30)**

R. Dohring III
Futaba Corporation of America, Plymouth, MN, USA
Booth 1140

F2.7: PCap Touch for Smart Wearables **(3:45)**

H. Singh Randhawa
UICO, Elmhurst, IL, USA
Booth 1434

An array of sensing technologies such as Infrared, Surface Acoustic Wave, Resistive, and Capacitive have enabled pervasive devices such as computers, kiosks, ATMs, palm pilots, smart phones, and more for decades. Of these, Projected-Capacitive (PCap) touch has defined the smart-phone user experience and emerged as the leader. PCap, known for its high-resolution and functional simplicity, has over time shown limitations. It false actuates when exposed to elements such as rain and extreme temperatures and also when used with everyday gloves. In this next evolution of smart devices worn on the body, PCap will have to perform even better to withstand more exposure to the elements and uphold the user experience. UICO has developed all-weather PCap technology that makes a seamless experience possible. The benefits and nuances of PCap for next-generation wearables that works everywhere – without limitations – will be discussed.

F2.8: The Evolution of Touch – Bigger, Better, Faster **(4:00)**

T. Chang
Cima NanoTech, Inc., St. Paul, MN, USA
Booth 646

Traditional touch technologies are challenged by new emerging technologies, and, today, we are spoilt for choice when it comes to selecting the right touch technology. In this presentation, the evolution of touch and how the company's proprietary SANTE® transparent conductive technology enables bigger, better, and faster projected-capacitive touch screens for applications such as interactive digital signage, interactive whiteboards, interactive table tops, and touch-enabled vending machines and kiosks will be discussed.

FILMS AND COATINGS

Wednesday, June 3 / 9:15 – 10:30 am / Executive Ballroom 210

Moderator: *Poopathy Kathirgamanathan, Brunel University*

F3.1: Energy Curable Products for Conformal Coatings and Functional High RI Coatings (9:15)

M. Hutchins
Allnex USA, Inc., Alpharetta, GA, USA
Booth 945

Allnex will present two novel products. The first product can be used to improve adhesion and reactivity in conformal coatings. The second is a customizable product for high-refractive-index coatings. Cured refractive indices up to 2.0 can be achieved and combined with outdoor durability, easy-to-clean performance, and/or a range of flexibilities.

F3.2: FLEXX Flim Developments and Applications (9:30)

M. Steward
Carestream Advanced Materials, Oakdale, MN, USA
Booth 941

Carestream's FLEXX transparent conductive films using silver nanowires (AgNW) technology are ideal for touch screens, displays, lighting, solar cells, and smart windows. AgNW films are easily manufactured by a roll-to-roll coating process, with high throughput and low cost. FLEXX film conductivities range from 10 to 150 ohms/square while maintaining high optical transmittance, and offer excellent flexibility, durability, and lower cost compared to ITO films. Recent successes, roll-to-roll manufacturing, and developments at Carestream in addressing how to overcome our challenges will be discussed. A product roadmap for AgNW transparent conductive films and potential-market opportunities will be outlined.

F3.3: Dexerials New Technology Trend of Anisotropic Conductive Film for Displays (9:45)

Y. Shin
Dexerials America Corp., San Jose, CA, USA
Booth 1134

An anisotropic conductive film (ACF) is a bonding material that is indispensable to the mounting of FPDs. A new trend in ACF UV-curable-type ACF realizes a low-temperature bonding process. A newly developed particle alignment type corresponding to a fine pitch will be introduced.

F3.4: New Solutions for Coating and Surface Treatment (10:00)

T. Kuenzel
Singulus Technologies AG, Kahl am Main, Germany
Booth 343

To achieve today's challenges in display technology, products and manufacturing processes with innovative processes and designs are needed. For single-substrate processes, static and linear dynamic deposition (LDD) is required. The LDD technology is especially designed for deposition of ultra-thin films, magnetic films, high-quality metallic, conductive, and insulating films. For large substrates, sputtering, evaporation, and wet-process solutions will show new ideas on how to improve the characteristics of the substrates. PVD, PECVD, CBD, RTP (rapid thermal processing), and wet cleaning and etching solutions will be described.

