YEAR-END HOT-TOPICS ISSUE

Information DISPLAY

Official Monthly Publication of the Society for Information Display • www.informationdisplay.org

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SOCIETY FOR INFORMATION DISPLAY

Nov./Dec. 2010
Vol. 26, Nos. 11 & 12

Green Revolution

How environmental responsibility is changing priorities in our industry

Plus

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COVER: The two hottest topics in the display industry right now are Green Technology and 3-D. For this end-of-year issue, several leading players examine both topics. Representatives from Samsung, Philips, and AUO discuss how they and other industry giants are contributing to the world-wide green revolution, while a group of researchers at Microsoft discusses a new technology that could possibly revolutionize the 3-D viewing experience.

Cover design by Acapella Studios, Inc.

Next Month in
Information Display

Optical Films and Coatings Issue
- Film Technologies for 3-D Displays
- TFT-LCD Optical Films
- Paper-Like Electronic Media
- Solution Coating Technology for AMOLED Displays

INFORMATION DISPLAY (ISSN 0362-0972) is published 10 times a year for the Society for Information Display by Palisades Convention Management, 411 Lafayette Street, 2nd Floor, New York, NY 10003; William Klein, President and CEO. EDITORIAL AND BUSINESS OFFICES: Jay Morreale, Editor-in-Chief, Palisades Convention Management, 411 Lafayette Street, 2nd Floor, New York, NY 10003; telephone 212/460-9700. Send manuscripts to the attention of the Editor, ID. Director of Sales: Michele Klein, Palisades Convention Management, 411 Lafayette Street, 2nd Floor, New York, NY 10003; 212/460-9700. SID HEADQUARTERS, for correspondence on subscriptions and membership: Society for Information Display, 1475 S. Bascom Ave., Ste. 114, Campbell, CA 95008; telephone 408/879-3901, fax -3833. SUBSCRIPTIONS: Information Display is distributed without charge to those qualified and to SID members as a benefit of membership (annual dues $100.00). Subscriptions to others: U.S. & Canada: $75.00 one year, $7.50 single copy; elsewhere: $100.00 one year, $7.50 single copy. PRINTED by Sheridan Printing Company, Alpha, NJ 08865. Third-class postage paid at Easton, PA.

Information DISPLAY

NOVEMBER/DECEMBER 2010
VOL. 26, NOS. 11 & 12

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editorial

Hot Topics: Green Technology and 3-D

Stephen Atwood

You are probably wondering what happened to your November issue of *Information Display* – the one where we promised to address the latest advances in "green" technology. Well, fear not. You didn't miss it and there is nothing wrong with our mailing list. We simply decided to merge the November and December issues into one large end-of-the-year special issue on two of the hottest topics in the business right now: 3-D technology and the Green Revolution. Why bring them together? Frankly, it's economics. *ID* magazine thrives primarily due to the generosity of our advertising partners and by a significant subsidy from the Society for Information Display. We work hard to bring value to all of our advertisers and we also strive to maximize the value of SID's investment in this enterprise. Earlier this year, we eliminated the July issue because the economy had not recovered enough to generate the advertising income we needed. We similarly realized as we approached November that more savings were needed. But don't worry. Not a single page of the November content was cut. However, as indicators go, our advertising revenue is still quite a bit below prior years and certainly hints that the economy is not recovering as fast as we would hope. If you are a member of the business team at your company, please consider what you could do to help *ID* keep our editorial calendar coming as well as how we could help you better communicate your products and services to the display industry. Call or write us anytime to share your feedback.

One industry partner that has stepped up recently to help us is Avnet. Thanks to their generosity and support, not only can we provide this combined issue, we can distribute it to many more readers than ever, helping increase the visibility of all our advertisers and further promoting the *ID* and SID brands. I hope you will take a few minutes and review their information on pages 24 and 25 of this issue.

Meanwhile, let me introduce the first of our two topics. The first is The Green Revolution of Displays, as wonderfully conceived and organized by our guest editor Greg Gibson. Here, we explore the notion of how environmental responsibility is changing the priorities of the display industry. To be honest, I'm somewhat unhappy that we are using the term "green" as a slogan for the new mindset in the display industry. To me, the term implies technology that is environmentally friendly or beneficial, rather than simply less harmful, and I'm not convinced that the display industry is truly friendly to our environment. That's not to say that display companies are environmentally irresponsible – quite the contrary. When compared to other industries, I believe semiconductor companies and especially display manufacturers have much less negative impact on our environment and are for the most part managed by truly responsible leaders. However, we need to recognize that practically all aspects of displays have some negative environmental consequences.

For example, as you will read many times in this issue, virtually every aspect of an LCD's life cycle generates some level of CO_2 emission, along with various waste materials. The majority of CO_2 is generated during the phase when an LCD is consuming electricity for whatever application it is running. As authors Jun Souk and Sangwoo Whangbo point out in their feature article, "Green Technology in LCDs," in 2006 the majority of TVs in the U.S. were still CRT based and consumed an average of just over 100 W per set. By 2009, the displacement of CRTs by LCD and plasma sets had raised the average power consumption to over 200 W per set. Assuming a rough guess of about 200 million TVs used for 4 hours per day, you can reach a staggering figure of over 58 terawatt-hours (TWh) of total energy consumed for a 1-year period.

(continued on page 44)

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New Energy Star Requirements for TVs May Take Effect Sooner

According to Environmental Protection Agency (EPA) team leader and Energy Star product-developer Katharine Kaplan, since so many televisions available for sale in the U.S. already meet the requirements for the current version of Energy Star for TVs, the EPA is considering moving up the May 2012 compliance date for version, 5.1. "With an eye toward highlighting the most efficient models for consumers and retaining the relevancy of the Energy Star mark, in the coming weeks we will propose an earlier effective date for the 5.1 requirements," she says. How much earlier the next version would supercede 4.1 is not clear, however, and would depend on a number of factors as well as a thorough review by the EPA.

Another important change coming to the Energy Star program is that as of January 1, 2011, all products will need to be third-party certified in order to bear the Energy Star label. Up until now, manufacturers have self-tested products according to Energy Star guidelines, which has caused some criticism of the project.

Energy Star, a joint program of the EPA and the U.S. Department of Energy, was introduced in 1992 as a voluntary labeling program designed to identify and promote energy-efficient products. Computers and monitors were tested and labeled first, but consumers now most strongly associate Energy Star with major household appliances. The specifications differ for each product category.

As mentioned above, companies have in the past tested their own products. The Department of Energy has, however, performed spot checks on appliances, and some products have been removed from the qualified list as a result. In January 2010, based on the results of DOE testing, the EPA disqualified 21 refrigerator models under two brand names. (The EPA notes that these represented less than 5% of all qualified refrigerators.) The manufacturer entered into a corrective action plan with the EPA that required it to remove the Energy Star label from the units and to provide a consumer hotline for the affected models.

Energy Star literature states that a market share of 50% or higher for qualified products in a particular category will prompt consideration for a revision. Other factors that might signal a revision include:

- A change in the Federal minimum efficiency standards.
- Technological changes with advances in energy efficiency which allow a revised Energy Star specification to capture additional savings.
- Product availability.
- Significant issues with consumers realizing expected energy savings.
- Performance or quality issues.
- Issues with test procedures.[1]

The EPA is reworking its revision schedule, however, with an eye to differentiating "short-lived" products from longer-lived ones.

Televisions began qualifying for Energy Star in 1998. Qualified TVs must now consume 1 W or less in standby mode. On-mode power requirements vary according to screen size (actually a two-dimensional total viewing area) and whether the unit is low, high, or full high definition. External power supplies (EPSs) packaged with TV products must also meet all Energy Star requirements for EPS devices.[2]

Version 4.1 went into effect on May 1, 2010. The biggest change that comes with Version 5.1 is that the maximum on-mode power consumption in watts gets reduced by about 32%, depending on screen size. Maximum allowable energy in download acquisition mode has also decreased, from 0.08 to 0.02 kWh/day. Another potentially challenging aspect of 5.1 is that although TV sets larger than 50 in. on the diagonal may still qualify for Energy Star, they must meet the on-mode requirement for 50-in. models, regardless of size. For more, details on the current and future criteria for TVs, visit http://www.energystar.gov/index.cfm?c=tv_vcr.pr_crit_tv_vcr.

Although it is too early to predict the extent to which an early implementation of Energy Star 5.1 would affect television makers, some industry experts say the effect of changing the date for at least this particular set of requirements would probably be less onerous than might be imagined. Many manufacturers are already in compliance or close to compliance with 5.1, or other stricter requirements, noted DisplaySearch analyst Paul Gray in a September 2010 blog entry: "A look at the Energy Star data for the latest sets shows how close TV sets already are to meeting future energy consumption requirements, such as the California Energy Commission requirements set to go into effect in 2011." [3]

[1]http://www.energystar.gov/index.cfm?c=products.pr_how_earn
[2]http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=TV
[3]http://www.displaysearchblog.com/2010/07/tv-power-consumption-data-shows-how-far-set-makers-have-come/.

– Jenny Donelan

Glasses-Free 3-D Products on the Horizon

The big news from the CEATEC show in Japan last month (October 2010) was Toshiba's unveiling of autostereoscopic TVs. Two models, a 12- and a 20-in. version, are scheduled for December 2010 distribution in the Japanese market only, at prices equivalent to US$1500 and 3000. Reporters' reactions were mixed – the TVs have a "sweet spot," requiring the viewer to sit close to the center of the display – but the sets were by all reports the biggest draw at the show. Another glasses-free 3-D product that is generating a lot of excitement is the Nintendo 3DS, announced by the company earlier this year. Prototype units are reported to be just slightly larger than the current DS version, and early reports of the viewing experience are mainly favorable. A 2011 launch is rumored.

– Jenny Donelan

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Green Technology in LCDs

The meaning of green technology is fairly broad. It can represent environmental friendliness, less wastefulness, less energy consumption, or a combination of these factors. This article attempts to bring order to green initiatives and categorize green technology as it applies to LCDs into "green process," "green factory," and "green device." The energy consumption during the life cycle of the LCD is also considered, from fabrication to end of use.

by Jun Souk and Sangwoo Whangbo

THE LCD MARKET has grown remarkably. Worldwide LCD production capacity has increased by an average of ~35% per year in recent years, and production capacity will continue to increase at the rate of ~20% for the next few years, based on the Gen 8 factories planned in Asia. In parallel with this production volume increase, there has been diverse and significant technological progress in LCD products during the last decade. After the LCD became the mainstream display product in the early 2000s, LCD makers competed to develop larger panel sizes and better picture quality. They tried to improve attributes such as screen luminance, color gamut, and contrast ratio, and they also applied higher frame-rate panel-driving techniques to eliminate the motion-blur effect. The resolution of LCD TVs has improved to its current full-HD level. Most recently, various types of 3-D panels have been introduced, which have given rise to a strong need for ultra-high-definition (UHD) resolution. Unfortunately, all of these technology trends have led to products that consume more power. Total worldwide LCD-related electrical power consumption is significantly increasing due to the explosive use of displays for various purposes and the larger-screen LCD TVs that have become popular in homes. While all this has been happening, worldwide concerns with regard to environmental issues, and recent energy regulations such as Energy Star, have led manufacturers to respond by introducing greener products.

Green LCD Technology

Green technologies for LCDs stem from sustainable practices related to energy conservation, renewable energy, environmental remediation, recycling, water purification, sewage treatment, and more. In addition, because an LCD fabrication involves a large scale of equipment and factory space,

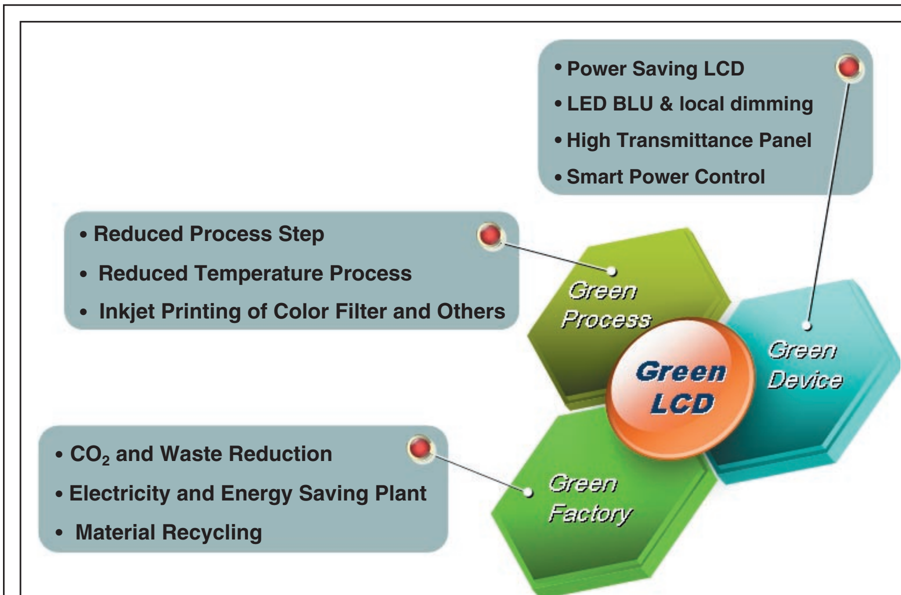

Fig. 1: Green technology as it applies to the LCD industry can be broken down into three areas: factory, process, and device.

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material/component reduction, standardization of manufacturing, recycling of end-of-life products, and waste treatment during production should also be included within the scope of green technology.

In order to simplify these diverse aspects, the authors have divided green technology for LCDs into three categories: (1) green factory, (2) green process, and (3) green device, as shown in Fig. 1. "Green factory" includes activities related to the reduction of CO_2 emissions, drainage, and waste. "Green process" covers activities related to TFT-LCD fabrication processes such as the reduction of manufacturing steps and the use of fewer chemicals and less electricity. "Green device" includes activities related mainly to energy efficient technologies for low power consumption.[1]

Lifetime Energy Consumption

How much energy is consumed by an LCD panel during its life cycle, from production to disposal? Figure 2 shows the result of a study tracing the converted energy consumption at each stage of an LCD panel's life, from fabrication, distribution, and operation until its disposal.[2] For this study, it was assumed that the panel was used for 10 years. The authors considered its carbon footprint index, the total set of greenhouse gas emissions caused by a product. They found that the predominant energy-consuming factor of an LCD is the electricity used during its lifetime. This means that 85.4% of the total energy used from birth to the grave is consumed during the LCD's operation time. Therefore, it is obvious that the most effective green action LCD makers can take is to enhance the power efficiency of the panel.

The average power used to operate a 40-in. LCD TV with a cold-cathode fluorescent-lamp (CCFL) backlight unit is about 200 W – almost double that used by a 30-in. CRT TV with an average power consumption of 115 W. Energy Star notes that U.S. residential electricity consumption for TVs has increased from 3.6% to 10% over the last 5 years.

The worldwide CRT-TV replacement rate for 2010 is over 70%. At the same time, the TV market is quickly growing, mainly in Brazil, Russia, India, and China, where 50% of the users still have CRT-based TVs. It is clear that in order to stave off greater LCD energy consumption on a global basis, the energy efficiency of the panels needs to be addressed, especially when consideration to supply newly emerging markets with product.

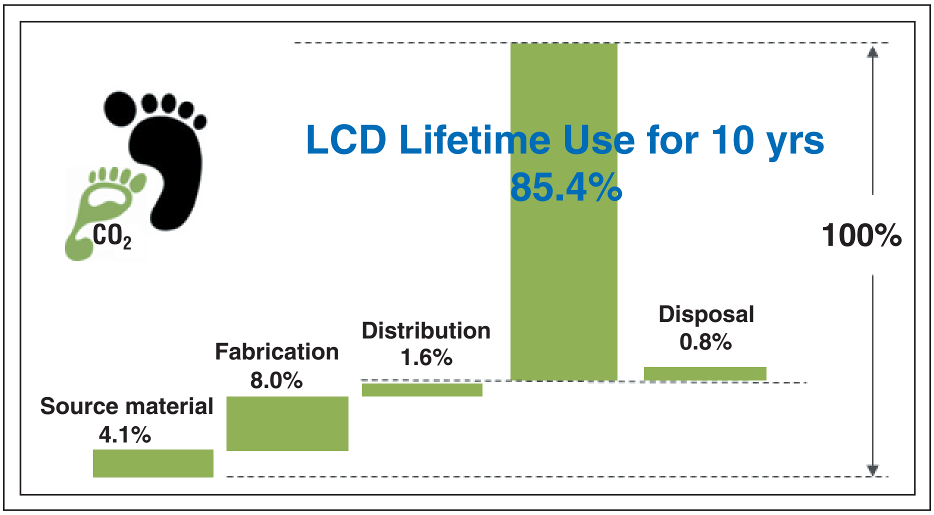


Fig. 2: The greenhouse gas emissions of an LCD panel during its lifetime are highest during its use rather than when it is being made or discarded.

Economics of Green LCD Devices

The Consumer Electronics Association (CEA) reported that 237 million CRT TVs in the U.S. used 53 TWh for 1 year in 2006.[3] This figure corresponds to about $5 billion from a rough estimation of US$0.1/kWh. By 2009, the electricity consumption of TVs, including LCD devices, more than doubled. Figure 3 shows the economics of TV power consumption. Thus far, panel suppliers have met energy regulation limits by adopting LED backlighting units (BLUs), resulting in a savings in energy consumption and cost.

