The Coming Advancement in Displays and Lighting

By Barry Young, Senior Vice President, DisplaySearch

Karl Ferdinadnd Braun invented the cathode ray tube (CRT) in 1897, but it wasn't until 1933 when Iowa State made history by broadcasting twice weekly TV shows and CBS didn't intiate color broadcasting until 1951. By the early 1970s virtually all TVs were color and the industry began a period of slow secular growth averaging between 2 and 4 percent per year. Then in 1999, LCD TVs were introduced and the industry turned to a fast growth pattern with PDPs and LCDs replacing CRTs. Now Howard Stringer, Sony CEO, announced that Sony would deliver a commercial OLED TV by the end of 2007 and both Toshiba and Panasonic followed with annoucements of OLED TVs by 2009. The repsonse from visitors to the CES in Las Vegas in January and the Display Technology Show in Tokyo in April was similar, overwhelming adulation on the form factor and performance of the OLED TVs. The question these announcements raised is twofold: will OLEDs become a distruptive technology comparable to color TV or flat panel TVs and just what are the benefits and attributes of OLED displays?

The Attraction of OLED Displays

Thin Film Transistor Liquid Crystal Displays (TFT LCDs) are the incumbent display technology, so it is useful to compare OLEDs with LCDs. First, OLEDs have outstanding performance:

- 1,000,000:1 Contract ratio vs. ~1000:1 for LCDs
- Thin Form Factor (1 piece of glass) < 1 mm in thickness vs. +1 mm
- Wide Viewing Angles: 180° with no degradation in contrast ratio vs. 120° to 150° with contrast ratio down to 10:1
- Fast Response Time: µsec vs. msec

Chemists can engineer the level of color saturation so that OLEDs are capable of meeting any standard , i.e. NTSC, PAL, SECAM, SMPTE 170M. Moreover, the combination of high CR and high color saluration has been proven to give the viewer the appearance of greater luminance, so that one display having a higher CR and color saturation than another operating at the same luminance will appear brighter by a factor of 20 percent to 50 percent. In the CIE Chromaticity figure, the OLED which operates at 100 percent of the NTSC standard at 100 percent of the gray sale and at 10 percent of the gray scale is compared to a typical LCD, which can recreate only 75 percent of the gray scale for NTSC and then at quite a bit less at 10 percent of the transmitted gray scale.

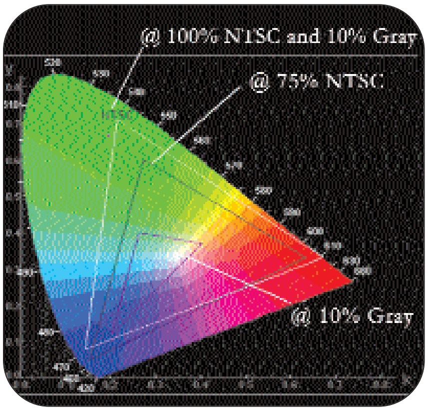

Figure 1. CIE Chromaticity

Manufacturing Process

OLEDs are manufactured by depositing and patterning thin layers of organic material set between a cathode and an anode, which are activated using low voltage electronics. The use of low voltage electronics and a high luminous efficiency gives OLEDs a cost and performance edge over PDPs. OLEDs are self-emitting and as a result do not require a number of components that are used by LCDs including color filters, backlights, polarizers and spacers.

In a large display, these components may be about 30 percent of the display cost. Since OLEDs use similar backplanes as LCDs, the manufacturing cost is about 20 percent less using our cost models assuming the yields and depreciation levels are comparable.

Capitalizing on TFT Infrastructure

One of the daunting tasks in bring a new technology into the display market is the cost of building a large active matrix Fab, which ranges in capital from $2 billion to $4 billion. But OLEDs can use the existing and mature TFT LCD backplane technology while eliminating the expensive alignment and LC filling process. The module process is the same so the OLED technology takes advantage of >2/3 of the existing infrastructure. Currently OLEDs use low temperature polysilicon (LTPS) technology, which represents about 7 percent of the total capacity, but the display suppliers are developing approaches to use a-Si, which has the other 93 percent of the capacity.

