Advances in LED Technology for LCD Backlighting

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From small cell phone liquid crystal displays (LCDs) to large 70 inch LCD TV panels, LEDs are rapidly becoming the backlighting technology of choice. Delivering high brightness, long life, uniform color and space savings, LEDs are trumping the standard cold cathode fluorescent lamps (CCFLs) in more and more applications.

Historically, different light sources have been used for LCD backlighting, including incandescent lamps, fluorescent lamps and LEDs. The selection criteria that OEMs use to determine which backlighting technology best suits their application include cost, brightness, uniformity, efficiency, lamp life, robustness, size, ease of integration and more recently environmental concerns.

LEDs have been the backlighting technology of choice for a number of years for small LCDs, typically under 5-inches diagonal, used in handheld devices like cell phones, PDAs, MP3 players, etc. For larger screen sizes, CCFLs have been traditionally more cost-effective and have been used in backlighting the majority of medium to large industrial displays. However, the shift to LEDs is underway due to the increasingly higher performance and steadily decreasing cost of today's high brightness LEDs (HB LEDs), which deliver the brightness required to compete with CCFLs for larger display backlighting.

Advantages of HB LEDs

HB LEDs have significant advantages over CCFLs in backlighting applications. HB LEDs can provide higher brightness than CCFLs and when properly integrated into a system, LED backlights have a longer lifetime. Additionally, HB LEDs can be operated efficiently over a wider temperature range, particularly at the low end. In applications where the high voltage required for CCFLs is an issue, LEDs offer a distinct advantage as they can be operated at low level DC voltages. Other advantages of HB LEDs include increasingly higher light output per electrical power input and the ability to optimize the color gamut. Finally, the wide range dimming capability of LEDs can be a valuable advantage in select applications.

As the price of HB LEDs continues to come down as volumes increase, many experts have projected that HB LED backlighting costs will eventually reach parity with CCFLs. This cost equation is already enabling OEMS to use HB LEDS in larger displays such as GPS systems, portable DVD players, notebook computers and desktop computer monitors, as well as in industrial LCDs in the 6.5 inches to 20.1 inches size. LEDs are also being used in LCD TVs in sizes ranging from 32 inches all the way up to large 70 inch panels. Table 1 demonstrates how LEDs compare to other commonly used light sources.

Parameter (typical)	CCFL	Flat Fluorescent Light	LED
Cost	Medium	High	High
Brightness	10,000 nits	7000 nits	> 10,000 nits
Efficiency	40 lm/W	30 lm/W	43 lm/W
Lamp life	10K to 30K hrs	Up to 100k hrs	Up to 100k hrs
Robustness	Glass (fragile)	Glass (fragile)	Solid State
BLU Thickness	45 mm	< 40 mm	45
Ease of Thermal Management	Fair	Good	Better
Turn on time	Slow	Medium	Fast
Dimming range	Limited	Limited	Wide
Mercury-free	No	Yes	Yes

Table 1. Comparison of light sources for BLU

Managing Uniformity

When a number of LEDs are used to backlight a larger LCD and the illumination from the LED light sources must be spread across a larger area, it is important to match the brightness and wavelength of each color for uniformity to avoid hot spots and dark areas. This is especially critical for direct projection LED back lighting units (BLUs), where even small variations in color can degrade the uniformity of the display. To better manage uniformity, it is desirable to have tight matching of the wavelength of each color per backlight -5 nm for green and blue as these are the most critical colors.

In LED manufacturing, there can be variations in performance around the average values given in technical data sheets. For this reason, LED manufacturers bin the components for flux, color and forward voltage (V_f). Fine binning for brightness and color can be used to obtain the proper consistency. For brightness, 0.25 binning with a 15 percent spread per bin is the standard.

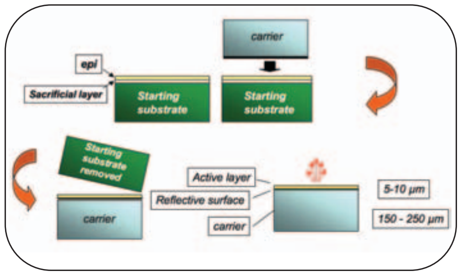

Figure 1. Conventional HBLED versus Thinfilm HBLED fabrication

Optimizing LED Lifetime

Proper thermal management of the LED BLU is important, as the efficiency of an LED can drop quickly as the driving current and junction temperature are increased, reducing brightness and shortening LED life. Increased current generates additional heating of the junction, and if nothing limits the current, the junction will eventually fail due to the heat, a phenomenon sometimes referred to as thermal runaway. Therefore, it is common practice to mount the LEDs on metal core PCBs to provide rapid heat transfer away from the LEDs. Depending on the overall design, active cooling of the LED backplane (such as use of a cooling fan) may be required.

Maintaining brightness and color consistency over the lifetime of the LED is also important. The three primary LED colors (red, green and blue) have different brightness degradation rates. Using a closed loop control system that maintains the individual brightness of the three colors is the best solution to achieving the optimum brightness and correct color balance over time and operating temperature range. A number of commercial tri-color photo sensors are available which, together with the appropriate control circuitry, will perform this function.

Advances in LED Fabrication Technology

The semiconductor technology used to fabricate HB LEDs is a critical factor in the overall performance of the end product. Conventional HB LEDs are typically fabricated with substrates composed of silicon carbide, sapphire or other materials. The substrates absorb some of the photons generated by the LED, which can reduce efficiencies.

To date, HB LEDs have typically been fabricated using one of two primary technologies: InGaN and AlInGaP (also referred to as InGaAlP). Different colors can be achieved with these two primary technologies. AlInGaP, with a forward voltage of around 1.8 V to 2.3 V is used to produce colors from green (570 nm) to super red (632 nm). InGaN is used to produce colors from blue (460 nm) to true green (528 nm) and phosphor-based colors like white (typically 3,250 K or 5,600 K). InGaN has a higher forward voltage, around 3.2 V to 3.8 V, depending on the color.