Panel makers are working to make more-energy-efficient products as follows:

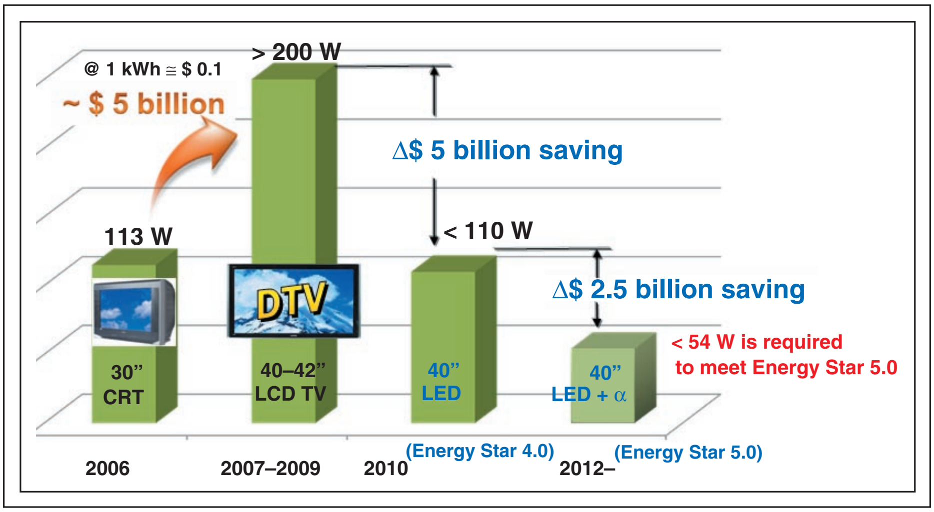


Fig. 3: Energy Star requirements will continue to impact the economics of TV power consumption and the electric bills paid by U.S. households. $5 billion is projected to be saved in 2010 versus the period from 2007 to 2009, owing to new energy-efficient TVs that are now in compliance with Energy Star 4.0 requirements. Energy Star is setting tougher new energy requirements with Version 5.0, so panel makers need to prepare new technologies. (Note: The "LED+α" (alpha) in the bar at far right refers to additional energy-saving technologies such as local dimming and the adoption of high-efficiency LEDs.)

- Panels with higher light transmittance; they currently have 4–6% transmittance and 8% is targeted for the near future.
- Multi-primary-color displays such as RGBY and RGBW.
- *The evolution of LED BLUs:* In the early stage, direct-lit LED techniques with local dimming to achieve true black, as well as saving power, were adopted, and, currently, edge-lit LED techniques, including two-dimensional dimming, are in development for the next generation.
- *Light-efficiency improvement of LEDs*: The adoption rate of LED BLUs is increasing dramatically, and the light conversion efficiency of white LEDs has been improved to higher than 80 lm/W.

With the use of LED backlights, LCD TVs in general have already achieved nearly 40% in power savings compared to previous TVs with CCFL BLUs. Due to upcoming changes in regulation limits from Energy Star, it is clear there is a new hurdle to be cleared by panel makers: an additional 50% in power saving is required to meet Version 5.0 by May 2012.

Green Process

Green process involves saving energy during LCD-panel manufacturing, which can be achieved by reducing the number of manufacturing steps and lowering the energy and temperature required for fabrication. Many efforts toward reducing fabrication process steps have been made. One example is the reduction of repeated photolithography during panel fabrication. Through steady efforts to cut down on the number of photolithography steps, the number of required photomasks to complete the TFT array has been reduced from an early stage of nine, to seven, to only four now. Although ink-jet-printing techniques are not quite there yet, eventually they could replace the photolithography processes for color filters[4] and column spacers. In addition, ink-jet technology enables savings on materials as well and is another key issue for the green process. With increasing glass substrate size, spin-coating of a photoresist was not viable anymore, so this process was changed into slit coating, and a significant amount of photoresist has been saved as a secondary profit. Lastly, replacement of the wet chemical process with a dry one is under development in order to save water and wet-chemical usage.

Green Factory

Worldwide, large-sized LCD-panel unit shipments are expected to rise at a compound annual growth rate (CAGR) of 13% by 2013, with the TV panel market exceeding 234 million units.[5] In part due to these types of market forecasts, LCD manufacturers are adding factories up to Gen 8–10. If we tally up the current factories and the officially announced construction plans for over Gen-8-sized factories, the total could be 11 factories or more by the end of 2012, or a 22% volume increase in total worldwide production. Although source material, fabrication, distribution, and disposal represent relatively small portions of an LCD's lifetime energy usage (as shown in Fig. 2), these aspects should not be overlooked. The amount of water, chemicals, and gases needed for the fabrication of this size will sharply increase over current levels and become a more serious issue for manufacturers.

Electrical power, water, and greenhouse gases (mainly, CO_2, SF_6, and NF_3) are the top three crucial resources for panel making that can adversely affect the environment. Over 90% of total CO_2 outgas is caused by electrical power consumption. As total fab capacity increases due to the use of larger substrates, the purification and recycling rate of waste water and liquid waste will need to be improved in order for manufacturers to cope with limited resources. Figure 4 shows the flow of inputs and outputs for a typical LCD factory, with green activities and components presented as well.

To become a well-established green factory, resources such as electric power, water, and non-hazardous materials should be supplied to the factory in the most energy-efficient ways and they also should be used effectively during fabrication as well to reduce waste. Perfluorocompound (PFC) gases such as SF_6 used for dry etching and NF_3 for CVD chamber cleaning in TFT-LCD fabrication both have a very high global warming potential. These two gases correspond to 67% of total gas emission during LCD panel fabrication and are expected to show about a 20% overall annual increase if green activities are not executed. For SF_6, outgassing can be reduced by installing a retreatment system to reduce emission levels nearly 90% from the LCD plants. There is also a way to replace PFC gases with a substitute such as COF_2 instead of SF_6, and F_2 instead of NF_3, but technology and budget issues must be resolved first.

Various types of chemicals and drainage water are currently being recycled for most LCD factories, and the recycling ratio rises each year. The wide footprint of an LCD factory often provides a good opportunity to generate a resource; for example, solar-cell implementations can be used on the roof and/or wall of factories, such as is being done

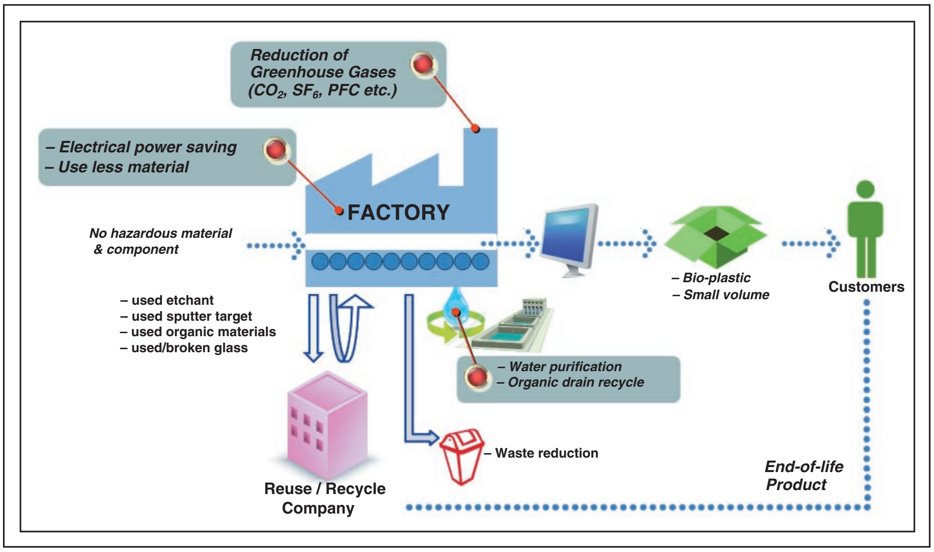


Fig. 4: *Components of a green factory include features such as reduction of greenhouse gases, a water-purification system, and eco-friendly packaging.*

at Samsung and Sharp, and a rain harvest system can be installed on the roof, as AUO has done.

Green Device

As mentioned earlier, the most effective way to obtain an energy-efficient LCD panel is to use LEDs as the backlight. The LED TV market volume increased from 3.7 million in 2009 to about 30 million in 2010 and the transition rate from CCFL TV to LED TV has been going faster than ever expected: it is forecasted to be over 40% in 2011.[6] With regard to light-efficiency levels for CCFLs and LEDs, white LED efficiency has advanced through the use of yellow phosphor such that the total power consumption gap between CCFLs and LEDs has continued to widen in favor of LEDs. LED lighting technology has also evolved from direct-lit, in which LEDs are regularly arranged under the entire panel area, to edge-lit, in which LEDs are located along the side areas of panel. This allows the total number of LEDs to be reduced to save power (Fig. 5).

In addition, by applying local-dimming technology, the display quality (contrast ratio) can be improved by controlling luminance locally or globally (according to the image content).

Another important criterion for green devices is eliminating hazardous components such as lead, mercury, cadmium, chromium VI (Cr^{6+}), bromine, polybrominated biphenyls (PBB), and polybrominated diphenyl ether (PBDE) in order to meet RoHS (Restriction of Hazardous Substances) standards. (The RoHS regulation on mercury currently used in CCFL backlights is waived until 2014.) The adoption of reusable/recyclable materials and the development of new recycling technologies are also expected to command more attention in the near future. A "green device" is therefore composed of (1) an energy-efficient LCD panel, (2) an energy-efficient backlight unit, and (3) eco-friendly components as depicted in Fig. 6.

Conclusion

Among many aspects of green initiatives for LCDs, the reduction of greenhouse gases and the creation of power-saving LCD devices are the most important, based on the higher level of impact on environmental issues. Making energy-efficient LCDs is the most effective way to reduce overall energy consumption

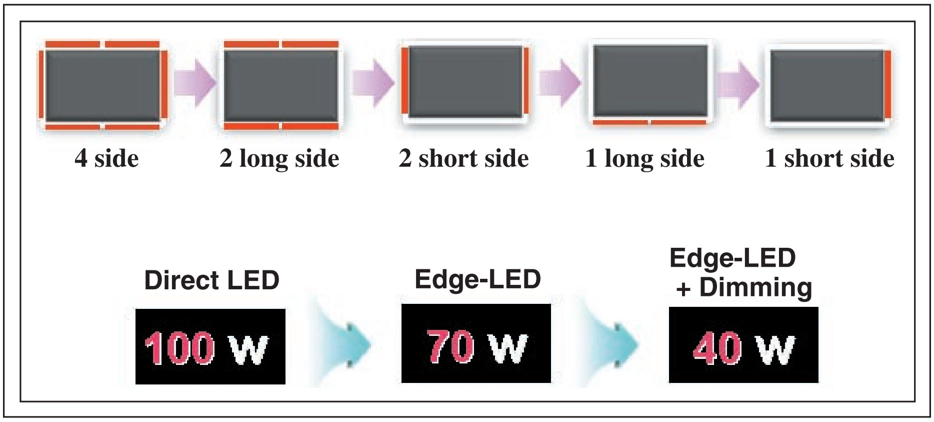


***Fig. 5:** Top: Edge-type LED-backlighting bars have evolved to reduce the number of LEDs. Bottom: The power consumption among different types of LED BLU is compared.*

and greenness. For example, energy-efficient LED backlights (mainly with white LEDs) with local-dimming capability can reduce power consumption by as much as 40%.

An external driving force for the green movement are international environmental/energy regulations. They make changes more urgent and necessary for LCD suppliers. The maximum power consumption level required by Energy Star Version 5.0 is nearly one-fourth that of current devices. All currently available state-of-the-art power-saving technologies have to be implemented in order to meet the specification.

Recent survey results for consumers' perceptions with regard to green devices show they are also willing to pay a premium for a green technology or green material used in embedded electronic devices.[7] (For more about consumer preferences with regard to green, see this month's Display Marketplace article, "Do Consumers Go for Green?").

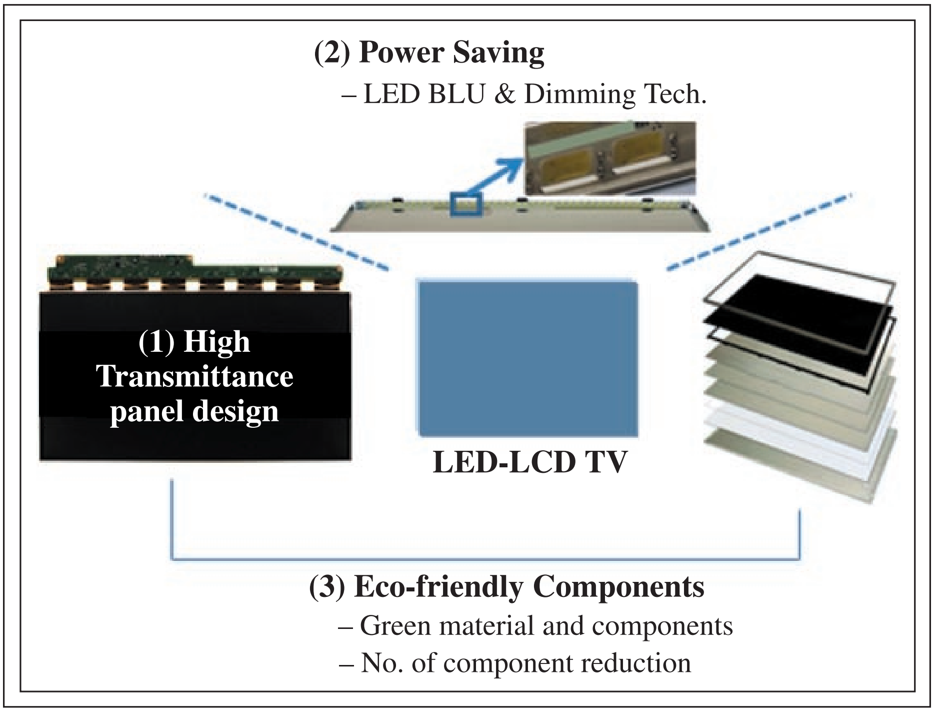
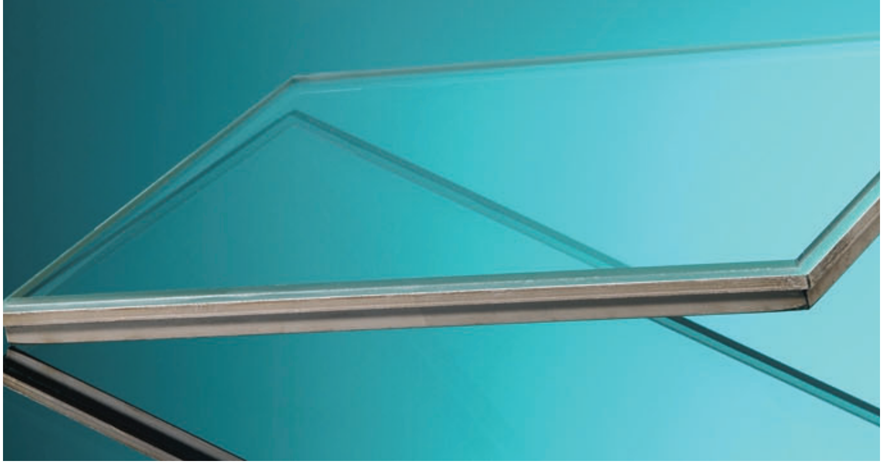


***Fig. 6:** Shown are the development activities necessary to produce a green device.*



As of today, these green technologies are governed by environmental regulations. However, in the near future, these efforts should become more strategic due to their impact on product competitiveness as measured by cost to produce and environmental friendliness.

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EcoDesign for TV Displays

The world population is still growing, while consumers in emerging markets are becoming more affluent and able to purchase electronic products such as televisions. The resulting environmental impact needs to be assessed for entire product life cycles. In televisions, displays dominate the environmental profile. Therefore, their performance is continuously monitored with Philips's EcoDesign approach.

by Kees (Cornelis) Teunissen and Leendert Jan de Olde

SOCIETAL TRENDS and environmental consciousness, in combination with emerging legislation, are requiring manufacturers of consumer-electronics goods to address ever more challenging conditions in which to do business. Sustainability and eco-design have become established phenomena in the design considerations of manufacturers, including television manufacturers. Successful industries and companies will effectively discover and use the opportunities these challenges pose. A level playing field is created by the implementation of rules and regulations, but is only guaranteed through verification by authorities. The latter is essential to support energy-saving and sustainability-related innovations in the highly competitive consumer-electronics market. In this article, the authors describe which eco-design challenges the display industry faces and how they offer opportunities for innovation and growth.

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Global Trends and Challenges

The world's rapid population growth, as shown in Fig. 1,[1] in combination with increasingly affluent consumers in markets such as Asia, will over the next decades place ever more severe stresses on the world's resources, including raw materials, water, and energy.

Global Footprint Network's latest data[2] show that humanity is currently consuming resources and producing waste (such as CO_2 emissions) at rates for which the ecological services of nearly two planets would be required just in order to meet demand through the early 2030s. Maintaining this rate of consumption could cause major eco-system collapses well before that threshold is reached. In 2006, the Energy Saving Trust predicted that by 2010 consumer electronics

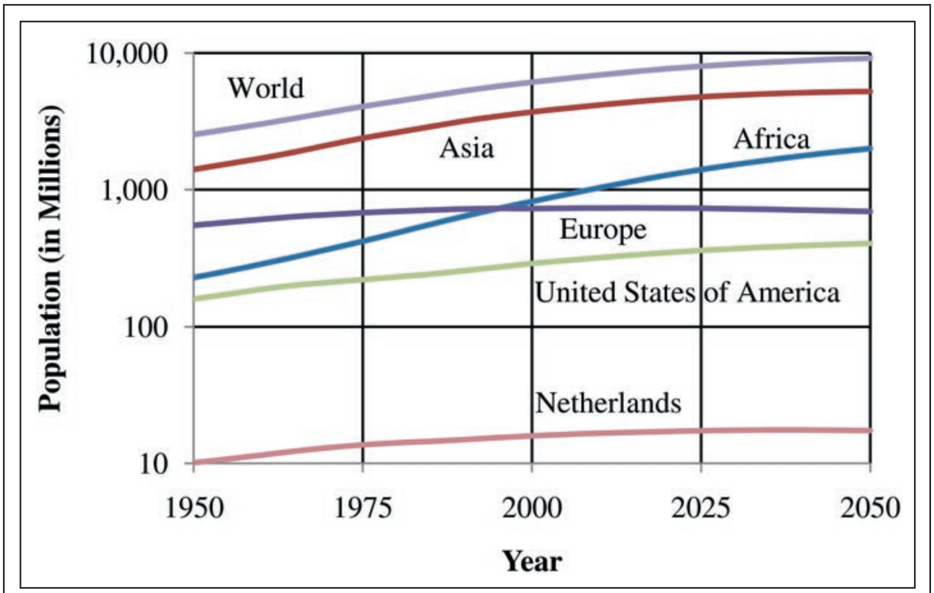

Fig. 1: In most parts of the world, with the exception of Europe, the population is expected to increase through 2050.

would become the largest single sector of consumer electricity consumption.[3] Governments are already acting on these developments with legislative measures designed to reduce energy consumption and overall use of resources. The entire industrial value chain will have to proactively address this situation while also continuing to create value from their activities.

