FlexTech Trends

News from the world of flexible, printed electronics, and displays

Volume 1, Summer 2008

FlexTech Trends

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USDC becomes FlexTech Alliance

Mission expanded to include flexible printed electronics

by Michael Ciesinski

Michael Ciesinski was appointed CEO of the U.S. Display Consortium in April 1995. From 1991-1995, Ciesinski was Vice-President and Director of North American Operations for Semiconductor Equipment and Materials International (SEMI) where he managed the Information and Communications Group, which includes market data, on-line market reports, electronic communications, education and training, and public relations. He also directed SEMI's North American Operations, which included regional offices, a variety of industry programs, and all flat panel display activity. Ciesinski was employed at SEMI starting in 1982. He is a graduate of the State University of New York at Albany.

On July 9, 2008, the US Display Consortium (USDC) announced that it was formally expanding our mission to support the emerging flexible, printed electronics market and, consequently, changing our organization's official name to the FlexTech Alliance. The USDC Governing Board took this important action to signal its intent to commit resources to the increasingly synergistic technologies driving advances in the emerging flexible and printed electronics sector. At the same time, the board recommitted its support for supply chain development for next-generation displays, such as OLEDs, flexible displays, MEMS and 3D displays. The move is a natural progression for the FlexTech Alliance, based on the success of the Flexible, Printed and Organic (FPO) Initiative launched in December 2006. The initiative was designed to gauge potential development and growth of this new electronics sector and industry interest has grown steadily with a definite need for programs dedicated to the sector. More than 50 companies, academic institutions and R&D organizations joined the initiative.

USDC and all of its programs are now part of FlexTech. In addition to continued strong emphasis on electronic display supply chain R&D, the FlexTech Alliance will focus on creating a flexible, printed electronics infrastructure within North America that will ultimately enable the production of active, ubiquitous devices. These devices will be manufactured using new, flexible form factors that deliver high functionality at low cost. Near-term applications for this market include RFID tags, sensors (chemical/biological), energy (e.g., solar cell panels, solid-state lighting, flexible batteries), medical/healthcare, disposable electronics and displays. Given their myriad applications, FPO electronics hold tremendous potential, with experts predicting that the market for some applications could exceed $50 billion by 2017.

The alliance will be overseen by a world-class Governing Board, along with a very capable management team that includes Dr. Mark Hartney as CTO, Kay Mascoli as director of development and planning, and Dr. Kevin Cammack as director of technical marketing and development. We will deliver our services in national settings, through an expansive industry web portal – www.flextech.org - and through regional chapters. To this end, the FlexTech Alliance will help the North American industry meet the challenges facing it by facilitating partnerships, ensuring R&D support, developing product demonstrators, identifying and addressing manufacturing issues, along with broadening funding opportunities. FlexTech's initial program is a technical workshop hosted by the Mark Andy Company, scheduled for August 20, 2008.

With respect to the electronic display industry, FlexTech will continue to expand and build upon USDC's strength in this field. We will initiate supply chain R&D projects in support of emerging display technology, building on our relationships in the private and public sectors.

FlexTech launches with a well-tuned organization and partnership network backed by an experienced management team and an advisory board of seasoned industry veterans. We have proven expertise in supply chain development, user group management, information exchanges and federal program creation and management. Based on all of this, there's no doubt – the FlexTech Alliance will soon prove to be the go-to organization in North America for accelerating the emergent flexible, printed electronics space.

News from the FlexTech Alliance

excerpted from Veritas et Visus newsletters

Lehigh University awarded FlexTech Alliance contract to explore alternative materials for backplanes

The FlexTech Alliance (formerly known as the US Display Consortium, or USDC), the only organization headquartered in North America devoted to developing the electronic display and the flexible, printed electronics supply chain, announced a contract with Lehigh University's Display Research Laboratory, which will investigate the suitability of a number of different metal foils for use in the manufacture of flexible display backplanes. The $270,000 cost-shared award will be the first-ever systematic study of metal foils with the goal of yielding alternative substrates to today's commonly used stainless steel. Specifically, Lehigh University will work cooperatively with Hamilton Precision Metals (HPM), a business unit of the Specialty Metal Products Division of AMETEK, Inc. to identify promising material candidates with parameters for improving yields on metal backplanes for flexible displays. Important factors in creating displays include good thermal coefficient matching and smooth substrate surfaces for minimal display defects, both of which are current issues with using stainless steel as a substrate. In addition, this study will assess the costs associated with each foil in a high-volume manufacturing environment – enabling selection of more cost-effective approaches to producing displays. The year-long project will be led by Dr. Miltiadis Hatalis, professor of electrical engineering and computer science at Lehigh. Once the film characterization has been completed and the most promising materials have been identified, additional samples of the selected foils will be made available to the US Army-sponsored Flexible Display Center (FDC) at Arizona State University to further test its capabilities. http://www.flextech.org

FlexTech Alliance to work with Applied Materials on metal-oxide films

The FlexTech Alliance announced a cost-shared contract award with Applied Materials, Inc. to develop metal-oxide films for next-generation thin-film transistors (TFTs). Oregon State University (OSU), a pioneer in transparent electronics, will work with Applied's Display Business Group-AKT, in this FlexTech-sponsored program, bringing together the US government, private industry and university research to enable critical innovations for future display technology. The R&D program will address two main challenges for future displays — to significantly improve device performance and reduce display cost per area. New metal-oxide films are one of the promising disruptive technologies for next-generation panels since they have higher electron mobility and the potential to reduce costs through lower temperature processing. Metal oxide films are also expected to be used for fabricating flexible displays and backplanes for OLED applications. The FlexTech program is expected to take a year to complete. Additional support will be provided by the US Army's Flexible Display Center at Arizona State University. http://www.fpoelectronics.org

FlexTech Alliance announces contract with Raytheon on electrophoretic displays

The FlexTech Alliance announced a one-year award to Raytheon to produce display demonstration units for military application field trials. Ultra low power, lightweight displays are of considerable interest for military applications where size, weight and power can greatly impact soldiers' effectiveness in the field. Ultra low-power displays can now utilize a new commercially available technology based on electrophoretic ink, which has many of the attributes needed for stringent military environment specifications. E Ink has demonstrated ultra-low power and daylight readability with its electrophoretic display technology. Raytheon will modify an E Ink color research prototype to meet stringent military operational requirements, especially for dismounted soldier applications. The modification will address key military requirements, including power, communication range and robustness. Raytheon will also characterize the suitability of the device for military use through both destructive and non-destructive environmental testing. http://www.flextech.org

User group formed on LinkedIn

A new user group for current and former members of the US Display Consortium to expand and maintain their networks was formed at LinkedIn. Interested parties with an appropriate affiliation with the USDC (or the newly formed FlexTech Alliance) can sign up for this group at http://www.linkedin.com/e/gis/117753/053C2A4CA21C

Sigma Technologies to develop new display coatings with high conductivity and transparency

The FlexTech Alliance recently announced a $280,000 cost-shared award to Sigma Technologies International, Inc. to develop and demonstrate new conductive, transparent polymer-based coatings for use in flexible displays, organic light-emitting diodes (OLEDs) and other applications such as solar collectors and image sensors. Sigma has demonstrated its ability to successfully produce these new coatings with an economical process that achieves a film thickness of as little as 2-3 nanometers. The project's goal is aimed at developing this alternative material for broader and more cost-effective commercial use. In this project, Sigma will determine the performance of silver nanoflakes for use in preparing transparent conductive coatings. Nanoflakes of indium tin oxide (ITO) and silver will be formulated into thin-film coatings using several conductive polymer binders. The proposed coatings are expected to have higher conductivity than conventional nanosilver-based coatings, and higher transparency over polymer-only conductive coatings or silver and ITO nanoparticle-based coatings. http://www.flextech.org

Plextronics develops new hole injection layer technology for OLEDs

The FlexTech Alliance announced that a recent project with Plextronics, Inc., has aided in the development of a new hole injection layer (HIL) technology to enable broad commercialization of high-performance, low-cost, organic light emitting diode (OLED) displays. Plextronics completed a $590,000 project with FlexTech to produce a new HIL technology that is expected to improve device performance by reducing surface roughness; improving charge injection; and allowing fine-tuning of work function. The materials that Plextronics developed utilize a new approach to conductive polymer chemistry that enables significant performance improvement. These HIL products will be cost competitive and a suitable replacement for currently used PEDOT: PSS materials. http://www.plextronics.com

Dow Corning completes project for new hole injection material

The FlexTech alliance announced the completion of its co-sponsored program with Dow Corning Corporation (Dow Corning) for the development of a new hole injection transport system that is compatible with OLED inkjet fabrication. This new hole injection material (HIM) formulation and inkjet process has demonstrated improved performance, while addressing many of the shortcomings of current HIM systems. Dow Corning's achievement has the potential to increase OLED performance and reduce OLED fabrication costs for use in the flat panel display industry. During the FlexTech-funded program, Dow Corning's team was able to achieve several objectives:

- synthesis and characterization of a new class of hole injection material candidates for integration and compatibility with existing light emitting materials;
- optimization of HIM candidates and fabrication of OLED devices with longer lifetimes, improved brightness and efficiency versus incumbent materials;
- and the development of the HIM for use in ink jet process fabrication of OLED devices.

"In order to achieve the program objectives we had to develop a novel HIM for light emitting polymer materials, conduct PLED fabrication, PLED testing and HIM characterization methods, and develop an ink jet printing process compatible with our new hole injection materials," explained Dr. Toshio Suzuki, principal investigator and associate research scientist of Dow Corning. "The support and collaboration of Dr. Ghassan Jabbour and his team at the Flexible Display Center at Arizona State University was invaluable to the success of this program." FlexTech's HIM program achieved its goal for developing a new group of siloxane-based hole injection materials, which can be cast as solid thin films with excellent transmittance, smoothness and solvent resistance," stated Dr. Mark Hartney, chief technology officer for FlexTech. "We are very pleased to see the results for improving ink jet printing, demonstrated through a viable application method for processing Dow Corning HIMs."

Fusion Optix applies diffusion films to thermoformed lenses

R&D engineers at Fusion Optix have successfully applied LightControl technology to thermoformed lenses. The result is a selection of domes and other shapes enhanced by the properties of the company's most popular diffusion films. Samples will be available in the near future. http://www.fusionoptix.com

E Ink announces mobile phone design wins in Japan

E Ink announced that Casio Hitachi Mobile Communications Co of Japan have selected E Ink Vizplex Imaging Film based displays for its newest family of mobile phones. CH-Mobile is planning on several product releases. These are the world's first clamshell style mobile phones to use E Ink's electronic paper technology on the outside. The Hitachi W61H phone was the first of these product releases, featuring a secondary display utilizing E Ink Vizplex display on the external surface of the phone. Japanese designer SeKiYuRiO created the Hitachi W61H to resemble a perfume bottle. The 2.7-inch diagonal E Ink display scrolls through 96 different images in a stylish animation and is activated when a call or message is received, or when the clamshell phone is opened for use. The Casio Model G'z One will be launched this summer. It will also feature E Ink's Vizplex display as a secondary "Silhouette display". Design details will be unveiled by Casio on their website. http://www.eink.com

Hitachi W61H cell phone features a secondary display utilizing E Ink Vizplex on the external surface of the phone

Esquire uses E Ink Vizplex to become first magazine to merge digital technology with printed pages

Esquire, one of America's iconic magazines, is turning 75 this year. As part of the celebration of this milestone, the October issue will be the first magazine ever to embed electronic paper into a mass-produced print product. In partnership with the all-new Ford Flex Crossover and in collaboration with E Ink Corporation Esquire's groundbreaking cover will make a profound statement about how the print medium can expand its capabilities while continuing to exploit its own unique strengths. Ford will prominently feature its highly-anticipated Ford Flex on the inside cover, utilizing the same E Ink Vizplex flexible display technology, in a double-page advertisement. In the summer of 2007, Esquire and Hearst, Esquire's parent company, contracted E Ink to develop a version of their electronic paper technology (which is used in devices like Amazon's Kindle and other e-books/e-newspapers) that could be used in a magazine. Throughout 2008, E Ink and Hearst's manufacturing division have worked to surmount the myriad manufacturing challenges the project presented. When the cover appears on newsstands in September, words and images will scroll across the flexible electronic paper display. http://www.esquire.com http://www.eink.com

Plextronics offers its solar cell inks in research quantities

Plextronics announced the introduction of its ink systems for organic solar cell fabrication at the IDTechEx PV Beyond Conventional Silicon Conference held in Denver, Colorado in June. Developed around its record-setting photovoltaic technology, the company is releasing two versions of its Plexcore PV ink system for use in research applications. Troy Hammond, Plextronics' vice president of products and a presenter at the conference, said that this is the first time the company has offered its organic photovoltaic (PV) product for sale. Plexcore PV is a ready-to-use ink system that consistently delivers world-class performance for printed solar power. The system consists of two inks custom-designed to work together: a p/n photoactive ink and a hole transport ink that are both solution-processable. Next generations of Plexcore PV ink systems will be designed for printing in pilot and early manufacturing lines, enabling further advances toward commercial production. http://www.plextronics.com

Sigma-Aldrich signs agreement with Plextronics to distribute Plexcore organic electronics materials

Sigma-Aldrich announced that the company has signed an agreement with Plextronics to distribute its organic semiconductors and conductive inks. Under the terms of the agreement, Sigma-Aldrich will exclusively distribute research quantities of Plexcore OS organic semiconducting polymers and Plexcore® OC organic conductive inks globally through the Aldrich Materials Science initiative of its Research Specialties business. Plextronics will continue to work closely with industry partners to deliver commercial quantities of the materials and focus on development of its Plexcore technology. http://www.sigma-aldrich.com/oel

UDC awarded $1.9 million US Department of Energy OLED lighting contract

Universal Display Corporation announced a $1.9 two-year US Department of Energy (DOE) contract to develop a ceiling-based white OLED lighting system. Universal Display plans to use Armstrong World Industries as a key subcontractor to fulfill the requirements of the grant. Funded through the US DOE Office of Energy Efficiency and Renewable Energy, this Solid-State Lighting (SSL) Program award supports the DOE's long-term commitment to advance the development and market introduction of energy-efficient, solid-state white light sources for general illumination. During this SSL Product Development Project, Universal Display and its subcontractor, Armstrong, will develop and deliver an integrated ceiling illumination system that is targeted to exceed the DOE's 2010 performance goals. The white OLED lighting panels will be designed and fabricated by Universal Display using its high-efficiency phosphorescent OLED technology. The panels will then be integrated by Armstrong into its TechZone open-architecture ceiling system. In addition, the team will deliver a white OLED lighting panel fabricated on a thin metallic foil substrate using UDC's PHOLED and other OLED technologies, to demonstrate the commercial product potential of white OLEDs with a flexible form factor. http://www.universaldisplay.com

UDC's white OLED technology exceeds 100lm/w milestone

Universal Display Corporation announced that the company has successfully demonstrated a record-breaking white OLED with a power efficacy of 102 lumens per watt (lm/W) at 1000cd/m^2 using its proprietary, high-efficiency phosphorescent OLED technology. Just in May at the Society for Information Display Symposium, Universal Display announced a new record of 72lm/W. Since then, Universal Display has continued to make significant advances in this area – achieving yet another major milestone toward commercialization. For the first time, white OLEDs have surpassed the power efficacy of the two incumbent indoor lighting technologies - incandescent bulbs are less than 15lm/W and most fluorescent lamps are 60-90lm/W. Funded in part by the US Department of Energy (DOE) through its Solid-State Lighting initiative, Universal Display's 102lm/W milestone is a significant achievement toward the DOE's roadmap goal of a 150lm/W commercial OLED light source by 2015. This OLED light source also offers a white emission with a color rendering index (CRI) of 70 and a coordinated color temperature (CCT) of 3900 Kelvin. This all-PHOLED structure uses complementary materials from Universal Display's collaboration partners at LG Chem and Nippon Steel Chemical Company. http://www.universaldisplay.com

Applied Materials releases statement on patent infringement

Applied Materials, Inc. released the following statement regarding its thin film solar technology: "Applied Materials believes that its SunFab thin film solar tandem junction technology does not infringe European Patent No. EP 0 871 979 issued to the University of Neuchatel (the 'Neuchatel patent'). Applied Materials' unique and proprietary manufacturing process and tandem junction cell structure are the result of substantial research and development. The SunFab line is the only integrated production line for manufacturing thin film solar modules using ultra-large 5.7m^2 glass panels. Applied Materials' belief of non-infringement is based in part on differences between the SunFab tandem junction technology (as verified by scientific analyses such as Raman spectroscopy and transmission electron microscopy) and the claims of the Neuchatel patent. In addition, the Neuchatel patent is already the subject of four separate opposition proceedings in the European Patent Office challenging its validity, based on prior art that was not disclosed or considered during the European patent examination process." http://www.appliedmaterials.com

IAF chooses AIXTRON CCS MOCVD tool for oxide based sensor development

AIXTRON AG announced a new order from the Fraunhofer Institut für Angewandte Festkörperphysik (Institute for Applied Solid-State Physics), Freiburg, Germany, (IAF) for a Close Coupled Showerhead (CCS) 6x2-inch MOCVD tool received in the second quarter 2008. To be used for the research and development of indium oxide (InO) based materials for sensor applications, the CCS reactor will be supplied with 1x4-inch wafer configuration in the fourth quarter 2008. The IAF is collaborating with fellow European researchers to bring to commercialization room temperature gas sensors. This has been an outgrowth of its development of ultra-high brightness (UHB) III-nitride LEDs. Last year the team published their first results on the development of a single-chip ozone sensor based on indium oxide nanoparticles and blue LEDs. http://www.aixtron.com

ASM ships 100th Pulsar ALD tool

ASM International announced that it has delivered its 100th Pulsar atomic layer deposition (ALD) process module. This milestone positions Pulsar as the industry-leading ALD platform, installed in over 30 fabs worldwide for high volume manufacturing, pilot production and process development. “Pulsar was first to market with its breakthrough technology, and is running in volume production for high-k gates and for several other applications,” explained Peo Hansson, general manager of ASM America. Films available for Pulsar include hafnium and zirconium-based oxide films for high-k gates, lanthanum oxide and aluminum oxide for dielectric caps needed to tune metal gate work function and high deposition rate aluminum oxide for flash inter-poly dielectrics. In addition to high-k films for logic and flash gate stacks, the flexibility of the Pulsar is further evidenced by its ALD processes for magnetic read/write (R/W) heads, ferroelectric RAM (FeRAM), microelectromechanical systems (MEMS) devices and OLED devices. http://www.asm.com

