OLEDs: The Displays of the Future

A radical new technology could transform ordinary windows into televisions, walls into glowing light sources, and can labels into animated recipe books. It will solve the common issues of bulky monitors and televisions, unaffordable plasma TVs, and heavy notebook computers. This technology, called organic light-emitting diodes (OLEDs), is a significant improvement over common LEDs as well as the relatively new liquid crystal displays (LCDs). It will completely revolutionize computer monitors and other displays, windshields, clothing, and even the common light bulb by using an inexpensive, thin, and versatile technology.

How it Works

OLEDs, whose structure is illustrated in Figure 1, are composed of layers of semiconductors, materials which conduct electricity when they are stimulated by an electric current. Electric currents that pass through them can remove a certain amount of electrons from the material, creating positively charged "holes" in its layer of filled electrons, making the material *p*-type. However, if excess electrons are added, the material becomes negatively charged and is called *n*-type. The extra electrons from the *n*-type then become attracted to the *p*-type and drop into positively-charged holes, emitting energy as photons of light. The amount of energy emitted generates different wavelengths, and thus different colors of light.

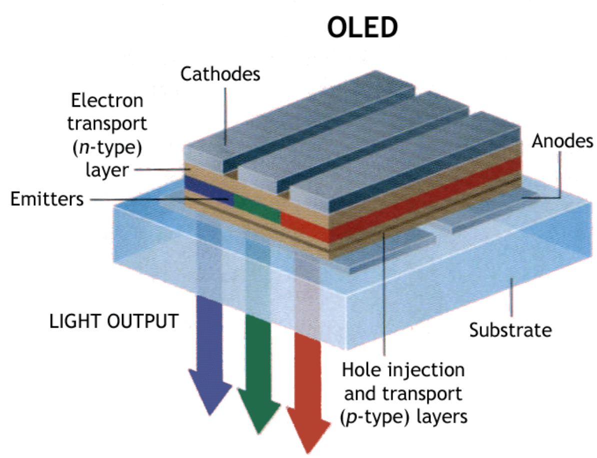

Figure 1: Diagram of an OLED (79 Howard).

The difference between LEDs and OLEDs is that OLEDs use organic semiconductors, while LEDs do not. Usually, two different types of organic materials are used — one that can easily become a *p*-type and one that can easily become an *n*-type. One of the materials has to be transparent so that light can escape.

To create an OLED monitor, individual OLED structures are put together in a large grid. Each OLED structure acts as a single pixel, an individual dot on the screen with its own color. Since OLED structures can only emit red, green, and blue light, colors are created by mixing combinations of them. The overall thickness of the layers of OLED structures is about 100 to 150 nanometers, much thinner than LEDs. Also, the organic materials are commonly attached to a glass substrate, an outer layer that protects them from water, damaging substances, and other harsh conditions.

Advantages of OLED Displays

OLED displays have many advantages over current liquid crystal diode (LCD) and cathode ray tube (CRT) displays. As depicted in Figure 2, OLED monitors are much thinner than the current LCD monitors. Not only are the light-emitting portions of the monitors thinner than the LCD's counterparts, but they also do not require a backlight for them to work, since the individual OLED structures emit their own light, while the LCD structures can only block light. In addition, OLEDs use up to ten times less power than LCDs, and in some situations do not require any power, since they do not require a constant electric current to keep the current image. Because they use power only to change the image, the monitor can be shut off, but the image can still be kept on the screen. Hence, OLEDs would work well on PDAs and notebook computers because of their small size and low power consumption.

Figure 2: Samsung's 15.5 inch OLED monitor prototype is only 1.8 mm thick (81 Howard).

The quality of OLEDs is also superior to that of LCDs. OLED displays have brighter pictures, higher resolutions (sharper images), wider viewing angles, and higher refresh rates (the frequency at which the image is updated) than LCD monitors. OLED displays compare to both plasma displays and CRT displays similarly. Finally, OLEDs can be discarded safely, since they do not contain the mercury found in LCDs or the lead found in CRTs.

Types of OLEDs and Their Uses

OLEDs have a strong potential to create completely new and revolutionary products, such as transparent displays, composed of transparent OLEDs. Instead of having an opaque layer and a transparent layer like standard OLEDs, transparent OLEDs have two transparent layers. Because of this, transparent OLEDs can also emit light on each side, making double-sided OLED displays. Transparent OLEDs can be used on glass or other clear objects, such as windows. This way, a window can be transformed into a TV. Transparent OLEDs could also be used on car windshields to display a vehicle's speed or any warnings. If a transparent OLED is placed on a solid black surface, the contrast can be greatly improved, especially in the sunlight.