In the television industry, new technologies such as plasma-display panels (PDPs) and liquid-crystal displays (LCDs) not only have enabled larger TVs, but have also turned them into "must-have" products. In particular, the rise in popularity of large plasma TVs was at one point expected to result in a major contribution to the energy consumption of households, as their average on-mode power consumption was measured to be up to four times higher than that of a normal-sized cathode-ray-tube CRT) TV.[3] In the meantime, these technologies have become more energy-efficient, but some still consume more energy than the same-sized CRT-based televisions.

TV-broadcast services are still a major source of information delivery. In 2008, TV watching increased to about 3.5 hours per day in Europe and 4.6 hours per day in the U.S.[4] Now, Internet-connected TVs are emerging, potentially increasing TV-on times and consequently the consumption of electricity. If not properly managed, the combination of large-sized televisions with increasing power-on time will result in a significant increase in electricity consumption around the world.

Environmentally Conscious Design

Environmentally conscious design or eco-design aims to improve the environmental performance of a product when viewed over its total environmental lifecycle. This requires data to be assessed from the mining of raw materials used to make the display until its end-of-life phase. The products' short lifecycle and the scarcity of resources used to make the products urge a re-evaluation of recycling at the last stage. Such an evaluation was published by Rose and Stevels[5] in 2001 for a set of consumer-electronics products, including CRT-based televisions, but the study shall be redone for televisions based on the newer display technologies.

In 2009, international standard IEC 62430, "Environmentally conscious design for electrical and electronic products," [6] was published. This standard provides a set of fundamental requirements for the process of environmentally conscious design and can be used as a base reference to ensure consistency throughout the electrotechnical sector.

Environmental Design at Philips

The environmental lifecycle approach to products has been in use at Royal Philips Electronics since the early 1990s. The company has created an environmental impact database and maintained it with regard to both external and internal sources. However, interpretation of lifecycle data can be difficult and for that reason it is not the most appropriate type of information to convey to product designers, nor to end users. Therefore, Philips uses "Green Focal Areas" that capture the main life-cycle aspects: energy, hazardous substances, weight, packaging and transport, and recycling and disposal. Analyzing not only Philips products, but also competitors' products in an environmental benchmark, and formulating improvement actions in terms of the green focal areas, has resulted in target-oriented actions. As a result, the percentage of Philips Green Product sales increased from 20% in 2007 to 31% in 2009, whereas 90% of the Philips TV portfolio has been awarded the EU Ecolabel after verification that the products met the EU's environmental and performance standards.[7] In September 2010, Philips launched its Econova LED TV (Fig. 2). Based on its "holistic approach to eco-design," Philips received the European Green TV EISA award 2010-2011 for this television.[8] In addition, the Dow Jones Sustainability Indexes Review 2010[9] identified Philips Electronics as a global sustainability leader for the Supersector "Personal & Household Goods 2010-2011."

Emerging Legislation

Over the past decade, many world regions have proactively started to accelerate their legislative activities in the environmental field. European directive 2002/96/EC on waste electrical and electronic equipment (WEEE)[10] ensures that products are being recovered and recycled, while directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS)[11] aims to limit environmental impact when the products have reached the end of their life. Display makers are urged to proactively meet the targets, as outlined in these directives, such that TV manufacturers can in turn meet their increasingly strict "green" requirements.

The amount of energy consumed by products during their life is also now being regu-

Fig. 2: The Philips Econova LED TV, 42PFL6805, features an LCD with an edge-lit LED-based backlight.

lated. In the year 2005, Europe published the framework directive 2005/32/EC[12] on eco-design of energy-using products (EuP). Under the EuP framework, a number of implementing measures were and are currently being developed that will address various product categories; some measures will even address specific aspects of product energy use, such as standby, independent of product categories. Products unable to meet the requirements for a category will not be allowed for sale on the European market; *i.e.*, the 27 independent sovereign European countries. One of the implementing measures addresses televisions, whereas another addresses computers and their monitors.

Commission regulation (EC) No. 642/2009[13] addresses eco-design requirements for televisions. Among other details, it sets limits on standby and on-mode power consumption of a television. For the on-mode power consumption, the following requirements apply:

As of 20 August 2010, the on-mode power consumption of a television with visible screen area A, expressed in dm^2, shall not exceed the following limits:

- ***Full-HD resolution:***
  $20\ W + A \times 1.12 \times 4.3224\ W/dm^2$ (1)
- ***All other resolutions:***
  $20\ W + A \times 1.00 \times 4.3224\ W/dm^2$ (2)

From 1 April 2012, the on-mode power consumption of a television with visible screen area A, expressed in dm^2, shall not exceed the following limits (for an example, see Fig. 3):

- ***All resolutions:***
  $16\ W + A \times 3.4579\ W/dm^2$ (3)

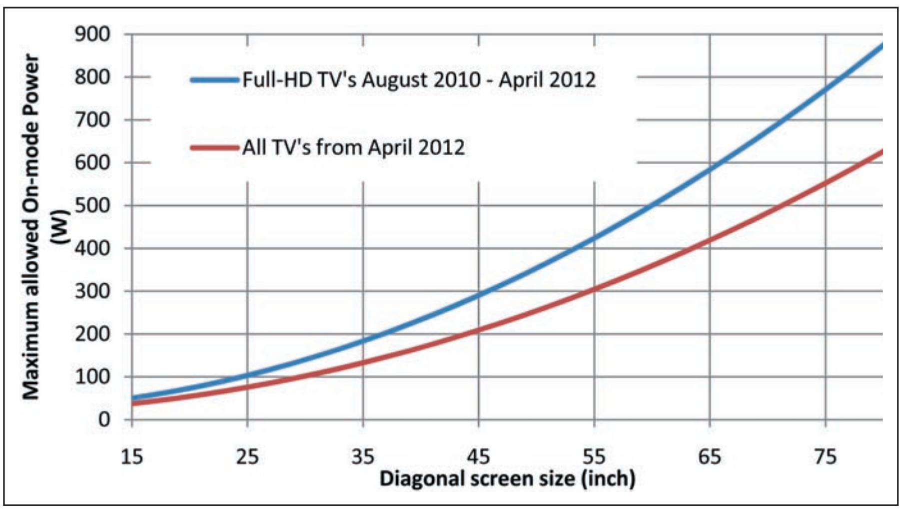

Fig. 3: *EC commission regulation[13] sets limits on the maximum on-mode power consumption for full-HD televisions as a function of diagonal screen size, Eqs. (1) and (3).*

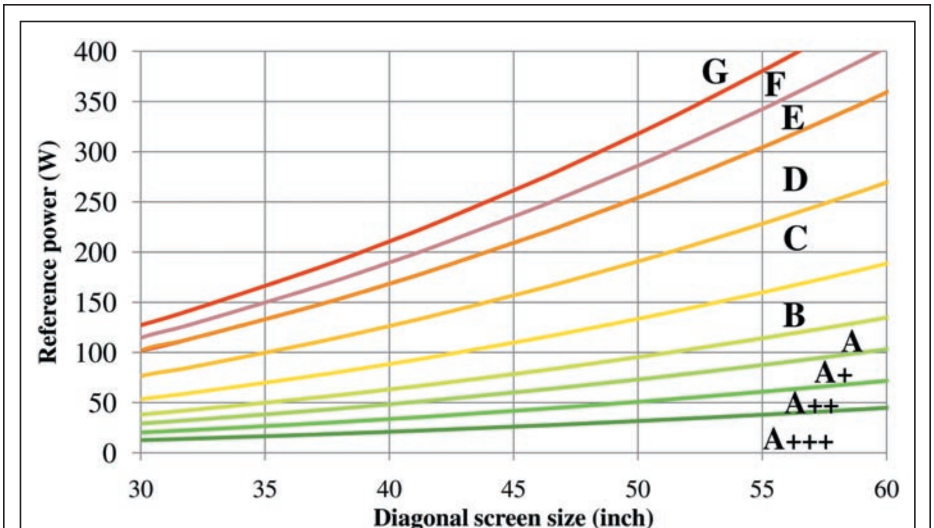

Fig. 4: *The above chart shows the power limits for the proposed energy efficiency classes for televisions as a function of diagonal screen size, derived from draft EU commission delegated regulation.[15]*

Televisions may have several modes that are preset by the manufacturer. The maximum allowed power consumption, but also the energy label, will be based on the energy use in the TV manufacturer's recommended "home-mode." To avoid televisions being put on the market with an unrealistically low luminance, *i.e.*, low power, in the "home-mode," a minimum luminance ratio of 65%, between the luminance measured in the brightest on-mode offered by the TV and the actual luminance in the "home-mode," has been defined. The 65% value is based on a market study performed in the UK at the end of 2008.[14] The downside of this approach is that it does not reflect or anticipate the expected improvements in energy efficiency and the brighter settings that are achievable as a result of more efficient displays. Additionally, it does not take into account that, by the end of 2008, most televisions were tuned to optimize picture quality instead of balancing picture quality with power consumption. Finally, it shall be noted that the test patterns to measure the actual luminance ratio have not yet been defined.

Next to the EcoDesign requirements, a labeling scheme that has proven to be successful in guiding consumers toward more energy-efficient white goods and home appliances sold in the EU market is currently under debate.[15] A political agreement has been reached that the existing A–G scale will see an expansion with A+, A++, and A+++ classes. (For an example, see Fig. 4.)

Periodic rescaling when more than a third of products reach the A++ or A+++ classes is foreseen. The energy labeling implementation measures for TVs are expected to be published by the end of 2010 at the earliest and could be relevant for products released on the European market 1 year after publication.

TV Power Consumption

In order to estimate the annual energy usage of TVs, IEC standard 62087[16] was revised to better reflect actual power draw during normal home TV-viewing conditions. A 10-minute dynamic broadcast-content video signal was created that contains various television fragments that represent a global average of what people watch on their TVs. The method of measuring the on-mode power consumption is rather straightforward; after an initial stabilization period, a meter will record the energy consumed during the playing of the 10-minute video, with all picture settings in the default, manufacturer recommended values. This international standard is now widely used to measure the on-mode power consumption for televisions.

Energy use in a TV not only depends on a vast amount of technological factors, but also on system-level implementations. The main technological factors are the type of display technology (CRT, LCD, PDP, and OLED), efficiency of the light generation, and power-supply efficiency. System-level aspects related to energy use are identified by set architecture, features offered, ancillary instruments (*e.g.*, light sensors), software algorithms, and default picture settings. IEC standard 62087 provides means to measure the power savings related to these features.

All flat-panel-display technologies are targeting reduction in energy usage to meet eco-design requirements and "Green" labels. LCD panels, dominant in both TV and monitor applications, are moving toward better efficiency through the use of technologies such as better optical films[17] and LED applications allowing localized dimming.[18] In the meantime, their energy efficiency has surpassed that of the CRT (see Fig. 5 for an example).

Energy efficiency measures in display technology need to go hand-in-hand with measures of reducing the power consumption of TV sets. Automatic adjustment of the display luminance as a function of ambient illumination is one example for reducing power. Another is video-based backlight dimming.

On the other hand, pushing innovations that are aimed at higher numbers in the product specification may have a negative impact on the TV power draw.[19] An example is the number of addressable display pixels. When the display has more pixels than the human eye can resolve at a given viewing distance, more power is consumed (smaller cells are typically less efficient) for the same perceived image quality. Another example is extending the display's color gamut beyond the gamut transmitted in the video broadcast material. Without a clear strategy to use the extended color space, this could result in less-energy-efficient displays without obvious benefits for the end-users. Therefore, we encourage the display industry to carefully consider the environmental impact when pushing technological innovations.

Level Playing Field

TV manufacturers operate in a highly competitive market and therefore legal requirements should support a level playing field. For products that are targeting the same consumers, the same energy-efficiency requirements should apply regardless of the technology that is being used. In most countries where legal requirements are established, this is ensured but there are exceptions, such as in China, where minimum requirements and a mandatory energy label for television are expected to enter into force in the short term.[20] The standards are established as such that separate less-stringent requirements are set for televisions with plasma displays as compared to liquid-crystal displays. This not only leads to misinformation for consumers when comparing power consumption of televisions, but also disrupts the market as some TV manufacturers are forced to make a bigger

Fig. 5: *A typical 32-in. CRT television in 1999 weighed around 45 kg and consumed 150 W, whereas nowadays a 32-in. LCD TV weighs 11 kg and consumes less than 90 W.*

investment to achieve the same grade on an energy label.

Governments not only play a vital role in establishing a level playing field through legislation, but must also be active in enforcement through verification. For example, consumers have become more conscious of energy efficiency and demand environmentally friendly products as one of the ways to reduce their electricity bills. Energy labels provide energy-efficiency information in a transparent way and have already proven to be successful in guiding consumers toward more energy-efficient products. When consumers purchase a new television, computer, or household appliance, they need to be confident that the information provided on the label is correct, meaning accurate and measured in compliance with the applicable legislation and standards. A study published in November 2009[21] and performed on behalf of the UK's Government Department for Environment, Food, and Rural Affairs (DEFRA), showed that 16 out of 24 washer driers tested did not perform in accordance with all declarations on their labels. Furthermore, four of the washer driers tested were unable to dry to the required level, which means that even where consumers have bought an apparently energy-efficient appliance, the need to dry clothes for longer periods of time may result in higher energy use than suggested on the label. Verification by authorities contributes to the credibility of the energy label and also assures that brands, willing to invest in sustainability, are rewarded for their energy-efficiency-related innovations and investments.

Conclusions

The demand for large-sized televisions is increasing. Global trends including the environmental consciousness of consumers and emerging legislation in all world regions continuously impose challenges for all consumer-electronics companies, such as TV manufacturers, to live up to. Consumers are increasingly sensitive to energy consumption because of the already existing labeling in the white goods sector and increasing legislation to ban incandescent light bulbs. Tools such as energy labeling for television products will provide relevant information more transparently. Legislation, scarcity of natural resources, and prevention of massive landfill problems demand recyclable products, which in turn require components and materials free of banned and hazardous substances. Consequently, the display industry needs not only to proactively contribute to meet legislative measures, but also provide transparency in used materials and underpin claimed energy efficiency with established measurement standards. A level playing field must be established through legislation, but verification by authorities is essential to assure that brands willing to invest in sustainability are rewarded for their energy-efficiency-related innovations and investments. Some innovations, such as LEDs and polarization recycling optical stacks in LCDs, already contribute to reducing energy bills. Only through continuous incremental and breakthrough innovations, particularly in the display industry, can TV manufacturers contribute toward reducing the environmental impact of TVs while at the same time capturing opportunities to continue doing business.

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Making a Greener TFT-LCD

Recently, green technology has become a key driver for TFT-LCD development. Green technologies in TFT-LCDs include product designs that are environmentally friendly, alterative manufacturing processes, and more. Achieving high transmittance of an LCD cell as well as reducing overall system power requirements are key elements, along with clean process alternatives for manufacturing. These are the most promising approaches for green TFT-LCDs. The authors from AU Optronics will describe the process involved in making a greener LCD.

by Po-Lun Chen and Ming-Kwan Niu

THE FIRST WAVE OF TFT-LCD development involved performance aspects such as contrast ratio, viewing angle, luminance, response time, and motion image quality. Cost reductions to allow more consumers to afford TFT-LCDs or to stimulate customers to purchase more TFT-LCDs were the second wave. Recently, a third wave of development has begun – green products and processes.

Green Considerations at AUO

AUO launched its Green Solutions initiative in 2008, a company-wide mission designed to promote environmentally friendly innovations, procurements, production, logistics, service, and recycling. AUO's environmental goals for the coming 3 years include the achievement of an 80% waste-recovery rate, reducing water consumption per substrate size by 70% from 2004 levels, and reducing greenhouse gas emissions per substrate size by 70% from 2004 levels. In addition, AUO has begun actively pursuing business opportunities such as entering the green energy market, making its move from achieving energy efficiency to creating energy, with plans including the development of a new factory for solar-panel production.

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After much improvement and optimization, Auo's 46-in. "Eco Plus" TV panel promises a 30% weight reduction, 30% thickness reduction, and 30% energy-consumption reduction over previous similarly sized models. This panel also promises 66% product packaging efficiency with reductions in packaging space and shipment weight. Green logistics have been introduced into product design, so as to effectively enhance transportation efficiency and mitigate impacts to the environment

Cell Transmittance Improvement

For a TFT-LCD, power consumption can be reduced through better transmittance and smarter backlight loading. The following

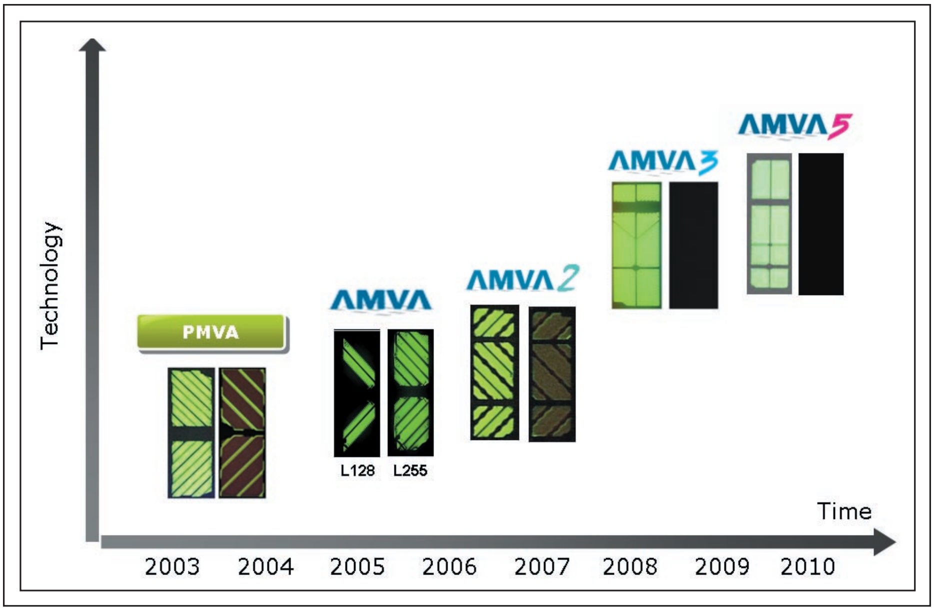

Fig. 1: AUO's recently developed AMVA5 technology significantly improves contrast ratio. (There is no AMVA4).