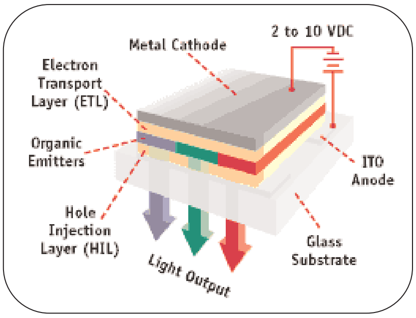

Figure 2.

What is Holding Back OLED Displays?

The first commercial OLED displays were sold in 1999 and by 2006, revenues reached about $500 million and 70 million units. But the target applications have been small displays with relatively low information content, because over 98 percent of the revenue was from passive matrix tyechnology. Target applications (mobile phone and MP3 displays) dropped in ASP by 30 percent to 40 percent in 2003 and 2004 due to excess capacity of TFT LCD Fabs and took the margins out of process. In order to compete in the larger display market, OLEDs will have to be designed with active matrix backplanes. The first commercial high volume active matrix OLEDs were introduced in 2007. There has been a difficult transition from LCD backplanes to OLED backplanes using LTPS because the yields were low resulting in high costs. LTPS backplanes have low uniformity because of silicon grain size differences and need to employ compensation circuits to address the resulting threshold voltage (Vth) shift. These compensation circuits both on and external to the display and external to the display have been developed and are in the process of correcting the problems.

Immediate Challenges for OLEDs

In addition to the active matrix backplane yields, OLED engineers must address a series of problems that are typical of emissive displays (similar to PDP) including:

- Image Sticking: what appears as burn-in when a image doesn't change, typical of icons and rolling news bars
- Differential Aging: material reduces efficiency in light output as it ages, so that the viewer can see the difference between a location that has high efficiency and one that has low efficiency
- Light Capture: light is output at 360° but in a typical display it only is seen through an 180° viewing cone. Moreover, the method of creating light is to cause an extra electron (from the cathode) and an extra hole (from the anode) to recombine in the doped (for color) emitting material

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and give off energy in the form of light. Some material will emit light for only one out of four of these re-combinations (called excitons), while other materials can emit light for four out of four excitons. To date the chemical engineers have been able to create four out of four commercial emitters for red and green but not for a commercial blue. The higher the efficiency the lower the power consumption, which is a major selection criteria for displays in mobile products.

• Material Utilization: the current evaporation process to deposit and pattern the organic material uses is only 5 percent efficient because of the extended distance between the crucible supplying the material and the substrate. In order to be cost effective the process will have to be improved to approach 50 percent utilization or higher. There are a number of companies attempting to solve this problem, including improving the efficiency of the evaporation process to >50 percent material utilization, eliminating the evaporation altogether and switching to a more efficient printing process.

Large Area Display Challenges

In order to compete in the TV market, OLED displays will have to switch from LTPS backplanes to a-Si backplanes because LTPS only scales to 4th generation (730 by 920 mm), which is inefficient when competing with a-Si Fabs using 5th and higher (upwards of 2,000 mm by 2,000 mm) to produce large area displays. The problem to be solved is the reliability of the a-Si TFTs, which when used with a high duty cycle tend to change the required Vth. LCDs require only a single TFT with a duty cycle of about 10 percent, while OLEDs require 2 TFTs, one with a duty cycle of 10 percent but the second has a duty cycle of about 90 percent, where the reliability of the TFT is insufficient. In addition, since the largest Fab making OLEDs is only 4th Gen the evaporation process has only been built to support 4th Gen facilities and may not scale beyond 4th Gen in its present structure. An alternative would be using a white material with a color filter to avoid the patterning problem which limits the scalability of the process. This approach works but has the disadvantage of increasing the cost (color filter) and reducing the light output, although RGB W approaches as developed by Kodak seem very promising. Another approach is to switch from an evaporation process to a solution based process using ink jet printing. The solution based materials have not developed as quickly as evaporation material and trail by almost two years in efficiency and lifetime progress. Recently CDT and its partner Sumitomo have shown very promising results and a new Fab using ink jet printing is being readied for mass profuction. Ink jet printing has been used to make 7th gen color filters for LCDs and are not constrained in size.