F3.5: AR+IR+AF Touch-Screen Coatings for Harsh Environments **(10:15)**

R. Bruce
Iridian Spectral Technologies, Ottawa, Ontario, Canada
Booth 1640

Touch-screen displays can be subjected to harsh mechanical and chemical treatment as well as significant solar-heat loads. Combining an IR reflector with a high-performance AR+AF coating reduces the heat load, improving the overall performance of the display as well as the durability of the display surface.

BREAK **(10:30–10:45)**

Session F4 **Exhibitors' Forum**

MATERIALS AND GLASS FOR DISPLAYS

Wednesday, June 3 / 10:45 am – 12:15 pm / Executive Ballroom 210

Moderator: *Jiangang Lu, Shanghai Tong University*

F4.1: Advanced Glass Solutions for High-Performance and Functional Display Requirements (10:45)

M. Iga
Asahi Glass Co., Ltd., Tokyo, Japan
Booth 333

New innovative displays are are required in various wide markets. Glass is also being expected to provide higher and multifunctional performances in order to realize new products in the IoT world. "Glass-Plus" provides advanced glass solutions that realize high-performance functional display.

F4.2: VISTA AR Glass and Acrylic (11:00)

C. Carter
Tru Vue, Inc., Faribault, MN, USA
Booth 1145

Vista AR is a non-conductive wideband coating designed to minimize reflection and maximize transmittance on glass and acrylic over the visible spectrum. Vista AR is a high-quality rugged thin film coating especially designed for the high-performance needs of display applications.

F4.3: Advanced Glass: Enabling the Display Evolution (11:15)

S. Sisk
Corning Incorporated, Corning, NY, USA
Booth 733

When displays evolve, their keystone components must evolve as well. Driven by consumer demand, the industry is driving toward thinner, brighter, larger displays that feature more accurate touch and enhanced functionality. Corning – alongside its customers – continues to innovate at unparalleled speeds, developing the latest specialty-glass solutions to power the most advanced displays.

F4.4: High-Performance Oligomers and Monomers for Use in Optical/Display (11:30)

B. O'Toole
Miwon Specialty Chemical Co., Exton, PA, USA
Booth 1542

Miwon will spotlight new and specialty high-performance products for use in market areas during SID 2015. Product and product families include high-refractive-index (RI) oligomers and monomers, tin-free urethane acrylate oligomers, melamine acrylate oligomer, and organic/inorganic hybrid resins. Markets/applications include UV Soft Touch, anti-fog coatings, high-abrasion/scratch-resistant hard coats, and pptical brightness.

F4.5: OPT Alpha-GEL: High-Performance Silicone-Based Optical-Bonding Material Delivering Superior Optical Performance and Shock-Absorbing Capabilities (11:45)

S. Szymanski
Taica North America Corp., Santa Clara, CA, USA
Booth 1415

Current OCR/OCA materials for optical-bonding applications have several manufacturing and performance limitations that can be solved by using Taica Corp.'s OPT Alpha-GEL, an advanced high-performance silicone-based OB material. It is fully cured before use, does not yellow over time, and comes in sheet format (in various thicknesses, depending on the application) for ease of lamination. OPT Alpha-GEL is also fully re-workable in-situ, meaning scrapped product is greatly reduced (almost eliminated). In addition, OPT Alpha-GEL provides shock damping and anti-vibration capabilities due to the fact that it is a soft and flexible silicone-based material. It can also be used over a wide-temperature range, making it suitable for everything from hand-held displays to POS displays, to automotive displays – and everything in between.

