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ORGANIC LIGHT EMITTING DIODE (OLED)

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ABSTRACT : *An Organic Light Emitting Diode (OLED) is a device composed of an organic layer that emits lights in response to an electrical current. Organic light emitting diodes have advanced tremendously over the past decades. The different manufacturing processes of the OLED itself to several advantages over flat panel displays made with LCD technology which includes its light weight and flexible plastic substrates, wider viewing angles, improved brightness, better power efficiency and quicker response time. However, its drawbacks include shorter life span, poor color balance, poor outdoor performance, susceptibility to water damage etc.The application of OLEDs in electronics is on the increase on daily basics from cameras to cell phones to OLED televisions, etc. Although OLEDs provides prospects for thinner, smarter, lighter and ultra-flexible electronics displays, however, due to high cost of manufacturing, it is not yet widely used.*

Keywords - *Electronic, Display, Devices, Lifetime, Application*

I. INTRODUCTION

Do you remember old-style Television set powered by cathode-ray tubes (CRTs)? The biggest ones were about 30–60cm (1–2ft) deep and almost too heavy to lift by you. If you think that's bad, you should have seen what TVs were like in the 1940s. The CRTs inside were so long that they had to stand upright firing their picture toward the ceiling, with a little mirror at the top to bend it sideways into the room. Watching TV in those days was a bit like staring down the periscope of a submarine! Thank goodness for progress. Now most of us have computers and TVs with LCD screens, which are thin enough to mount on a wall, and displays light enough to build into portable gadgets like cell phones. If you think that's good, wait till you see the next generation of displays made using OLED (organic light-emitting diode) technology. They're super-light, almost paper-thin, theoretically flexible enough to print onto clothing, and they produce a brighter and more colorful picture. What are they and how do they work? Let's take a closer look!

The purpose of this research work is to explore the ground-breaking technology of the OLED. The following are the specific objectives:

i. How an OLED works
ii. Types of OLEDs
iii. Advantages and disadvantages of OLEDs
iv. Current and future OLED applications

This work discusses the Organic Light Emitting Diode (OLED) with interest on how it works its material properties, its prospects, limitations and application areas.

This work is intended to showcase the groundbreaking technological success in the electronics display world, in this masterpiece called the OLED. This research is also intended to supply sufficient information to students in their choice of electronic display for their electronics projects. Similarly, electronics engineers/technicians and mainstream display manufacturers, with the information in this research work could consider employing the use of OLEDs in their displays by taking advantage of all its jaw-sagging features.

II. ORGANIC LIGHT EMITTING DIODE

The first observations of electroluminescence in organic materials were in the early 1950s by André Bernanose and co-workers at the Nancy-Université in France. They applied high alternating voltages in air to materials such as acridine orange, either deposited on or dissolved in cellulose or cellophane thin films. The proposed mechanism was either direct excitation of the dye molecules or excitation of electrons.

The first diode device was reported at Eastman Kodak by Ching W. Tang and Steven Van Slyke in 1987. This device used a novel two-layer structure with separate hole transporting and electron transporting layers such that recombination and light emission occurred in the middle of the organic layer; this resulted in a reduction in operating voltage and improvements in efficiency that led to the current era of OLED research and device production.

Research into polymer electroluminescence culminated in 1990 with J. H. Burroughes *et al.* at the Cavendish Laboratory in Cambridge reporting a high efficiency green light-emitting polymer based device using 100 nm thick films of poly(p-phenylene vinylene).

Before you can understand an OLED, it helps if you understand how a conventional LED works—so here's a quick recap. Take two slabs of semiconductor material (something like silicon or germanium), one slightly rich in electrons (called n-type) and one slightly poor in electrons (if you prefer, that's the same as saying it's rich in "holes" where electrons should be, which is called p-type). Join the n-type and p-type slabs together and, where they meet, you get a kind of neutral, no-man's land forming at the junction where surplus electrons and holes cross over and cancel one another out. Now connect electrical contacts to the two slabs and switch on the power. If you wire the contacts one way, electrons flow across the junction from the rich side to the poor, while holes flow the other way, and a current flows across the junction and through your circuit. Wire the contacts the other way and the electrons and holes won't cross over; no current flows at all. What you've made here is called a junction diode: an electronic one-way-street that allows current to flow in one direction only.