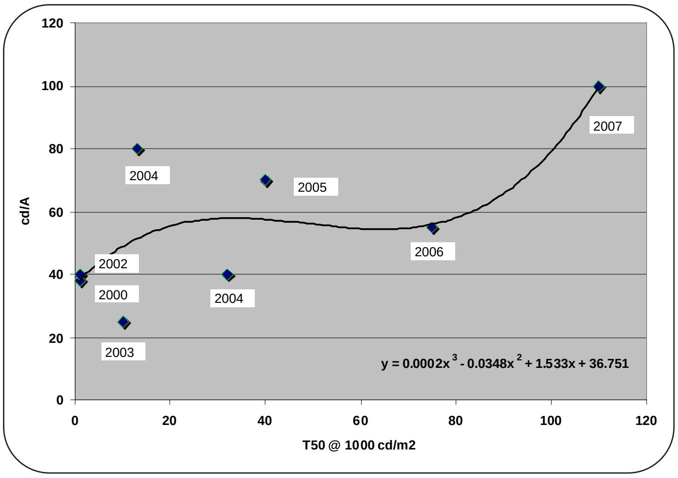

Figure 3.

OLED General Purpose Lighting

Following right behind displays as an application for OLEDs, is the general and specialized lighting industries. As indicated, OLED light is a 360° diffusive source and while requiring special handling for displays, it is a clear advantage for lighting. OLED efficiency and lifetimes are being engineered to produce a white light at >100 lm/W, with an initial luminance of 1,000 cd/m2, a CRI of 80 and a lifetime >100,000 hours to 0.5 luminance. Many companies such as Osram, Philips, GE, Siemens, Mitsubishi and others are developing the material and the manufacturing for a roll to roll process.

The previous figure shows the improvements in lifetime and efficiency for green material from UDC, which is now at the 100 cd/A and >100,000 hours for a 1,000 cd/m2 initial luminance. OLEDs are a green technology and do not have carbon discharge as candescent bulbs do and do not use mercury the way fluorescent bulbs do. Moreover the lights are both robust and conformable. GE has demonstrated how a hole can be punched through the light and it will continue operating. As they reach the performance level required for general purpose lighting, OLEDs may also serve as the most cost effective backlight for LCDs, since the cost per square inch and per lumen should be the lowest in the industry.

Figure 4.

The future of OLEDs for displays and lighting is extremely bright. In the next four to five years, AMOLEDs will target the small handheld devices, such as mobile phone, games, MP3, PMP and camera markets, where they have a competitve advantage and should capture $3 billion to $4 billion in revenues. Sony is expected to be the first supplier with a large area display at 11 inches in diagonal at the end of 2007, but it is likely to take four to five years before large area OLED displays (>20 inches) are available on the market at competive prices. Almost concurrent with the release of these large area displays, OLEDs will target niche lighting markets, where thin, conformable and flat lighting is desired. It will then grow to be very competitive as roll to roll processing will bring down the costs to todays mass production levels. With the roll-to-roll process developed for lighting, the approach could be used in developing flexible displays using OLEDs and open up a whole new range of applications such as curved automobile displays consoles, clothes with embedded displays, glass walls with embedded TVs and other forms of video entertainment and curtains with embedded lighting to change the ambiance of the room. The technology has challenges, but it also shows promise and has attracted a wide variety of display makers, chemical and lighting companies that are investing to bring the promise to fruition.

Figure Sources

1. Samsung SDI, 2. Kodak, 3. UDC, 4. GE

Barry Young is senior vice president of DisplaySearch. Barry was CEO and President of OWL Displays where he co-developed innovative driver technology. He was awarded a key patent on an innovative architecture for driving low temperature polysilicon TFT LCDs. Barry is one of the industry's leading authorities on OLEDs, has authored all of DisplaySearch's OLED reports and has visited all OLED manufacturers worldwide. Barry Young may be reached at barry @displaysearch.com.