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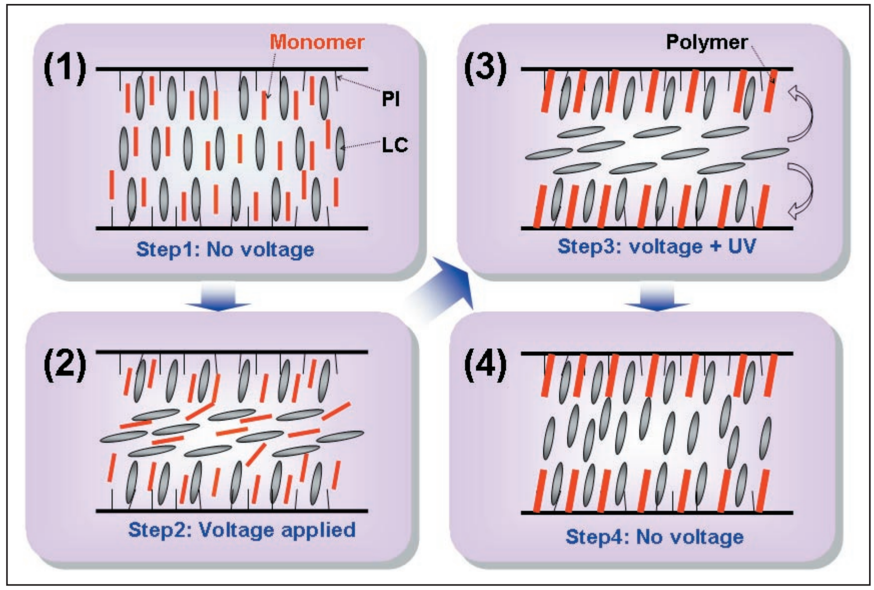
improvements have been implemented to achieve this.

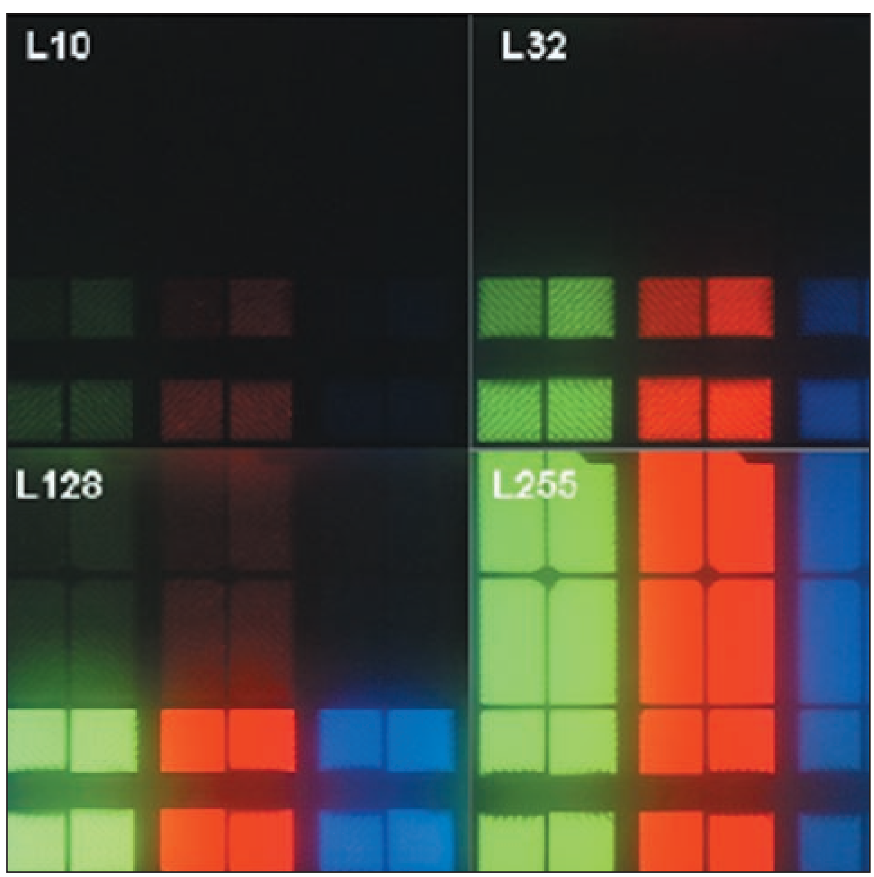
VA-LC modes: To achieve a significant transmittance improvement, the following aspects need to be improved: LC transmission, aperture ratio, and pixel-rendering methods. For better performance from a TFT-LCD panel, AUO developed a series of vertical-alignment (VA) technologies over the past few years (Fig. 1). Recently, the company developed its AMVA5 technology not only to improve the contrast ratio to 16,000:1, but also to enable an LC transmission improvement of 30% compared to AMVA1 in 2005. This was accomplished by effectively improving the LC disclination line using newly developed polymer-stabilized vertical-alignment (PSA) technology.[1]

The key control mechanism in PMVA is to impose protrusions on a color-filter (CF) substrate in order to make VA-LC subpixels (single red, green, or blue pixels) having a four-domain orientation. The key concept in AUO's AMVA[2] for eight-domain VA is to use a capacitive coupling method with an ART transistor that can provide good color-washout performance. AMVA2 is an improved version of AMVA in terms of contrast ratio. PSA, as shown in Figs. 2(a) and 2(b), was applied to AMVA3 to improve the transmittance for an eight-domain VA, and AMVA5 provides further improvements in contrast ratio and transmittance via storage-capacitor modification and CF material optimization.

Pixel aperture ratio: Another way to improve cell transmittance is to enlarge the aperture ratio of a pixel. Several methods used to achieve a higher aperture ratio can be adopted, including narrow bus-line design, closer electrode arrangement, and black-matrix (BM) shielding area shrinkage. For narrow bus-line design, a lower resistivity metal such as copper (Cu) should be considered. The Cu process[3] and design are other important aspects for aperture-ratio improvement, especially for products larger than



(a)



(b)

Fig. 2: AUO's AMVA5 PSA technology provides good transmittance that in turn reduces power consumption. (a) The technology incorporates the basic PSA process and the LC molecular reorientation principle. (b) The microscopic photography of the uni-pixel shows that the PSA operates at different gray scales.

65 in. and 2k × 4k at 120 Hz. For closer electrode (bus lines and pixel electrode) arrangement, ultra-high aperture (UHA), color filter on array (COA), shielding metal under the bus line, or placing a bus line under the shielding metal structures are possible ways to improve aperture ratio. These methodologies can provide about 10–20% aperture-ratio improvement, depending on the pixel size and LC modes used. For the shrinkage of the BM shielding area, an acceptable optimization between light leakage and BM shielding can be considered. The assembly accuracy of the upper and lower glass substrate during manufacturing also influences the BM shielding-area design quite a bit. The BM shielding area is always tightened if the assembly process is not accurate. COA also provides a good solution because the BM as well as the R, G, and B color layers are all fabricated in the bottom substrate.

RGBW rendering: Pixel rendering with red, green, blue, and white subpixels is also an effective way to improve transmittance. A color LCD is made with a color filter with red, green, and blue subpixels. However, more than two thirds of the light from the backlight is filtered out. If white subpixels can make up a specific ratio of the total display area, the transmittance of the LCD will be increased. A technique for mapping the color reproduction from a conventional red, green, and blue color system to a red, green, blue, and white color system can be developed without sacrificing too much color performance. By using this method, the transmittance can be improved by about 20%. However, faded color and the existence of some artifacts are two challenges of RGBW rendering.

Backlight and Electronics System

Local dimming is an effective way to reduce the power consumption of a TFT-LCD. With this technology, the backlight does not need to be continuously on at the highest brightness; the power consumption can thus be reduced by a factor of 2 or more. A 32-in. TFT-LCD, for example, with a conventional back-lit driving method, needs 100 W for the module, but only 50 W or less are needed for a module that utilizes local dimming, and the CR can also be significantly improved. LED backlighting is necessary for the local-dimming design.

Color-sequential displays without a color filter. Color-sequential displays without CFs[4] can reduce power consumption by a factor of about 50%. This methodology also provides a boost in contrast ratio. However, there are no effective LC modes that can provide fast response times for a field-sequential operation. Optically compensated bend (OCB), ferroelectric LC (FLC), and the currently popular blue-phase LC are three LC modes that could possibly provide a response time smaller than 1 msec. However, OCB requires a complicated optical film compensation that is currently not adopted for TV-LCD applications. (For more aboult OCB mode and blue phases, see the November 2008 and November 2009 issues of *Information Display*, respectively.) FLC has a very fast response time but requires a small cell gap of about 1 μm so that it also can not be used for current TFT-LCD applications. Blue-phase LC will provide a fast response of below 1 msec for each gray-to-gray switching, but several issues with the material itself still need to be resolved.

Green Product Design: Thickness Reduction with LED-Backlit Modules. Another key to delivering a green product is to reduce the module thickness. It not only saves the materials used but also provides advantages when being transported and packaged. The most popular way to reduce the thickness of a TFT-LCD module is to use LED backlighting. Conventional direct-type CCFLs result in a module thickness from 100 to 40 mm. An edge-type LED module design is required to reduce the thickness as well as the weight. Thus, a module as thin as 20 mm or even thinner is possible. However, the trade-off between local dimming (by using direct 2-D array LEDs) and thickness reduction (by using edge-type LEDs) needs to be considered. The main focus of the direct 2-D array LED module is to introduce a good radiation pattern by optimizing the number of LED chips used and the thickness of the gap between the LEDs and optical films. The main focus of the edge-type LED module is to introduce an light-guide plate (LGP) to maintain a uniform light distribution. Figure 3 shows an LED-backlight module for TFT-LCD TVs. It provides thickness reduction and local dimming.

Table 1 sums up the key approaches that AUO employs in fabricating more eco-friendly panels. AMVA5, Cu bus line, and COA are all technologies used for pixel aperture-ratio improvement. By using these methods, a product that consumes less power can be delivered. Besides, slim LEDs not only provide better color reproduction, they also make slimmer and lighter-weight products.

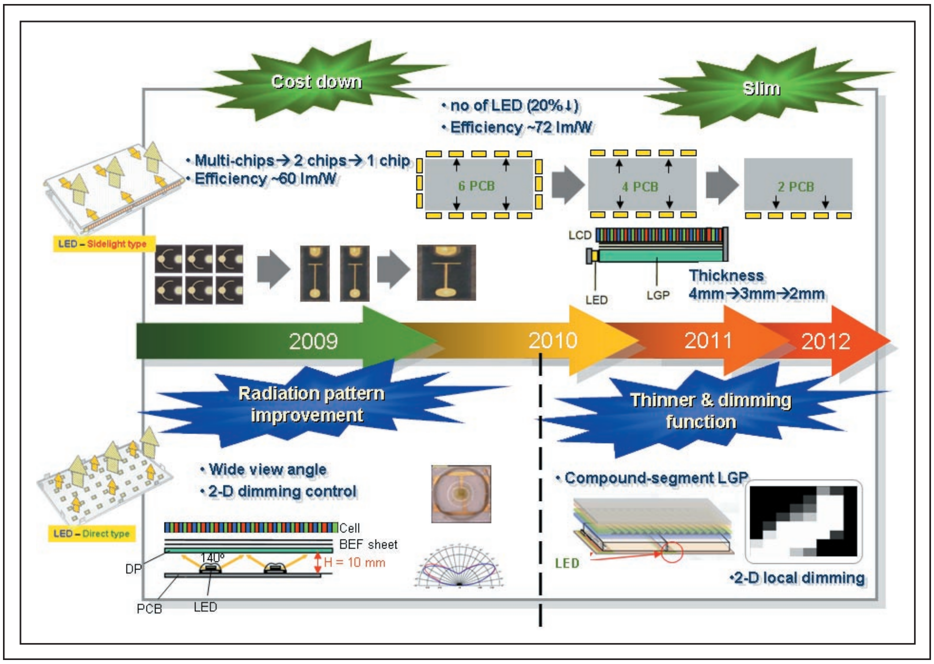


Fig. 3: *Progress for LED-backlight modules for TFT-LCD TVs from 2009 through 2013 includes thinner form factors and improved dimming functions.*

Table 1: AUO uses several methods, as shown below, in order to achieve a low-power, lightweight product.

Technology	AMVA5	Cu	COA	Slim LED
Green advantage	High cell transmittance	High aperture ratio	High aperture ratio	Thin & lightweight
Size	55-in. FHD	55-in. FHD	46-in. FHD	42-in. FHD
Frame rate	60 Hz	120 Hz	60 Hz	60 Hz
Brightness	500 nit	500 nit	500 nit	500 nit
Power consumption	150 W (30% ↓)	150 W	68 W (× 1/2.5)	—
BLU type	CCFL	CCFL	CCFL	Side LED
Driving scheme	—	3 sides	—	—
Thickness	—	—	—	11 mm (× 0.31)
Spec. w/normal technology	220 W	4 sides	170 W	35 mm
Announced at	FPD Intl. 2009	Display Taiwan '09	China FPD 2010	FPD Intl. 2009

Green Manufacturing

It is also very important to keep reducing the power consumption and waste generated when products are produced. AUO has set targets of a 90% process water-recovery rate, a 90% construction waste-recovery rate, and 21% in total energy savings.

AUO's LEED-Certified Fab

AUO's L8A fab (Gen 8.5) is the world's first Leadership in Energy and Environmental Design (LEED), a U.S.-based internationally recognized green building-certification-program gold-certified TFT-LCD fab. There are only five LEED gold-certified facilities in the world at this time, and among them the AUO fab is the largest in terms of facility size and is also the world's first TFT-LCD hybrid fab, consisting of both Gen 8.5 and 7.5 lines. It can deliver 21% in total energy savings, compared to a fab without green technology incorporated, equivalent to US$9 million per year when fully operational. The site is designed to achieve a 90% water-recovery rate, saving 3 million tons of fresh tap water annually – enough to fill 1430 standard swimming pools. In addition, 90% in construction waste has been reclaimed. Furthermore, with extensive tree plantings, as well as 130M kWh of power savings per year, the AUO Gen 8.5 fab can deliver a significant 87,000 carbon emission reduction annually, an effect equivalent to that of 23 New York City Central Parks.

In order to make all this possible, the following innovations have been put into effect:

- (1) *Uninterrupted Exhaust-Driven Wind-Power Generator:* AUO installed wind turbines on top of some air outlets. These turbines, operating at speeds selected so as not to affect air-flow efficiency, are capable of generating more than 100 kWh of electrical power per day.
- (2) *Waste Heat Recycling:* The waste heat from the chilling system is used to generate the preheating and reheating energy for the MAUs (Fig. 4).
- (3) *Dual-Temperature Chilled-Water System:* In the past, AUO used water chilled to a single temperature (8°C) to cool all process equipment. But for the new fab, the company implemented temperatures in dual mode (8 and 14°C) to meet the cooling demands of different equipment. (Energy consumption simulations helped ensure the feasibility of this method beforehand.)
- (4) *Water Inter-Use System (WIS):* The WIS uses an innovative design that connects manufacturing process points so as to save 335,000 tons of water annually.

Green Manufacturing Alternatives

Ink-Jet Printing (IJP) for the CF Process. This is another key green consideration to reduce power consumption and waste during production. The conventional process for array fabrication is a vacuum-based photolithography process. A five-mask array process is used to repeat a cycle of functional layer deposition, photoresist (PR) coating, photoexposure, PR developing, etching, and

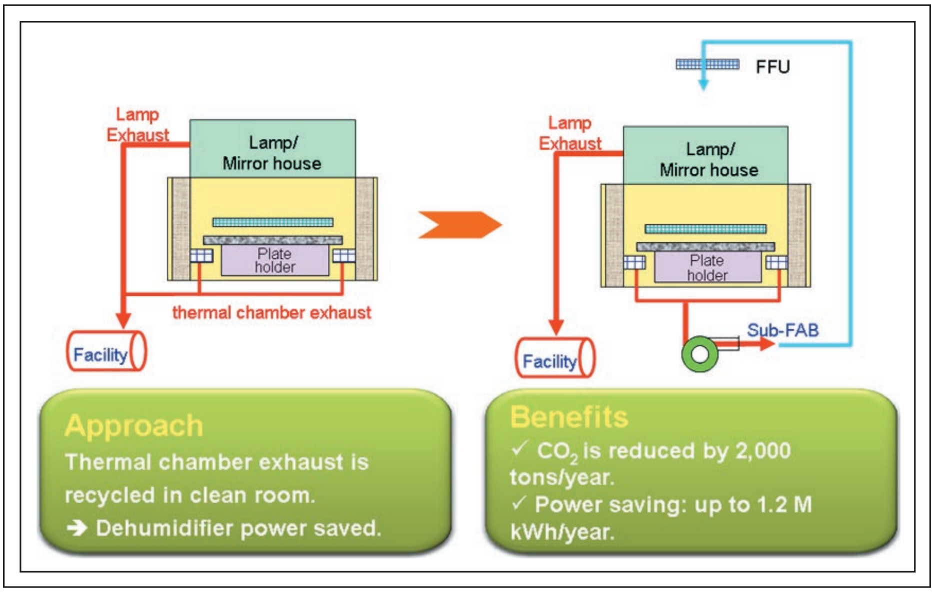


Fig. 4: *Waste-heat recycling: the thermal chamber exhaust is designed to be recycled in a clean room to spare the de-humidifier from using power. The equivalent power savings is as high as 1.2M kWh/year in a fab.*

PR stripping. If we can directly deposit the functional layer with the expected pattern, only a few minutes instead of the usual one- to two-day cycle is required. Printing methods including gravure printing, flexo-printing, and ink-jet printing (IJP), which can dispense the functional layer in targeting positions, are good methods of implementing direct patterning. AUO has tried to implement IJP processes to fabricate photo-spacers, alignment layers, and even R, G, and B layers of a CF. However, IJP cannot only save the material consumption, but also simplify the process steps. Figure 5 shows an illustration of R, G, and B fabrication for both the conventional process and the IJP process.