FUJIFILM Dimatix announces SAMBA single pass piezo DOD inkjet technology

FUJIFILM Dimatix announced a new-generation piezoelectric drop-on-demand (piezo DOD) inkjet technology that delivers the breakthrough quality, speed and scalability required for wide-width single pass production inkjet printing and materials deposition applications. Developed jointly by FUJIFILM Dimatix and FUJIFILM Corporation, the new SAMBA inkjet technology utilizes Dimatix’ proprietary MEMS fabrication methods, VersaDrop multi-pulsing jetting capability and “Meniscus Replenishment Technology”. Collectively, these technologies and other innovations enable printhead nozzles to be arranged in a matrix array with improved meniscus formation and ink re-circulation to provide unparalleled stability, uniformity, maintainability and scalability in a compact package. The first implementation of SAMBA inkjet technology is in a parallelogram-shaped “printhead on a chip” that measures a mere 45mm deep and packs 2048 jets per module at 1200 dot-per-inch spacing, and is capable of pulsing fluids at up to 100,000 cycles/second – the highest jetting frequencies yet developed. http://www.dimatix.com

GE announces exploration of strategic options for spinning out consumer and industrial divisions

GE announced July that it is continuing to explore all options for its consumer and industrial businesses with a primary focus on spinning-off the entire unit - Appliances, Lighting and Industrial - to existing GE shareholders. The company announced on May 16 that a spin-off was one possible outcome of the strategic review of its appliances division. “As we explored our options for appliances, it became clear that the fastest, most efficient step we could take in completing the transformation of our industrial portfolio would be to focus on a possible spin-off of the entire unit,” GE Chairman and CEO Jeff Immelt said. “This is consistent with the strategy we have been executing to transform the GE portfolio for long-term growth and makes sense for GE shareholders.” http://www.ge.com

Westaim updates shareholders on strategic alternatives related to iFire

The Westaim Corporation recently updated shareholders about the status of iFire. Previously, the company announced that it was taking steps to reduce operating costs, dispose of non-core assets and consider strategic alternatives. As previously announced, Westaim has discontinued the development plan of its iFire Technology subsidiary in the face of increasing technological barriers to entry and steep price reductions with the incumbent technologies in the flat panel television market. While iFire made progress on certain aspects of its development plan, overall progress was slower than expected and consequently the product development timeline extended past the timeframe originally anticipated. In addition, iFire lacked the resources required to complete the development work necessary for commercialization. Over the past six months Westaim contacted prospective purchasers to solicit interest in purchasing iFire. To date, no expressions of interest in acquiring iFire en bloc have been received. Consequently, the Company has turned its attention to seeking buyers for the assets of iFire and expects to substantially complete the sale of such assets by the end of 2008 for proceeds that will likely range between $3 and $7 million. http://www.westaim.com

HP licenses technology to Xtreme Energetics for creation of solar energy system

HP and Xtreme Energetics (XE), a solar energy system developer based in Livermore, California, announced they have entered into an agreement for the development of a solar energy system designed to generate electricity at twice the efficiency and half the cost of traditional solar panels. Under the technology collaboration and licensing agreement, HP will license its transparent transistor technology to XE in return for royalty payments. The transparent transistor technology that will be used in XE's solar energy device was co-developed by HP and Oregon State University. The technology includes thin film transparent transistors, which are made from low-cost, readily available materials such as zinc and tin. The materials raise no environmental concerns and allow for higher mobility, better chemical stability and easier manufacture. The transistor technology enables control of XE's concentration and tracking system as it provides a transparent electronic mechanism to maximize the concentration of light. When coupled with XE's system, the technology improves conversion efficiency as maximum light can get through without being blocked by traditional non-transparent electronics. "Blending art and science, our ultra-high efficiency solar energy systems can serve both the central utility and rooftop markets using low-cost, ecologically harmonious and architecturally inspiring designs," said Colin P. Williams, chief executive officer, Xtreme Energetics. "Our agreement with HP allows us to bring an advanced solar energy solution to the market that is superior to other offerings currently available." The flat design of XE's system eliminates the need for mechanical tracking of the sun as it traverses the sky. Also, with HP's transparent electronics technology, the system can be artistically patterned to mimic the appearance of any building material or terrain for aesthetic appeal. This low-profile design also overcomes the persistent dilemmas of mechanical solar trackers, which cast shadows onto themselves, require large maintenance costs and are vulnerable to high winds, making rooftop installations especially difficult. http://www.hp.com/go/ipl

Westar introduces the EZwindow video windowing device

Westar Display Technologies introduced the EZwindow video windowing device. The EZwindow is available in configurations with 2, 3, 4, or 5 video inputs. Any region in each input can be placed as required in the output video active area, allowing unlimited windowing options. In addition, one or more inputs may be designated as an overlay or blending source for a particular window or the entire output area. The EZwindow supports most video input formats, including analog RGB (separate syncs, sync-on-green, or composite sync), NTSC, PAL, DVI, RS-343, and more. Outputs are analog RGB and DVI. Resolutions up to 1920x1200 are supported on inputs and output. EZwindow is appropriate for any application requiring windowing and/or overlays with the lowest possible latency and high resolution. Applications include: training and simulation (for instructor monitors or simulation of complex multi-function displays), command and control rooms, and professional presentation rooms. http://www.westardisplaytechnologies.com

Goldeneye develops "brightest" green source

LED projection light sources that deliver 300 lumens/mm^2 in the green wavelength at a drive current of only 1 amp per mm^2 have been demonstrated by Goldeneye. Complete three-module RGB units using the company's patented light recycling technology can produce over 1720 lumens to a light engine in an étendue equivalent to a 4 mm^2 emitting area without exceeding LED drive currents of 1 amp/mm^2. The combined white output at these drive currents is over 430 lumens/mm^2, another industry record. Higher outputs can be obtained at higher drive currents. "This is nearly double the brightness of any competing flat light LED source," according to Goldeneye CEO Bill Livesay. "Green LEDs have typically been a limiting factor in making high brightness LED powered projectors, but this technology now enables projectors with outputs of 1000 on-screen lumens." The light sources, which the company is now sampling to select customers, are more collimated than a Lambertian emitter, enabling them to couple more efficiently into projector light engines. In conventional flat light sources, 30-50% of the light is thrown away when coupling into a light train. Integrated optical elements in the Goldeneye source can provide over 1200 green lumens in an étendue of less than 12 steradian-mm^2 with more than 94% of the output contained within a ±45 degree angle. Goldeneye's "light recycling" cavities, which form the core of the sources, take advantage of the inherent reflectivity of the LEDs to increase the output while maintaining a smaller emitting area and lower drive currents compared to conventional flat light sources. http://www.goldeneyeled.com

Potomac develops miniature electronic circuits

Extending its Mill and Fill technology for fabrication of high density electronic interconnect circuits, Potomac has developed techniques for mounting miniature active and passive components to produce functional electronic circuits of reduced size. This new capability can produce size and cost reductions in medical devices, sensing systems and networks, and military/homeland security applications. The Potomac Mill and Fill approach produces embedded silver conductors and can be applied to a variety of popular substrates. Line widths and feature spacing can be as small as 12 microns. The use of small, embedded conductors allows novel routing techniques to be used to minimize layer count and is compatible with almost any SMT component package. A very simple example of the technology is the LED flasher circuit shown in the photograph. The circuit comprises a small dual inverter IC, two capacitors and an LED in 0402 packages, and three resistors in 0201 packages. The overall width of the circuit is approximately 3mm. Novel routing of the small embedded conductors allows fabrication of the entire circuit on a single-layer Al2O3 substrate. http://www.potomac-laser.com

Merck showcases isishape photovoltaic solution

Merck will present its latest achievements in structuring solutions and other offerings for the photovoltaic sector at the European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC) held from September 1 to September 5, 2008 in Valencia, Spain. Under the brand name isishape, Merck has developed printable etching pastes being able to selectively etch anti-reflective coatings (e.g. SiNx) and passivation layers (e.g. SiO2) on solar cells as well as on transparent conductive (e.g. ITO) materials. The concept of isishape offers environmentally friendly and highly efficient materials for smart and simple patterning for the photovoltaic industry. For organic solar cells, Merck also provides novel printable polymers (lisicon), highly developed hole transport materials (livilux), anti-reflective coatings (solarpur), ionic liquids for dye-sensitized solar cells, and special chemicals for the CIS technology. http://www.merck-chemicals.com

Orbotech reaches agreement to acquire Photon Dynamics

Orbotech Ltd. and Photon Dynamics, Inc. announced that they have signed a definitive agreement for Orbotech to acquire Photon Dynamics, a leading provider of test and repair systems for the LCD display industry. Under the terms of the agreement, Orbotech will pay $15.60 per share in cash for all of the issued and outstanding shares of Photon Dynamics' common stock, making an aggregate merger consideration value for the transaction of approximately $290 million. The acquisition will be financed through a combination of internally-generated funds and external-source financing. This acquisition is a major part of Orbotech's strategy for growth and diversification in its flat panel display business. http://www.orbotech.com

Optomec and Applied Nanotech Holdings announce cooperation on copper inks

Applied Nanotech Holdings announced that its subsidiary, Applied Nanotech, Inc. ("ANI"), established a strategic development program with Optomec. As a part of the commitment, ANI will install a dedicated Optomec M3D Aerosol Jet printer at its facilities in order to adapt its revolutionary copper ink to Optomec's patented ultra high resolution printing technology. By utilizing ANI's copper ink, the Optomec printer will offer the solar, display, flexible circuit and PCB manufacturers contact-free deposition of high quality, low cost metal lines. The Optomec printing solution is able to produce much finer lines than is currently possible with traditional screen printing and inkjet printing equipment. The combined ANI/Optomec copper ink printing solution will provide an alternative to silver inks facilitating lower cost, coupled with the promise of higher reliability. Furthermore, ANI's copper inks do not require expensive vacuum installation or inert gas environment lowering the cost of the capital for manufacturing equipment. http://www.appliednanotech.net

Cinépolis and RealD announce exclusive digital 3D partnership

Cinépolis, the world's fifth largest cinema exhibitor, and RealD announced that Cinépolis will add 500 RealD 3D screens to its circuit. The rollout of these 500 RealD 3D screens has already begun with six new screens installed for the release of Journey to the Center of the Earth, and will continue through 2010. The partnership makes RealD the exclusive choice of Cinépolis for digital 3D and creates a strong platform in the market for the upcoming slate of over thirty major studio 3D releases in 2009 and 2010. http://www.reald.com

Kent Displays launches Reflex and eGo (electronic skin) cholesteric displays

At SID 2008, Kent Displays exhibited a variety of cholesteric liquid crystal display modules and electronic skins products, trademarked as Reflex and eGo. The company also introduced plastic substrate displays that will be manufactured in Kent, OH on a new roll-to roll production line. This roll-to roll line is a world first and will increase the supply of flexible, low power displays for unique product applications such as credit cards, curved surfaces, product tags and other e-paper applications. The brand name Reflex is derived from the fact that all Reflex displays are reflective and inherently flexible in nature. They are ideal for portable devices that demand long battery life, a wide viewing angle, and paper-like viewing in all ambient lighting conditions including bright sunlight. These displays can operate on virtually no power, and can be as thin as 30 microns. The company also offers a line of customizable electronic skins (eGo) for mobile computing devices, and electronic writing tablets (eTablet) for many markets. http://www.kentdisplays.com

eGo electronic skin on a mouse

SiPix to launch electronic books by end of 2008

US-based SiPix Imaging, which develops electrophoretic display (EPD) technologies, expects to launch electronic books by the end of this year, according to the company. SiPix said it is working with display module makers, including Chi Hsin Electronics (CHE), Chi Lin Technology, Chunghwa Picture Tubes (CPT), and Wintek, to separately develop electronic books, and the products may be unveiled by the end of 2008. SiPix, which uses its roll-to-roll technology to make EPD materials, has a production facility for display module development in Chungli, northern Taiwan. http://www.sipix.com

InFocus presents high-powered meeting room solution

InFocus Corporation introduced its IN3100 series, a meeting room multimedia projector. The new IN3100 series is the world's first projector series featuring DisplayLink technology, using a standard mini-USB cable to instantly synchronize laptop with projector. In addition, the IN3100 series features the new LiteTouch keypad that is visible only when needed. InFocus' new LiteTouch keypad replaces standard button controls with an exclusive backlit touch-sensitive keypad – giving the IN3100 series a sleek, smooth look. The IN3100 series includes multimedia projectors with 3000 to 3500 lumens, a choice of 1024x768 or1366x768 resolution, and 2000:1 contrast. Additionally, the IN3100 series supports HDMI and LiteShow II wireless connectivity. http://www.infocus.com

Corning acquires Optimum Manufacturing Corporation

Corning announced that, through a subsidiary, it signed an agreement to acquire Optimum Manufacturing Corporation for inclusion in its Specialty Materials segment. Located in Charlestown, N.H., Optimum is a manufacturer of precision-machined components serving the aerospace and defense, scientific, medical and communications industries. Terms of the agreement were not disclosed. Through its Specialty Materials segment, Corning is recognized for process innovation, materials science, opto-mechanical design, diamond turning, optical grinding and polishing, and thin film coatings. Optimum focuses on complex, technical projects and exhibits a superior ability to engineer and manufacture precision-machined components with extremely tight tolerances. In addition to high-end, advanced components, Optimum also has extensive engineering and machine programming expertise. Combining capabilities will help to strengthen Corning's position as a premier, full-service optical solutions provider. http://www.corning.com

Sencera to build 35MW solar module factory in Charlotte, North Carolina

Sencera International Corporation, a manufacturer of thin film solar (photovoltaic) modules is expanding in Charlotte. The company plans to invest $36.8 million and create 65 jobs during the next three years. It was made possible in part by a $62,000 One North Carolina Fund grant as well as local incentives from the City of Charlotte and Mecklenburg County. Sencera, which is headquartered in Charlotte, develops and manufactures amorphous and microcrystalline thin film solar modules using its proprietary Viper plasma enhanced chemical vapor deposition platform. The company also operates an R&D lab serving the solar energy industry. The company is planning to construct a solar module facility that will produce solar cells and assemble them into photovoltaic panels. Total manufacturing capacity will exceed 38 megawatts by 2011. http://www.sencera.com

UniPixel acquires display technology patents

UniPixel, the developer of color display technology called Time Multiplexed Optical Shutter (TMOS), announced it has reached an agreement to acquire a block of patents that are applicable to UniPixel's TMOS display technology. The acquisition of the patents, apparently from Philips, increases the total number of UniPixel's TMOS display-related patents to 106 patents issued and filed. The patent transaction is a direct result of collaboration efforts entered into during 2007 surrounding the development and assembly of its TMOS display technology. According to Mr. Reed Killion, President and CEO of UniPixel, "Our development efforts to bring TMOS display technology and Opcuity films to commercialization continue to result in the rapid expansion of our IP portfolio. The acquisition of this block of patents adds immediate value and protection for UniPixel and TMOS licensees moving forward. Furthermore, these patents augment our existing UniPixel patents in a number of the disciplines included within TMOS architectural, electromechanical, panel fabrication, system assembly and process related intellectual property." http://www.unipixel.com

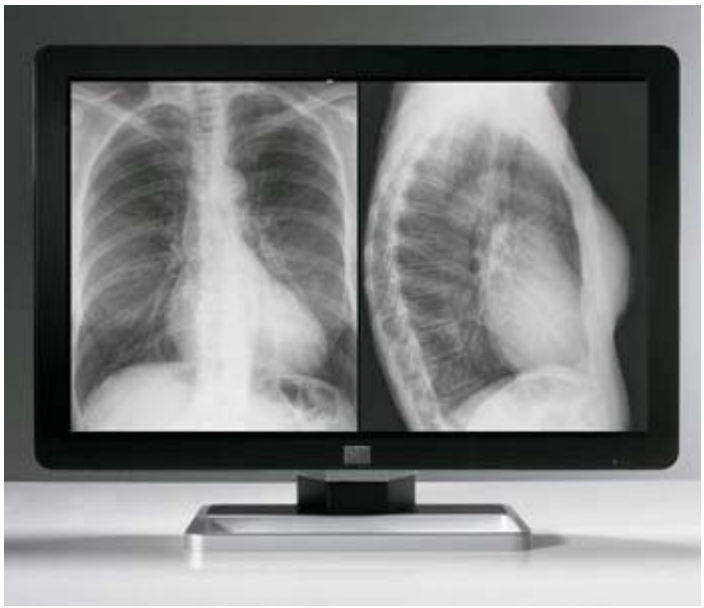
New high brightness LED light line from SCHOTT products bring higher contrast to inspection

SCHOTT's Fiber Optics Division introduced two new high brightness (HB) LED light line products at the Semicon West show: the Surface Mount Device (SMD) and the Chip on Board (COB). Both offer high luminosity beams and are suited for such industrial operations as web-scanning and surface inspection. Each integrates MayTec profile grooves into their housings, allowing for flexible mounting onto production lines. An acrylic cylindrical lens on the SMD can be adjusted to modify the working distance from 50-100 mm. This enables it to generate a focused light source with an illuminance of 400 kLux and homogeneity of plus or minus 5% in the plateau level. The light beams can be either red or white, as needed. Using high LED assembly densities on its circuit boards, the COB has an illuminance of up to 200 kLux, and is available in red or blue light. In addition, all light lines can be customized by SCHOTT to meet particular specifications. http://www.us.schott.com

NanoGram Corporation receives PV award from US Department of Energy

NanoGram Corporation has been awarded an Energy Innovator Award from the US Department of Energy's Office of Energy Efficiency and Renewable Energy. The award recognizes businesses, individuals and governmental agencies that have successfully developed or deployed energy efficiency and/or renewable energy technologies, services or policies. NanoGram is developing a breakthrough crystalline silicon-based solar module manufacturing process that dramatically reduces module cost to the level of thin film photovoltaics while delivering high efficiency. The process leverages NanoGram's proprietary laser reactive deposition (LRD) technique, which drives down PV module costs by reducing silicon consumption to less than 25% compared to typical wafer-based approaches. Significant cost reductions generated using this approach are expected to bring module costs well below $1.00/Wp when high volume manufacturing production levels are reached in 2012. An R&D pilot plant is currently under construction at NanoGram's headquarter facilities in Milpitas, CA. http://www.nanogram.com

Barco's 6-megapixel diagnostic display system gains wide acceptance



Coronis Fusion 6MP DL, the world's first 6-megapixel diagnostic display system developed by Barco, is rapidly finding its way to the radiology reading room. After early contracts in the US, Australia, Korea, Belgium, Germany and France, Barco announced that it has also received a significant order for this product under a PACS installation project in the Beatrix Hospital in Gorinchem, the Netherlands. The order fits within a larger PACS installation program carried out by Philips Healthcare. Coronis Fusion 6MP DL is the latest extension of Barco's diagnostic display offering. The system introduces the world's first seamless 30-inch color LCD that can be used either as two seamless 3-megapixel heads or as one wide-screen 6-megapixel display. This makes it possible for radiologists to read chest X-ray, CT, MR, cath and echo cardiogram images, or any other combination, side by side on a single diagnostic screen. http://www.barco.com

Plastic Logic receives $50 million round of venture capital

In early August, Plastic Logic announced it has raised a new round of $50 million in equity finance led by existing venture capital investors Oak Investment Partners and Amadeus Capital Partners, joined by its previous investors. To date, the company has raised more than $200 million.