Recently, Osram developed a new approach to LED fabrication called Thinfilm. In the Thinfilm approach, LED wafers are fabricated using a process similar to conventional AlInGaP and InGaN wafers, except that a sacrificial layer is added under the epi layer (Figure 1). The wafer is then inverted and bonded to a new support carrier, which contains several components that provide a highly reflective mirrored area. Next, the original substrate is removed by lift-off, using different techniques, depending on whether it is an AlInGaP or InGaN chip. The compound wafer is finished using conventional metallization processes and then diced into individual LED chips and packaged. The resulting die has an emission layer, with no side emissions, and offers new levels of efficiency.

Using Light Guides

When space is at a premium, a light guide with tri-color LEDs can be used in to accommodate designs where there are space constraints and the thickness of the BLU must be kept to a minimum. One solution is the Osram 6-lead MULTILED (Figure 2), which contains three Thinfilm chips for red (R, 625 nm), true-green (G, 528 nm) and blue (B, 458 nm). The close placement of the three chips within the same package provides optimum color mixing without the need for a wide mixing area in the light guide and the LED offers high optical efficiency and increased lifetime (> 50,000 hours). The 6-lead package provides access to each anode and cathode for serial electrical connection of each color to adjacent LEDs, simplifying drive circuitry. The requisite white balance point can be achieved by adjusting the drive current for each color independently.

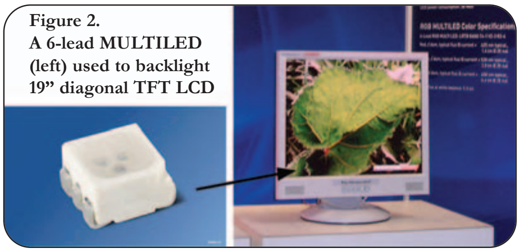

Figure 2.
A 6-lead MULTILED (left) used to backlight 19" diagonal TFT LCD

Figure 3. Premium HDTVs such as the SONY 70XBR will continue to be backlit by RGB LEDs with color gamut > 105 percent NTSC

By choosing the appropriate number of LEDs, display sizes up to 24 inches can be backlit using a side-firing light guide. For the 19-inch display shown in Figure 2, 154 of the 6-lead MULTILED units are used with the LEDs mounted on two Insulated Metal Substrate (IMS) PCBs, replacing two CCFLs. In this example the original housing, light guide and optical films were retained, eliminating the need for a complete re-design.

Direct LED Backlighting for LCD TVs

For LCD TVs, direct LED backlighting is preferred as it can provide a higher system efficiency of up to 80 percent. One direct backlighting solution is the Golden Dragon Argus LED using Thinfilm technology combined with a lens specially designed for backlighting. The wide radiation characteristic of this LED provides the advantage of the three primary colors overlapping uniformly over a very large area, delivering a homogeneous color mix within minimal depth.

For the design of a complete backlight unit, RGGB QuadLEDs composed of Golden Dragon Argus LEDs can be systematically arranged in a matrix. In test constructions, typical BLU heights of 35 mm to 45 mm were achieved for a QuadLED pitch of up to 85 mm.

To address the cost concerns associated with Tier 2 (medium grade) LCD TVs, one potential solution is the use of multi-phosphor converted white LEDs that generate a color gamut of over 95 percent NTSC, (color standards established by the American National TV Steering Committee) better than most CCFLs. The cost savings result from using fewer LEDs (compared to red, green, blue combination [RGB]), with only a single drive channel necessary. Premium quality Tier 1 TVs such as the Sony 70XBR, where higher quality comes at a premium, will still use RGB with a color gamut greater than 105 percent NTSC. (See Figure 3)

Scalability to Larger LCDs

As HB LEDs continue their migration into larger scale LCDs, the continued advancement in LED brightness and efficiency will reduce the number of LEDs and the power consumption required to produce large LCD backlights, making HB LEDs a more feasible option for larger scale applications. At this point in time, CCFLs still represent a more cost effective solution for certain backlighting requirements, particularly in industrial applications that do not require the advantages of LEDs. However, as HB LEDs continue to decline in price and increase in performance, cost will become less of a barrier for designing in HB LED BLUs, even for these applications.

Other Benefits of LED Backlights For Large Screen LCDs

Motion Blur Reduction and Contrast Enhancement: the fast switching speeds of LEDs will enhance the performance of LCD displays by increasing the dynamic brightness range and contrast with "active drive" and reducing the "motion blur" encountered when video information exceeds the switching speed of the liquid crystals. This is achieved by modulating the brightness of the LEDs in relation to the picture information, which cannot be done as easily with CCFLs because they have a much slower switching time and a limited brightness adjustment range.

It is foreseeable that, in the not too distant future, faster LCDs will be available, allowing the use of sequential color mode where each of the three colors is switched on one at a time. This will eliminate the need for color filters, which constitute a big cost component of TFT color LCDs and potentially reduce LED BLU system cost to below that of CCFL-equipped display screens.

HB LED technology has attained the brightness and efficiency levels necessary for larger LCD backlights where wide color gamut, brightness uniformity, longer life and durability are important. Continued increases in HB LED brightness will reduce the quantity of LEDs required for the BLU, reduce the necessary power consumption and increase overall LCD luminance. The cost of HB LEDs will continue to decline as penetration increases into more high-volume applications such as general illumination and mid-size to large LCDs used in consumer products. All signs point to the increasing substitution of LEDs for CCFLs in backlighting larger LCDs.

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