The use of the IJP CF process is estimated to reduce CO_2 consumption by 20,087 tons/year based on a Gen 7.5 fab with 120K capacity. It is equivalent to the CO_2 consumption that would be used in driving a car 139,000 times around the island of Taiwan. (Note: 1 tree = 4.5 kg/year; 1 car = 0.2 kg/km). Besides, it also saves on material consumption and the number of photomasks used. Table 2 shows the advantage of IJP for the CF process.

IJP for Cell Process: IJP can also be used in cell processes for polyimide (PI) layer coating and spacing imposition. The conventional way to coat PI layers for LC alignment consists of roller coating by using an APR plate attached to a cylindrical roller. The PI is continuously supplied by another roller that requires more material (PI material and the consumption part) consumption compared to IJP. Figure 6 shows the operational principles for conventional and IJP PI processes. IJP can also be applied to impose the spacers on the glass substrate for the post-step cell assembly. The conventional way of imposing spacers is by photo-stripping, in which PR coating, photo-exposure, and stripping are all required. A small portion of the coated PR remains as the spacer. The IJP spacer process can eliminate a large amount of chemical use and also reduce equipment complexity. It seems to be a very good method for green production. Figure 7 compares the operational principles for conventional and IJP PI processes.

Four-mask array process: The current TFT process requires five repeating photolithography steps and is therefore referred to as a five-mask process. Each mask includes thin-film deposition, PR coating, photo-exposure, etching, and PR stripping as mentioned above. If one photomask exposure can be removed from the process, it means the company can save not only the cost of one photomask, but also one PR coating and stripping process. Thus, manufacturing space as well as chemicals can be saved.

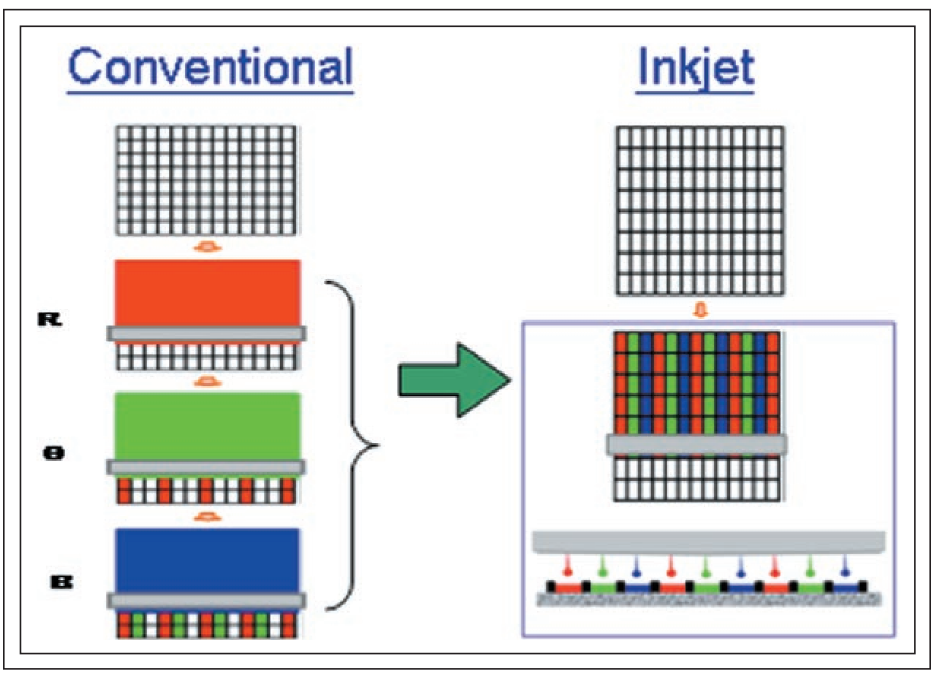


Fig. 5: *R, G, and B fabrication can be used for both the conventional and the IJP processes.*

Table 2: Ink-jet printing has advantages for the CF process.

	Conventional	**Ink-Jet Technology**
Photomask	– RGB mask method	– RGB mask free
Process simplicity	– Complicated: Exposure & development system	– Simple: Printing system
Material consumption	– Consuming more material: Two thirds of RGB material lift-off	– Material saving: RGB printing to the right position
Equipment & space	– More equipment & space Three photo-lines required	– Equipment & space saving: Printing system

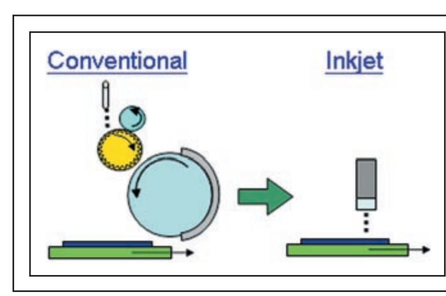


Fig. 6: *Operational principles for the conventional polyimide (PI) process and the IJP PI process are shown.*

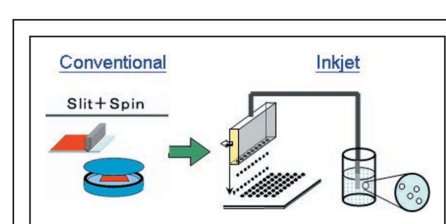


Fig. 7: *Operational principles for conventional spacer process and the IJP PI process are compared.*

Table 3: Shown is the estimated performance of CO_2 reduction by different methods.

Technology	CF by IJP	Exhaust-driven-wind facility	AMVA5	COA	Slim LED
Green advantage	• CO_2 emission ↓ • Materials ↓	• CO_2 emission ↓ (generate electricity)	• CO_2 emission ↓ (power saving)	• CO_2 emissionm ↓ • Materials ↓	• CO_2 emission ↓ (Transport saving)
Size	46-in. (G7.5: 6 up)	46-in. (G7.5: 6 up)	55-in. FHD	46-in. FHD	42-in. FHD
Power consumption	—	—	150 W (70 W ↓)	68 W (102 W ↓)	—
Thickness	—	—	—	—	11 mm (ˇ0.31)
Specs. w/normal technology	—	—	220 W	170 W	35 mm
Power saving (per pcs/per year use)	• 5.6 kWh ↓ (during production)	• 0.0047 kWh ↓ (during production)	• 127.8 kWh ↓ (5 hours/day in use)	• 186.2 kWh ↓ (5 hours/day in use)	(Transported 200 km by car & 2000 km by flight)
CO_2 reduction (per pcs/per year use)	• 2.3 kg ↓ (during production)	• 0.002 kg ↓ (during production)	• 53.3 kg ↓ (5 hours/day in use)	• 77.6 kg ↓ (5 hours/day in use)	• 2.5 kg ↓ (per transportation)

Total CO_2 consumption saving by IJP-CF:
• 20,067 tons/year (based on G7.5 120K)
• Equivalent to the electricity consumption: 20,087,000 kg/year = 48,208,800 kWh/year

Remark:
• 1 car = 0.2 kg/km (1 cargo: 1000 pcs)
• 1 flight = 32.5 kg/km (8 cargo: 8000 pcs)
• 1 kW device @ 1 day:
– 1 day = 24 hours ⟶ 1 kW x 24 hours = 24 kWh (electricity)
– 24 kWh ~ 21 kg (coal)
– 24 kWh ~ 10 kg (CO_2)

The Carbon Footprint of AUO's 32-in. Module

By converting the total power consumption during raw-material preparation, product manufacturing, customer usage, and final disposal to carbon emissions tells us the product's contribution from cradle to grave. The carbon estimation and calculation on four steps of the total pipeline are listed below:

- (1) *Stage 1 (Raw Material):* Issuing a questionnaire to obtain carbon footprint data; secondary data is used when primary data is not available
- (2) *Stage 2 (Manufacturing):* Inventory based on the experience of ISO14064 & ISO14040, and data obtained from primary data.
- (3) *Stage 3 (User Usage):* Measuring the power consumption based on Energy Star 3.0 STD and then follow-up with Top Runner, Japan's program to set the efficiency standards for a wide variety of products, to perform the calculation.
- (4) *Stage 4 (Disposal):* Based on the principle of dismantling WEEE 3R products, we calculated the ratio of recovery and recycling of materials, then referred it to the WEEE directive database for calculation.

Our estimation shows that about 60% of carbon emissions derive from consumer usage, while 28% comes from raw-material preparation and another 12% from manufacturing. These findings imply that very low power consumption is the most important feature in reducing TFT-LCD carbon emissions, while the use of better materials with low carbon emission and green processes for manufacturing are another two key principles.

Power-Consumption Discussion

We have already discussed green technology in terms of both product and manufacturing advances adopted and developed by AUO. Another area of interest is the analysis of the power consumption of a product during its entire lifetime. Two key considerations are the power used during manufacturing and the power used to operate the display. If we take 1 year as the standard calculated time period for power use and translate this power into CO_2 emission, we find that the CO_2 emission for AUO's eco- designed products are 53.3, 77.6, and 2.5 kg for AMVA5, COA, and slim LEDs, respectively. Table 3 shows the estimated performance of CO_2 reduction brought about by different methods.

Conclusion

Green TFT-LCDs can be achieved through innovative designs to achieve more efficient transmittance and smart backlighting systems. It seems that the high transmittance of an LCD cell as well as low power considerations from a systems point of view, as well as clean process alternatives for manufacturing, are the most promising approaches for green TFT-LCDs. We also drew up a roadmap of product carbon footprint reduction, aiming at a 30% decrease in carbon footprint levels from 2009 by 2012, to help generate an all-new low-carbon product for consumers.

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[4]H-P. D. Shieh, *et al.*, "Invited Paper: An LCD-TV Powered by a Battery?" *SID Symposium Digest* **40**, 228(2009). ■

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LQ030B7UB02	LQ057Q3DG01	LQ104V1DG81	LQ150X1LG91
LQ035Q3DG01	LQ057Q3DG02	LQ104V1LG81	LQ185T1LGN3
LQ035Q3DW02	LQ070Y3DG3A	LQ121K1LG52	LQ190E1LX51
LQ043T3DG01	LQ070Y3DG3B	LQ121S1LG81	LQ215M1LGN2
LQ043T3DG02	LQ070Y3LG4A	LQ121X3LG02	LQ231U1LW31
LQ050W1LA0A	LQ104S1DG31		

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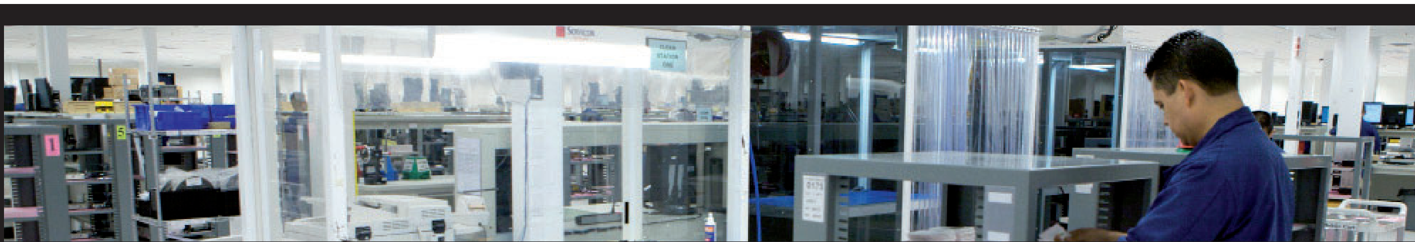
- Motion sensing lighting control throughout
- Work from home schedules and shared printers
- Green cleaners used throughout facility
- Recycling events for old PC equipment
- One-half ton of cardboard and pallets recycled daily
- Employee carpool rewards



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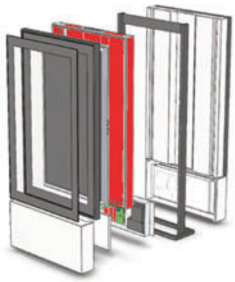
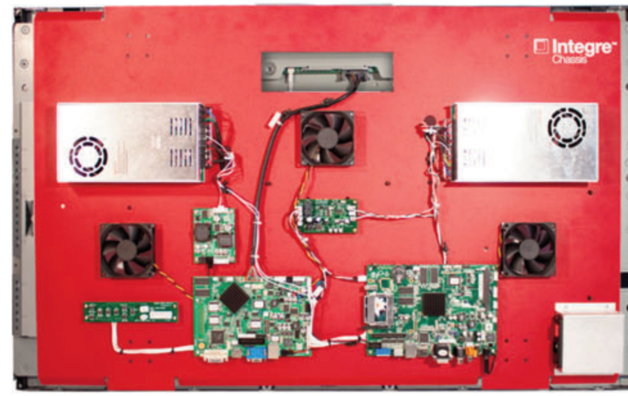


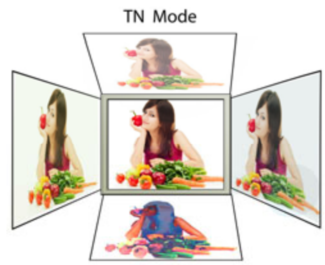


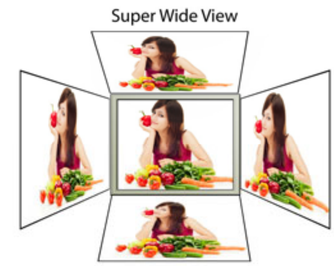
Optrex New Technology Spot Light

Super Wide View Technology for TFT-LCDs

Super Wide View technology reduces the amount of light scattering in the matrix, provides a super wide viewing angle of greater than 170º and ensures that colors will be the most accurate when viewed from any direction.

This technology is well suited for graphic designs, medical devices, and other applications that require accurate and consistent color reproduction with super wide viewing angles.





Features:

- Wide viewing angle of 85/85/85/85
- Minimum color shifting from any angle
- No image inversion, best image performance

Applications:

- Medical devices
- Testing equipment
- Avionics and automotive

Part number	Size (inch)	Resolution	Brightness (Cd/m^2)	Contrast Ratio	Viewing Angle	Interface	Operating Temperature (C)
T-55423GD050J-LW-A-AAN	5.0	800 x 480	200	500:1	85/85/85/85	CMOS	- 20 ~ 60
T-55583GD050J-LW-A-AAN	5.0	800 x 480	800	900:1	85/85/85/85	CMOS	- 20 ~ 70
T-55561D090J-LW-A-AAN	9.0	800 x 480	400	900:1	85/85/85/85	LVDS	- 30 ~ 80
T-55618D090J-LW-A-AAN	9.0	960 x 540	400	1000:1	85/85/85/85	LVDS	- 20 ~ 60
T-55519D150J-LW-A-AAN	15.0	1024 x 768	350	1000:1	85/85/85/85	LVDS	-20 ~ 70
T-55519D150J-LW-A-ABN	15.0	1024 x 768	1100	600:1	85/85/85/85	LVDS	-20 ~70

Note: Specification subject to change without notice

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Features:

- Super high contrast ratio
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- Minimal color shifting from any angle

Applications:

- Medical devices
- Point of sales, ATM machine
- Testing equipment and automotive

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Do Consumers Really Go for Green?

The market for green consumer goods has held steady, even through the recession. Green electronics, including those with displays, appear to be an important part of that market into the future. But determining which types of green electronics will sell, and why, is far from an exact science.

by Jenny Donelan

HOW IMPORTANT is environmental friendliness when it comes to the purchase of a product? Judging from the proliferation of "green" items for sale – from planet-friendly paper towels to hybrid cars to mobile phones made from recycled plastic – the answer would seem to be "very important." But are such offerings more a nod to product differentiation than a testament to the concerns of companies and customers for the planet? Do consumers really care about buying a television that uses less energy when they can buy a more power-hungry model for less money? The answer is yes – and no. The underlying reasons why people make purchases of any kind are, as advertising agencies have known for years, as much based on emotion as practicality.

Consumer Motivation

People buy green for many reasons: to save money, to make a statement, to act in accordance with their lifestyle, to keep themselves and their families safe – or any combination of these and more. The lifestyle factor is probably the easiest to predict for a certain segment of the population. These are the people who are almost always going to make the "environmentally correct" choice, and they tend to be educated with regard to what that is. For example, most of the televisions on sale at Best Buy stores in the U.S. carry the label for complying with current Energy Star regulations. But the labels, or lack thereof, are not always a point for buyer comparison. As Chris Curran, a Magnolia Home Theater specialist at Best Buy in Dedham, Massachusetts, puts it, "I wouldn't say that a lot of people pay attention to it, but there's always a handful that do."

Saving money by buying green resonates with just about everyone, but customers need to be convinced of the payoff. Replacing an elderly refrigerator is an obvious wise move, for example. If you own a large side-by-side that was built between 1980 and 1989, you are probably paying about $250 a year to run it. If you were to replace it with an equivalent new Energy Star model, your electricity costs would plummet to about $60 a year. You would save nearly $1000 over a 5-year period.[1] It is true that some individuals have trouble thinking that far ahead, and certainly there is the matter of having to pay for the new refrigerator up front. (And once you do take the plunge, the installer may explain that you will be lucky if it lasts 5 years, but that's another story.) In general, most consumers understand that large, old appliances gobble electricity. Large TVs, however, do not trigger that kind of recognition. People are not accustomed to thinking of TVs as potential energy hogs, and they are not as likely to shop accordingly – at least not yet.

As the TV page on the Energy Star Web site notes, "TVs are getting larger. In fact, some of the largest, high-resolution direct-view TVs (versus rear-projection products) can use as much electricity each year as a new, conventional refrigerator, or roughly 500 kWh, every year." [2] Energy Star is a joint program between the Environmental Protection Agency and the U.S. Department of Energy that was introduced in 1992 to promote energy-efficient products and practices. Its site also states that Energy-Star-qualified TVs use, on average, 40% less energy than non-qualified units. Even among the approximately 730 qualified LCD, plasma, and other models listed as having met the requirements, energy usage varies a great deal, with display size being the surest predictor. 19-in. LCD TVs from one major manufacturer, for example, consume between 49 and 58 kWh/year. 47-in. models from the same manufacturer range from 132 kWh/year to well over 200 kWh/year, and the company's 60-in. unit consumes 367 kWh annually. In stores, qualified TVs come with basic Energy Star labels earned on a pass/fail basis, with no ratings, but interested buyers should consult the spreadsheets available in both PDF and Excel formats on the Energy Star TV pages.[2] kWh consumed per year are listed for each model, as well as many other specifications, including screen resolution, power consumed in sleep mode, and luminance in default mode as shipped.