> "We are approaching very significant milestones in the creation of the plastic electronics industry with the opening of our Dresden plant and the pending launch of our first commercial consumer electronics product," said CEO Richard Archuleta. "This new investment will enable expanded business operations in support of our first commercial product early next year while we continue to develop our IP to deliver on our broader long-term vision."

Plastic Logic maintains research and development in Cambridge, England, and is bringing online a new high-volume manufacturing facility in Dresden, Germany that is scheduled to open Sept. 17, 2008. The company also recently established a Mountain View, California, headquarters for management, product engineering, product supply chain, sales and marketing. http://www.plasticlogic.com

Vitex Systems achieves lifetime record on flexible copper indium gallium selenide solar cells

Vitex Systems announced a key breakthrough in protecting flexible copper indium gallium selenide (CIGS) solar cells against moisture and oxygen. The efficiency of flexible CIGS solar cells laminated with Vitex's flexible glass remained unchanged after being tested in extremely high temperatures and high humidity for over 1,100 hours. With CIGS' potential for being produced using a low cost, roll-to-roll manufacturing process, it has quickly become one of the most promising thin-film photovoltaic technologies. However, similar to cadmium telluride (CdTe) cells, CIGS is also sensitive to moisture and oxygen. Commercially available flexible CIGS solar cells only have a guaranteed lifetime of two to three years because testing shows that their efficiencies degrade quickly in high-temperature and high-humidity environments. Some manufacturers have demonstrated that the use of rigid glass in the final modules extends product lifetime. However, there are added weight, costs (not only production, but also shipping and installation costs) and loss of flexibility when working with such rigid packaging. The CIGS solar cells that achieved the lifetime record of over 1,100 hours were made on stainless-steel foil and laminated with Vitex's flexible glass 200 with a proprietary lamination process. With a total thickness of approximately 0.3mm, the module was lightweight, flexible and unbreakable. After testing at Pacific Northwest National Laboratory (PNNL), the CIGS cells maintained more than 98% of their original efficiency after 1,100 hours — exceeding the requirements of IEC's 61646 standard. The tests are continuing at PNNL to determine the ultimate lifetime of these devices. http://www.vitexsys.com

LUXEON Rebel from LumiLeds enables highly efficient modules for recessed lighting

New, highly efficient solid-state lighting solutions for the general lighting market are now available with the North American debut of Philips Fortimo and Lexel downlight modules using LUXEON Rebel power LEDs. Both modules, with accompanying thermal and power systems, enable lighting OEMs to quickly and easily equip the architectural and specification communities with complete white and tunable downlight solutions. Fortimo modules can potentially reduce energy consumption by as much as 50% compared to CFL and Lexel modules can deliver perfectly controllable illumination.

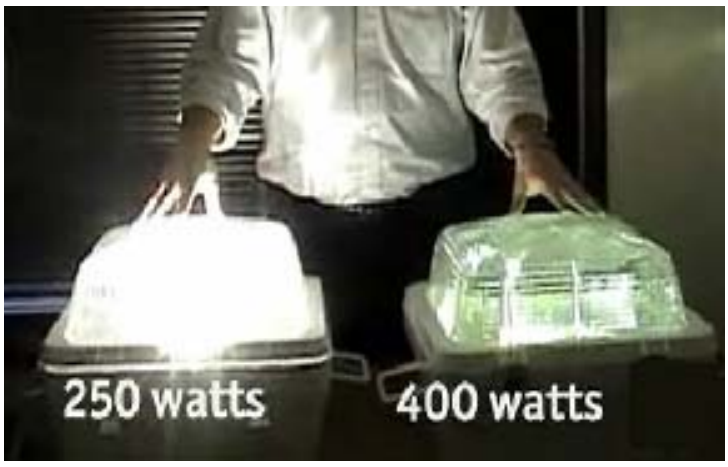
The Fortimo DLM 1100 uses 18 royal-blue LUXEON Rebel LEDs and a remote phosphor lens at the top of a mixing chamber to create a white-light module delivering 1100 lumens of light output with an efficiency of 62lm/W. A second version of the Fortimo module delivers 2000 lumens at 45lm/W. Initially introduced with a 4000K correlated color temperature, the use of different remote phosphor lenses allows for the possibility of additional white CCT options in the future. By using royal-blue LUXEON Rebel LEDs, the Fortimo solutions maximize the photonic energy directed at the remote phosphor lens. Careful matching of the wavelength of the LEDs to the characteristics of the phosphor in turn maximizes the light output and efficacy of the module. The small 44x82x83mm Fortimo footprint allows the modules to be integrated with a wide variety of reflector solutions used in downlights. http://www.philipslumileds.com

Luxim launches LIFI entertainment light source

Luxim announced the introduction of its new LIFI Entertainment solid-state high intensity light source product line. The new module outputs up to 12,000 lumens from a small emitter in a forward intensity pattern with a color-rendering index (CRI) of 91 and a 20,000-hour lifetime. In applications like moving heads, scanners and follow spots, LIFI Entertainment light sources enable 50% higher fixture efficiency than conventional lamps. As a result, designers of entertainment lighting can increase beam intensity and reduce optical system size. In addition, LIFI Entertainment systems last seven times longer than those using conventional HID lamps and are safe to use in any application since they do not experience explosions or broken glass. Each LIFI Entertainment light source is equipped with an individually addressable micro-controller that can provide energy saving dimming and strobe. This lighting feature is compatible with various network protocols. http://www.luxim.com

Luxim develops recording-breaking efficiency light source

Luxim has developed a light bulb the size of a TicTac that gives off as much light as a streetlamp. It uses plasma technology to achieve its brightness. The device contains an argon gas in the middle, as well as a component called a “puck”. The bulb is partially embedded in a dielectric material. When electrical energy is delivered to the puck, the puck acts like an electrical lens. It heats up the argon to a temperature of 6000 degrees Kelvin, and turns the gas into a plasma that gives off light. The plasma, whose 6000-degree temperature is similar to that of the surface of the sun, also emits a spectrum that looks very similar to the spectrum of sunlight. The plasma bulb uses 250 watts, and achieves around 140 lumens per watt. By comparison, conventional light bulbs and high-end LEDs get around 15 and 70 lumens per watt, respectively. Luxim is using different versions of its electrode-less plasma technology to develop lighting for ultra-bright projection displays, retail and street lighting, microscope lighting, and various medical applications. A video showcases the technology: http://news.zdnet.com/2422-13568_22-192842.html



Continued growth at the FlexTech Flex conference

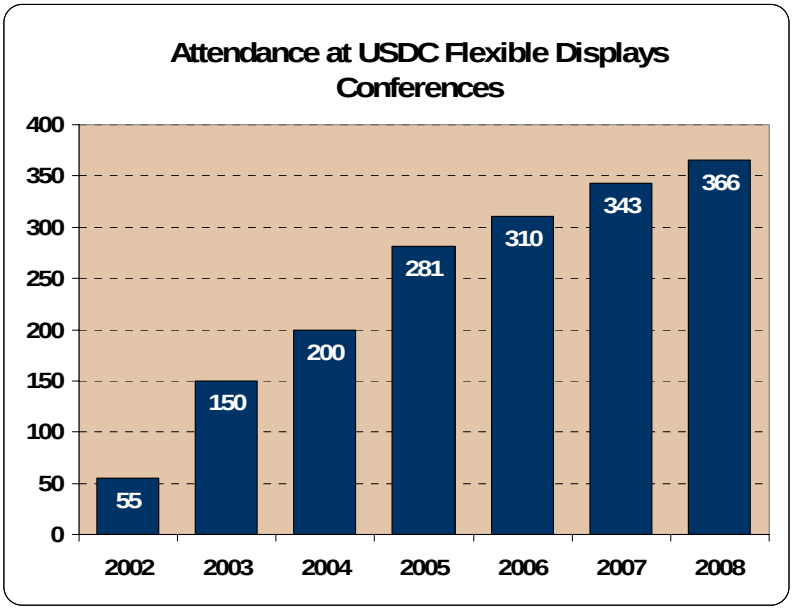
by Mark Fihn

This article is excerpted from the April 27, 2008 edition of the *Flexible Substrate* newsletter from Veritas et Visus, which is available at http://www.veritasetvisus.com.

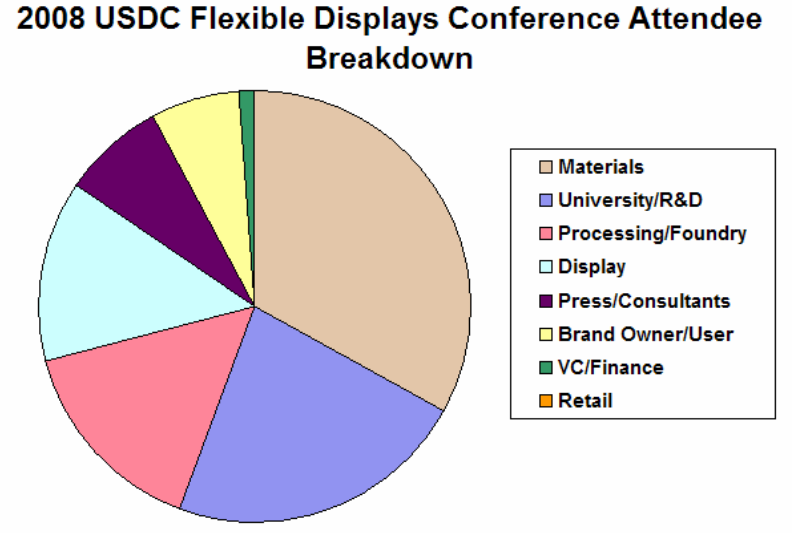
FlexTech's Flexible Displays conference was the first conference devoted specifically to the topic of flexible displays, first held in 2002. Each year, the conference has succeeded in attracting an increased number of attendees. They've done this even though the FlexTech event now faces competition from numerous other organizations that are also focused on the topic of flexible displays. The 2008 conference, held as usual in Phoenix, attracted a record number of 366 attendees.

The growth trend of the FlexTech conference has undoubtedly been challenged by the huge growth of competitive conferences (several of which are covered later in this newsletter) like the IDTechEX conference held in early April in Dresden, Germany.

While conference attendance is not a sure fire way to assess the health of an industry, it's easy to suggest that both the growth of attendance and the number of conferences covering the topic can attest to the tremendous interest in the entire field associated with flexible electronics.



Of the 366 attendees to FlexTech's 2008 event, it's significant to note that the majority came from groups that I've classified as being either materials-related or from university or industry-related research groups. A large portion also came from the production and processing side of things and the display makers ranked 4th in terms of representation at the conference. Importantly, only a small number of brand owners attended the conference and arguably no one really attended the conference that represented actual commercial applications. Note that there is some subjectivity associated with these categories and the assignment of different companies into each of the categories, but it's certainly accurate to suggest that the conference attendees are still largely early-stage technologists.



The preceding paragraph was lifted verbatim from my summary of the breakdown of attendees at last year's conference. The only noticeable differences between the 2007 and 2008 pie charts was that the number of attendees from universities increased and the number of attendees from VC/Financial interests decreased.

A look at the companies represented by the speakers at the FlexTech conferences provides some interesting insights. In seven years, although the industry is filled with small, start-up companies, the speakers at the FlexTech conference represent companies that seem to be quite stable – with very little "consolidation".

Speakers at FlexTech's conferences

7-time Speakers						
2002	2003	2004	2005	2006	2007	2008
Avecia	Avecia	Avecia	Avecia	Merck	EMD	EMD
E Ink	E Ink	E Ink	E Ink	E Ink	E Ink	E Ink
Plastic Logic	Plastic Logic	Plastic Logic	Plastic Logic	Plastic Logic	Plastic Logic	Plastic Logic
UDC	UDC	UDC	UDC	UDC	UDC	UDC
PARC	PARC	PARC	PARC	PARC	PARC	PARC

6-time Speakers						
2002	2003	2004	2005	2006	2007	2008
	DuPont Teijin	DuPont Teijin	DuPont Teijin	DuPont Teijin	DuPont Teijin	DuPont Tejin
Princeton	Princeton		Princeton	Princeton	Princeton	Princeton
	Spectra	Spectra	Spectra	Dimatix	FUIJI-Dimatix	FUJI-Dimatix
	SiPix	SiPix	SiPix	SiPix	Sipix	Sipix
Vitex	Vitex	Vitex	Vitex	Vitex		Vitex

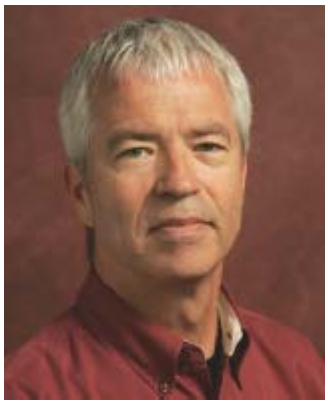
5-time Speakers						
2002	2003	2004	2005	2006	2007	2008
Applied Films		Applied Films	Applied Films	Applied Films	Applied Materials	
	Dow Corning	Dow Corning	Dow Corning	Dow Corning	Dow Corning	
		HP	HP	HP	HP	HP
	Kent		Kent Displays	Kent Displays	Kent Displays	Kent Displays
	Creo	Creo	Kodak	Kodak	Kodak	
		Philips	Philips	Philips	Philips	Philips

4-time Speakers						
2002	2003	2004	2005	2006	2007	2008
			ASU	ASU	ASU	ASU
			Binghamton	Binghamton	Binghamton	Binghamton
Brown	Brown			Brown	Brown	
	ECD			ECD	ECD	ECD
			ITRI	ITRI	ITRI	ITRI
			FDC	FDC	FDC	FDC
			GE	GE	GE	GE
			Samsung	Samsung	Samsung	Samsung
	Sigma			Sigma	Sigma	Sigma

Five organizations stand out as participating in all seven of the FlexTech conferences, with five more participating in six of the seven events to date. Mike McCreary from E Ink stands out as the only individual who made a presentation at all seven events.

It's probably a stretch to consider metrics associated with attendance and participants at FlexTech's Flexible Displays Conferences to be a key indicator of market place growth, but in the absence of any actual sales-through data, at least we can say that an analysis of the FlexTech conferences provides positive indications about the likelihood of future success in the industry.

Interview with Greg Raupp from the Flexible Display Center



Gregory B. Raupp, (B.S. Ch.E. with distinction Purdue University, 1976; M.S. Ch.E. Purdue University, 1978; Ph.D. University of Wisconsin, Madison, 1984) is Professor of Chemical Engineering and Director of the Flexible Display Center at Arizona State University. His research expertise and experience in chemical reaction engineering and chemical reactions at surfaces span interdisciplinary application areas from processes and novel materials for flexible displays and electronics, microelectronics and packaging, to biocompatible and "smart" responsive coatings. He has published more than 120 technical papers and is the holder of three US patents. Prior to assuming the director's position at the center's launch in spring 2004, he was ASU's associate vice president for research, and from 1999-2002 he was associate dean for research in the Fulton School of Engineering.

Please give us some background about the establishment of the Flexible Display Center. After conducting an intensive three-stage national competition, the US Army established the Flexible Display Center (FDC) at Arizona State University in partnership with the State of Arizona in February 2004. The center was formed through a cooperative agreement (the first Army center to be established with such an agreement) with the Army Research Laboratory (ARL), Sensor and Electron Devices Directorate, managed in conjunction with the Army Natick Soldier RDE Center (NSRDEC). Through the cooperative agreement we work with the army and our industry partners to speed the commercialization of full-color flexible display technology.

Tell us a bit about your current membership and any membership requirements about which prospective companies should be aware. To achieve its mission the FDC has established a dynamic university-industry-government collaborative partnership summarized in the figure below. This strategic partnership currently includes 20 industrial members: EV Group (EVG), Universal Display Corporation (UDC), FlexTech Alliance (formerly United States Display Consortium, USDC), E Ink, LG Display, AKT (Applied Materials), Kent Displays, DuPont Teijin Films, Honeywell, Hewlett Packard, SSI, Ito America, Litrex, EITI, Plextronics, PMS, General Dynamics, Raytheon, L-3 Communications and Boeing. These partners leverage the FDC's world-class flexible-display infrastructure focused on pilot-line manufacturing to advance their technology and products. The center also collaborates with seven different universities and a not-for-profit lab through a variety of research-focused projects. In turn, the FDC leverages the world-class capabilities, IP, and industrial knowledge of the industry partners. There are no specific membership requirements, but it is important to note we seek partners who each bring a critical technology and expertise to the table. The center then acts as the focal point and driver of a collective strategic plan to integrate the technology components and dimensions and demonstrate manufacturable solutions.

With the US Army as one of your major supporters, are your development efforts primarily tilted towards military applications or do you also expect to support the development of commercial products? We see the army and the military in general as "early adopters" of this revolutionary information display technology. In the end the army would like to be able to acquire flexible displays from commercial manufacturers at commercial quality and commercial (read "reasonable") costs. In that context, and to enable us to readily work with foreign companies and foreign nationals, the center's technology focus is on consumer standards (i.e. form factors and resolutions) and consumer-type display panels.

Having said that, one of the ways that we deliver value to the army is through a close partnership with military system integrators, who work with us to develop product-level technology demonstration devices to showcase the game-changing capabilities of flexible displays. Member companies General Dynamics, Honeywell, L3 Communications, and Raytheon have all contributed to the identification of demonstrator projects whose success will help meet the technical requirements of their roadmaps for future system offerings. In turn the

display requirements for these demonstrator projects help define the detailed objectives of the center's development programs. An example of one of these demonstration devices, a "mission briefer" produced by General Dynamics, is shown in the photograph below, along with photographs of a flexible 3.8-inch diagonal 320x240 EPD panel for such a device.