Another type of OLED is called a stacked OLED, in which the red, green, and blue emitters are stacked on top of each other (Figure 3), instead of being placed side-by-side like in other OLEDs, LCDs, and CRTs. As a result, for the same display area as other OLEDs, stacked OLEDs have resolutions three times greater. The stacked OLED displays' pixels can be scaled very large and still look normal. In other large OLED and LCD displays, one could see the individual red, green, and blue components of each pixel; however, this is not the case in stacked OLEDs, since each pixel's red, green, and blue emitters are placed behind each other instead of next to each other.

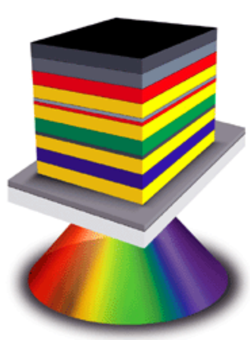

Figure 3: Structure of stacked OLEDs (Universal Display Coorporation).

OLEDs can also be made bendable by using flexible substrates instead of the standard glass substrates. Flexibility allows them to be put on clothing, be used as labels on cans, or be used as newspapers. Also, because they are lightweight, they can be used as displays on laptops, PDAs, or wall-mounted televisions to significantly reduce the devices' weights. They can even be used as wallpaper to illuminate rooms without the need of lights. Flexible OLEDs are also more durable, since they do not use glass, and they can cost much less than other OLEDs.

Limitations of OLEDs

Although OLEDs have many advantages over current LCDs and CRTs, there are many limitations that must be overcome before they can compete as computer monitors. One serious restraint is that the red and blue emitters last only a few thousand hours, while the standard for displays is 10,000 hours or more. Additionally, although OLEDs have the potential to be much more power efficient than current LCDs, today's OLEDs are only 30% more efficient, not enough to tempt consumers to switch to OLEDs. Finally, though OLEDs have the potential to become flexible, scientists must first find a substrate that is both flexible and durable, which may take a few years.

OLEDs in the Present and the Future

OLED displays, which are being developed by more than 100 companies, currently are found in only a few products, such as cell phones and digital cameras, since these devices do not require long-lasting screens. The first active-matrix OLED screen, a screen that constantly updates, was released in the Kodak EasyShare LS663 digital camera (Figure 4).

Figure 4: Kodak's EasyShare LS633 digital camera is the first released product that uses an active-matrix OLED screen (76 Howard).

In the future, OLEDs can be expected to slowly replace other displays. Philips Research plans to mass-produce foldable plastic displays in 2005. However, these will only be monochromatic, meaning they can only display two different colors. Within two to four years, large, full-color OLED displays should debut, such as the 15.5-inch Samsung monitor (Figure 2), as well as other sizes, such as 17-, 20-, and 24-inch screens. A few years after that, flexible OLED displays, such as wearable computers and rollable displays, should be introduced. In five to ten years, OLEDs might become available for general lighting, such as OLED "wallpaper" or OLED safety lights for vehicles and clothing. Analysts estimate that by 2007, the OLED display market could reach one-tenth of the revenues of the current LCD and plasma market. However, experts predict that LCDs will last for another 15 to 20 years before OLEDs completely take over.

References

Anonymous. "Coming soon to a laptop near you." The Economist Jun. 21, 2003: 5.

Anonymous. "Futuristic OLED gadgets." R & D Mar. 2003: 42.

Anonymous. "OLED: The Thinnest of All." PC Magazine May 4, 2004: 115.

Anonymous. "Technology." Universal Display Corporation. May 2, 2004. <http://www.universaldisplay.com/tech.php>

Howard, Webster E. "Better Displays with Organic Films." Scientific American Feb. 2004: 76-81.

Krane, Jim. "Monitors that roll up, twist, bend? ; OLED technology could spawn slew of dream products." Seattle Times Dec. 16, 2002: C.3.

Levin, Carol. "Materials: OLED Displays ; An illumination revolution." PC Magazine Jul. 1, 2003: 92.

Robb, Drew. "Displays Go for Sharper Image." Computerworld Jan. 12, 2004: 28.

Simons, Tad. "Nature's little lantern, OLEDs." Presentations Jun. 2003: 38.

Snider, Mike. "Future of TV, PC screens appears thinner every day." USA Today Nov. 17, 2003: E.09.