F4.6: New Optical Bonding System (12:00)

M. Sakakibara
Momentive Performance Materials
Booth 1734

Optical bonding, one of the optimum solutions to create clear vision, is a system commonly used in the display industry. Specially, plastics such as PMMA and polycarbonate offer design orientation to automotive interiors. It provides distinct advantages in future designs, even curved screens. Lamination adhesives must provide a stable optical property for a long time, less cure shrinkage, and stress relief for the different substrates, which often have different coefficients of thermal expansion or out-gas. Liquid-silicone interlayer adhesives have been developed that provide the adhesion required by automotive display designs. It is also important to provide a mild curing system for automotive displays, which are sensitive to temperature change and have a large black-matrix area. Curing at lower temperature is better, and a UV-less system is most attractive.

LUNCH (12:15–2:00)

DISPLAY METROLOGY

Wednesday, June 3 / 3:30 – 5:00 pm / Executive Ballroom 210

Moderator: *Chick Yin, Square, Inc.*

F5.1: Display Measurement Technology (3:30)

R. Klimek
Konica Minolta Sensing Americas, Inc., Ramsey, NJ
Booth 816

Join Konica Minolta Sensing Americas, Inc., to learn about the latest offerings in display-measurement technology. Providing advanced optical technology that precisely measure color and light, our products have become a staple in research and manufacturing environments. Learn how we can help your organization meet product quality and operational goals with less waste, time, and effort.

F5.2: Advanced Imaging Colorimetry (3:45)

M. Wolf
Instruments Systems GmbH, Munich, Germany
Booth 818

A new type of imaging colorimeter that combines the benefits of imaging technology with color and luminance accuracies approaching those of high-performance spectroradiometers will be described. Applying to displays of all types, it sets a new benchmark in testing and characterization quality.

F5.3: Display Cable s12p Simulation and Measurement (4:00)

G. Young
I-PEX USA LLC, Austin, TX, USA
Booth 142

Precise and accurate measurements of the physical properties of liquid crystals made with Instec's bench-top ALCT have been performed. Testing methods for bend, splay, and twist elastic parameters (K11, K33, and K22), dielectric constants, ion density, residual DC, and voltage-holding ratio will be discussed.

F5.4: From Manual Inspection to AOI: Perceptions and Realities (4:15)

J. Koenig
Schenk Inspection Systems, Woodbury, MN, USA
Booth 423

Considering Automated Optical Inspection (AOI) as a replacement of increasingly costly human inspection, the discussion amongst the stakeholders is often subject to the perceived adequacy of the current procedure. With insight into the perceptions and realities associated with human inspection versus AOI, successful implementation of AOI in symbiosis with human inspection is possible.

F5.5: Stable Measurement of Water-Vapor Transmission Rate in Barrier Materials by Intermittent Accumulation and Release by a Cold Trap **(4:30)**

T. Shimada
Hokkaido University (Uniglobe Kisco), Sapporo, Japan
Booth 645

An ultrasensitive and stable instrument for water-vapor transmission rate evaluation will be reported. Water-vapor permeated through a gas barrier is condensed by a cold trap and measured by a mass spectrometer. Intermittent absorption and release operation of the cold trap enables the measurement immune to gradually change the background H_2O.

F5.6: Revolutionary Multi-Modality Image Inspection Technology for Enhanced Defect Detection and Classification **(4:45)**

R. B. Tolila
Orbotech, Ltd., Yavne, Israel
Booth 1526

An increasing demand for high-quality displays from leading electronics manufacturers while panel prices steeply decline has resulted in high pressure for yield improvement. This revolutionary Multi-Modality Imaging Technology Detection and Classification system will be introduced and and how it contributes to yield and enables manufacturers to increase efficiency will be described.