How do you protect the intellectual property brought to the FDC by member companies and manage intellectual property that is developed at the FDC? Very carefully! In all seriousness… industrial participation is governed by a unique partnership agreement that spells out the co-investment requirements, membership benefits, and intellectual property rights of the participating organizations. We negotiated this agreement with nine charter industry members, and it has to date stood the test of time in that many subsequent members were able to accept the agreement as-is, and we have operated smoothly under the agreement since its adoption. From ASU's perspective, we negotiated the agreement with the understanding, and indeed the desire, that our industry partners would ultimately enjoy commercial successes from our joint venture. The IP framework in the agreement is designed to protect member technology brought to the table, and to incentivize and reward participation and innovation. The agreement covers two key dimensions: protection of member company IP and ownership and access to center-created IP. In short, members bringing their technology forward for integration retain full commercial rights to their technology, with guarantees of confidentiality within and external to the center. For new technology that is created through center projects, IP ownership follows inventorship, with co-ownership and shared benefits in the event that an innovation is co-invented.

What are the display technologies are you working on to develop flexible displays? Do you see advantages in one technology over another? The FDC is focused on high-information content, high-performance flexible display technologies. In that context, all our technologies are based on a foundational platform of active matrix thin-film transistor (TFT) arrays on flexible substrates, such as thin stainless steel or transparent plastic. This challenging large-area microelectronics technology is the critical subsystem that is required to control an array of electro-optical devices to create a digital display. We chose three electro-optic technologies imaging layer display technologies for their compatibility with flexible substrates, their power advantages, and their relative maturity. Once down-selected, we then sought best-in-class partners for each of the respective technologies: E Ink for ultra-low-power reflective electrophoretic ink displays; Kent Displays for low-power reflective cholesteric liquid crystal displays; and UDC for vibrant full-color and full-motion video organic electroluminescent displays.

You recently demonstrated a solvent-based debonding process to release an electrophoretic display from a glass carrier. Tell us more about this accomplishment and what enabling technologies had to be developed. You are referring to a major manufacturing issue for flexible displays that everyone is facing; specifically, how do you handle flimsy non-self-supporting flexible substrates in automated manufacturing tools that expect to handle a rigid sheet of glass? Our approach, adopted very early in the center's lifetime, has been to temporarily bond the flexible substrate to a rigid carrier, process the bonded substrate through the TFT fabrication steps, and then debond the substrate without damaging the TFT array or the substrate finish or the carrier (so it can be re-used). Without going into all the issues in detail, suffice it to say that there are many materials, process, and toolset issues embedded in this approach. The best solutions therefore require that you work simultaneously with materials suppliers and manufacturing toolset suppliers, which is exactly what we did. We took a systems-level approach where we considered the substrate system to include the flexible substrate itself with appropriate planarization, the temporary adhesive, and the carrier. We worked with National Starch who developed a new "semiconductor-grade" temporary adhesive tailored for our application through a USDC (now FlexTech Alliance) funded project. We identified a novel carrier material and worked with a materials supplier to provide high quality carriers for use in our pilot line. We simultaneously worked with toolset companies, including our partner EVG, to adapt process and metrology tools for the bonding and debonding pilot line processes. In short we believe we have a full workable solution for automated bonding of stainless steel substrates and automated debonding without employing a solvent and without yield loss or damage to the carrier. Over the course of this focused development effort we identified all the key issues and created effective approaches for addressing these issues, which helped us achieve subsequent success with plastic substrates much more quickly.

You've also fabricated high-quality low-temperature active-matrix amorphous silicon arrays directly on flexible substrates. Tell us a little more about this achievement. The key to making high-quality high-performance flexible display technology demonstrators is in fact the production of high-quality active-matrix TFT arrays on flexible substrates, so this was indeed a critical achievement for us. We are now able to fabricate arrays with performance that rivals that of major manufacturers, and at very high TFT yield – essentially 100% on rigid substrates allowing us to make defect-free demonstrators, and better than 99.99% on flexible substrates, allowing us to build very low defectivity flexible demonstrators. There was no one breakthrough that enabled this advance, instead it was good small-step-by-small-step solid engineering work rapidly conducted through many designed experiments on our professionally-run pilot line. Perhaps the most crucial experiments were those designed to find low-temperature process windows for the active semiconductor stack that produced high-quality silicon nitride, amorphous silicon, and n^+ amorphous silicon contact layers.

In the future, do you expect to focus your manufacturing process efforts more on the debond process or directly on the flexible substrate? In the system-level concept, the two are intrinsically linked, and so I really can't make an effort level distinction. To be fair, I should say that the development and improvement of the flexible substrate itself is conducted by our substrate partners at their respective partner sites, with feedback to the partner based on our pilot line work here. Here at the center, work will focus on achieving the complete systems-level solution for the flexible substrate-adhesive-carrier systems, and on scale-up of materials, processes and toolsets to Gen 2.

Give us your opinions about the roll-to-roll manufacturing processes for displays. Roll-to-roll (R2R) is an exciting possibility that would represent a truly disruptive manufacturing paradigm. However, in the arena of high-information content displays, the challenges of achieving high resolution, layer registration and low defectivity can probably not be met in the near term. That's not to say that less demanding technologies such as flexible solar cells, RFID tags and the like could not be effectively manufactured with roll-to-roll toolsets in a foreseeable time horizon. And many organizations around the world, including Binghamton's University CAMM here in the US, are working hard to develop solutions targeted at displays in the long term.

With that in mind, here at the FDC we seek solutions that are R2R-compatible, although we implement them in a sheet-to-sheet format. For example, a roll-to-roll version of the Azores Gen 2 photolithography stepper installed at the FDC over a year ago has recently been installed at the CAMM. A large-area coater developed for us by EVG and now commercialized was designed with roll-to-roll compatibility built in. In addition we are working directly with HP on elements of their break-out self-aligned imprint lithography (SAIL) process that circumvents the photolithographic resolution and registration issue cited above.

Please explain the advantages and disadvantages associated with the various substrate materials that you've used to date. Any preferences? Like all other major players in the arena, we have experimented with metal foils, various plastics, and thin flexible glass. We have down-selected the options in metal foils to a low-CTE 430 stainless steel (SS) supplied by Nippon Steel. For plastics, our preferred material is the high-performance, high-temperature, heat-stabilized polyester poly-ethylene naphthalate (HS-PEN) provided by our member company DuPont Teijin Films.

SS foils are attractive candidates because they are inherently impermeable, thereby requiring no environmental barrier layer, and because they can be processed at relatively high temperatures. However, they require a planarizing and electrical isolation layer, and the material employed may introduce its own constraints of dimensional stability, CTE mismatch, moisture absorption, etc. A significant liability for the metal foils is limited flexibility – they tend to irreversibly "crinkle" under modest bending. However, for applications in which rugged and lightweight are the desired display attributes and a rigid planar or conformal display format is desired or acceptable, this limitation is a non-issue.

A key limitation of the plastic HS-PEN material is its upper temperature limit of ~200°C., requiring us to limit process steps to a maximum temperature of 180°C. The HS-PEN we use has been extensively characterized and benefits from relatively good thermal dimensional stability, low moisture uptake, moderate CTE, and excellent surface properties. The most crucial issue we have had to address is process-related dimensional stability – plastics tend to stretch or shrink during TFT build processes, which can cause problems for high yield layer alignment. We recently announced a major breakthrough in that we can now process HS-PEN *with essentially no distortion*.

With regard to the substrate material, please describe any quality/performance improvements that still need to be engineered? Our substrate partners have worked hard to improve their materials and engineer in the desired properties, making them as close to anything out there from the context of "display-manufacturing-ready". Having said that, we are working directly with our substrate partners on continuing improvement programs focused on defectivity reduction and management.

Will ITO be adequate as a transparent conductor for flexible displays, or do you see a real need for an alternative conductive material? It depends on the product you want to build, or more specifically, the degree of flexibility of the display. For displays that are rigid, rugged, or conformal, that is, are flexed very little or not severely, ITO should do the job. For a bendable or rollable display, we'll need a materials replacement. Potential solutions to fill this technology gap are something we are monitoring.

What about barrier technologies? Are we close to an adequate solution? Speaking of gaps… for flexible OLED displays, we see robust high-performance barriers as one of the most significant. Not that there aren't candidates, but in the context of a complete cost-effective manufacturing solution – materials, low tact time process and scaled-up toolset –there is no clear-cut option. Put another way, if we were faced with acquiring a Gen 2 flexible barrier/encapsulation process tool in the next six months, I'm not sure what we would buy. As

with ITO replacements, this is an area we are monitoring, and are in fact starting a collaboration this year with one equipment supplier company on a promising novel solution.

To date, what do you think has been your single biggest problem in terms of materials? This is probably not the kind of answer you wanted… but here it is anyway! A huge problem we face over and over again is the fact that we are working with developmental materials in a pilot line environment with a goal of producing high-quality, high-performance display technology demonstrators at reasonable yield. Imagine Intel, Freescale and other microelectronics manufacturers attempting to develop new high-performance microprocessors using developmental single crystal silicon wafers or developmental sputter targets or developmental photo-resists! The challenge for us is to identify not just candidate materials solutions but reliable materials developers such as DuPont Teijin Films, Honeywell Electronic Materials and Nippon Steel, who have the resources and capability to work with us to provide materials of the quality and quantity required for pilot line developmental and qualification runs, and the wherewithal to scale to full production for the industry at large once a solution is achieved.

What's the biggest problem you've faced in terms of manufacturing? It's difficult to rank them because they have been so many, but I'd have to say temporary bonding-debonding has certainly been one of the toughest problems and most critical to achieving technical success.

Describe the most satisfying thing that the FDC has accomplished to date. We've had many fantastic technical achievements that run the gamut from simulation and design to processing, fabrication and technology integration, but from a center director's perspective I'd have to say it's the fact that we are realizing the vision of advancing flexible display technology commercialization. At this still early stage of the center's existence, we are realizing this vision through our enabling materials and manufacturing supply chain partners. For such companies, the center provides an unparalleled integrated manufacturing pilot line development environment in which they can create and test new products for the emerging field of flexible displays and microelectronics. For example, center member DuPont Teijin Films recently announced commercialization of Planarized Teonex, a version of their HS-PEN with a novel integrated polarization layer to improve surface quality and processability; the center's pilot line provides a test bed through which film characteristics were improved and tailored for flexible or printed electronics. Center member Honeywell Electronic Materials developed a new solution-based hybrid organic-inorganic dielectric passivation material that has been qualified on the FDC developmental pilot line and used in our E Ink technology demonstrators to improve front screen image quality; they announced commercialization of this PTS-series of materials for the flat panel display industry at Semicon West last year. In the critical area of manufacturing equipment, center member EV Group (EVG) developed a unique and versatile tool for the nano-mist coating of ultra-high uniformity films of conventional photo-resists and unconventional materials such as adhesives and solution-based dielectrics onto large area substrates at very high materials utilization efficiency (greater than 90%) specifically for the center. The FDC served as the beta-test site for this tool as we employed it in our pilot line for photoresist coating and, as a direct result, EVG has recently received an order for a number of these new machines scaled to Gen 3.5 from Plastic Logic for their new manufacturing plant in Dresden.

At the same time we are also seeing our display panels integrated into technology demonstrators for army systems. In addition to the GD Mission Briefer, we have worked with InHand Electronics to produce a rugged

and compact networked "Soldier Flex PDA" shown in the photograph (*above*) as a candidate for transition to Program Executive Office (PEO) Soldier. The device incorporates a rugged, low-power reflective E Ink display on an FDC backplane and weighs only 13 ounces. This application was demonstrated as part of the Army Future Force Warrior program at the "On the Move" exercise at Ft. Dix in July 2007 and was very well received by the soldiers who evaluated it. These glimpses of the art of the possible are also quite satisfying, although I won't be fully satisfied until flexible displays are fully fielded and their benefits in terms of saving lives and enhanced operational effectiveness are fully realized.

Looking forward, what do you foresee are your next big challenges? The mountain only gets steeper as we continue the climb for higher-quality, higher-performance displays and associated manufacturing processes and materials. From a center director's perspective, the challenge is managing the ever-increasing complexity of the technology while scaling the enterprise. This year's remaining big technical challenges include production of a flexible 4-inch QVGA OLED demonstrator on plastic and full qualification of the 370 x 470 mm Gen 2 TFT pilot line.

Any plans to expand to an even larger substrate size? None at this stage. Our Gen 2 pilot line scale was strategically chosen as a scale that would enable production of large form factor technology demonstrators up to 17.0-inch diagonal, while demonstrating that the FDC designs, materials, processes, are manufacturable. We'll rely on commercial manufacturers to scale our technology to larger substrate size.

Are you working in cooperation with other initiatives related to flexible displays in the US (including the CAMM and FlexMatters)? As a matter of fact I am on the CAMM's Technical Advisory Board and have been advising them on their activities as they have moved forward. The analogous Azores photolithography toolset I mentioned earlier provides a great opportunity for direct collaboration on photo-patterning, and we are making plans to work together in earnest this year on this key technology issue.

We are also a champion of the new and exciting FlexTech Alliance Flexible and Printed Organic Electronics (FPOE) initiative, and have been participating in workshops and planning meetings.

Please tell us what you anticipate the FDC will look like as an organization three years from now. Bigger and better! As we continue to develop and improve core capability in flexible electronic and photonic platforms, we see ourselves evolving beyond (but still including) displays to other exciting revolutionary technologies, including for example flexible solar cells, communication technologies such as large conformal antenna arrays, ubiquitous environmental sensing and on-body/in-body human health monitors. The application space will expand as well, from a military focus to the fields of security, health care, space exploration and consumer applications. With this technology and applications evolution we will see a corresponding evolution in the center membership with an ever-diverse set of corporate, government and academic partners. When I talked about the challenge of "scaling the enterprise" in response to one of your earlier questions, this is what I meant.

Is it realistic to expect mass-production manufacturing of flexible displays in the US within the next decade? One of my favorite philosophers once said something like, "It's difficult to make predictions, especially about the future" (Y. Berra). And so I won't go out on a limb… either the yes or no limb. I will say I think the decision to site a particular manufacturing plant in a particular site is a complex decision influenced by many factors. However, if one of the influences is whether or not a core capability in flexible display technology development and the associated supply chain exists in the US, then we are working to make the center the strongest possible influence in the manufacturer's decision-making.

Near term, will the fruits of your efforts be transferred to Asian LCD production facilities? Certainly a logical transition path for our technology is to the major manufacturers in Asia. We now have several technologies that have reached a stage of maturity where direct technology transitions discussions can have real substance. . Stay tuned for further announcements!

Interview with Phil Downen from Westar

Phil Downen has enjoyed working in the flat panel display industry for the past 10 years and is currently the sales manager for display measurement solutions at Westar Display Technologies, Inc. in Saint Charles, Missouri.

Please give us some background about the establishment of the Westar Display Technologies. Westar Display Technologies began in 1993 as the Electronic Systems Group (ESG) of Westar Corporation, which, at that time, was privately held. As a Westar division, ESG entered the display market by providing test equipment and display drive solutions for US-based LCD players such as Kaiser Electronics, OIS, Planar Advance, dpiX and others in the aerospace industry. As our display industry customer base grew through the early 1990s, our division name changed to Display Test and Electronic Systems (DTES) to reflect our growing focus on flat panel display related test equipment and drive electronics. In the late 90s, the Westar DTES group formally became Westar Display Technologies (WDT) and broadened its product offerings to include industry standard FPD performance measurement systems (FPM Systems), bench top LCD drive systems (T-Drive), video adapter boards (VP-series) and video processing boxes (EZ-series). Today, Westar Display Technologies is a global solution provider of display drive and measurement systems for display products ranging from microdisplay to mobile to notebook to monitor to TV. We serve and support customers in over 24 countries.

Since you are part of QinetiQ North America (and a wholly owned subsidiary of the Westar Aerospace & Defense Group), is it reasonable to assume that a sizable portion of your business is defense-related, or do you also have a significant commercial presence? Westar Display Technologies became a subsidiary of QinetiQ North America when QinetiQ purchased Westar Aerospace & Defense Group in 2004, but we had already established ourselves as a solution provider to the aerospace and defense industries. We maintain a healthy balance of business among the commercial, industrial, defense, and aerospace display sectors.

What do you rate as Westar's key display metrology technology? For our display measurement systems business, you might expect the answer to be a specific light measurement device we use, our T-Drive universal test pattern generator, or our patented FPM system configuration but it's not that straight forward. We've learned over the last 15 years that our key strength is in total system integration – delivering a complete solution to our customer that considers all aspects of optical instrumentation, display drive, cabling, and fixturing, motion base control for achieving the required measurement geometries, and an integrated software suite that supports both manual and automatic system control. Almost every system we deliver has something unique about it. The system size and motion base arrangement, the combination of optical instruments, display drive equipment, industry standard test sequences such as ICDM DMS, ISO 13406, TCO, etc. all vary from customer to customer. To handle each new application, we follow a disciplined approach to developing new options and features that may be re-used across systems. This has resulted in a rich catalog of display measurement solutions that we can mix and match to produce an optimized system configuration for each customer. We hope that after spending an hour or so with our sales team and engineers discussing their unique requirements, customers feel they have come to the right place.

Westar instruments perform a very broad range of display metrology tests. Are there any performance parameters that you do not yet test? Our solutions focus on the traditional front of screen quality measurements such as uniformity, viewing angle, contrast ratio, chromaticity (color gamut), gamma, reflection, response time, flicker, motion blur and all variations of these fundamentals as called out by the industry standards. Drilling down in an LCD, the test and measurement emphasis shifts to device level parameters such as "transmission vs. voltage," pre-tilt angle, and temperature dependencies. We've not developed solutions targeted at these particular device level parameters, however many of our module level test systems are available in temperature chamber configurations for performing environmental testing at the panel level.

Since display metrology is continually evolving, can you share some thoughts about performance testing that still requires improvement? No doubt display metrology is an evolving science. The best work is being done by the International Committee for Display Metrology (ICDM) Display Measurement Standard (DMS) group. Westar Display Technologies, and many other experts in the display industry, are actively involved in this standard development effort. The ICDM is currently preparing version 3.0 of the DMS standard which is due for publication in late 2008. This new release will address metrics that heretofore have not been defined adequately or have recently become more relevant as FPD technologies and applications have become more sophisticated and ubiquitous. Among the newest metrics are measurements of 1) motion artifacts (quality detractors fundamentally caused by the sample-and-hold nature of LCDs combined with the limited response time of the LC pixel), 2) reflection testing (quantifying the surface reflection properties of a display to assess its suitability in a particular lighting environment), 3) 3D stereo display quality, and 4) touch screen quality. ICDM is a good place to learn the latest methods and conventional wisdom when it comes to measuring displays.

