Abstract: Backlights are indispensable for the operation of LCD. Light sources or lamps belong to the core components of backlights. There are many kinds of light sources for backlight such as cold cathode fluorescent lamp (CCFL), external electrode fluorescent lamp (EEFL), hot cathode fluorescent lamp (HCFL), flat fluorescent lamp (FFL), and light emitting diode (LED). Many kinds of LCD backlights as well as the characteristics of light sources for the backlights are addressed.

I. Introduction

Liquid crystal displays (LCD) notebooks, LCD monitors, and LCD TVs belong to non-emissive displays so that backlights are necessary to generate colors on LCD screen. Backlight structures are different depending on the applications. Edge type backlights are used for notebooks and monitors. And direct type backlights are usually used for LCD TVs. The edge type backlights and direct type backlights are shown in Fig. 1.

The edge-type backlight structure uses light guide plate (LGP) to direct the side light emitted from the CCFL's or LED's to the LCD panels through the prism and diffusion sheets. The number of CCFLs or LEDs used in the edge-type backlights are limited so that the luminance of LCD monitors have some limitation. The peak luminance of LCD monitors is not greater than 300 nits.

The direct-type backlights usually have more luminance than that of the edge-type backlight. The parallel array of CCFLs, EEFLs, and the strings of LEDs usually generate very high luminance at the surface of the backlights. But the assembly of the direct type backlight using CCFLs, EEFLs or strings of LEDs is almost being done manually due to the nature of light sources. The FFLs provides high luminance as well as simple process for assembly of backlight because FFL is just one body lamps with its size up to about 40" in diagonal until now.

The quality of LCDs depends on the quality of backlight used in the LCDs. Therefore, it is valuable to review the structures and core components of backlight. The various structures of backlights as well as the characteristics of lamps for backlights including CCFL, EEFL, FFL, and LED are discussed and analyzed.

II. Structures of LCD Backlight

There are basically two kinds of backlight structures as shown in Fig. 1. The edge-type backlights are mostly used for small size LCDs including cell phones, notebooks and monitors. The major light sources of the small size LCDs are mostly LEDs. The major light sources for notebooks and monitors are CCFLs but the number of LED backlights for notebooks and monitors are increasing due to the development of high efficiency LEDs and reduced cost of LEDs.

Fig. 2 shows the structure of edge-type CCFL backlight for notebooks and monitors including all the parts and components of the backlight. There are too many number of components and sheets used in the edge-type backlights. The CCFL lamp can be replaced by the strings of LEDs. The assembly process for this backlight is almost being done manually due to the nature of parts and sheets used in the backlights. The assembly of this type of backlight should be done within the clean room to remove any dust particles within the backlight.

The direct-type backlights are mostly used for small size LCDs including cell phones, notebooks and monitors. The major light sources of the small size LCDs are mostly LEDs. The major light sources for notebooks and monitors are CCFLs but the number of LED backlights for notebooks and monitors are increasing due to the development of high efficiency LEDs and reduced cost of LEDs.
protector sheet. There is no light guide plate used. Parallel array of CCFLs generates high luminance needed for LCD TV application.

**Figure 3.** Internal view of direct-type CCFL Backlight.

The CCFL backlights for TV application need as many inverters as CCFLs used to achieve lamp to lamp brightness uniformity. It makes the EEFL multi-lamp backlight more attractive because it needs only one inverter to drive many lamps uniformly. Fig. 4. shows the structure of EEFL backlight.

**Figure 4.** EEFL backlight system.

Backlight is a really a burden for LCD TV because of the backlight cost. The assembly of CCFL or EEFL backlights are usually done manually so that it is not easy to reduce the total backlight cost. FFL may solve that price issue due to the nature of FFL backlight. FFL is just one body lamp that matches with the TFT panel. Therefore, the LCD TV assembly process may not need backlight unit. FFL is just one of the components in the process of LCD TV assembly. The backlight cost can be substantially reduced as soon as the new LCD TV structure of FFL is developed. Fig. 5 shows the cut view of FFL backlight.