Making a statement is yet another motivator for buying green. Earlier this year, the *Journal of Personality and Social Psychology* published a widely circulated article, "Going Green to Be Seen: Status, Reputation, and Conspicuous Conservation," which proposed

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that many individuals buy lower performing, higher priced products for the sake of showing that they care, and perhaps also to show that they can afford to care.[3] One of the authors' primary examples is the highly successful Toyota Prius, a hybrid gas–electric car that is less expensive to fuel and has lower emissions than many cars, but often costs more up front than a comparable well-performing, conventional yet still fuel-efficient car. Because a car in particular makes a public lifestyle statement, the authors suggest that "Prii" can serve as "conspicuous displays of altruism" that convey social status on the buyer. Their research even suggests that many green products that do not come at a price premium are less attractive to buyers (from this standpoint, an inexpensive, non-motorized push lawnmower has less appeal than a more expensive, gas-powered ride-on model) and that people tend to buy fewer green products for private use when there is no possibility of gaining status through doing so. In the case of the push lawnmower, however, very few people would be willing or able to mow an acre of grass with one. Some personal sacrifices are just too great, even if the entire neighborhood is watching. An exception to the private use trend would be food and household cleaning products, many of which are perceived to present a potential hazard to users, who may opt for more "natural" or organic alternatives, particularly where offspring are concerned.

Green Sector Is Strong; Green Electronics Coming Along

Although their reasons may vary widely, many consumers are reaching for that green product on the shelf, according to a recent study from market-research-firm Mintel International Group. Mintel's February 2010 report, "Green Living – U.S.," found that the green market, which had expanded rapidly for several years, went essentially flat in 2009; in other words, it outperformed the overall economy at the time. Mintel forecasts that the market will increase in step with the economy, and, in any case, "will continue to outperform the larger U.S. consumer market for the foreseeable future."[4]

According to Mintel senior-market-research-analyst Colleen Ryan, "55% of consumers claim that they are willing to pay a premium for green products in general. This number fell sharply during the recession, from 70% in 2008 to 55% in 2009." As stated above, Mintel expects these numbers to recover if and when the economy does. "Of course," says Ryan, "not all of those people will follow through on their green intentions, and the number who are willing to go out of their way to figure out which brands are green is much smaller." This is demonstrated in Table 1, which shows a breakdown for the influence of green factors on major purchase decisions.

Green Display Products

According to the Mintel report, green electronics products represent a growth area within green consumer goods overall. Many of these products contain displays. Cell phones, although small, have very short lifecycles and have thus come under scrutiny for their contribution to the e-waste stream. Major retailers such as Best Buy and Walmart now offer nationwide recycling programs, not only for phones but for many other electronic devices. But manufacturers are also looking at what goes into the products.[5] Companies such as Merck, which makes many of the materials that go into displays, such as liquid crystals, have made great strides in developing more energy efficient products and processes, helping the industry overall. The average consumer, however, is not tuned in to this part of the supply chain and is most likely to be attracted by a product that is clearly labeled "green."

One example of a green product that is marketed as such is Sony Ericsson's GreenHeart line of cell phones, which features reduction or elimination of "unwanted" substances, an in-line (as opposed to paper) phone manual, post-consumer recycled plastics, and water-borne paint. All this, claims the manufacturer, means that overall CO_2 emissions for these phones' "footprints" are reduced by approximately 15% over non-GreenHeart models. These phones (see Fig. 1) are streamlined but do not advertise their greenness in any obvious way.

Table 1: Mintel surveyed Internet users about the importance of green factors when making major purchases. Across the board, and for two consecutive years, the percentage of users planning to consider green factors in the future far exceeded the percentage of those claiming to have done so in the past. However, in most categories, including electronics, the overall percentages went up in 2009, a recession year, over 2008. Source: Mintel.

Influence of Green Factors on Major Purchases: 2008 and 2009

Major purchase by category	2008 Thought about green factors in last purchase	2008 Plan to consider green factors in next purchase	2009 Thought about green factors in last purchase	2009 Plan to consider green factors in next purchase
Base: Internet users aged 18+	2216	2216	2000	2000
Major appliance (such as washers, dryers, or refrigerators)	24%	46%	24%	52%
Cars or trucks	19%	50%	18%	51%
Small kitchen appliances (such as toasters, blenders, microwaves)	16%	51%	18%	54%
Paint or varnish	14%	49%	15%	52%
TVs, stereos, PCs, or other electronics products)	13%	50%	17%	53%
Other hardware or home supplies (such as floors or cabinetry)	11%	49%	11%	50%
Furniture	9%	48%	11%	50%

The analysts interviewed by *Information Display* did not have market share figures for green phones or other green products *vs.* non-green versions (nor did Best Buy), but they were much in agreement that, in the future, green might figure prominently into the purchase decision for televisions in particular. "I think it [greenness] is more important for a TV because consumers expect it to have a much longer life and it, self evidently, uses a lot more materials and power," says Bob Raikes, Managing Director for display-market-research-specialist Meko Ltd. "I don't have any data on the other items [laptops, phones]," he says, "but I would be surprised if greenness was a major factor."

Of course, as previously mentioned, consumer awareness of the potential for big TVs to draw energy is currently limited. Says Ryan, "As TVs get bigger, their impact on a family's energy budget becomes substantial. In theory, this should mean that people are willing to pay a premium for efficient TVs. Energy efficiency can be a strong motivator for products that consume a lot of energy, but so far there does not seem to be much public awareness of how much energy TVs consume. Product categories where consumers have been well-educated about energy costs and savings (major appliances and cars) are the leading categories for green shopping." She continues, "TVs and other displays are now so complex, with such an array of technical features, that most consumers are confused by all of the choices. We don't have specific data on this, but I suspect that environmental issues, even ones like energy efficiency, which can have a big impact on household budgets, get lost in the noise for the vast majority of shoppers."

***Fig. 1:** The 3G Cedar is a new member of Sony Ericsson's GreenHeart line, designed to appeal to environmentally conscious consumers. This model is set to launch in Europe in late 2010. Image courtesy Sony Ericsson.*

TVs and Energy Star

This is a situation that Energy Star has begun addressing. It collected data, for example, on consumer buying habits and awareness of Energy Star labeling for large-screen televisions for the first time in the biennial report, "2010 Energy Conservation, Efficiency, and Demand Response." Among the findings: of 676 surveyed consumers asked to report an unprompted product association with the Energy Star label, 31% named washing machines, 6% televisions, and 1% computer printers. Another interesting aspect of the Energy Star labeling – why it may not seem to matter, according to DisplaySearch analyst Norbert Hildebrand – is that more and more televisions are meeting the current Energy Star requirements, so that the label has become fairly common. In fact, notes Katharine Kaplan, Team Leader for Energy Star Product Development, the EPA is preparing to propose an earlier-than-planned effective date for the 5.1 requirements, as the number of products that now meet Energy 4.1 requirements is large. "Anecdotally," says Kaplan, "it's from 50 to 80% of the market." After 5.1 kicks in, presumably fewer TVs will sport Energy Star logos for a time, until everyone catches up, at which point the requirements will become harder to meet again. (For more about Energy Star 5.1, see this month's Industry News section.)

One of the reasons that companies are so far ahead of the game, notes Hildebrand, is that they are finding it behooves them to keep designing to meet future requirements. However, he cautions: "From a display manufacturer's point of view, this development is not gradual but in stages. For example, LCD backlights can become very efficient as you transition to LEDs from CCFLs. But what was easy this time may not be as easy for the next level of Energy Star requirements if no new technology [such as LED backlighting] comes to the market to allow an equivalent increase in efficiency." In other words, the schedule might be moved up but it could take the industry longer to catch up to the next set of requirements. Even so, catch up they will, eventually. And even if that means regulators such as the EPA in the U.S. and the EU in Europe keep raising the bar, everyone wins – the environment, the consumer, and, eventually, the company that is farthest along the way toward meeting or exceeding regulations – especially if the consumer can be convinced of the value of greenness.

With regard to that value, if customers currently do not base their display-product buying decision on environmental friendliness, what do they base it on? "It depends on which consumer we're talking about," says Hildebrand. "A certain percentage will do environmental factors, but price is probably the larger." Raikes believes the same thing. "I would say price, image, and energy consumption – in that order." In other words, consumers look for the best image quality they can get at their target budget price. Green is important, but low-power displays will not be successful if they do not look good. If a company can create a TV that combines great imagery and efficient operation at a reasonable price, it will command a powerful share in the marketplace.

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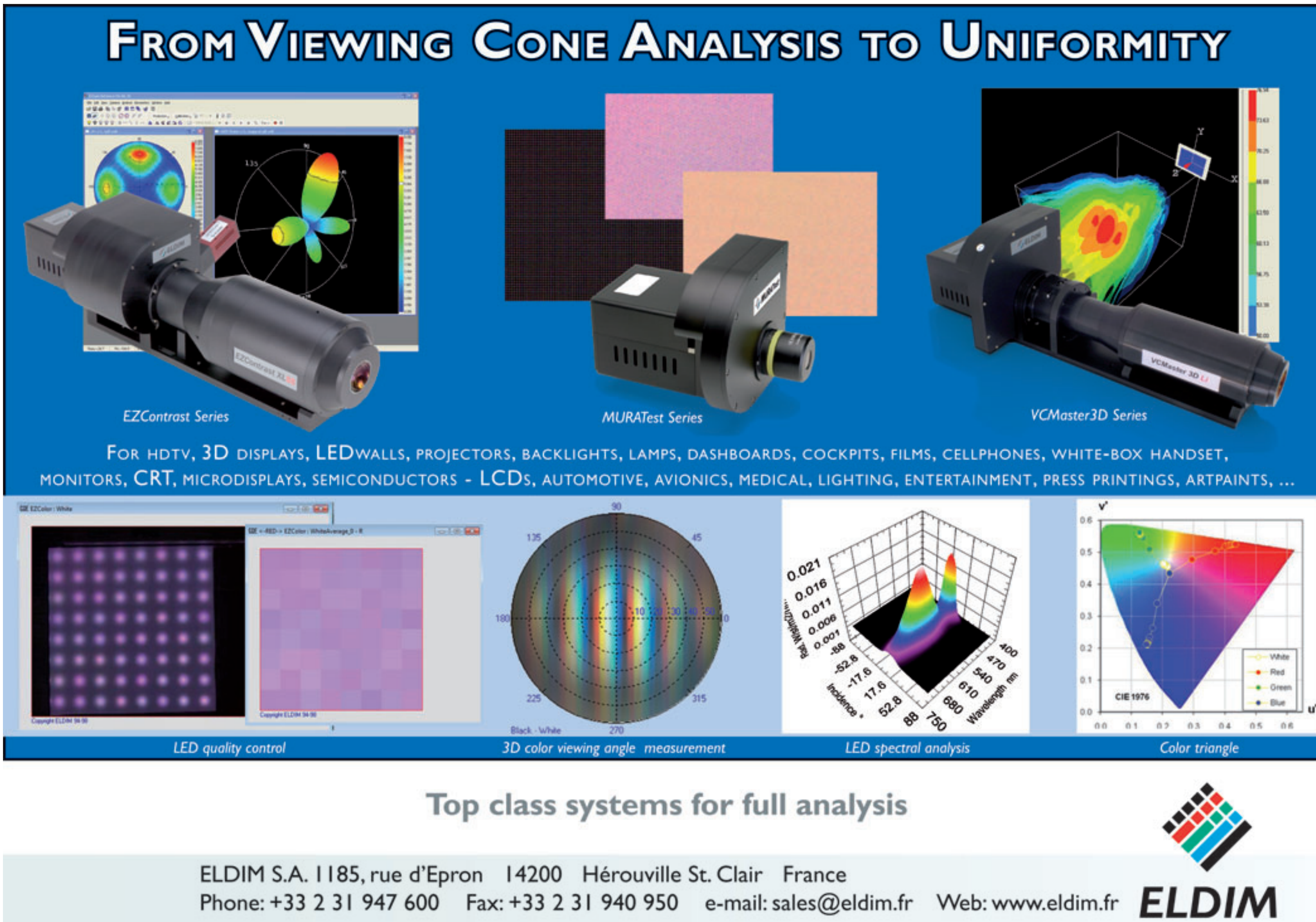
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3-D TV from the Consumer Perspective

Enthusiasm for 3-D TV will build more slowly than consumer-electronics manufacturers would like, but consumers will eventually take it up in large numbers.

by Matthew Brennesholtz and Chris Chinnock

2010 has certainly been the year of 3-D TV. Starting with the mega-promotions and hype for the Consumer Electronics Show (CES) in January, the noise, products, and promotion have been continuous. But is the consumer listening? And, more importantly, is the consumer buying? In this article, we will explore these questions more deeply, but the quick answers are yes and somewhat.

First, let's put this current cycle of 3-D in perspective. 3-D has had several boom and bust cycles with consumers over the last 60 years, but it has never really taken hold. There are perhaps two fundamental reasons why 3-D has a better chance of sticking around this time:

- ***Digital technology:*** The creation of 3-D content using digital production allows for much better control of key 3-D experience parameters. Digital displays eliminate many synchronization problems and other issues, allowing for a more stable 3-D experience.
- ***Innovation:*** The pace of innovation and product introduction is very rapid today; new technologies are continuously entering the market in a bid to find the right combination of price and performance to allow 3-D to take hold.

Waves of Technology

Although Insight Media predicts that the outcome will be different for 3-D this time around, a number of years will still be required for this most recent 3-D vision to be realized.

We see 3-D TV coming in a series of waves:

- ***First Wave:*** LCD and PDP 3-D TVs based upon active-shutter glasses.
- ***Second Wave:*** LCD 3-D TVs and home-theater projectors using passive, mostly polarized, glasses.
- ***Third Wave:*** OLED 3-D TV and glasses-free 3-D TVs.

These waves will overlap, with the first and second waves already a few years old, but are just now expanding into the mainstream consumer TV space. The first inklings of the third wave will arrive in 2011, but it will be years before these technologies form the basis of a more mainstream TV approach.

Although CRT-based 3-D TV had been around for many years, the first wave of modern 3-D TV actually started in about 2007, with the introduction of DLP-based 3-D-capable TV systems, as shown in Fig. 1.

Fig. 1: *This 3-D-ready DLP TV was shown at CES in 2007. Image courtesy M. Brennesholtz.*

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Many of the 2 million or so people who bought TVs like this were not even aware the sets were 3-D capable. The first wave is now well under way, with shutter-glass offerings from all the major CE manufacturers. In addition, at the CEDIA Expo for residential electronics systems this year, there were a significant number of 3-D home-theater projectors that worked with passive glasses.

The first wave has also been greatly aided by the introduction of key standards, including a 3-D Blu-ray standard and the HDMI 1.4a interconnectivity standard. These standards are required not only for the first wave, but will carry forward into the second and third waves as well.

Second-wave-type 3-D TV systems with passive glasses have been offered in the past, but not at competitive prices. Real introduction of competitive products for these lines is expected in 2011.

Third-wave products have been demonstrated but not offered as consumer products. For example, Toshiba has demonstrated a 20-in. glasses-free TV and LG Display has shown 3-D OLED systems. Also, most 3-D OLED TVs demonstrated have required active glasses, although there have been demonstrations of micro-polarized 3-D OLED systems that use passive glasses. The consumer is not expected to take a step backward from passive to active glasses just to obtain an OLED TV.

While the first wave is well under way at the consumer level, competitive second-wave consumer products should be available in 2011. Competitive mass-market third-wave products are yet further in the future because there are still technology and manufacturing problems to be solved. Realistic consumer take-up of third-wave products is unlikely before the 2013–2015 timeframe. One barrier for consumer take-up of glasses-free 3-D technologies is likely to be the relatively poor performance of these systems when showing 2-D material. There are known technical solutions to this problem, such as switchable lenses, but they require additional development and cost reduction before they are ready for consumer prime time.

We see at least 20 years of innovation coming in the 3-D space, so defining success can be tricky. But success in any of the waves mentioned above will require the same key elements, as defined below:

- Education and promotion.
- A successful 3-D viewing experience.
- Acceptable price.
- Enough quality content.

Let's take a look at the state of these elements for the first wave, with some comments on impacts for the second wave.

Education and Promotion

There is certainly no lack of promotion with regard to 3-D TVs for the consumer. In fact, we are in a period of over-promotion, with 3-D TVs being pushed by the TV makers, retailers, and even to some extent by the content creation and delivery companies. In the short term, this is bound to be tempered as the realities of 3-D TV viewing become better understood by the consumer.

However, expect new waves of promotion and education as additional waves of 3-D technology enter the market. This also has the potential to create a group of very unhappy consumers – those who bought first-wave products with expensive active-shutter glasses may be a little upset when they discover that just 1 year later, they can buy a 3-D TV that uses passive polarized glasses for less than what they paid. This current generation of TVs with active glasses will not be convertible to passive glasses, so the buyer will be locked into an active-shutter glass "solution."

Nevertheless, the education and promotion of 3-D TVs by the manufacturers continue at a blistering pace. For industry professionals, there is a trade show nearly every week now that has some 3-D associated with it – a huge change from a year or two ago. 3-D film festivals, awards, and media coverage are blossoming worldwide. One can hardly look at a blog about television without reading about 3-D. Mainstream publications such as *The New York Times* have had multiple articles on different aspects of the arrival of 3-D TV. Industry-oriented press has published ample material on 3-D. Take as an example what is closest at hand: this issue of *Information Display* with a special focus on 3-D.

Some of the promotional events are for professionals and consumers alike. For example, the 3-D Experience event in New York City (see Fig. 2) in September of 2010 offered a consumer-oriented agenda that consisted of a variety of exhibits by various manufacturers.

This space is also currently hosting the King Tut Exhibit, so it is not a low-visibility venue. Other areas of Times Square that were part of the 3-D Experience included the NASDAQ market site and the AMC Empire 25 Theater on 42nd St. The Empire Theater not only hosted a day-long series of press

***Fig. 2:** The 3-D Experience featured a variety of consumer-oriented 3-D exhibits from various manufacturers. It took place on 44th street just off Times Square in New York City, in the Discovery Times Square Exposition space. Photo credit: 3-D Experience*

briefings but also screened a number of 3-D movies over the three-day event.