In the past couple of years, interest in several new performance parameters has grown considerably. Can you comment on what sort of requests you are seeing for next-generation metrology tools related to touch, 3D, flexible displays, and reduced power consumption technologies? We have seen a smattering of inquiries for test solutions among all these second tier technologies. Touch technologies require more attention to reflection properties since the display surface is typically modified with a sensor layer. 3D displays remain in a class by themselves and require careful measurement of the viewing envelope performance of the left and right channels. Flexible displays (reflective, OLED) might require additional environmental stress testing to ensure operation under mechanical strains. Reduced power technologies usually means cholesteric or electrophoretic, both reflective types, and can be evaluated using a traditional reflection apparatus.

One of the unfortunate outgrowths from display metrology seems to be specsmanship. Is there anything a company like Westar is doing to help minimize specsmanship in the industry? Absolutely. Westar Display Technologies has actively participated in the development of display measurement standards that define the methods and technologies required to make accurate, robust, and honest measurements. We've taken what we've learned from the standards bodies, our own R&D, and our customers and produced our own standard display qualification test suite. Our standard test suite is being used by most notebook display makers, their ODMs, and the brands that use them. It largely finds its basis in the methods prescribed by the FPDM standard. We also diligently educate our customers with formal training programs and seminars that communicate the ABC's of display measurements with detailed treatment of the optical science, the instruments, the standards, and the methods that form the foundation of display metrology. This mini course is available to all Westar customers and is called "Display Measurements 101". Still, in this competitive and fast moving market, specsmanship remains. As with any set of facts, pundits can emphasize, spin, or selectively report data to skew the customer's perception of image quality. We strive to promulgate comprehensive test suites and methods which address the key metrics affecting display quality and thereby "tighten the noose" around specsmanship. One challenge is that the quality criteria often differ greatly by display application and this requires the measurement suite to be tailored accordingly. In one application, minimal surface reflection and response time might be most important (a cockpit display showing sensor video) while another application enjoys high diffuse reflection and response time is not critical at all (an e-book application).

Westar FPM-520 system

Many analysts have suggested that performance parameters such as contrast ratio are particularly susceptible to specsmanship games. Do you agree? Is there any real meaning behind a claim of a 1,000,000:1 contrast ratio? Is there a better measure? Yes. Not really. Yes. This is a classic spec that appears like a medal on the bezel of too many monitors. Measured contrast is defined as the simple ratio of full white luminance to black (or dark state) luminance. Some standards call for a spot measurement in the center of a full screen white or black pattern; others require a smaller white and black patch on a gray background. This deceptively simple metric is subject to first order measurement errors known as veiling glare and lens flare (errors resulting from improper masking or shielding of unwanted light that contaminates the measurements). More subtle factors (perhaps where specsmanship thrives) include the atypical optimization of the display settings prior to the measurement of white and/or black, cherry-picking the display sample or spot location for spec establishment, tweaking gamma and/or the color point to enhance the measured contrast, and even optimizing the ambient temperature prior to measurement. Fair-minded set up of the display under test, diagnosing and eliminating any measurement errors, and carefully controlling the ambient conditions will go a long way to producing a more meaningful contrast ratio measurements and specs.

Ratios on the order of 1,000,000:1 draw concern and skepticism. The high ratio usually results with display technologies that produce darker than usual black levels, not so much because of super bright white states. With a bright display producing a 1,000 nit white level (very bright), the black state must squelch nearly all traces of light for a 0.001 nit reading. This magnitude of contrast more typically results from non-LCD technologies such as OLED and CRT where, in the black state, the display is literally turned off resulting in near zero luminance. Not many LCDs can do that today and it raises the question “is there any perceptible information in the dark end of the gamma curve that contributes to image quality anyway?”

This question leads to the issue of the human visual system performance limitations and what we can and can’t see. What a scientific-grade photometer sees in two separate spot luminance measurements and what the human eye perceives in spatially complex and temporally dynamic imagery are clearly quite different and may not even correlate. There is a place for metrology here, but the contrast ratio metric is only a metric. Assuming the measurements are made accurately and under controlled conditions, the contrast ratio measurement has a place on the spec sheet. To imply, however, that this correlates to the customer’s experience is a stretch. Because of the nature of the content displayed (complex and dynamic), the display’s *perceived contrast* could, for example, be dominated by the response time of the panel, the surface reflection properties, or even ambient temperature instead of the simple ratio of white/black luminances.

The lesson here for spec writers is to publish meaningful contrast ratio specs based on standardized measurements and using typical display settings. The lesson for the consumer is to consider the fact that human vision will likely limit the perceived contrast well below that of the published spec.

How about in the area of bit depth? Is it really possible for the human visual system to see meaningful differentiation between “billions of colors”? Is it even possible to measure? There is a transition underway from 8-bits per color (24-bit color space, or 16,777,216 colors) to 10-bits per color (30-bit color space, or 1,073,741,824 colors) among media displays. This is supported by the QLVDS (quad low-voltage differential signaling) and DisplayPort interfaces which may allocate 10 (or more) bits per RGB color and support very high bandwidths. Here, again, the human visual system kicks in and arguably limits the perceptible number of discernable hues to a number much less than 1 billion.

There is, however, a big gap between 16.8 million and 1 billion and those consumers demanding smoother color rendering (even if only in certain regions of the color gamut), such as graphic artists, will appreciate the increased fidelity and depth with which images may be captured, stored, and manipulated. To this end, a display that supports a 30-bit gamut is necessary. Deeper color depth is also beneficial when the total available gamut is increased by advanced technologies such as RGB LED backlights or additional primaries (beyond RGB). In these newer designs, the total color gamut area well exceeds the long-held, phosphor based, reference NTSC gamut and the case for slicing it more finely (through deeper color depth) is easily made.

To the measurement question, the instrument’s chromaticity accuracy limit comes into play. While spectroradiometers measure color with an accuracy around ±0.0015 in the 1931 CIE x,y space (near the

"Illuminant A" calibration point), the human visual system's "Just Noticeable Color Difference" is around 0.01 to 0.05 according to the widely accepted MacAdam ellipse definition of the JNCD unit in the same 1931 CIE color space. This implies that a decent spectroradiometer is adequate to measure a given color with precision equal to 1/7 ~ 1/33 that of the JNCD.

However, resolving the full 30-bit color space with optical instrumentation is another matter. As a "back of the envelope" exercise, if we conservatively assume a 0.7 x 0.8 rectangular color gamut on the 1931 CIE chart and divide that gamut up into a grid with resolution equal to the typical spectroradiometer accuracy (0.0015), we end up with a 467x533 grid or 248,911 resolvable color points. This number is clearly less than the 1 billion colors purported by the 30-bit space or even the 16.8 million colors offered by the 24-bit space. Moreover, the 30-bit space includes millions of colors in the dark end of the gamma curves that are arguably well below the color vision threshold of perception.

Motion blur has recently consumed a considerable amount of creative energy amongst display manufacturers and metrology companies. Do we have good ways to measure motion blur and then describe it to end users? Yes and no. Like basic contrast and uniformity, we have a "motion picture response time" metric known as the "Moving-Edge Blur" measurement that is a fundamental measure of how moving images (edges) on a display screen smear or blur as they move across the screen. The instrument makers, including Westar Display Technologies, have created several solutions for measuring blurred edge width and the ICDM DMS group is currently conducting a round-robin experiment to evaluate the methods and compare results. As for communicating the metric to end users, that is still a subject of discussion. If a standardized, robust method can be established, then communicating a uniformly accepted metric to the customer should follow easily. However, there will always remain the question of correlating the instrument's answer to the subjective visual experience of the user. The ICDM group is studying this issue carefully.

The Flat Panel Display Measurement document, long considered to be the industry's primary guide to metrology, has been in need of a revision for some time now. What's Westar's involvement in SID's recent efforts to revitalize the FPDM? How's it going? The recently transplanted FPDM standard is doing quite well under the newly formed ICDM group which is part of the SID organization (http://icdm-sid.org/). The effort has more participants than ever (and has maintained key contributors from the previous VESA group) and is actively meeting and pursuing their roadmap to the ICDM DMS Version 3.0 release in late 2008. Westar actively participates in the motion artifacts sub-committee and continues to provide general commentary to the authors and editors on a variety of issues we see as needing clarification or improvement.

Is there a concern that metrology standards may inhibit innovation, or do you think that good standards will actually promote improved display performance? We've not sensed any ill effects of metrology standardization on innovation, although clearly some standards are LCD centric and do not adequately treat or consider alternate technologies. Performance differences in OLED, LCD, plasma, electrophoretic, cholesteric, CRT, VFD, etc. do require different metrics and methods. The ICDM DMS group has done the best job of accounting for display technology differences and tries not to be LCD centric even though LCDs dominate the FPD market.

To what extent do major companies establish in-house requirements that may be better or worse than industry standards, and what effect do such independent efforts have on assuring or disrupting global compliance with industry standards? We've seen an encouraging move toward reliance on industry metrology standards (ICDM DMS, ISO 13406-2, TCO '03 and TCO '05, etc.) within the brand name leaders such as Dell, HP, Lenovo, 3M, Sony, Sharp, AUO, BenQ, their ODMs, and the panel makers at large. It wasn't always this way and it's taken many years for the standards to get the adoption they now enjoy. Even in the aerospace sector, we see gravitation toward the more complete and sophisticated methods of the ICDM DMS and away from 1980s era MIL standards. In most cases, however, the new standards only form the starting point for the savvy R&D engineer or quality assurance manager. There are always customizations, special tests, and modified methods involved in optimizing the display measurement solution. Many of these are application specific as mentioned before; some are required to meet the different needs of engineering, quality assurance, and full rate production testing.

There's long been talk about convergence between the CE and PC industries in terms of interconnectivity. Is convergence realistic or do you think the display performance requirements are fundamentally different enough to require differentiated interfaces? We simply react to whatever interface each market segment chooses.

How many pieces of test equipment are required to run a "complete" battery of display metrology tests on a single display? About how long does it take to run such a series of tests? Of course it depends upon what's in the battery. For 75% of the cases, the basic measures of luminance, contrast ratio, uniformity, viewing angle, color gamut (chromaticity), gamma, response time, and flicker are sufficient to tell 95% of the quality story. To this end, Westar Display Technologies has developed a series of integrated display measurement systems that contain a recurring theme in their architecture. Each system includes: 1) a sub-system to physically position the light measurement device (LMD) relative to the display under test (DUT), 2) a sub-system to drive and control the DUT (test pattern generator, power supply, special interface circuitry), and 3) the optical instruments, or LMDs, to actually perform the luminance, chromaticity, and temporal measurements. The key fourth component is our system software which pulls all the hardware elements together under a single control console and presents the test engineer with tools to define and automate test procedures, log raw data, and post-process raw data into meaningful figures of merit, statistical data, and reports.

For example, our production rate QuickTest system was optimized for full electro-optical characterization of cell phone displays in less than 30 seconds. It is widely used throughout Asia by nearly every small format LCD display maker. Our larger scale FPM systems are more flexible in design, allowing for integration of the widest range of LMDs, test pattern generators, and ancillary equipment. A full test suite on the FPM system might take 10 to 60 minutes depending upon what's included.

Out of curiosity, do you see regional differences in terms of preferences associated with different display metrology parameters? In other words, are there physiological or cultural differences, region by region, associated with the results of your display performance measurements? I've only heard of different preferences in the adjustment of CCT (correlated color temperature), or the "white point" of LCD monitors between western countries and Asia. Since we're not in the business of defining pass/fail criteria (or performance specs of any kind), we leave it to our customers to determine the design goals of their display products. We're just happy they are using our solutions to gather accurate data and arrive at their own conclusions.

Is the goal of display metrology to determine how accurately a display device aligns to the capabilities of the human visual system, or do you have a different performance target? Great question. The charter of the ICDM DMS group has always been to produce robust measurement methods and techniques without commentary on the performance targets – that is left to the negotiators who buy and sell displays. In the ISO and TCO standards, however, there are clearly stated performance thresholds that are pragmatic in origins. They consider the limitations of the human visual system and ergonomics but do not put unreasonable expectations on candidate FPD technologies. This is to be expected since these standards define what is acceptable for well defined applications where viewing conditions and user task loads are understood; e.g., office computing applications.

From a display metrology perspective, what display technologies consistently provide the "best results?" Or are there just too many variables to make a general statement in that regard? This is as difficult to answer as the question many of us in the display metrology business face from our neighbors and friends, which is: "Which TV should I buy – and why?" Clearly TFT LCDs are at the top of the heap and have enjoyed a near 20-year R&D effort which has seen numerous performance and size barriers demolished. From cell phones to projectors to notebooks, monitors, and TVs – LCDs rule and the market data proves it. However, there are still strong arguments to be made for applications where OLED, plasma, reflective, laser-based, and even passive matrix display technologies win. It really does depend upon the application, content being displayed, viewing environment, and criticality of the tasks involved.

Interview with Candice Brown Elliott from Nouvoyance

Candice Brown Elliott is currently CEO of Nouvoyance. She earlier founded Clairvoyante in July 2000 to develop and license enhanced display architectures and subpixel rendering technology. Ms. Brown Elliott is a 30-year veteran of the display and semiconductor industries, holding positions in R&D, manufacturing, and engineering management at Fairchild, Advanced Micro Devices, Planar Systems, and the Micro Display Corporation. Ms. Elliott has been granted 19 US patents along with numerous foreign cognates and pending patents. She holds a dual B.S. in Physics and Psychology from Excelsior College, University of the State of New York.

Clairvoyante is gone, replaced as a result of your acquisition by Samsung, by a new entity named Nouvoyance. Please give us some history up until the acquisition. Clairvoyante was founded in 2000 for the purpose of developing display solutions based upon subpixel rendering. Over time, a substantial body of patents for layouts, algorithms and systems were developed. More than 20 companies were engaged in solutions that involved Clairvoyante's PenTile technology. Target applications for this included cell phones, digital still cameras, personal media players, wireless Internet devices, navigational displays, picture viewers, automotive displays, notebook PCs and HDTV. The key criteria has been driven by a need to save power for higher resolution applications, i.e. >20 cycles/degree of visual resolution. In 2007 Clairvoyante was approached by several companies who were interested in acquisition. By 2008 it was apparent that the capabilities of PenTile technology were best matched to the needs and interests of Samsung Electronics, culminating in the sale of the Clairvoyante's assets to SEC in March of 2008.

In March 2008, Samsung bought all of Clairvoyante's assets and intellectual property, and Nouvoyance was created as a separate entity. So what is it that Nouvoyance does today? Nouvoyance is engaged in the research, development, and engineering of PenTile solutions for display products. Since inception, all of this work has been funded by Samsung with the intention of Samsung selling and licensing PenTile solutions that Nouvoyance develops in collaboration with Samsung's engineers.

In addition to Samsung, Clairvoyante had previously licensed RGBW/Pentile technology to several other companies. Are these other companies now being supported by Samsung, or is Nouvoyance providing a service to support these licensees? Licenses signed by Clairvoyante in the past were primarily development licenses. At this point all such development and IP licensing will be done by Samsung. It is the intention of Samsung to continue to license PenTile technology to other manufacturers of display products. When such licenses are signed between Samsung and another display maker, Nouvoyance will be engaged in supporting the engineering activity called for by the mutually agreed specifications. In this manner, Nouvoyance, as an independent company, will be working directly with such licensees, able to provide confidential custom support.

Please give us a bit history about how you developed the Pentile Matrix technology, along with the various evolutions on the way to actually developing a commercially viable solution. Over the years, a variety of layouts and associated algorithms were developed to suit the needs of a variety of applications. All of them were based on knowledge of the human vision systems needs. Early layouts like L1 and L1W were suitable for resolutions of 300dpi in cell phones, but such a high-resolution market never developed. The development of L6W and "metamer rendering" were key milestones in making PenTile technology suitable for a wider variety of fonts and images in resolutions of 200dpi or higher. In the past year this technology was combined with dynamic backlight control (DBLC) to further save significant power without sacrificing the appearance of bright saturated colors. Other technology for HDTV is still in the research stage and is planned for further development in the years to come.

Your early papers and talks were compelling in the way they sought to find an optimal balance between the capabilities of the human visual system and the technologies used to manufacture flat panel displays. Do your current solutions accomplish that goal, or are there still further improvements that can be made? This was a question that was asked the very first year at Clairvoyante. We felt that there would always be the potential for improvement; so far we've proved that that is true. Every technology can benefit from continued invention. That certainly continues to be the case for PenTile technology where we are constantly inventing and improving it to meet the specific needs of our customers. That which we offer today is more than suitable for current mobile applications, but we anticipate that users will continue to grow their expectations. Nouvoyance must anticipate this and prepare solutions in advance of that new demand. We expect to see continuous improvements in power savings, cost savings, higher contrast, wider color gamut, dynamic range, and general image quality.

In the initial stages of Clairvoyante, your solutions were RGB structures. How did you come to an RGBW solution? RGB solutions still make sense for technologies that are not capable of white subpixels such as OLED. The addition of W greatly enhances efficiency for LCD systems, as had been known for years, but had experienced some drawbacks related to simultaneous contrast in bright saturated colors. Issues related to simultaneous contrast are now being nicely overcome with our latest DBLC technology and the corresponding subpixel rendering algorithms. RGBW also allowed us to use metamer rendering to improve subpixel rendering, which provides very sharp text and photos.