INNOVATIVE DISPLAY TECHNOLOGIES AND APPLICATIONS

Thursday, June 4 / 9:15 – 11:00 am / Executive Ballroom 210

Moderator: *Afsoon Soudi, IRYSTEC*

F6.1: Bidirectional Expansion of Collimated Laser Beam as a Backlight for a Holographic 3D Display (9:15)

D. Gloss
Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, Dresden, Germany
Booth 222

A bidirectional expansion of a collimated laser beam is proposed as a backlight for a holographic 3D display. An optical-fiber exit is morphed into a plane coherent wave, which is a requirement for holographic applications. An angle of incidence of 85° causes an expansion of the laser beam of at least a factor of 10. With this anti-reflective coating, reflection losses of the s-polarized fraction were reduced from more than 90% to below 5%.

F6.2: The Device and Circuit Simulation for Display Technology (9:30)

W-S. Lee
Silvaco, Inc., Santa, CA, USA
Booth 344

Silvaco's software provides a TFT simulation solution for technologies such as a-Si, LTPS, oxide TFT, and OLED for various types of display applications. The electrical characteristics of the TFT devices create several undesired effects due to the material science, DOS, and structural effects. The threshold of the TFT device in the circuit fluctuated because of the effect of stress. Silvaco's simulation approach helps to reduces the undesired effects.

F6.3: New Technologies Enabling Ubiquitous Displays (9:45)

K. Ng
Solomon Systech, Ltd., Hong Kong
Booth 917

Displays appear everywhere, including high-brightness dimmable outdoor advertising and indoor/outdoor decorations using OLED lighting technology, high-definition bendable healthcare wearables using PMOLED technology, and ultra-low-power high-contrast displays on smartcards using bistable technology. Solomon Systech offers various IC solutions to enable these display applications.

F6.4: New Advances in Resized LCDs: The Great Enabler (10:00)

L. Tannas
Tannas Electronic Displays, Inc., Orange, CA, USA
Booth 1115

LCDs can literally and cost effectively be cut to a new, smaller size to enable new applications including signage and avionics, and to replace EL displays, CRTs, and plasma panels. New techniques have been developed to dramatically improve yield and make resized LCDs even more cost effective in almost any application large or small.

F6.5: High-Speed Serial Interface IC for the Next-Generation Display (10:15)

T. Lee
Macnica USA, San Jose, CA, USA
Booth 1740

THine Electronics is a global leader in high-speed serial interfaces and a provider of mixed-signal LSI and has offered new valuable solutions for global customers based on its own innovative technologies. THine's display-interface ICs, such as V-by-One HS, which is a de-facto standard for next-generation high-resolution interfaces, will be introduced.

F6.6: Specialty Display Products and Enhancements (10:30) Highlighting Specialty Display Platform Strategy, Optical-Enhancement Services, R&D, and Product Development Capabilities

B. Caldarella
Optika Display, Huber Heights, OH, USA
Booth 1419

Our company focus, skillset, and capabilities are core to a wide range of specialty display technologies. Optika provides optical enhancement and integration services in an extensive integrated display solutions practice. Optika Display designs/develops specialty display solutions across a number of LCD technologies for a variety of demanding applications and environments.

F6.7: The Innovative Idea of Technology: Flexible OLED Displays: The Present and Future (10:45)

H. Oh
UBI Research, Seoul, South Korea
Booth 1823

Flexible OLED displays are attracting a lot of attention on researching and developing possible future applications. During the last 5 years, there have been about 22 types of designs of flexible OLED panels from a few key players. As technology development is expanding the area of display design from bendable to foldable to rollable, not just display manufacturers but other related industries, including automotive, fashion, and gaming, have been showing great interest in this technology. However, there are still issues to be discussed and resolved for the further growth of the flexible OLED display market. The main characteristics of the technology will be presented and the key technical issues need to be addressed.