In another example, Panasonic held a press conference on 3-D at the 2010 U.S. Open tennis championships, a sporting event that in some years has had the highest attendance of any event in the world. There was a demonstration room showing Panasonic 3-D products that was open to all attendees, not just the press. The authors can vouch for the fact that this demonstration area was full of curious consumers. In fact, there were so many consumers it was difficult talking to some of the people there. This is probably not a problem that Panasonic minded too much.

For retailers, the Consumer Electronics Association (CEA) organized "3-D Demo Days" on September 10–12, 2010. This event included participation by 65 electronics retail chains with stores in all 50 states as well as the District of Columbia, Puerto Rico, and Canada. "3-D Demo Days," not surprisingly, was designed to show the consumer what 3-D TV was like. During the event, ESPN showed the Ohio State *vs.* Miami game live, plus additional 3-D content including footage from the FIFA World Cup, X Games, and the Harlem Globetrotters. In a telephone interview with Insight Media's Art Berman, Megan Pollock of the CEA declared the event a "huge success," with "tons of customers" and "lots of buying."

And there are other resources out there for the consumer, such as the CEA FAQ file about 3-D that was part of 3-D Demo Days and is now on-line at http://digitaltips.org/video/3-D-faq.asp. Amazon has a similar FAQ section, as do some of the TV makers and retailers. The industry-neutral 3-D@Home Consortium is also developing consumer-oriented materials to educate and inform about 3-D.

However, even with this and all the other publicity 3-D TV has been receiving, sales have been sluggish and well behind the inflated expectations of the TV makers. In February, for example, Insight Media issued our "expected" 2010 worldwide forecast for 3-D TVs of about 3.3M units. While there was initial enthusiasm for 3-D TVs, interest has slowed, along with sales of any type of TV. We expect some serious pricing reductions to move TVs (2-D or 3-D) for the 2010 holiday selling season. Whether the market meets our 3.3M-unit forecast will depend on a number of factors, as detailed next.

The 3-D Viewing Experience

Many consumers have experienced 3-D in the cinema, and their impressions have generally been favorable. As we have seen, consumers are also being exposed to it at retail. But what about the 3-D TV viewing experience in the home? There are multiple elements that will help create an acceptable 3-D viewing experience in this venue, but these can be boiled down to two categories: ease of use and human factors.

Ease of use refers to how easy it is to access, display, and enjoy the 3-D content (we will deal with content availability later). If the content is Blu-ray, it does connect easily with the 3-D TV and it displays properly, but other sources of 3-D content are not as easy to access and display. This is likely a short-term problem, but will slow adoption. Perhaps the most important element in ease of use is the need to wear the active-shutter glasses. First, people do not want to wear glasses. Surveys have shown, however, that people who have actually seen content on a 3-D TV are more willing to wear glasses than people who have never seen 3-D TV. Maybe this suggests that the key for CE manufacturers and retailers is to get the consumer to watch 3-D TV for the first time. This first-time experience must, of course, be enjoyable for it to have the effect desired by the CE manufacturers and retailers. *Information Display*'s Steve Atwood wonders about the occasional poor soul, such as himself, who does not enjoy 3-D outside the movie theater. He commented "I tried a number of glasses on at a major retailer recently. I was uncomfortable and even a bit queasy with several of them."

Also of concern is people's desire to multitask while watching TV, something consumers will find difficult to do if they have to wear the glasses. Until glasses-free 3-D systems arrive, this will remain an issue. Even with glasses-free TV, viewers' head positions are restricted, limiting multitasking, so newer designs are likely needed to eliminate this issue.

Human factors refer to the impact 3-D content watching has on the human body and mind. It is well known that poor 3-D content can create headaches and nausea – something that rarely happens with 2-D content. It is vitally important that content creators understand how what they do will impact consumers and the 3-D viewing experience. It will take lots of training and time to help ensure that the content pipeline has content that is as good as it can be. Bad viewing experiences will occur, however, and this will slow adoption.

Content

Content is a persistent issue for 3-D TV. The shortage of 3-D content is one of the clear reasons why consumers are slow to buy 3-D TVs. The manufacturers have not made it any better by linking specific Blu-ray movies to specific brands. For example, *Alice in Wonderland* on 3-D Blu-ray is bundled with Sony systems and *Monsters vs. Aliens* on 3-D Blu-ray is bundled only with Samsung hardware. If you like Samsung hardware and you want to watch *Alice in Wonderland* in 3-D, you are out of luck for now.

This bundling issue is likely to resolve itself soon. Other problems with 3-D Blu-ray, such as difficulties related to re-mastering large-screen content for TV-sized screens and the authoring of 3-D Blu-ray discs, are expected to resolve themselves soon as well. Insight Media expects perhaps 20–30 3-D Blu-ray discs to be available at retail for unbundled purchase by the end of 2010.

Content issues are, in fact, more fundamental than the temporary issues associated with Blu-ray discs. 3-D content is available from satellite and cable providers, perhaps most notably DirecTV which is currently offering three channels of 3-D programming: movies, general content, and sports. The general content is sponsored by Panasonic and the sports are from ESPN sports. But even this content availability, plus other channels including the Internet, does not solve the fundamental problem: there just is not very much content. Most of what is on DirecTV and many of the other evolving 3-D delivery systems will feature mostly repeats of the same content. All of the 3-D content ever made could currently be seen in about 16 weeks of 6 hours per day of viewing – if the content was even available on that schedule. The pipeline has been created, but it will take years to fill.

On the other hand, the amount of content needed for 3-D TV is much less than is needed for 2-D TV. The authors believe 3-D TV viewing is likely to be event-driven, rather than the norm for TV viewing. Sports, movies, and special broadcasts will be in 3-D; the local news and most talk shows will not. The multi-tasking and head-tilt issues for the consumer and the bandwidth issue for the broadcaster have no obvious solutions, plus 3-D adds little to many types of programming. While the currently existing 3-D content is not sufficient for even this restricted viewing paradigm, the additional content in the pipeline may be enough.

More fundamentally, the creation of 3-D content is different from the creation of 2-D content. The shots, camera positions, use of pans and zooms, framing, and blocking – all need to be executed differently. These choices also impact human factors and the 3-D viewing experience. There is a rush now to fill the pipeline with 3-D content, but not all of it will be good – and consumers will realize this.

Price

The final issue is cost. 3-D TV sets are more expensive than 2-D TV systems, but the premium is part of a package that includes other high-end features. For example, a 50-in. 3-D plasma TV set, including two pairs of glasses, is currently available for about $1000. 3-D LCD TVs are somewhat more expensive, with 46-in. 3-D LCD TVs selling for about $1400, and 55-in. models for as low as $2300 for a bundle that includes four pairs of glasses and an Internet-enabled Blu-ray player. Comparison shopping is difficult, in part because every manufacturer or retailer offers a different bundle with TVs and other components.

Most of the 3-D TVs are premium products. So when consumers are shopping for a TV, 3-D capability appears to be only one of the items they consider. Internet connectivity, apps and widgets, LED backlighting, great 2-D picture quality, great motion response, thin form factor, styling, and other aspects are also just as important – and in many cases more important – to the consumer than the 3-D capability. The result is that consumers buy 3-D-capable TV for any or all of the above reasons. But just because they have a 3-D-capable TV does not mean they are watching 3-D content. They may be buying for the great 2-D picture quality and "future proofing" for the 3-D part, or merely getting the 3-D capability because it comes with the package they want.

End users seem to recognize the high quality of the 2-D images produced by 3-D TVs. For example, one user from Louisville, Kentucky, commented on the Best Buy Web site after buying a 40-in. 3-D TV:

> *"I did a significant amount of research before purchasing the [new] LED TV, but I was still concerned that maybe I didn't pick the best available TV for the money. After seeing the picture with high-def material, it is clear that I made the right choice. Set up was very easy ... even the wireless Internet connection. The 3-D may not be something we use often, but it is still a nice feature and it works very well."*

This was not an uncommon sentiment. For this particular model of 3-D TV, 15 out of 15 reviewers would recommend it to their friends. All the reviewers raved about the picture quality, even if they had never watched 3-D content on the set and never planned to watch any.

The second issue relates to the cost of the glasses. Almost all current 3-D TV offerings, including LCD, plasma, and DLP projection, require the user to buy one pair of active glasses at $100-$250 a pair for each viewer. For a gamer who wants to play "World of Warcraft" in 3-D, buying one pair of glasses is not a major issue. For a family of five to watch TV, five pairs of glasses are required and the cost is significant. Want to throw a 3-D Superbowl party, assuming the Superbowl is in 3-D? Forget it – 25 pairs of glasses for a special event to show off your new 3-D TV and earn neighborhood bragging rights is out of the question for most of us. Oh, and by the way, those Panasonic 3-D glasses are not compatible with a Sony 3-D TV. Nor are Samsung glasses compatible with LG TVs, and so on. As volumes go up, the authors expect the price of glasses to come down because the estimated bill of materials of a pair of active glasses in high-volume production could support a price as low as $30-$50 per pair.

Coming next year in the second wave will be 3-D TVs that allow the use of passive polarized glasses, which can cost less than a dollar each. Patterned retarder solutions (alternate rows have polarizations of different states, sometimes called micro-pol or X-pol) based upon a glass-based overlay of the LCD are in the market today, but are expensive. This approach will be less costly as film-based patterned retarders are introduced. A second approach, called active retarder, will also enter the market. Developers claim these TVs will be cost competitive with active-shutter 3-D TV solutions. The low cost of the glasses will help a great deal, but consumers will still be required to wear glasses.

Summary

The introduction of 3-D TV has been compared to the introduction of two other TV technologies: high-definition TV and Internet connectivity for TV. Perhaps these products can serve as guidelines for the future of 3-D TV.

HDTV was first introduced in 1998 and now is essentially universal in terms of new TV sales in the U.S. The first years of HD were slow, however, with consumers confused, little content available, prices high, and sales disappointing. One difference between HD and 3-D is the government mandate. Digital TV was mandated by the federal government and HD was bundled under the federal rules with digital TV. This is not likely to happen with 3-D TV – no government mandates can be expected here. On the other hand, digital TV is an enabler of 3-D TV. With digital broadcasting and cable and satellite transmission, adding the extra data for 3-D becomes a relative piece of cake.

Internet TV was first announced in 1996 and is now becoming common – so common, in fact, that sales are expected to be in the 40M-unit range this year. One difference with Internet TV is that there is no lack of content on the Internet. Also, it does not require a new TV to access it, unlike 3-D. Add-on boxes such as the $99 Apple TV system can convert any TV into an Internet TV. While glasses are not required, a keyboard is, unless you are willing to use a clumsy remote control coupled to a virtual on-screen keyboard.

The introduction of 3-D TV will be slower than consumer-electronics manufacturers would like to see, but consumers will eventually take it up in large numbers. For now, any glasses-based solution will remain an "event" on TV. Instead of the evening news, sitcoms or news shows, movies, sports, and special events will be shown in 3-D. The 2012 Olympics opening ceremony in 3-D, anyone? ■

A Backlight for View-Sequential Autostereo 3-D

A backlight that emits collimated light whose direction can be scanned through 16° has been demonstrated. Combined with a high-frame-rate LCD, this could enable a stereo 3-D display that does not require glasses.

by Adrian Travis, Neil Emerton, Tim Large, Steven Bathiche, and Bernie Rihn

THE recent launch of 3-D displays has been thrilling, but let us not pretend that people actually want the glasses. No, what they really want is a 3-D image that they can see by doing nothing other than glancing at the screen. Providing this is quite a challenge, so many of the attempted solutions have been somewhat radical, requiring, for example, carefully registered lenticular arrays and high-resolution panels. What would be ideal would be to make minimal changes to technology that already exists. This article explains how we might get a 3-D LCD to work without glasses by altering the shape of the light guide in the backlight.

It is easy to forget that we see a picture on a display because rays of light travel from that display to our eyes. The glasses used with a classic stereo 3-D display block the rays traveling to one eye at a time so that the display can control what each eye sees. An alternative strategy is not to send the rays of light to that eye in the first place.[1] This would require a backlight that is like that of an overhead projector in the sense that it has the area of a liquid-crystal panel, but concentrates rays to a point that for our purposes is one eye of the observer. We must also be able to switch the direction in which rays are concentrated so that we can shine them into the other eye. Automobile headlights do this when they are dipped by switching between light bulbs in the focal plane of a curved mirror. However, overhead projectors and automobile headlights are rather bulky, so this article describes how to perform the same trick in a slim light guide.

The wave guide behind a conventional liquid-crystal panel is usually a wedge embossed with structures that make its emission uniform and diffuse. The passage of rays is predictable by tracing them through a stack of replicas of the wedge[2] and the emission can be made partially collimated by letting fan-out take place in the same wedge as that from which light emerges.[3] View-sequential 3-D, however, demands precise collimation, which requires that the surfaces be smooth and that the geometry of wedge replicates alone be used to achieve uniform intensity.[4] We explain here how the direction of emitted light alters with the point of input in the manner needed for view-sequential 3-D.

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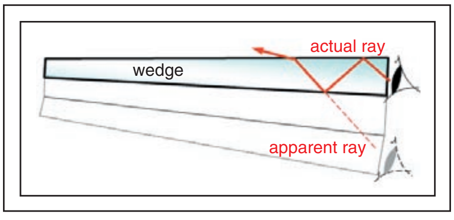

***Fig. 1:** Rays appear to travel straight through a stack of light guides.*

Theory

Rays leave a light guide only upon reaching the critical angle, so we can trace rays in parallel at this angle backward from the surface at which they are to emerge. From within, any light guide appears like a kaleidoscope – as if the rays were traveling in straight lines through multiple reflections of the guide, as shown in the cross-section in Fig. 1.

The authors arranged for the rays to reflect off the thick end before they emerge and curved the thick end so that the multiple reflections of Fig. 1 stack into a curve of constant radius, as shown in Fig. 2.

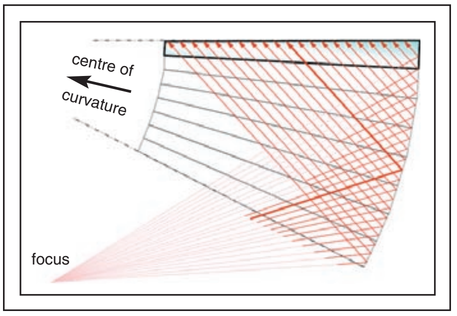

***Fig. 2:** The thick ends stack into a curve, which would focus rays to a point if they remained guided.*

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When parallel rays reflect off a curve, they converge toward a point of focus, but the rays in Fig. 2 will reach the critical angle and cease to be guided before they reach this point. So, we embossed the thick end with facets sloped to reduce ray angle and truncated the wedge at the point of focus, which is halfway to the center of curvature from the thick end.

The facets should ideally swivel the point of focus to a position where the central ray (the thick ray in Fig. 3) is reflected parallel to the plane of the wedge because the ray bundle will then be symmetric, which maximizes the ability of the light guide to collect light.

However, mirror images of the facets are formed at the interface between adjacent wedges, so the embossed structure must be symmetric, *i.e.*, a zig-zag, which means that one-half of all backward-traveling rays are lost to the system.

In reality, the rays are traveling forward from the thin end to the thick end and because the situation they encounter is symmetric, no rays are lost: rays hitting upward sloping facets emerge from the upper surface of Fig. 1, while rays hitting downward sloping facets emerge from the lower surface. It was then a simple matter to add a mirror to one surface of the wedge so that all rays finally emerge from the same side.

The direction of rays resolved in the plane of the light guide must also be made parallel, which was done by giving the thick end of the light guide the same curvature as shown in Fig. 1; *i.e.*, its surface (ignoring the facets) is spherical. Lastly, we added the usual prismatic film so that the rays that emerge into the surround at a shallow angle to the plane of the light guide were turned to the perpendicular.

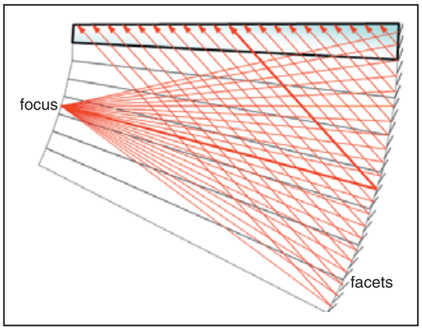

Fig. 3: *The thick end is curved and faceted so that ray paths can be concentrated to a point at the input.*

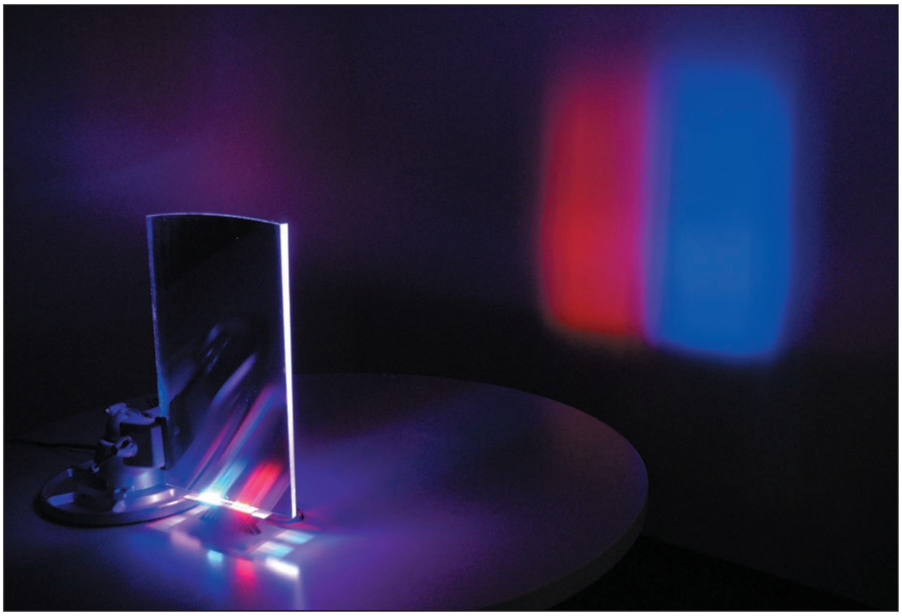

Fig. 4: *Shown is a projection onto a screen 2 m from a wedge backlight with 60 mm between red and blue sources at the input.*

With the uniform, collimated illumination that emerges, it is a simple matter to add a Fresnel lens that concentrates rays into the eye of a user. It is possible to switch between different points of concentration in the horizontal plane by switching between different LEDs at the input to the light guide. Two LEDs will be sufficient if there is only one user who is prepared to hold the screen perpendicular. Otherwise many LEDs and head-tracking may be necessary.