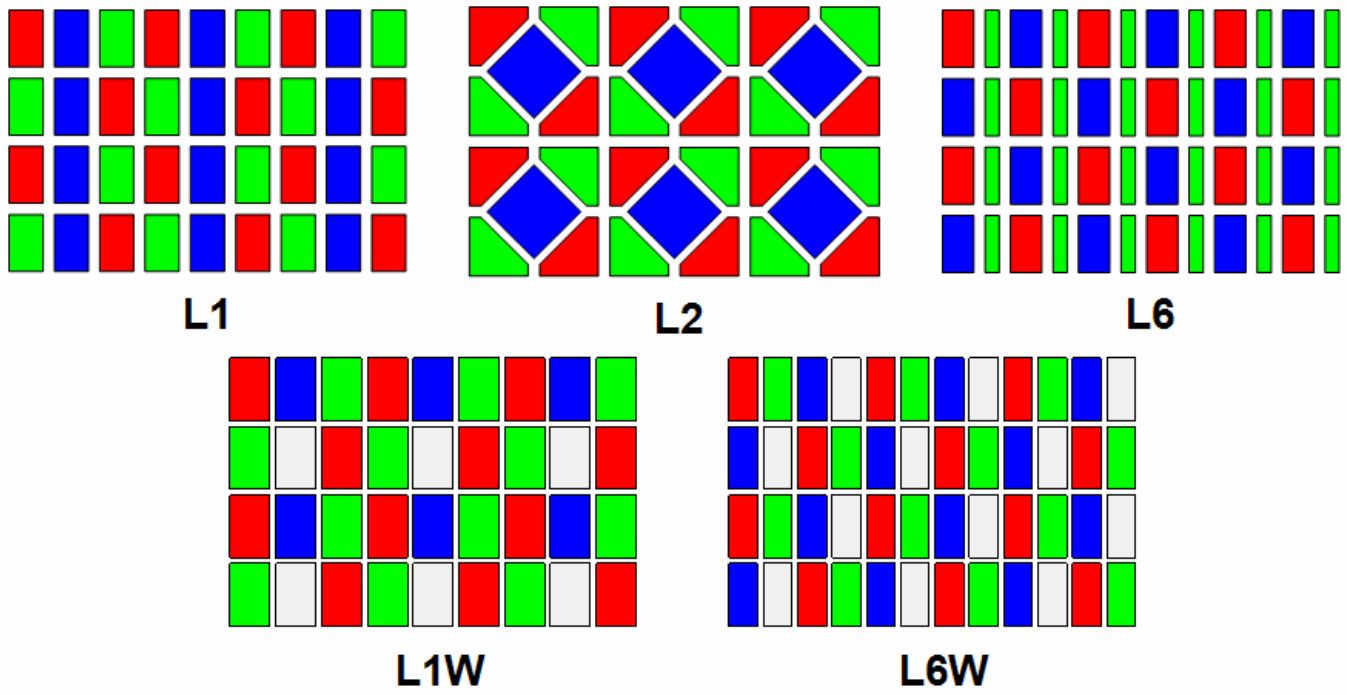
Nothwithstanding the current President of the United States, why is "W" of significance? The W subpixel is formed by removing color from the color filter array. Subpixels without any color filter offer tremendous improvement to non-saturated color (black & white) transmissivity, especially as displays migrate to higher NTSC ratios. Most images are predominately non-saturated, so the W subpixel is used quite often in rendering images. This is key to the power advantages of PenTile RGBW technology. Most images will have backlights set to approximately 50%, providing significant power savings. The brightness improvement of the W subpixel is even more important with transflective displays that force light to traverse the thickness of the color filters twice. The existence of a white subpixel in such a transflective display enables whites to be much brighter and higher contrast, enabling true sunlight readable displays.

From your years of research, can you describe what you believe is the subpixel architecture that best matches the human visual system? The answer depends on what one is trying to optimize for.

- If one is trying to optimize for best power savings combined with the best text performance at high resolution, with improved subpixel efficiency at 2.0 subpixels per logical pixel, the PenTile RGBW (L6W) w/DBLC and metamer rendering is best. This is the preferred choice for today's applications. Given present display resolutions in the market, the need for greater power efficiency, the PenTile RGBW (L6W) is clearly the best solution for LCDs.
- For OLEDs, the best solution today is the L6 layout and associated subpixel rendering at 2.0 subpixels per logical pixel. However, for a future RGB OLED panel at ultra-high resolution, the classic PenTile (L2) may yet be the chosen solution. If one is optimizing for the least number of subpixels per logical pixel for ultra-high resolution the classic RGB PenTile (L2), with five subpixels per repeat group, is best, as it uses only 1.25 subpixels per logical pixel, compared to 2.0 subpixels per logical pixel for the PenTile L6. Of course, both are significantly better than the conventional RGB stripe layout at 3.0 subpixels per logical pixel.
- At some resolutions between today's high resolution and ultra-high resolution, the L1W layout may be the best compromise between subpixel efficiency and power savings, as it uses only 1.5 subpixels per logical pixel, yet also has a W subpixel for increased LCD transmissivity.

The bottom line is that product engineers should consult with their panel suppliers and Nouvoyance applications engineers for the best solution for their future applications. However, for today's LCD applications, the PenTile RGBW remains the best choice.

Resolution is difficult to explain when using alternative subpixel architectures to the traditional RGB striped solution. Tell us how you think resolution should best be objectified. Put another way – what does 1080p mean if we're to consider an RGBW solution? At Nouvoyance we endorse the resolution measurement which calls for resolution to be determined from Michelson contrast, measured using a moving aperture grille. This methodology values the resolution in just the same fashion as does the human eye. It can be applied equally well to RGB stripe as it can be to PenTile RGBW. Given that the MTF of a PenTile 1080p pane, using one third fewer subpixels, is the same as for an RGB stripe panel, then one can say the resolution is equivalent regardless of the configuration of the subpixels. Nouvoyance can provide on request, a white paper discussing how the PenTile RGBW meets and exceeds the Michelson contrast measurement specifications for resolution.



Pentile Matrix Layouts

Subpixel rendering algorithms (such as Microsoft's ClearType) offer obvious advantages to image quality over standard pixel rendering. Tell us how your solutions serve to further improve the utilization of subpixels. PenTile RGBW technology can provide an equivalent experience with one-third fewer subpixels. When used at resolution in excess of 200dpi a cell phone display with ClearType looks just as good with PenTile technology as it does with RGB stripe. That is why we say that PenTile technology is additive to other forms of improvement such as ClearType. The viewing characteristics of ClearType are not degraded by PenTile and can benefit at the same time from power savings. This is possible because the conventional RGB stripe layout was never designed to be optimized for subpixel rendering, or even the needs of the human vision system. It was optimized for ease of manufacture while providing full color at very low resolution. While PenTile layouts have been carefully designed to be optimized for subpixel rendering and compatibility with the needs of the human vision system.

Does the RGBW structure provide any advantages to reflective displays? Yes, as with transflective displays it enables whites to be much brighter since there is no light attenuation at the W subpixels.

If you were forced to identify the primary advantage of RGBW solutions, would it be related to resolution, color, or brightness/power consumption, (or something else)? The key advantage for mobile displays is to enable high-resolution displays to work with substantially less power consumption relative to RGB stripe. For HDTV the PenTile solution enables a display with a larger color gamut to be constructed with an LED backlight that has half the number of LEDs saving on the BOM cost as well as on power.

You've recently submitted patent applications that discuss "pre-subpixel rendering". What is that and what do this mean for the future of displays? Pre-subpixel rendering is a technique of subpixel rendering an image or partial image at an earlier point in the video-processing pipeline. Currently, the PenTile subpixel rendering algorithms are located in the display driver chip on the panel or flex-circuit. This allows conventional RGB image data to be sent to a PenTile RGBW panel, making the PenTile panel "plug'n'play" compatible with conventional RGB stripe panels.

In some applications it may be desirable to perform the subpixel rendering earlier in the pipeline, as this offers two potential benefits. First, the bandwidth required to transmit the image is reduced, allowing lower clock speeds, saving power and reducing electromagnetic interference (EMI). Second, it allows images to be rendered from super-sampled data sets to improve the resulting image quality. When the image sent to the panel is a conventional RGB data set, the PenTile processing does it's best to render the image so that it looks the same as it would on a conventional RGB Stripe panel, to a human viewer. However, this conventional image does not fully take advantage of what could be accomplished had the image been subpixel rendered from a super-sampled data set, or even directly subpixel rendered in a graphics processor rendering graphics primitives.

At Clairvoyante, we envisioned a situation where most images to be displayed on a PenTile panel would be conventional RGB data sets; but some of the images would be pre-subpixel rendered. We devised and filed patents for techniques to pre-subpixel render, embed, transmit, detect and extract for display, such pre-subpixel rendered images in conventional RGB data sets. This would allow mixing conventional images and higher quality pre-subpixel rendered RGBW images in the same video frame. The text and icons in one application might be pre-subpixel rendered, while JPEG images may be conventionally rendered in another application, by the host processor, then sent together to a PenTile RGBW panel with subpixel rendering processing, with a detector to extract pre-subpixel rendered portions to be seamlessly blended together in the final image seen by the user.

Do you think that RGBW structures will eventually displace RGB solutions? What about 5 or 6-color subpixel solutions – do they provide value for the cost? We see a good future for mobile products built with RGBW. On the other hand we feel that it will be take significant time to displace much of the RGB products due simply to market momentum. As for 5-6 color solutions, there are advantages to this for HDTV, but one has to be careful to not sacrifice aperture ratio or efficiency in going to such systems. Nouvoyance has filed on some very effective multi-primary solutions that use only 2.0 subpixels per logical pixel using advanced subpixel and metamer rendering. When combined with DBLC, these multi-primary HDTV systems will also be very power efficient as well as high contrast and dynamic range. They will also allow reduced BOM costs. We see a bright future for subpixel rendered displays with five or six-color subpixels, as they will actually cost less than RGB stripe based panels, while providing far superior color and image quality.

Speaking of cost, you've demonstrated improved resolutions, improved color gamut, and improved brightness/reduced power consumption, with a lower cost of driver electronics – which seems like a powerful combination. So why aren't we seeing RGBW solutions all over the place? A solution that is so different is not adapted easily. We feel that after the first product introduction that the momentum will improve for RGBW technology. It is not uncommon for such innovative products to take eight years or more to make it to the market; PenTile technology is no exception. We are confident that a commercial product will emerge by Spring of 2009, thanks, in part, to our business relationship and close cooperation with Samsung Electronics.

The world of electronics has unquestionably jumped on to the "green" bandwagon. Given the inherent benefits offered by RGBW solutions to increase brightness and/or reduce power consumption, it would seem that advocates of "green" electronics should be all over your technology. Why don't we see any RGBW LCD TVs or notebook PCs? PenTile technology is suitable for any high-resolution application with pixels at 20 cy/deg or higher of human vision. The demand for such high-resolution PenTile technology has good application to HDTV for LED backlit solutions with extraordinary color gamut. The current cost of LEDs has been a key factor in the acceptance of LED backlit HDTV. In time, this will improve as demand for expanded gamut increases. At that point PenTile multi-primary technology will offer further cost savings by

reducing the number of LEDs by half as well as by reducing the number of drivers by one-third. At the same time it can cut power consumption of LED backlit HDTV by more than half. This will enable PenTile technology to provide very good green solutions by 2010.

Is there a commercial RGBW solution in the market today? There are designs in place that will see commercialization by 2009. It is possible that some PenTile solutions will even come to market by late 2008.

When an image is captured (with a camera, scanner, or other input device), or is created via software using some display technology, the image is created using an RGB structure of some sort or another. What is involved in transposing this RGB image into an RGBW image? The simple answer is that a lot of vector algebra is used. Conversion from RGB to RGBW is an example of "an embarrassment of riches" in that more than one combination of RGBW values will provide the same color and brightness as the original RGB. Each possible combination is called a "metamer".

The Nouvoyance algorithms are all generated with this in mind. RGB data is interpreted as it is received and converted at high speed to RGBW formats allowing for color correction, DBLC and all calculations that are required with only two horizontal lines of delay. All of this takes place inside of the driver chip which is used to run the PenTile display.

The best RGBW metamer is chosen from among the possible combinations. First a valid W value for each incoming logical pixel is determined. Then new RGB values are determined to give the same hue, saturation, and brightness as the original. The new RGBW values per logical pixel are then subpixel rendered down to the subpixel layout, where a final adjustment is made to the RGBW values to find the best metamer that provides a sharp, crisp rendering of text and fine details of the image, using a metamer rendering algorithm. These values are then adjusted to complement the selected backlight values determined from a survey of the image in the DBLC algorithm.

A more complete explanation is given in my contributed chapter "Image Reconstruction on Color Sub-pixelated Displays" in the recently published book, "Mobile Displays: Technology and Applications" from Wiley and the SID Series in Display Technology.

3D display technologies are increasingly gaining attention in the market – tell us how your technology might help improve 3D display performance. The favored technology today is autostereoscopic 3D. By virtue of this design one must give up half of the resolution to go from 2D to 3D in conventionally rendered displays. With subpixel rendering on a PenTile 3D panel, the resolution is maintained, using a combination of subpixel rendering and more efficient layouts. PenTile technology enables high light throughput for high resolution designs. With a PenTile display one can maintain or even increase the resolution of an autostereoscopic display while minimizing the impact on light throughput. The end result is a better image at lower cost.

Based on your start-up experiences, is there any advice you'd like to share related to getting a good idea to market? Somewhat related - is a licensing model alive and well in the display industry, or is the best you can hope for that a big company will buy you out? The real key is finding great partners. Licensing IP is not an easy route and is becoming increasingly difficult with the new patent office regulations, but it still remains possible to build a successful IP licensing company. It is important for an IP licensing company to develop key relationships with the technology manufacturers and their customers. Such a company must continue to invent to continue to prove their value to their customers so that there will be little incentive for those customers to invent around the current IP.

Thin film advances at UniPixel

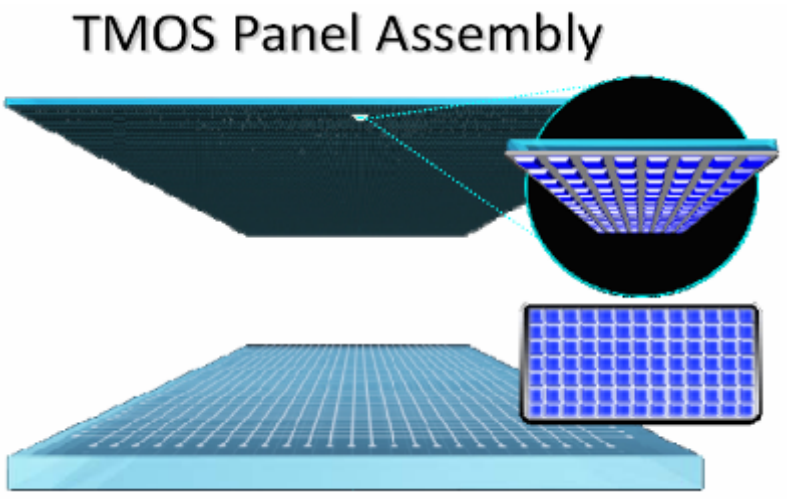
by Jim Tassone

James A. Tassone joined UniPixel Displays as chief financial officer in August of 2003. Prior to joining the company, he was the founder, managing director, and CFO of Mindwave Research, Inc. where he remains on the board of directors. Early in his career, he was with IBM, Digital Equipment Corporation and Comdisco, Inc. before joining market research leader DataQuest/Gartner Group. After Gartner Group, Tassone became managing director at IntelliQuest. He left a research company start-up he launched under CMP Media (Reality Research) to found Mindwave.

Uni-Pixel Displays, Inc., (UniPixel) has developed and patented a new display system architecture it calls "time multiplexed optical shutter" (TMOS). TMOS is a polymer MEMS approach to display panel production that offers current LCD panel manufacturers the potential to convert their existing fabrication plants (fabs) over to TMOS production. These converted fabs will combine two sheets of glass to trap and position a single thin film membrane instead of combining two sheets of glass to form and fill liquid crystal cells to create an LCD panel. This special membrane forms a polymer MEMS system wherein each pixel is similar to a small drum head. The polymer membrane drum head is controlled by a thin film transistor (TFT) which functions to actuate the pull-in of the membrane into contact with one of the glass sheets. This contact frustrates total internal reflection (TIR) and allows the light to couple out of the glass to the viewer.

UniPixel has faced a number of technical challenges during implementation of its polymer MEMS system. Many of the challenges were specific to the thin film component including the ability to create precision geometric micro structures between 2 and 10 microns tall on the surface of a thin film, patterning conductors in three dimensions around the micro-structures, finding and implementing surface treatments to the film that address phenomena like stiction that occur in MEMS systems, and ensuring that the optical design and operation of the system meets the desired targets. Finally, UniPixel worked hard to ensure that these solutions are compatible with integration into a roll-to-roll film production system.

By demonstrating its fully functional prototypes at the SID conference last May, UniPixel has demonstrated that it has implemented solutions to overcome these challenges. To that end, UniPixel can now produce thin films in its labs that incorporate all of the technical elements required. The next phase of its efforts are focused on the detailed specifications that will integrate the processes for making the thin film into the roll-to-roll production system that will produce UniPixel's Opcuity films in high volume to support its licensing partners. UniPixel has branded its thin film, and other innovative derivations, under the family name of Opcuity. UniPixel currently is pursuing licensing arrangements with LCD companies to commercialize TMOS panel production that will incorporate its Opcuity films.

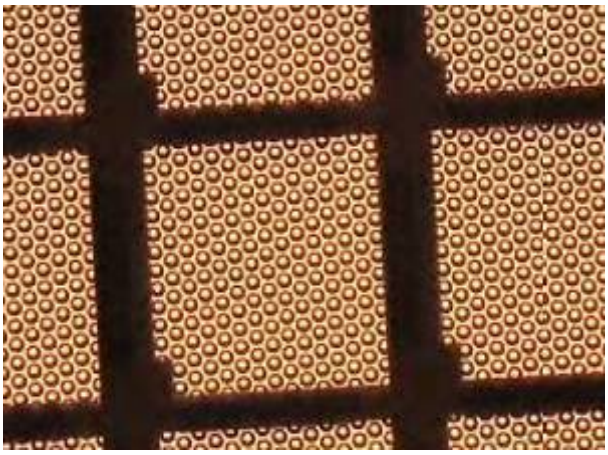


Opcuity film mounted to top glass in preparation for mating to a TFT backplane

UniPixel's Opcuity films, key to the TMOS architecture, are unique in that they are precisely formed and that its innovations in film design, mastering, micro-replication, and conductor integration have the potential to be applied to a number of new and emerging technologies. In addition to being the key material for TMOS display

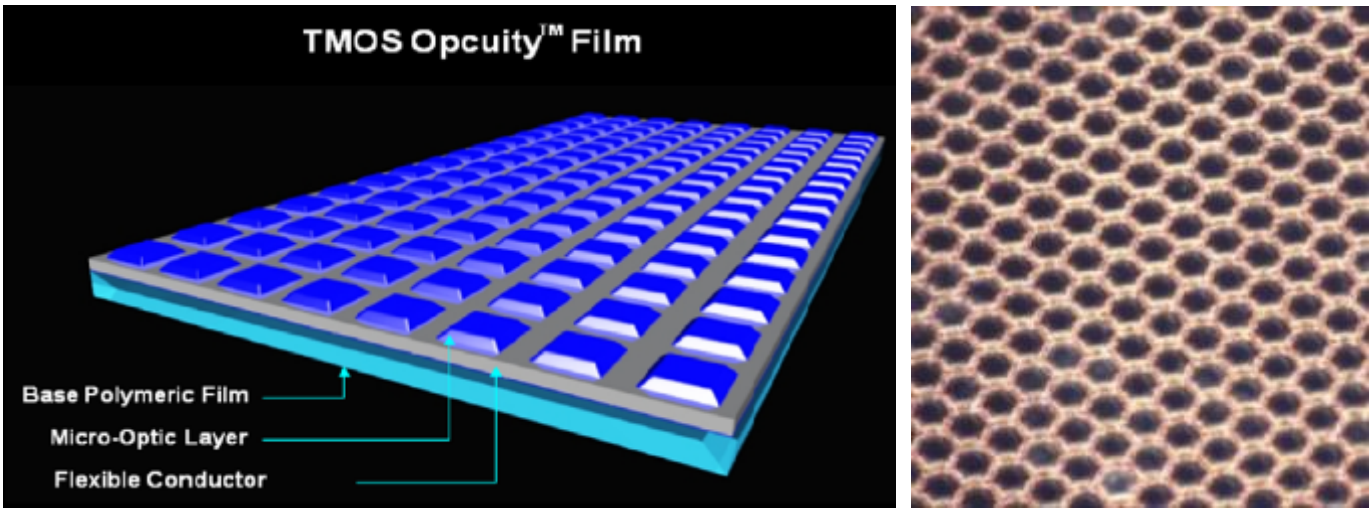
production, UniPixel has developed a version of Opcuity (Opcuity FPR) that can be sold directly to OEM and retail markets for touch-screen applications. UniPixel also has envisioned versions of Opcuity that can potentially enhance solar system efficiencies or be the basis for flexible thin-film multi-layered circuits. The company believes that its expertise and continuing innovation in this arena can bring a number of optical thin films to market that have large market and revenue opportunities over time.