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Joerg Winkler, Plansee SE, Reutte, Austria
Tian Xiao, CBRITE, Inc., Goleta, CA, USA

Display Measurement

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Marja Salminaa, Nokia Research Center. Tampere, Finland
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Display Systems

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Emissive Displays

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Seth Coe-Sullivan, QD Vision, Inc., Redondo Beach, CA, USA
Harm Tolner, Tolner Technology, Eindhoven, The Netherlands
Linsu Tong, Southeast University, Jiangsu, China
John Van Derlofske, 3M Co., Saint Paul, MN, USA
Larry Weber, PLEXIE, New Paltz, NY, USA
Ki-Woong Whang, Seoul National University, Seoul, South Korea

e-Paper and Flexible Displays

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4.1:
Apparatus for Manufacturing Flexible OLED Displays: Adoption of Transfer Technology
S. Idojiri, M. Ohno, K. Takeshima, S. Yasumoto, M. Sato, N. Sakamoto, and K. Okazaki
Advanced Film Device, Inc., Tochigi, Japan

K. Yokoyama, S. Eguchi, Y. Hirakata, and S. Yamazaki
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

8.3:
Next-Generation Display Technology: Quantum Dot LEDs
J. Manders, L. Qian, A. Titov, J. Hyvonen, and J. Tokarz-Scott
NanoPhotonica, Gainesville, FL, USA

J. Xue
University of Florida, Gainesville, FL, USA

P. H. Holloway
NanoPhotonica, Gainesville, FL, USA, and University of Florida, Gainesville, FL, USA

35.1:
Auto-Calibration for Screen Correction and Point Cloud Generation
J. Deglint, A. Cameron, C. Scharfenberger, A. Wong, and D. Clausi
University of Waterloo, Waterloo, Ontario, Canada

M. Lamm
Christie Digital Systems Canada, Inc., Kitchener, Ontario, Canada

37.1:
A Novel Blue -Phase LCD Applying Wall-Electrode and High-Driving-Voltage Circuit
C-Y. Tsai, F-C. Yu, Y-F. Lan, P-J. Huang, S-Y. Lin, Y-T. Chen, T-I. Tsao, C-T. Hsieh, B-S. Tseng, C-W. Kuo, C-H. Lin, C-C. Kuo, C-H. Chen, H-Y. Hsieh, C-T. Chuang, N. Sugiura
AU Optronics Corporation, Hsinchu, Taiwan

C-L. Lin and M-H. Cheng
National Cheng Kung University, Tainan, Taiwan

54.1:
A Switched Emissive Transparent Display with Controllable Per-Pixel Opacity
Q. Smithwick
Disney Research, Glendale, CA, USA

57.3:
New Pixel Circuits for Controlling Threshold Voltage by Back-Gate Bias Voltage Using Crystalline Oxide-Semiconductor FETs
M. Kaneyasu, K. Toyotaka, H. Shishido, T. Isa, and S. Eguchi
Semiconductor Energy Laboratory Co., Ltd., Kanagawa, Japan

H. Miyake, Y. Hirakata, S. Yamazaki, M. Dobashi, and C. Fujiwara
Advanced Film Device, Inc., Tochigi, Japan

60.1:
A Capacitive Touch Panel for Simultaneous Detection of Non-Conductive and Conductive Objects
C. Brown and A. Kay
Sharp Laboratories of Europe, Oxford, UK

Y. Sugita and K. Kida
Sharp Corp., Nara, Japan

69.2:
High-Reliable a-IGZO TFTs with Self-Aligned Coplanar Structure for Large-Sized Ultrahigh-Definition OLED TV
C. Ha, H-J. Lee, J-W. Kwon, S-Y. Seok, C-I. Ryoo, K-Y. Yun, B-C. Kim, W-S. Shin, and S-Y. Cha
LG Display Co., Ltd., Gyeonggi-do, South Korea

DISTINGUISHED STUDENT PAPERS

3.2:
High-Image-Quality Wearable Displays with a Fast-Response Liquid Crystal
Z. Luo, F. Peng, H. Chen, and S-T. Wu
College of Optics and Photonics, University of Central Florida, Orlando, FL, USA

