Current Status of OLEDs Technology

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Abstract

The current status of OLEDs technology is reviewed. Comparison has been made between small molecule based OLEDs and polymer LEDs. In addition, advantages of OLEDs technology and technical issues for commercialization are addressed. Details of these issues will be discussed at the meeting.

Introduction

Organic light emitting diode (OLED), also referred to as organic electroluminescence (OEL), is a relatively new type of flat panel display technology in which electric current is converted to luminescent light in device structures made from organic thin film materials. OLEDs may be fabricated using either small molecular materials or polymers. A technology based on small molecules was pioneered by C. Tang et al. at Kodak in the late 1980s [1], which was soon after followed by the invention of polymer light emitting diode (PLED) by R. H. Friend et al. at Cambridge University [2].

Advantages over conventional LCD technology are often said to include lower power consumption, faster response time, higher brightness levels in a variety of lighting conditions, wide viewing angle and thinner design. While there remain tough barriers for commercialization, OLEDs technology appears to be quite well suited for advanced electronic display applications. Currently feasible applications cover passive monochrome and multi-color displays for automobile applications, and there have been efforts to apply the innovative technology to portable devices such as cellular phones and PDAs among other things.

In this report, I will briefly review the current status of OLEDs technology and address technical issues for commercialization.

Device Structure and Characteristics

A matrix of display pixel is formed by depositing organic layers and orthogonal rows of cathodes, in sequence, on rows of patterned indium tin oxide (ITO) formed on a transparent substrate. Applying the appropriate bias voltage to the intersecting rows and columns causes current to flow and light to emit from the pixel formed by the intersection. Figure 1 depicts a cross-sectional view of a typical cell structure used for a passive-matrix OLED fabricated on a transparent substrate. OLED basically has a single layer or more typically multilayers of organic material(s) sandwiched between cathode and anode. The organic layer(s) must be capable of performing various functions such as transporting injected charge and providing for charge recombination. PLED often has a smaller number of organic layers compared to small molecules based OLED, which, along with its simpler film forming nature, presumably make possible the reduction of fabrication cost. Interface issues are critical to successful fabrication and product performance. Figure 2 shows *I–V* and *I-L* characteristics of a typical green monochrome OLED.

Small Molecules vs. Polymers

Although small molecule based OLEDs have already reached the market (Pioneer, Japan), proponents of PLEDs argue that their technology will be less expensive for mass production. Fabrication of small molecule devices requires many steps to be carried out in vacuum, whereas some steps of PLED fabrication processes can be accomplished in inert atmosphere. PLED appears to turn on at a lower voltage, which is a substantial advantage. It is currently much easier to fabricate a full color display using small molecules.