The initial challenge in TMOS development was the creation of precise micro-structures that vary from 2 to 10 microns in size while maintaining precision edges in three-dimensional structures such as truncated hexagonal pyramids. Initially, UniPixel found that both non-structures and large 30+ micron micro-structures were available, but that no firm had perfected micro-structures in the required size range needed for TMOS. Understanding that these structures needed to be deployed on continuous thin film surface, UniPixel pursued methods for creating the structures that are compatible with high-speed micro replication processes. After evaluating a broad range of approaches, UniPixel has developed the capability to create master molds of the structures and to use these molds in a continuous flow process for film production. At the base thin film level, UniPixel had achieved its first objective.



Opcuity Film mounted on TFT backplane

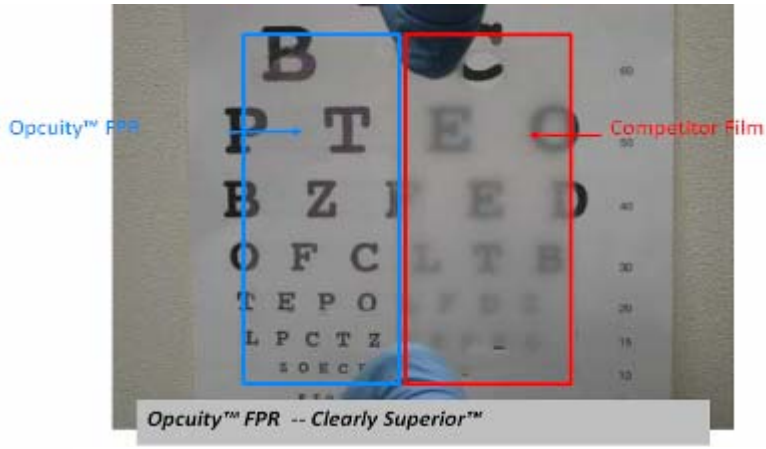
TMOS Opcuity film requires a precisely patterned conductor on its three-dimensional surface. Initially, UniPixel could not find a readily available solution for this requirement. This challenge was further complicated by the fact that the conductor could be located only in the valleys and gaps between micro-structures and the flat top surfaces of the structures must be completely clear of material. The top flat areas of the micro-structures serve as the coupling interface for the frustration of TIR light and any obstruction on the top surface would impact the optical functionality of the system. So UniPixel was challenged to pattern the flexible conductor in trace widths of 3 to 4 microns wide and 3 to 4 microns tall precisely between the film's surface features. All the while, the conductor needed to form a continuous ground plane on the surface of the film. The solution developed accomplishes this objective by forming a lattice mesh of interconnected conductor traces around the bases of the micro-structures. The interconnected traces are contiguous across the thin films surface and have been demonstrated to resistivity levels of less than 15 ohms per square. The conductor deposition process uses standard ink jet technology in a two-step method to create the lattice mesh of copper traces.



On the left is a conceptual View of Opcuity film for TMOS with patterned flexible conductor. On the right is an actual micrograph of Opcuity film with patterned copper conductor.

The next challenge involved the development of surface treatments that could be used to manage the interaction of the polymer membrane coming into contact with the light guide glass. When two materials come into contact it typically results in “stiction”. Stiction is a well known, but not well understood, phenomena in the world of MEMS thus UniPixel found itself challenged to address it effectively within the context of the TMOS system. The resulting effort explored the broadest range of potential solutions finally focusing on a unique set of nano-materials and self-assembling mono-layers. UniPixel’s efforts to model and understand the forces at work in stiction and the resulting surface engineering of the thin-film materials with the surface treatments allowed the company to control and leverage it in the current TMOS prototypes. The deposition techniques for the nanomaterials and SAMs are all continuous flow process compatible to fit the process design requirement.

This effort by UniPixel has created a unique film development platform that leverages the solutions created for Opcuity for TMOS. The initial product offering is Opcuity FPR (fingerprint-resistant) film. This innovative product provides any touch-screen enabled device with a protective layer that prevents scratches, is anti-glare, and most importantly, is fingerprint-resistant. UniPixel has filed patents for Opcuity FPR and has established initial interest for it with large touch-screen system OEMS that produce cellular phone, notebook PCs, and personal navigation products. Opcuity for TMOS is another product and will be needed to support the development efforts and commercialization of TMOS panels as UniPixel’s development partners advance TMOS toward production.



Side-by-side comparison of Opcuity FingerPrint Resistant (FPR) Film and a similar anti-glare product

UniPixel currently is evaluating a small pilot production capability to support the business development of its Opcuity films. This pilot production environment will allow UniPixel to quickly and fully develop films for market applications thus allowing the production processes to be finalized for transition to dedicated production facilities. The company anticipates that the Opcuity film business will leverage a combination of sub-contracted production, licensed production, and potentially in-house full production of the films over time. The small pilot production operation is expected to be used to feed all three types of volume production environments and will support UniPixel through its next stage of commercialization.

UniPixel is engaged in discussions with a variety of licensees for its TMOS panel production and various sub-components for modules, which include its edge-light injection systems and drive control chips. The company expects to move forward with its Opcuity film pilot line to support these relationships. Further, UniPixel is receiving multiple requests for samples of its Opcuity FPR film for potential OEM system integration, ODM attachment, and retail packaged peripheral sales.

Optical thin films have become an innovative arena that offers a wide variety of opportunities to firms properly positioned to compete with a full set of tools. UniPixel has demonstrated its ability to solve the most challenging technical issues in the field while working on TMOS development and is now positioning its core competencies with the tools needed to capitalize on the opportunities it has created. TMOS licensing and Opcuity film sales are both moving forward in discussions and represent significant revenue opportunities. However, the accomplishments at UniPixel in addressing its challenges in TMOS prototyping have opened the doors to a platform capability that combines one to ten-micron precise geometric micro-structures, with optical design and engineering, with surface modifications using SAMs or nano-materials, and the ability to pattern very fine conductor traces in three dimensions on the film’s surface.

Over the course of its three and a half years of funded development efforts, UniPixel has built its portfolio up to 106 US and International patents and filings. As the company solved its need for a film for its TMOS systems, it

has developed the ability to more broadly apply these capabilities to create optical thin films that can address a wide variety of needs. In addition to TMOS licensing, developing, producing, and selling these Opcuity films is UniPixel's other revenue-generating element of its business model. In the immediate term, UniPixel expects that its Opcuity FPR will provide touch screen system users with a better viewing experience by preventing optical degradation resulting from fingerprints on the touch-screen surface. Further out, UniPixel sees its solutions providing the opportunity for LCD companies to build better performing display panels at significantly lower cost in their existing fabs by implementing TMOS. Along the way, UniPixel expects that the thin-film platform capabilities it has developed will continue to find broader based applications for a wide range of technology implementations.

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Printed electronics materials outlook: Printed OLED lighting

by Lawrence Gasman

Lawrence Gasman is principal analyst and founder of NanoMarkets, in Glen Allen, Virginia. He has over 25 years of experience as a high-tech consultant for companies including Analog Devices, Cisco, Hewlett-Packard, IBM, Intel, Fujitsu, NEC, Nortel and NTT, and is also the author of three books on telecommunications topics. He is also on the editorial board of the Foresight Nanotech Institute and is a regular speaker at various nanotechnology and display related conferences. This article is the "Executive Summary" from NanoMarkets' recent research report entitled: "Printable Electronics Market Outlook: An Applications-Based Assessment" http://www.nanomarkets.net

Printed lighting has been around in the form of EL lighting for many years, but is limited in the applications it can serve, by the lack of brightness. Every so often there are innovations in EL materials, but no one is really expecting major changes that could revive the fortunes of EL, whose traditional markets are slowly being eaten up by high brightness LEDs. At the other end of the scale an entire new generation of printed lighting may emerge as the result of current R&D and productization work being carried out using the emissive properties of carbon nanotubes.

With all that said, most of the interest and opportunities are to be found in OLED lighting, a technology that may address a broad range of lighting applications and which for the last couple of years has received funding from both government and private interests. Potentially, OLEDs bring a number of very attractive features to the lighting marketplace. They are low power consuming, bright, can be fabricated on flexible substrates, and can serve as floodlights. As far as the last of these items is concerned, HB-LEDs are more spotlight-like, so OLEDs are potentially complementary to HB-LEDs. The next year should prove a formative one for the OLED lighting industry, because some of the R&D projects are coming to an end and the performance of the first products (perhaps in 2008) will set the pace for how fast this segment grows. Today, printability is certainly a secondary issue in the OLED lighting space. However, some research groups are specifically looking at printing OLED lighting panels.

While many of the materials issues that come up in the context of printed OLEDs are the same whether the applications are displays or lighting, but there are certainly some differences when it comes to the requirements for efficiencies, lifetimes, brightness, color quality and environmental resilience, for example. This opens up the market to specialist materials, although it will be several years before volume opportunities in this space.

Implications for materials: Some of the biggest names in electronics and lighting are involved in R&D on OLED lighting including Add-Vision, GE, Kodak, Novaled, Osram, Philips, and Siemens. All of these firms are involved in materials issues to some extent. And OLEDs are very much a materials game: a full 40% of the Euros going to projects in the European Community's OLLA OLED development program (see below), for example, were for materials development.

Obviously, many of these issues and the ones involved with printing OLED lighting are very similar to those discussed for OLED displays, but there are certainly some differences when it comes to the requirements for efficiencies, lifetimes, brightness, color quality and environmental resilience, for example. Requirements also differ across the gamut of lighting applications, as they do across different FPD application spaces. What is suitable for an OLED used as an LCD backlight, for instance, may not serve for general lighting applications, and vice versa; just as a passive monochrome OLED FPD is fine for the secondary display of a cell phone, but not for its primary display. Today, printability is certainly a secondary issue in the OLED lighting space. However, we note that the UK's Department of Trade and Industry's Knowledge Transfer Network project specifically has an objective of printing lighting.

Generally, speaking the brightness demands on OLED lighting are more extreme than they are on OLED FPDs. By analogy with current LCD-based products, an OLED display for a laptop computer screen or desktop monitor would be required to deliver about 200 nits of brightness in most situations, and as much as 400 nits or so in some niche industrial and military applications. An OLED lamp used to backlight an LCD on a laptop, on the other hand, would need to crank out upwards of 4,000 nits to deliver just 200 nits to the user. The reason is that LCDs are extremely inefficient in the amount of generated light that gets through to the eye. Size is also a major challenge; for an entry-level OLED lamp aiming to replace a conventional fluorescent fixture, the area requirement would be three feet on the diagonal or more - quite a challenge for OLEDs, which are today usually just a few square inches. Achieving uniformity in the large-area deposition of OLED materials may also pose a challenge for lighting applications.

The state of the art for OLED lamps today is roughly in the 10-30 lm/W range, but that's likely to be a short-term frontier. The DOE's technology roadmap points to possible efficiencies of 100 to 150 lumens/W for OLED lighting in the long run. Blue has traditionally been the most difficult color to deal with, for both OLEDs and ILEDs, but there's a great deal of work being done in this area to good effect.

Lifetime requirements for OLED lamp applications are, like other parameters, highly application dependent. A few thousand hours of life may be adequate for a cell phone backlight, but other applications such as TV backlights will require one hundred thousand hours of life or more. For early lighting applications, such as effect lighting, the Osram-OS team believes a lifetime of at least 1khr for 1,000 nits is required. Add-Vision believes that 1khr life is "a key commercialization target for our partners and customers", but this company is focused on some backlighting segments for which 100-200 nits is sufficient.

The lifetime of OLEDs has grown by leaps and bounds over the past few years. However, the gods of organic chemistry have imposed the law of differential aging among the primary red, green, and blue (RGB) colors conventionally used to create white light. As the brightness of the material in, say, a green lamp declines over time, the lamp grows dimmer. But as the green material in an RGB white lamp glows less, the color balance of the RGB system is thrown off. Color stability is a serious issue for the lighting materials market, complicated by this differential aging issue. As usual, blue is the worst offender.

In concluding this section, a couple of comments on EL and CNT lighting materials may be worth making. New developments in EL lighting materials occur from time to time, but none of them seem likely to propel EL lighting into new markets in any significant way. It is worth noting, however, that all EL lighting is printed. Applied Nanotech is a firm that has been behind many of the announcements for CNT lighting. However, commercialization in this segment is a relatively minor activity when compared with the work being done on OLED lighting, although the work on CNT lighting does seem to typically involve CNT inks.

Flexible Displays Break the Glass Ceiling

by Jennifer Colgrove

Jennifer Kong Colegrove, Ph.D. was most recently a senior analyst of display technology & strategy at iSuppli. She was responsible for research about emerging display technologies, display manufacturing, and strategic analysis. She also performed custom research studies and developed and maintained display manufacturing cost models. Before iSuppli, Dr. Colegrove was a senior display engineer at Intel Corporation for over two years. She was responsible for the display technologies from LCD, OLED to bi-stable displays, from two-inch small size display to 17-inch LCD for notebook PCs. She has performed technology due diligence for Intel Capital, investigating new investments in outside companies. Before Intel she worked for a handful of startup companies: she was a consultant on Holographic Polymer Dispersed Liquid Crystal for dpiX-Xerox spin-off; a senior material engineer on electrically-switchable Bragg gratings for Digilens; as a research and development engineer on laser packaging for Silicon Bandwidth, and a project manager for Crystal Research. Her Ph.D. is from the Liquid Crystal Institute at Kent State University, Ohio.

For years, technology companies and consumers have dreamed of a technology that could break through the limitations of glass-based displays. These limitations are apparent in today's mobile devices, where fragility, weight and shrinking form factors combine to place constraints on the size and capabilities of the display. What if displays could be rugged, lightweight, and foldable, so that large screens could fit into small devices?

This display dream is rapidly becoming a reality, as new devices enter the market that employ flexible screens. Leading the charge is Polymer Vision's Readius - a truly rollable e-book and mobile phone with a high-quality active matrix (AM) electrophoretic display that will be available to consumers during the second half of 2008. The Readius, along with other plastic-substrate AM electrophoretic displays from E Ink, will open up a host of new business and revenue opportunities, not just for e-ink producers, but also for companies throughout the consumer electronics, industrial and military fields as a host of new products arrive that take advantage of this blossoming technology, iSuppli Corp. believes.

In light of the introduction of such products, iSuppli forecasts the total flexible display market will reach $2.8 billion by 2013, 35 times the $80 million in 2007. Beyond the introduction of the new products, rising shipments of flexible displays are being enabled by the establishment of several batch and roll-to-roll facilities.

With a compound annual growth rate (CAGR) of 80.9% from 2007 to 2013, this represents an enormous financial opportunity for display vendors manufacturing the materials for this technology and for those companies developing and manufacturing applications for end markets. And as flexible displays become more commonplace and more attention is paid to these displays, it is highly likely the market will see many new entrants with new applications and targeting new areas. These companies will attempt to take advantage of the buzz surrounding the technology, similar to what has happened in the touch-screen display market courtesy of Apple Inc.'s iPhone.

Flexible fame: In a major sign that

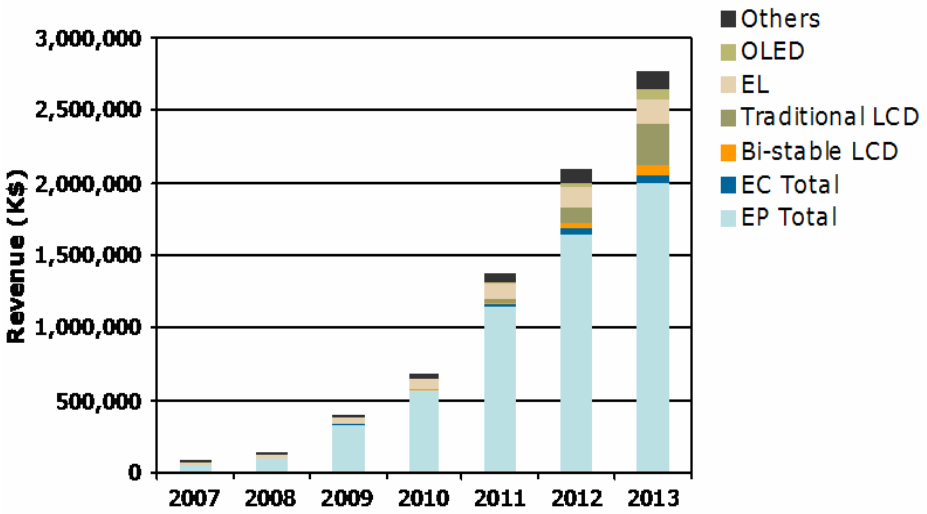

Figure 1 shows iSuppli's forecast for worldwide flexible display revenues for the period of 2007 through 2013

flexible displays truly have arrived, the technology for the first time ever will be featured on the cover of a major non-technology publication. The 75th anniversary edition of Esquire magazine in October will show a flexible electrophoretic display from E Ink on the cover. Esquire will distribute 100,000 issues with the special cover to be sold by the major bookstore chains Borders and Barnes & Noble as well as by select newsstands.

2008 is "year one" for flexible AM displays: Flexible displays entered consumers' daily lives long before Readius, with products such as Motorola Inc.'s display for its Motofone handset, electronic card displays and t-shirt displays, as presented in Figure 2 below.