M. Hu
Xi'an Modern Chemistry Research Institute, Xi'an, China

19.2:
Compensation of OLED I–V Drift for Suppressing Image Sticking in a Digital AMOLED Display Module
P. Volkert and C. Xu
Institute of Microelectronics, Saarland University, Saarbruecken, Germany

20.4:
Quantum-Dot LEDs with Charge-Generation Layers
H-M. Kim, J-G. Kim, J-E. Lee, and J. Jang
Advanced Display Research Center and Department of Information Display, Kyung Hee University, Seoul, Korea

24.4:
Floating 3D Image for High-Resolution Portable Device Using Integral Photography Theory
C-W. Shih, J-H. Wang, and C-H. Ting
Department of Photonics & Institute of Electro-Optical Engineering, National Chiao Tung University, Hsinchu, Taiwan, ROC

Y-P. Huang
Display Institute, National Chiao Tung University, Hsinchu, Taiwan

38.2:
High-Efficiency Three-Stack Tandem White OLEDs
Y. H. Son, J. M. Lee, B. Y. Kang, and J. H. Kwon
Department of Information Display, Kyung Hee University, Seoul, South Korea

43.4:
A Fast-Response A-Film-Enhanced Fringe-Field-Switching LCD
H. Chen, Z. Luo, D. Xu, F. Peng, and S-T. Wu
College of Optics and Photonics, University of Central Florida, Orlando, FL, USA

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AU Optronics Corp., Taiwan, ROC

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Field-Sequential-Color Displays Based on Reflective Electrically Suppressed Helix Ferroelectric Liquid Crystal
L. Shi, Y. Ma, A. Srivastava, V. Chigrinov, and H-S. Kwok
Hong Kong University of Science and Technology, Kowloon, Hong Kong

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Y. Gao, Z. Luo, R. Zhu, Q. Hong, and S-T. Wu
College of Optics and Photonics, University of Central Florida, Orlando, FL, USA

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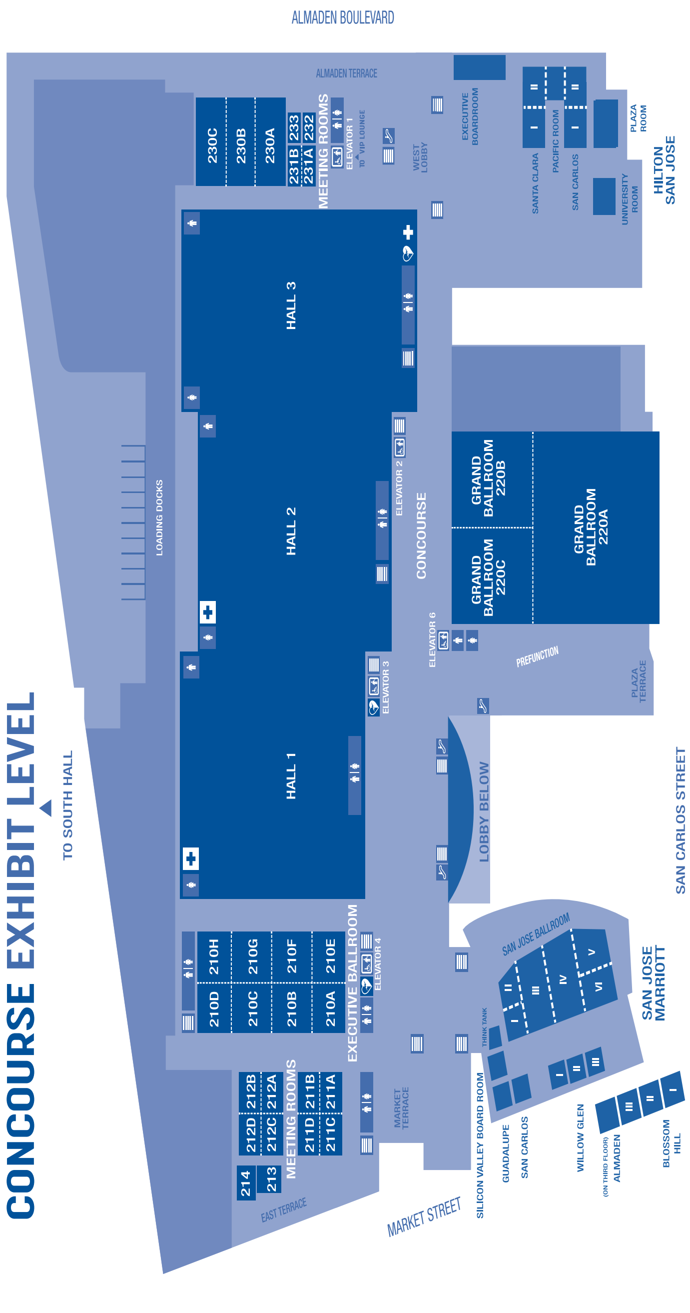