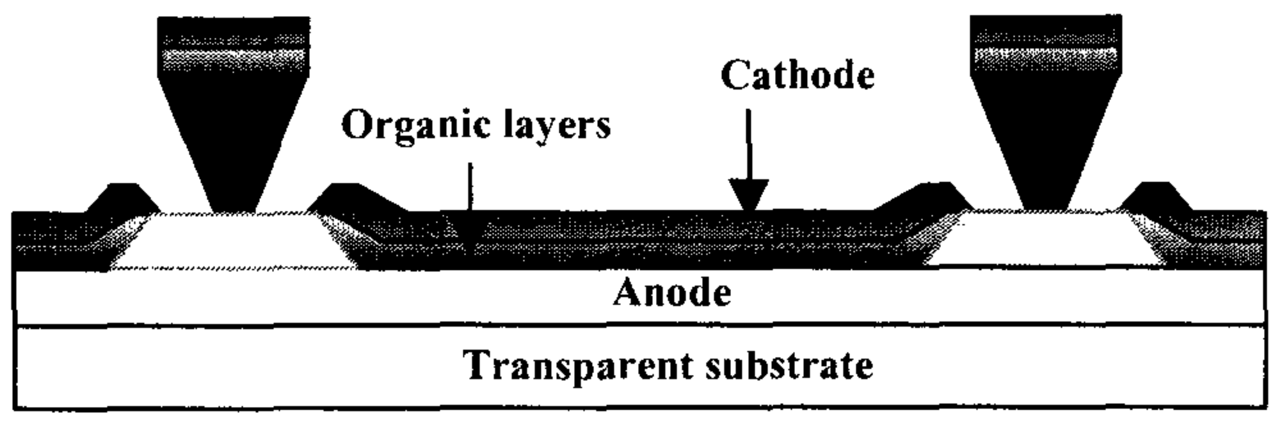

Fig. 1 Cross-sectional view of a passive-matrix OLED

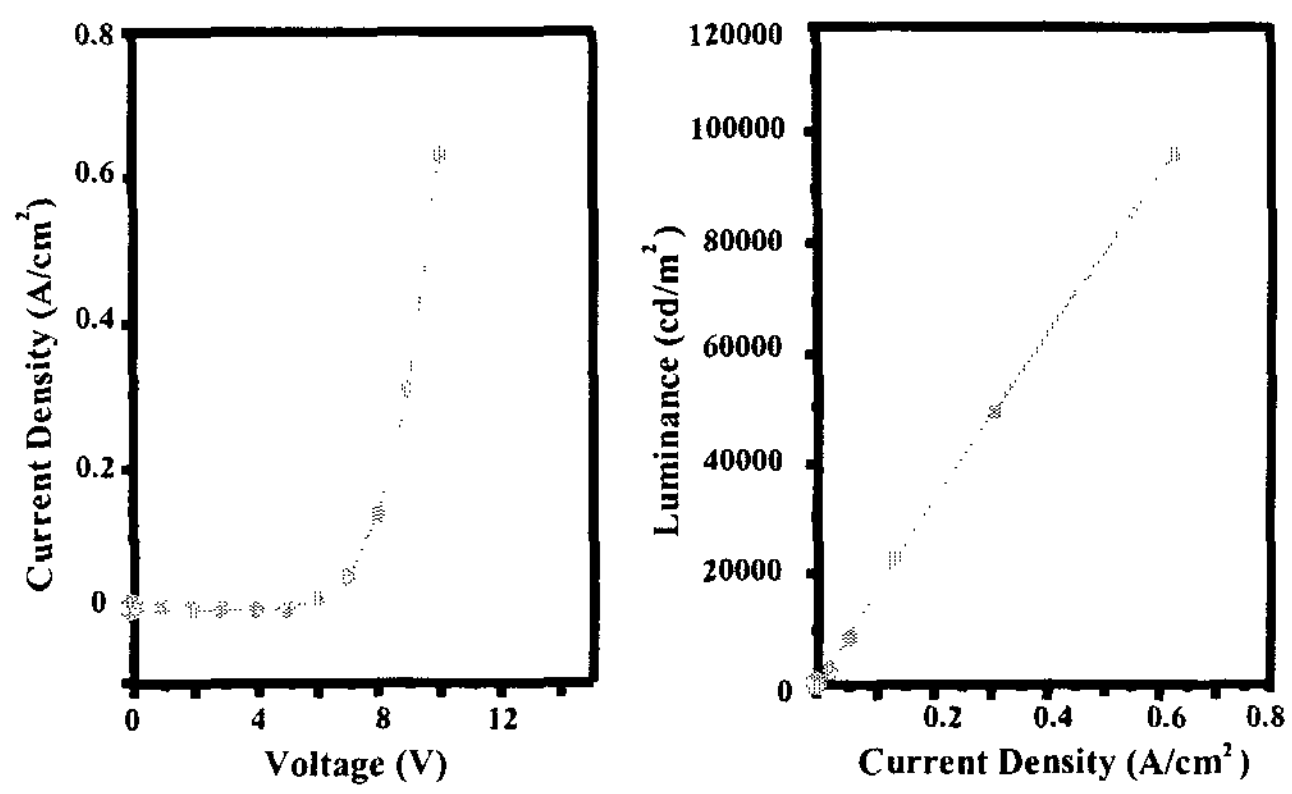

Fig. 2 *I-V* and *I-L* characteristics of a typical green OLED

Advantages and Barriers

The following advantages of OLEDs have often been mentioned in various literatures.

- Thin and lightweight
- Low voltage and power consumption
- Self-emissive (no backlight)
- Fast switching (< 1μs)
- Wide viewing angle
- Simple fabrication processes

OLED technology will need to compete in many applications with mature LCD devices. The following issues must be addressed properly before the potential of OLED technology can be realized.

- Organic materials: A novel red emitter, currently least efficient among RGB, is absolutely required for the fabrication of full color OLEDs using an RGB separate deposition method. Efficient blue emitter and color down-converters are in demand for a different method of color generation. Overall power efficiency and heat-resistant characteristics need to be improved.
- Cathode patterning: Due to the fragility of organic materials with respect to solvents, heat and UV light, a conventional photolithography is not an appropriate option for the cathode patterning. Since post-deposition patterning is particularly difficult, most of the current effort is being focused upon means by which the pattern is formed during deposition, either by shadow masking, lift-off processes, or ink-jet printing. The limitations and implications of each of these approaches need further study. Most of small molecules based OLEDs are currently fabricated using a kind of patterning method involving the construction of a base/pillar combination that performs a shadow function at each pixel site. However, the patterning method does not appear to be quite effective for the mass production of full color OLEDs, and a simpler method strongly needs to be devised.
- Device stability: Both shelf life and operational life are critical. Exposure to humidity and heat can be particularly damaging. Although the employment of encapsulation and getter materials can reduce the impact of hostile environments, a low cost solution that preserves the advantages of low weight and thin profile has yet to be demonstrated.
- Driving: While the passive addressing is a simple and cheap solution, it is limited to around VGA. The barriers include large RC delay, reduced power efficiency and additional heat-induced degradation. Active addressing is an alternative solution, but the cost will increase. In contrast to TFT-LCD, the TFTs must control the current across the pixel diodes that is producing the light as well as switching pixels on and off, which requires mobile poly-Si instead of amorphous Si. Even worse, multiple TFTs are required in each pixel to ensure spatial uniformity and temporal stability. The technological challenges of fabricating full color LTPS OLEDs are apparently significant, but they are expected to produce power efficient, high contrast and high dynamic range pixels.
- Plastic substrates: Light-weight flexible displays are less prone to breakage than devices on glass substrates, which could be very attractive for small portable devices such as cellular phones and PDAs. Barriers to their adoption include high gas permeability, narrow temperature window for processes and high cost.

Conclusion

Commercialization can be long and painful, especially when competing for market share with alternative technologies. In addition to display performance, one needs to carefully evaluate issues such as lifetime and durability, manufacturing yields and throughput, the cost of equipment and materials. Despite a variety of obstacles, OLEDs technology is still very promising as a new flat panel display technology. The ultimate goal will be large flexible displays driven by organic TFTs.

Acknowledgments

The author is grateful to researchers at LG-CIT, LG Micron and LG.Philips LCD.

References

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