Figure 2 shows several examples of flexible display products in the market. On the left is Motorola's Motofone with an E Ink display, a shirt from Quanxin, smart card solutions from SiPix and Aveso, and a media solution from Flex Media.

However, all the flexible displays in the market before 2008 were direct-drive or passive-matrix types. Until now, AM flexible displays did not exist that could provide the kind of image quality that users expect from their LCD-TVs and PC monitors. Because of this, 2008 represents "year one" for flexible AM displays. Prime View International (PVI), LG Displays and Plastic Logic Ltd. all have announced that they will commence production of high-resolution flexible AM displays during the second half of 2008.

Value-chain complexity: The value chain for flexible displays is more complex than for glass-based displays. There are more than a dozen display technologies can be made into flexible screens, including traditional LCD, bistable LCD, electrophoretic, electrochromic, electroluminescent (EL) and OLED. Furthermore, there are many substrate materials can be used for flexible displays, as well as several transparent conductors and multiple thin-film transistor (TFT) material types. For participants in the flexible display industry, this means many choices need to be carefully made according to one's strength, weakness and applications.

Technology leaders: Electrophoretic displays have been the leading flexible technology in terms of unit shipments and will maintain their dominance during the next five years. Electrochromic flexible display shipments are likely to pass electrophoretic after that, due to their usage in smart labels and other high-volume

applications. However, electrophoretic flexible displays will lead in revenue for the foreseeable future, increasingly driven by high-value applications such as e-books.

EL displays posted the second highest revenues of all flexible display technologies in 2007; applications include clothes/wearable, mobile handsets and point of purchase (POP)/signage/advertisement. Conventional flexible LCDs and EL displays will rank second and third in revenue among all technologies during the next five years.

Plastic was the dominant substrate material for flexible displays in 2007, accounting for nearly all of the total area. iSuppli forecasts that plastic substrates will continue to be the leading material for flexible displays, with more than 94% of total area in 2013. Stainless-steel substrates will enter the market in 2008 with applications in AM electrophoretic displays and later in active-matrix OLED displays and LCDs.

Entering the active matrix: As mentioned earlier, the introduction of AM technology represents a major turning point for the flexible display industry. iSuppli forecasts that AM flexible display sales revenue will increase dramatically, reaching 74% of the total market value by 2013. Several hundreds of millions dollars worth of investments have been made in flexible AM displays during the last few years, allowing production capacity to expand. For example:

- Polymer Vision received $27 million in funding and spun-off from Philips in January 2007.
- PVI has announced it is commencing mass production of flexible AM electrophoretic displays in the second half of 2008.
- LG Displays announced mass production of flexible AM electrophoretic displays in the second half of this year.
- Plastic Logic received $100 million in funding in January 2007 and an additional $50 million was raised in mid 2008. The company is building a manufacturing plant in Dresden, Germany with the support of the German government and will start production in the second half of 2008. Initial capacity will amount to more than 1 million display modules – equivalent to the 10-inch diagonal size - per year.
- Several roll-to-roll facilities have been or are being established.

In terms of the form factor, iSuppli forecasts that truly bendable/flexible display unit shipments will increase to reach 26% of total flexible shipments in 2013, up from 13% in 2007; the majority of “flexible” displays are expected to be used in flat or formed configurations, and won’t be bendable or rollable.

Market drivers: Flexible displays are intuitively appealing to end users and product designers because of their ruggedness, thinness, lightweight and novelty. Such displays also offer manufacturers the potential for inexpensive fabrication because they can be made using new printing methods or roll-to-roll processing. Furthermore, flexible displays have the advantage of easy and relatively inexpensive shipping and safety handling compared to conventional rigid screens. When flexible displays break, they don’t have any sharp edges that can cause injuries or further damage.

Mobile handsets were the leading application for flexible displays in terms of unit shipments in 2007. This application will remain a significant source of demand, but will not grow very fast, falling behind smart labels, electronic display cards and other applications.

Flexible displays have been and will continue to be used for many areas, including e-readers/e-newspapers, electronic display cards, electronic shelf labels, automotive applications, clothing/wearable, POP, public signage and advertisements, removable storage devices and other products. And as this technology becomes pervasive, expect to see numerous other products and innovations coming from current players and new players looking to cash in on the buzz.

The drawback? - I guess in an e-newspaper, it’s hard to cut coupons…

Covering The Business of 3D

3D Biz-Ex

Insight Media
Display Intelligence

USDC
U.S. Display Consortium

September 29-October 1, 2008
Sheraton Universal Hotel, Universal City, CA

Conference

The conference is focused on highlighting key trends and opportunities in the 3D industry so decision makers can develop products and service to suit the growing markets. Speakers from all over the world are being invited, representing a variety of inputs and applications, to discuss the changing dynamics of of *the business of 3D*. Insight Media analysts with numbers and data, the conference will cover the forecasts for many professional applications.

Exhibits

The old axiom 'seeing is believing' is more true in the 3D world than anywhere else. The 3D Biz-Ex exhibits is where visitors are immersed into the world of 3D. Theatre, home, medical offices, cameras, signage ... the number and types of applications will be defined by our exhibitors' creativity. There are opportunities for booths, table-tops, or a more flexible space for sponsoring companies. If your company is interested in reserving an exhibit booth or tabletop, please contact Heidi Hoffman at heidi@usdc.org.

Special Events

The location is spectacular for showcasing the latest in 3D theatres and movies. Stay tuned for some exciting news on events and activities to add another level of networking with your colleagues old and new!

Marketing

Joint marketing and a full-on PR blitz gives participating in this event your edge to attracting customers and clients. Contact us for more infomation on how the 3D Biz-Ex is working together to help the industry grow and prosper

Would you like to put your mark on 3D Biz-Ex? Contact ETC Event Management at 831.402.4227 or email: info@etc-eventmanagement.com.

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Flexible and Printed Electronics

by J. Kevin Cammack

Dr. Kevin Cammack joined FlexTech in January, 2008 as Director of Technical Marketing and Corporate Development, where he is responsible for technical and market reporting and analysis; management of project contracts; and outreach activities to the financial and entrepreneurial communities. Kevin is a graduate of Stanford Graduate School of Business, earned his Ph.D. in organic chemistry from the University of California, Berkeley and his BS (Phi Beta Kappa) from the University of Florida.

The microchip has transformed the lives of everyone on this planet in ways that could not have been imagined 50 years ago. Today, a new technological revolution is emerging that could have a similar impact on our lives. Flexible and printed electronics, or FPE, are transforming the way we live and interact, and organizations like the FlexTech Alliance for displays and flexible, printed electronics (http://www.flextech.org) are helping to make FPE a reality. Integrated electronics are no longer only just about smaller and faster; today's important metrics include larger area, ruggedness, weight, power budget, conformability and green/clean manufacturing and products that can be integrated seamlessly into all aspects of life.

> *"In the future, structural materials will incorporate sensing, reporting, and even healing functions...."*
>
> — ***National Academy of Sciences**, "Materials Science and Technology: Challenges for the Chemical Sciences in the 21st Century"*

The market for flexible and printed electronics will grow rapidly in the near future. FPE underpins emerging products in the fastest growing markets in the world – photovoltaics and electronic displays. The global market for all FPE applications today is estimated at just under $1.2B. NanoMarkets estimates those markets will increase to a $10B market by 2012, and a $300B market is projected by 2025.

The Technology: Flexible and Printed Electronics describes a broad set of technologies applicable across a multitude of products. FPE may be very small, such has cell phone components, or very large (literally thousands of square meters), enabling applications that can only be dreamed of today. The common theme of FPE is that it enables the production of electronic devices that can be readily integrated into all aspects of life in a seamless manner, at low cost, on large scales, using inherently green processes and materials. The elements of FPE – flexible and printed – each describe a different aspect of improvement over traditional silicon electronics.

Flexible – unlike silicon microelectronics, FPE can be bent or shaped without damage. This allows integration into everyday items and places, such as paper or textiles, which are not generally flat and shock protected. The two keys hurdles to making electronics flexible are the availability of high quality flexible substrates and the development of robust semiconducting materials. Today metal foil is commonly used as a substrate, primarily for low performance applications such as photovoltaics. Unfortunately, for high performance applications such as displays and RF components, foil is not compatible with operation of the device. Several innovators such as Professor Jim Sturm at Princeton, and researchers at DuPont, in partnership with FlexTech and its member organizations, are developing clear plastic substrates that have the advantages of foil – high temperature stability, low coefficient of thermal expansion, etc. but which do not interfere with the normal operation of the device. In the future, many in the industry even anticipate that it will be common practice to print electronic devices directly on paper – making desktop manufacturing a reality.

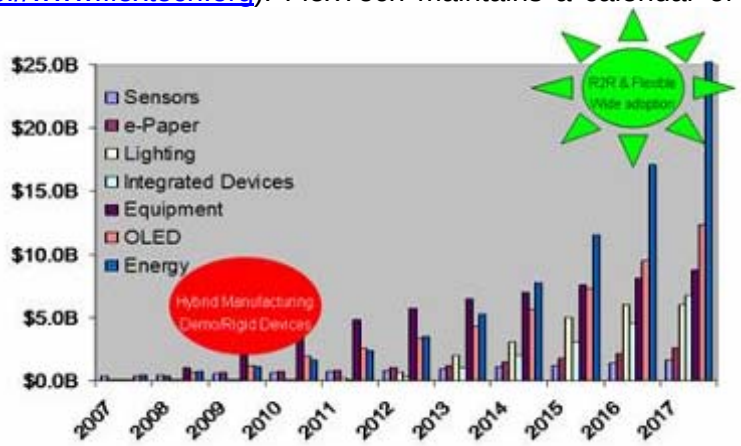
Printed – Printing innovations make high volume production of FPE at low cost, using green materials and on flexible substrates possible. Most of the printing methods used today, including offset, gravure, flexo and ink jet can be adapted to FPE. FPE are inherently green, and in many cases replaces the materials in traditional electronics, including toxic metals such as germanium, with plastics and inks.

These new materials have the advantages of low energy consumption, high fault-tolerance, transparency, light weight and shock resistance. The common themes among these elements are:

- Lower materials and manufacturing costs
- Enabling novel applications not practical to manufacture today
- Transformation of U.S. print manufacturing capacity for microelectronics manufacturing

Learn More: Firms and individuals interested in learning more about flexible and printed electronics should consider attending the Quarterly Flexible Printed Electronics Workshop on August 20, 2008. The workshop is free to attend and hosted by FlexTech and Mark Andy at the Mark Andy headquarters in St. Louis, Missouri. Attendance is limited – interested individuals need to RSVP to Kay Mascoli (kay.mascoli@flextech.org) to reserve a spot at this or the next workshop, which is anticipated to be held either in the 3rd week of October or 2nd week of November, 2008 in Silicon Valley, CA. The FlexTech Alliance for Flexible, Printed Electronics and Displays website is also a wealth of information (http://www.flextech.org). FlexTech maintains a calendar of industry events, the most complete directory of organizations working in flexible electronics, news feeds and blogs from several industry experts. Several new developments are also underway at the website, including an interactive forum, or wiki, dedicated to the world of Flexible Electronics, and the addition of web 2.0 tools that will allow users to post directly to the industry calendar and directory.

Market/Product Opportunities: Products made possible by FPE in displays, lighting, Sensors and solar are only now beginning to come onto the market today. FlexTech estimates that by 2017, FPE revenues will exceed $5B annually in several industries, including indoor lighting, photovoltaics, integrated displays and smart packaging.



Predicted growth of FPE markets through 2017
(Source: FlexTech, 2008)

Example product areas of intense industry interest include:

Flexible solar panels – Traditional photovoltaic solar is made from a silicon wafer encased in glass, and are expensive, heavy and easy to break. With the support of the Department of Energy (DOE), pioneering (primarily in the U.S.) entrepreneurs are now inventing lightweight, flexible solar cells. Today, the development of flexible photovoltaics is primarily a US industry, and with 80-100% year on year growth (according to SolarBuzz) and over 200MW of annual production capacity, it is the fastest growing industry in the world.

Printed solid state lighting – Printed OLEDs are a lighting technology that can be 100% efficient – pure light with no wasted energy creating heat. Low-cost OLED lighting installed as wallpaper and ultra-high contrast, flexible displays are among the applications being developed by companies such as UDC and Philips. While mass market applications are likely a few years in the making, some high end products are already becoming available.

Medical devices – FPE enables medical innovations that dramatically lower healthcare costs while improving overall quality of care, such as smart, flexible electronic bandages that monitor health, dispense prophylactics, and warn when you need more serious treatment. According to Professor Chris Ober at Cornell University, newer flexible materials will make implanted artificial eyes and brain-linked artificial limbs possible for the first time.

Emerging opportunities: FPE will also enable capabilities that can only be dreamed of today, such as intelligent clothing, structure-integrated sensors, wearable medical diagnostic tools, and implantable RF devices.

Worth the ride…

by Bruce Berkoff

Mr. Berkoff is the Chairman of the LCD TV Association, a global not-for-profit marketing trade association dedicated to "informing, promoting, improving and connecting" the entire LCD TV supply chain and their related companies, to help promote "a great LCD TV in every room in the house!" For over 6 years, residing in Seoul Korea, Mr. Berkoff was also the executive vice president of marketing and chief marketing officer (CMO) for LG.Philips LCD. He has also been the CEO of a fables semi start-up in the video processing space and general manager of Philips Flat Display Systems software and electronics business unit. Prior executive positions also include UMAX Computer Corporation, Radius, SuperMac Technologies and ZD Labs. Mr. Berkoff is a speaker and author in the display and electronics industry. He has display related patents both granted and pending in the US and China. He holds an undergraduate degree in physics from Princeton and a graduate degree in biophysics from the University of California Berkeley. Mr. Berkoff currently sits on the boards of five publicly traded companies: LG Display (LGD), Tvia, Inc. (TVIA) and Uni-Pixel, Inc. (UNXL), and is known for his many visionary talks at display and technology related conferences around the globe.

I am honored to be a part of this inaugural newsletter FlexTech newsletter. Having been part of the TFT LCD revolution in the past, the growing LCD TV Association (http://www.lcdtvassociation.org) at the moment, and planting the seeds for a greener future via the Global PV Association as well. I believe that lightweight and flexible electronics can play an important role in our progressively brighter future. Not just via smaller and lighter weight devices, which save energy and landfill space, but via "built-in photovoltaic" devices (lighter weight and easier to install) that conserve energy by creating clean electricity closer to the point of consumption, thus minimizing the need for big new power plants as well as reducing the energy wasted in transmission from a long distance.

I think many fine lessons from the past efforts of semiconductors and thin film displays can be useful for learning and advancing the field of thin and flexible electronics. Surely the FlexTech Alliance has a great pedigree from its past existence as the USDC, as do many of its members with a common technology evolution in the equipment and materials space leading from semiconductors, to thin film displays, and now to the dawning era of thin film photovoltaics. Many companies have already benefited from various recent investments and technical advances in thin film electronics that span these various areas and many more will follow, across the entire supply chain for flexible printed electronics.

Consider global examples from the LCD manufacturing space to new factory investments (like those recently for Plastic Logic in Germany), to new areas like lightweight, moldable, and bendable photocells (from folks like Ascent Solar), to new optical technologies like TMOS (from UniPixel) which could lead to new cost-effective display devices. In all of these cases, many of the lessons learned from the evolution of the thin film supply chain will come in handy, as more and more companies seek to make that difficult leap from a great science "project" to an actual shipping "product". In fact, there will be even more issues moving to scale in the required scope for real world industries. Many past experiences should be remembered and applied, like those I have summarized as "Berkoff's Law" which states that "science always loses to engineering, which loses to economics, which in turn always loses to politics". Many new learning experiences remain for the next wave of CE devices and the vast solar energy industry, which will both benefit from advances in flexible printed electronics manufacturing.

The mission of the FlexTech Alliance is "devoted to fostering the growth, profitability and success of the electronic display and the flexible, printed electronics supply chain" will benefit from the many lessons learned by the past players and participants in the thin film and related industries. I am sure this new endeavor will lead to even more successes in the future, and I can't wait to see how it all evolves. One thing is for sure, our global economy is increasingly "flat" and our future electronics will be both "flat and flexible", though many of the best success stories have yet to be told, or even imagined, it surely will be worth the ride.

8th Annual Flexible Electronics and Displays Conference

February 2-5, 2009
Pointe Hilton Squaw Peak
Phoenix, Arizona

The Flexible Electronics and Displays Conference and Exhibition 2009 (http://www.flextech.org) is the premier US event on flexible printed electronics and displays. The conference addresses technical and business issues, advancements impacting the flexible electronics field, as well as areas where displays are a key driver. Conference sessions will focus on the emerging field of flexible, printed, and organic electronics manufacturing, including solar, solid state lighting, RFID, sensors, and flexible display applications and markets.

In 2009, the conference will also include three distinct types of tracks: 1) Fundamental Research Track with peer-reviewed abstracts and a full technical paper requirement, published by IEEE; 2) Business, Markets, Applied and Developmental Research Track, with committee-reviewed abstracts and a proceedings of Power Point presentations (NO full technical paper); and, 3) a Student Research Poster Track, with peer-reviewed abstracts, and a competition for best poster(s).

The conference agenda will focus on all critical topic areas in displays and the emerging field of flexible, printed, and organic electronics:

- Strategic Market and Business Overviews
- Materials Advancements for Flexible Electronics
- Manufacturing on Flexible Substrates
- Flexible Displays
- Flexible Electronics Based Applications and Products, including RFID and sensors, photovoltaics, solid state lighting and OLEDs, printing processes and technologies, as well as equipment for high-throughput manufacturing of electronics

In addition to the three-day market and technical tracks, the conference now features an all day business investment summit and a variety of short courses. The business investment summit, which will be held Monday, February 2, 2009, will address issues of relevance to industry innovators, manufacturers and investors in the flexible and printed electronics market. The all-day event will feature visionary and pragmatic talks from invited speakers, market research firms, investment banks, and venture capital firms.

Multiple short courses are being planned prior to the conference opening in response to enthusiastic demand from previous short course offerings. The courses will reflect the variety of technologies being developed in flexible, printed electronics and will offer an excellent opportunity for collaboration between industry and academia. Six half-day courses, running concurrently, will be held on Monday, February 2, 2009.

Abbie Gregg of Abbie Gregg Inc. and Dan Gamota of Motorola return as conference co-chairs. They are joined this year by Dieter Schroth, managing director of EMD Chemical's new Materials Research Lab.

For more information on the conference and for exhibiting information, please contact Heidi Hoffman or Kay Mascoli at USDC at 408/993-8111.