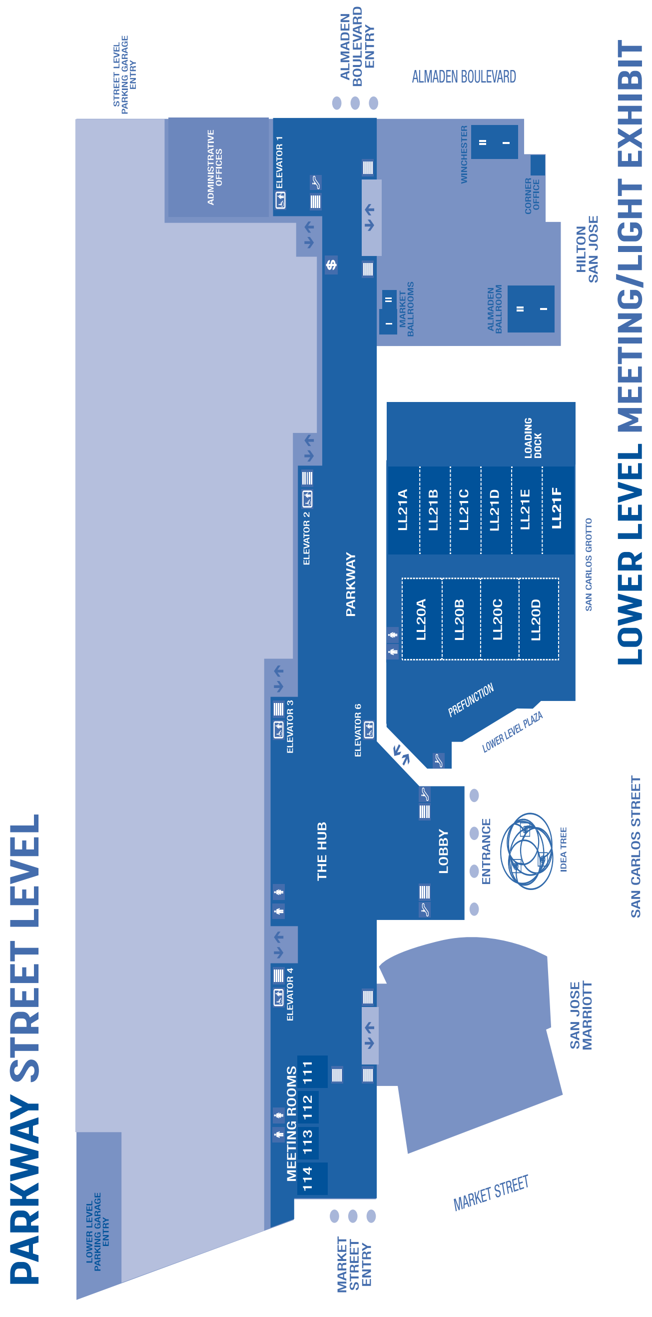

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