**Figure 5.** Cut view of 32” FFL backlight.

LED backlight is one of the candidates for LCD TV application. The efficiency of LED has been increasing continuously and the color gamut as well. LED backlight is expected to be the ideal backlight eventually if the production cost reaches lower than any of the existing backlights. Field sequential driving of LED backlight using red, green, and blue LEDs will remove the color filter process in the TFT panel, which will reduce power consumption and cost drastically. Fig. 6 shows an example of LED backlight.

**III. Light Sources for LCD Backlight**

There are many kinds of light sources for LCD backlights. The light sources for LCD backlights include CCFL, EEFL, FFL, LED, hot cathode fluorescent lamp (HCFL), organic light emitting diode (OLED), and electroluminescent (EL) devices. The most conventional light sources include CCFL, EEFL, FFL and LED.

**Figure 6.** Cut section of LED backlight [2].

The CCFL has been the major light source of LCD backlight since the birth of active matrix (AM) LCD. The structure of CCFL is shown in Fig. 7.

The CCFL is the fluorescent lamp which is operated in the range of normal glow discharge. Rare gas and a small amount of mercury (a few mg) are filled in the glass tube coated with phosphor (fluorescent material). By application of high electric field at high frequency between electrodes at both ends of the glass tube, glow discharge occurs in the low pressure mercury vapor. Mercury atoms which are excited by its discharge, emit ultraviolet rays (253.7 nm), and this
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ultraviolet rays excite the phosphor. The visible light is emitted as the excited atoms of phosphor return to low energy level. The wave length of emitted light varies according to the composition of phosphor materials.

**Figure 7.** Light emission mechanism of CCFL.[3,4].

The EEFL became more important for direct type backlight for LCD TV application. The structure of EEFL is shown in Fig. 8. Light emission mechanism is similar to that of CCFL. Life time of EEFL depends on the formation of pin holes generated by the bombardment of ions on the inner surface of the glass tube.

**Figure 8.** Electrode structures of EEFL[3].

Flat lamp has been considered as a perfect light source for high brightness LCD TV for years but the development speed of flat lamp was slower than expected. Recently, Samsung Electronics started to use flat fluorescent lamps for its 40" LCD TV demonstrated at IMID/IDMC '06 booth. The sizes of FFL reported were 32" and 40" in diagonal. Fig. 9 shows the formed surfaced of FFL. Glass forming technology is required to form the channels of FFL so that production equipment development should be accompanied with the development of FFL backlight. Volume production of FFL backlight is already started by this year. Reliability of FFL backlight needs to be approved for the acceptance of FFL backlight to LCD TV.

**Figure 9.** FFL in operation

HCFL was not used as a light source for LCD backlight. But recently, it was reported as a candidate of LCD TV backlight light source. High brightness and high efficiency are the major advantage of HCFL backlight. The very short life time of HCFL lamp was the problem which caused HCFL not to be used as a backlight light source. Electronic control of filament resolved the life time issue of HCFL so that it can be used as backlight light source now.[5] The uniformity of brightness could be resolved by using diffuser with collimator as shown in Fig. 10.

**Figure 10.** T5 HCFL and collimating diffuser[5].

Various kinds of mobile LCDs use LED backlight. White LED or red, green, blue LED are used as light sources of backlight. Edge-lit LED backlight are mostly used in mobile displays including cell phones. LED backlight for LCD TV will be one of the hot issues of backlight in the near future. One example of backlight with LED is shown in Fig. 11 [6].

**Figure 11.** Cross section of a typical LED BLU stack up with Golden DRAGON® with lens [6].
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IV. Conclusion
Backlights are indispensable for the operation of LCD. Light sources or lamps are of the core components of backlights. There are many kinds of light sources for backlight such as CCFL, EEFL, FFL, HCFL, and LEDs. Currently, CCFL, EEFL, and FFL are used as light sources of LCD backlights. The FFLs are expected to be cheaper than any other light sources for LCD TV.

High efficiency LED and very efficient optical design of backlight will be one the most important issues of LED backlights. LCD TV without color filter will be possible with R, G, B LED backlight with field sequential driving, which will eventually reduce backlight material cost substantially.

References