Results

The Wedge backlight is an acrylic slab that tapers from a thickness of 6.2 mm to 10.8 mm over a distance of 320 mm and is 195 mm wide. At ±30 mm from the center of the thin end, three red, three green, and three blue light-emitting diodes were placed from right to left. Initially, only the red and blue light-emitting diodes were switched on, and they formed the image shown in Fig. 4 on a white surface placed 2 m in front of the backlight.

Next, a Fresnel lens was placed over the surface of the light guide, whereupon there formed on a distant screen the image shown in Fig. 5.

The width of the projected image was 160 mm, the result of which would be a 3-D image with a field of view of 16°.

If we exchanged the distant screen for a head, its left eye would see rays only from, say, one of the red LEDs and its right eye would see rays only from one of the green LEDs. Switching between a pair of white LEDs instead, and adding an LCD panel fast enough for stereo, would provide the desired 3-D image.

Lastly, the central green LEDs were switched on alone and white diffusive paper was placed over the surface of the wedge in order to show uniformity. A photograph of the result is shown in Fig. 6, and more rigorous measurements at various points across the surface indicated a non-uniformity of less than ±10%.

In order to assess the performance when illumination is off-perpendicular, the red LEDs were switched on instead, but there was no perceptible shadowing or vignetting.

Discussion

A nascent market for autostereo 3-D exists in portable devices, for which 3-D glasses are almost unacceptable. A portable display typically has a single user, whose natural tendency is to hold it square-on, so head-tracking is unnecessary. The backlight described here would also help to reduce power consumption by not wasting light to wide angles, and the portrait orientation typi-

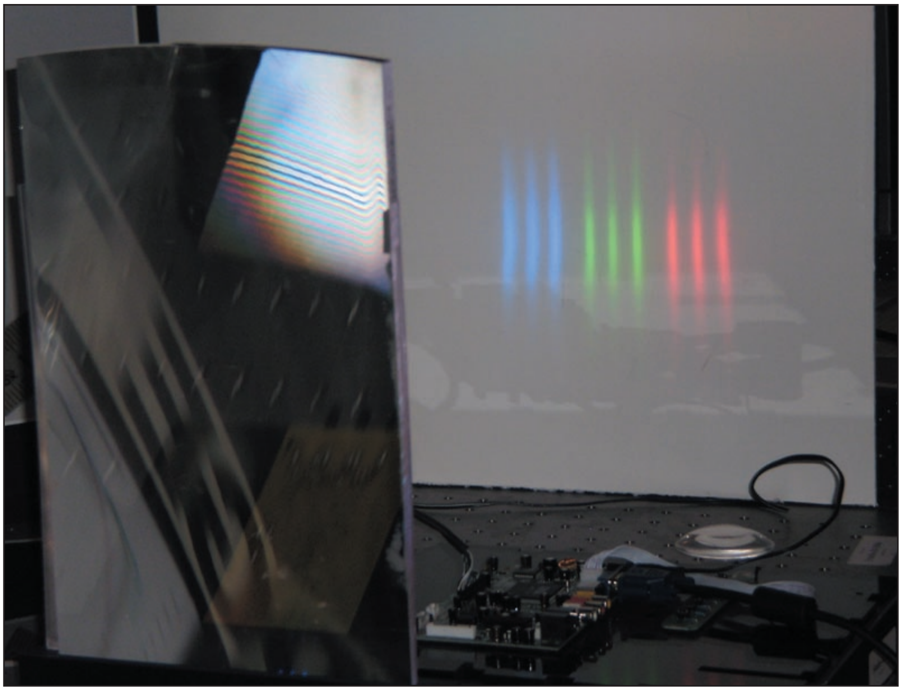

Fig. 5: Here, a projection from a wedge backlight travels through a Fresnel lens onto a screen.

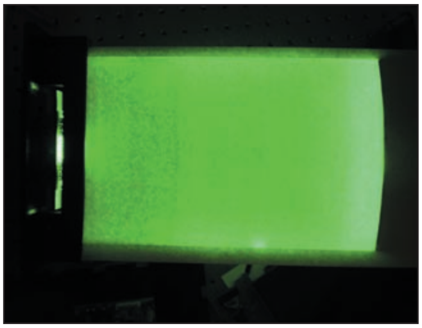

Fig. 6: This wedge backlight example uses three green LEDs within a 30 mm width at input and with a white paper diffuser over the surface.

cal of a portable device works well with the optics of the light guide. The success of 3-D based on glasses may stem from its limited aims, and perhaps the lesson for 3-D is at first to be content with cracking one application at a time.

To the extent that it collimates light, the new light guide can be thought of as a flattened lens with a quasi one-dimensional focal plane at the thin end. Like all lenses, it has aberrations that limit performance both at large angles to the perpendicular and at short focal lengths, *i.e.*, when the display is much wider than it is high. There exist more radical approaches, based, for example, on electrowetting[5] and virtual imaging,[6] but if we want a wide field of view, we will need an LCD with the high frame rate needed to display more views or head-tracking or both.

Ferroelectric liquid crystals and polysilicon transistors have long had the switching times required to enable high frame rates, but the display industry has instead developed nematic liquid crystals and amorphous-silicon transistors, which switch too slowly for the display of many views. However, work on stereo 3-D and color-sequential displays has prompted the development of liquid crystals[7-9] that switch on and off in less than 1 msec yet have the gray scale lacked by classic ferroelectrics. These effects typically require undesirably high switching voltages of more than 50 V, but LCDs are nevertheless following a trend of a rising frame rate.[10] Simultaneously, advances in head-tracking technology have led to a reduction in the number of views needed and therefore to a reduction in the frame rate required of the LCD. The authors therefore see a bright future for the view-sequential approach.

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The following papers appear in the December 2010 (Vol. 18/12) issue of *JSID*.
For a preview of the papers go to sid.org/jsid.html.

SID
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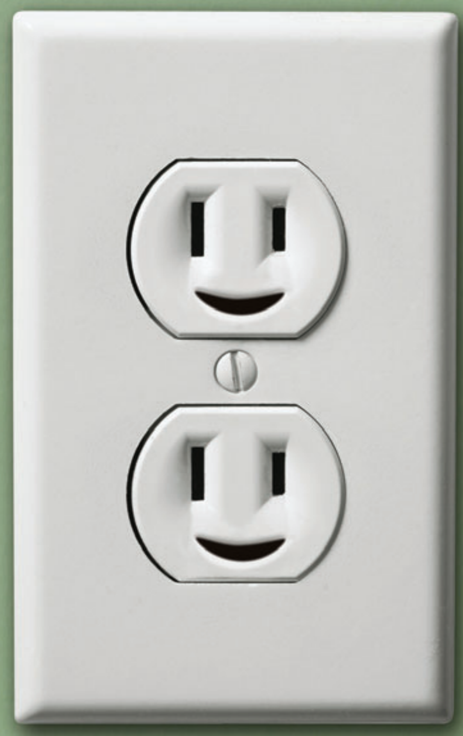
Monitors with 3M Films Use 30% Less Power.



By refracting and recycling light that normally goes to waste, 3M Display Films can significantly boost the energy efficiency of LCD monitors. In fact, when Vikuiti™ Dual Brightness Enhancement Film (DBEF) and Vikuiti™ Brightness Enhancement Film (BEF) are used together, LCD monitors require an average of 30% less energy. The films enable monitors to operate with two bulbs instead of four *with no reduction in performance*. A 19″ monitor with Vikuiti DBEF and BEF, for example, can run on 10 fewer watts. Find out more about making displays more energy efficient at 3M.com/displayfilms.

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Display Week 2011

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SID is ready for its close-up! Home to Hollywood, Los Angeles is the epicenter of the television and motion-picture industry. The recent advancements in 3-D technology make LA the perfect host for the 2011 SID International Symposium, Seminar & Exhibition. Display Week will be held May 15–20 at the Los Angeles Convention Center, with the exhibition open from May 17–19.

Display Week is the once-a-year can't-miss event for the electronic-information-display industry. The exhibition is the premier showcase for global information-display companies and researchers to unveil cutting-edge developments in display technology. More display innovations are introduced year after year at Display Week than at any other display event in the world. Display Week is where the world got its first look at technologies that have shaped the display industry into what it is today; that is, liquid-crystal-display (LCD) technology, plasma-display-panel (PDP) technology, organic light-emitting-diode (OLED) technology, and high-definition TV, just to name a few. Display Week is also where emerging industry trends such as 3-D, touch and interfaces, flexible and e-paper displays, solid-state lighting, digital signage, and plastic electronics are brought to the forefront of the display industry.

Watch the Stars Shine

continued from page 2

Even if that number is slightly exaggerated, it still puts the scope of the problem in staggering perspective.

In the vast majority of cases that electricity comes from the burning of fuels such as coal, natural gas, and oil. Now, regardless of your perspective on the root causes of global warming, I think most of us can agree that generating more CO_2 emissions due to the conversion of fossil fuels or coal must have a negative impact on our fragile environment. Therefore, the reduction of that electrical demand due to better display efficiency is a noble effort with clearly positive consequences, but it really just reduces the amount of environmental unfriendliness that can be attributed to that display. To be literally green, I suggest that a display would actually need to convert enough ambient light back into electricity to replace the power it consumes – something akin to a merger between solar technology and LCD technology. While I admit that is a bit of a stretch for a full-sized TV, it may not be such a fantasy when applied to portable devices that require meaningful amounts of energy to constantly re-charge themselves. Imagine if these devices combined the ability to recycle the kinetic energy of being carried around with the conversion of ambient light when being used to recharge themselves; that would be an incredible achievement! But regardless of the semantics, I certainly applaud all the people who are working on reducing the energy consumption and environmental impact of displays. A 50% reduction in total energy consumption across the board could have an amazing effect when extrapolated over 10 or 20 years into our future – and I plan to be here to benefit from it with all of you as well.

Whenever we talk about green technology innovations at the *ID* staff meetings, I always ask Managing Editor Jenny Donelan to find some evidence related to whether consumers will actually pay a premium for better energy efficiency in their TVs and other display products. I think it is a valid question and relates to how effective the Energy Star ratings are likely to be in changing people's buying habits. The average 200-W television used for 5 hours a night, 7 days a week consumes 365 kW of energy per year. At a $0.1/kWh energy cost, that equates to only $36.50 of electricity per year. Even if your local power rates are twice that, it's hard to argue that an equivalent TV that uses half of that energy warrants more than a $200 price premium for its initial purchase. Just as it has been hard to convince people to buy relatively expensive cold-cathode fluorescent lamps (CCFLs) rather than cheap incandescent bulbs, my cynical view is that it will be hard for manufacturers to drive consumers to more energy-efficient displays if the price is much higher.

As Jenny explains in her Enabling Technology feature, "Do Consumers Really Go for Green?" the answer is "Well, sort of." While a disappointing 17% of small-electronics buyers in 2009 actually considered environmental concerns in their buying choice, over 50% say they will next time. Maybe most of them will – we can hope. Perhaps the only way to be sure this will happen is to do what some governments in Europe (and the State of California) have started doing, either limiting the availability of unfriendly products or making the cost of energy high enough to be a disincentive. In their feature article, "Eco-Design for TV Displays," authors Kees (Cornelis) Teunissen and Leendert Jan de Olde discuss the various measures being adopted by the EU, including restrictions on the use of hazardous materials in display manufacturing, strict recycling guidelines for end-of-life devices, and, of course, mandated power-consumption limits. The authors go on to discuss the rating system being used to guide consumers and how it has limitations based on the default operating modes of the TVs.

But while we keep coming back to the issue of power consumption, it is not by any measure the only major concern. As Po-Lun Chen and Ming-Kwan Niu from AUO explain in their feature article, "Making a Greener TFT-LCD," AUO is not only focused on the many improvements of the panel, but on the many ways the factory itself can be made greener. Factors such as water recycling and re-use, power-generating turbines on exhaust ports, judicious interconnection of waste heat and chilling systems, and various process improvements in the fabrication of the LCD can all add up to save significant amounts of energy as well as preserve precious raw materials.

But still, the challenge remains: how do we actually offset the remaining environmental footprint we create to achieve the green goal? Well, AUO does it by planting trees, lots of trees. Many fabs, including AUO, Samsung, and Sharp, have adopted solar panels as supplementary power-generating methods. AUO has even gotten into the business of making solar panels. In some areas, large venues such as sporting arenas and racetracks are now installing solar power and wind generators to completely offset the energy they use, helping to bring down the cost of these industrial-park-sized projects to manageable levels. I think neighborhoods and small office parks will soon follow. Consumers as well can do their part by making smart choices in the products they buy, using those products responsibly, recycling them correctly, and supporting alternative energy projects in their areas as well as entertainment venues that build offsetting systems, and, most importantly, by rewarding display manufacturers who make the environmentally responsible choices. At the end of the day, we all need an innovative and profitable display industry that can also sustain a healthy and bountiful world in which to live.

And now we turn our attention to the ever-increasing realm of 3-D technology. As I learned recently while attending the "3D@Home 3D Workshop" sponsored by Insight Media and the 3D@Home consortium, a very viable eco-system for 3-D entertainment has grown up over the past few years, even in the absence of consistent standards among display manufacturers. At every stage in the process, from content generation and delivery through the display to the consumer's eyeballs, lots of technological innovation is at play and just as many real-world implementation problems remain. The mission of the 3D@Home Consortium is "… to speed the commercialization of 3-D into homes worldwide and provide the best possible viewing experience by facilitating the development of standards, roadmaps, and education for the entire 3-D industry, from content, hardware, and software providers to consumers." They have their hands full, though they have already made great progress in pulling together a veritable who's-who of industry partners. I mention this mostly because as we continue our coverage of 3-D technology, we'll want to keep a close eye on the evolution of the enabling standards to make the consumer experience more plug-and-play rather than trial-and-error. You can keep tabs on the Consortium as well, at www.3dathome.org, and my thanks to Chris Chinnock, a longtime *ID* supporter who did an outstanding job boiling the entire 3-D eco-system down to a mere 8 hours of presentation material.

And while I'm at it, let me introduce our Display Marketplace feature this month, contributed by Matthew Brennesholtz and Chris Chinnock, both of Insight Media. Their survey of "3-D TV from the Consumer Perspective" discusses the three "waves" of consumer adoption and technology evolution that are coming (or already here). They also discuss how the industry is promoting 3-D and educating consumers, as well as some of the challenges the industry faces for widespread adoption.

This month we also welcome back returning Guest Editor Brian Schowengerdt, who is the SID Program Chair for the Display Systems Committee and Program Vice Chair for 3-D. Brian has brought to us a great article from the people at Microsoft that reveals their innovative design for "A Backlight for View-Sequential Autostereo 3-D." With currently available consumer and professional-grade 3-D flat panels, the user must wear glasses of some type, either passive or active, to view 3-D content. These glasses are a significant impediment to wide consumer adoption of 3-D, either because of price, ergonomics, or both. In this case, authors Adrian Travis, Neil Emerton, Tim Large, Steven Bathiche, and Bernie Rihn describe a new technique for producing an autostereoscopic 3-D LCD by way of collimating the backlight with a special wedge light-guide design. The result is a display that can produce 3-D images with a 16° field of view in azimuth. The light guide itself can be thought of as a flattened lens with a quasi one-dimensional focal plane at the thin end. This innovation clearly will improve over the previous attempts at autostereocopic LCDs with front-face filters or other techniques that require very exacting viewer positioning and some amount of visual compliance that is usually objectionable. The authors believe this design could be enabled first in portable devices, where it could save power as well as create a new user experience. I agree and I think this innovation could appear in handheld devices in the not too distant future.

Whew! That's a lot for one month. If you really read through this entire Editor's Note, thank you. Even if you didn't, I hope you enjoy this issue to close 2010. Whatever your faith or personal beliefs, I hope the celebrations of this season bring you peace, prosperity, and happiness. God Bless. ■

SOCIETY FOR INFORMATION DISPLAY NEWS

Display of the Year Awards Nominations Deadline Is Fast Approaching

The Display of the Year Awards committee members work diligently each year to discover all the best display products, applications, and components, but they cannot do it without your help. December 31, 2010, is the last day to submit a nomination for the Society for Information Display's 2011 Display of the Year Awards.

The DYAs are the most prestigious awards in the display industry. The annual winners are selected in three categories – display, display application, and display component – by an international committee consisting of leading members of the technical display community. When determining the winners, the Display of the Year Awards committee considers many factors, including technical innovation, commercial significance, and potential social impact.

The awards committee accepts third-party nominations, but in recent years has opened up the process to allow companies to self-nominate their own products, applications, and components. The source of the nomination will in no way influence the committee's final selections of award winners: anyone can nominate any product, application, or component, regardless of company affiliation.

To be eligible for a 2011 award, the product, application, or component must have been introduced and been commercially available at some time between January 1, 2010 and December 31, 2010. The awards will be announced and presented at Display Week 2011 which will take place in Los Angeles, California, May 15–20, 2011. An article on the winners will also appear in the May/June issue of *Information Display*.

To download a nomination form and find out more about the Display of the Year Awards, visit http://www.sid.org/awards/dya.html. Videos from two of last year's Gold winners, LG and N-trig, can be viewed at www.youtube.com. Search on "Display of the Year SID." ■

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Guest Editor for this Special Section is **Dr. Michiel A. Klompenhouwer** from Philips Research Laboratories, Eindhoven, The Netherlands.

Authors are invited to submit manuscripts online in electronic files to the ***Journal of the SID*** **by following the instructions listed under the Information for Authors tab on the JSID Web page,** or at **http://sid.aip.org/jsid**. Authors submitting their manuscript must identify their manuscripts as being submitted for the Special Section on **Solid-State Lighting** by selecting **Dr. Michiel A. Klompenhouwer** as the guest editor. The **Information for Authors** document provides a complete set of guidelines and requirements required for the preparation and submission of a manuscript.

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SOCIETY FOR INFORMATION DISPLAY
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