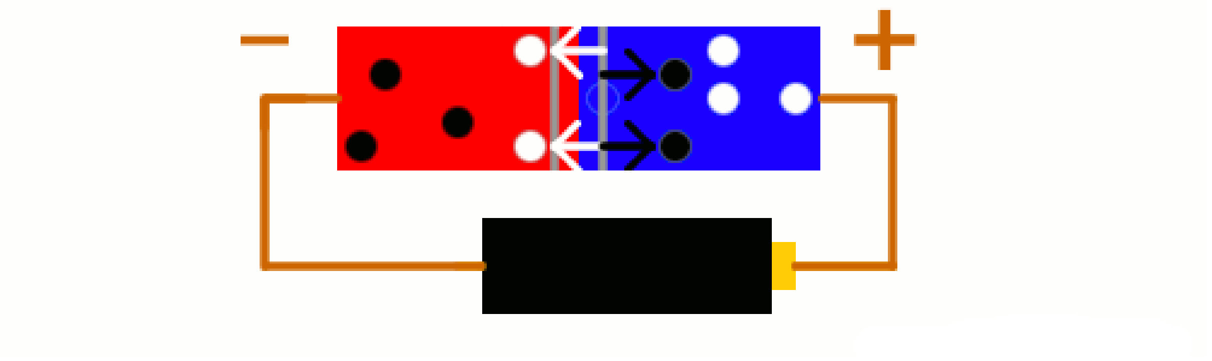

Fig.1. A junction diode in a forward biased condition

Fig.1 shows how a junction diode allows current to flow when electrons (black dots) and holes (white dots) move across the boundary between n-type (red) and p-type (blue) semiconductor material.

An LED is a junction diode with an added feature: it makes light. Every time electrons cross the junction, they nip into holes on the other side, release surplus energy, and give off a quick flash of light. All those flashes produce the dull, continuous glow for which LEDs are famous.

OLEDs work in a similar way to conventional diodes and LEDs, but instead of using layers of n-type and p-type semiconductors, they use organic molecules to produce their electrons and holes. A simple OLED is made up of six different layers. On the top and bottom there are layers of protective glass or plastic. The top layer is called the seal and the bottom layer the substrate. In between those layers, there's a negative terminal (sometimes called the cathode) and a positive terminal (called the anode). Finally, in between the anode and cathode are two layers made from organic molecules called the emissive layer (where the light is produced, which is next to the cathode) and the conductive layer (next to the anode). Here's what it all looks like:

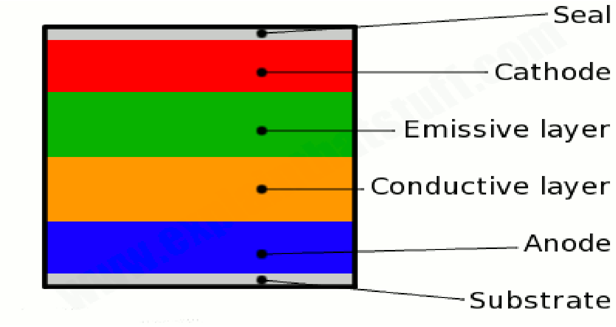

Fig. 2: The structure of an OLED

How an OLED Emit Light

How does this sandwich of layers make light?

1. To make an OLED light up, we simply attach a voltage (potential difference) across the anode and cathode.

2. As the electricity starts to flow, the cathode receives electrons from the power source and the anode loses them (or it "receives holes," if you prefer to look at it that way).

3. Now we have a situation where the added electrons are making the emissive layer negatively charged (similar to the n-type layer in a junction diode), while the conductive layer is becoming positively charged (similar to p-type material).

4. Positive holes are much more mobile than negative electrons so they jump across the boundary from the conductive layer to the emissive layer. When a hole (a lack of electron) meets an electron, the two things cancel out and release a brief burst of energy in the form of a particle of light—a photon, in other words. This process is called recombination, and because it's happening many times a second the OLED produces continuous light for as long as the current keeps flowing.

We can make an OLED produce colored light by adding a colored filter into our plastic sandwich just beneath the glass or plastic top or bottom layer. If we put thousands of red, green, and blue OLEDs next to one another and switch them on and off independently, they work like the pixels in a conventional LCD screen, so we can produce complex, hi-resolution colored pictures.

III. TYPES OF OLED

1. Passive-Matrix OLED (PMOLED)

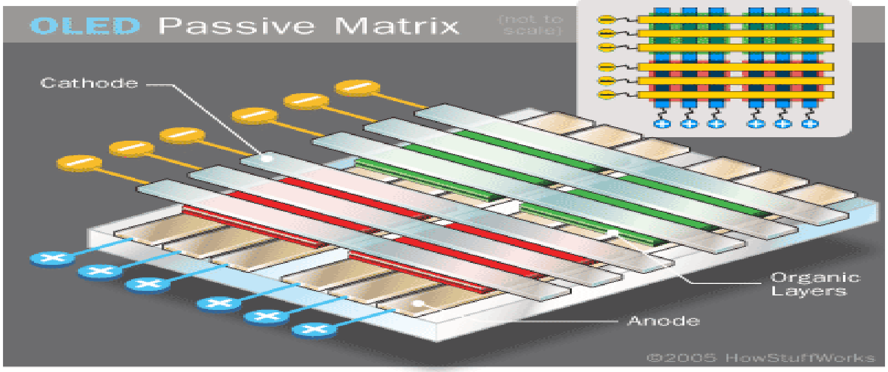

Fig.3: structure of a PMOLED.

Presumably this will be the first to hit the market since it was the passive LCD screens that came out first and more than likely OLEDs will follow in those footprints. PMOLEDs will be more expensive and will need more power than other OLEDs, though they will still use less power than LCDs out today. They are made up of a matrix of electrically conducting row and columns making pixels. Between these rows and columns are the organic layers and on the other side is the substrate. They are most efficient for smaller screens (2-3”) such as PDAs and cell phones

2. Active-Matrix OLED (AMOLED)

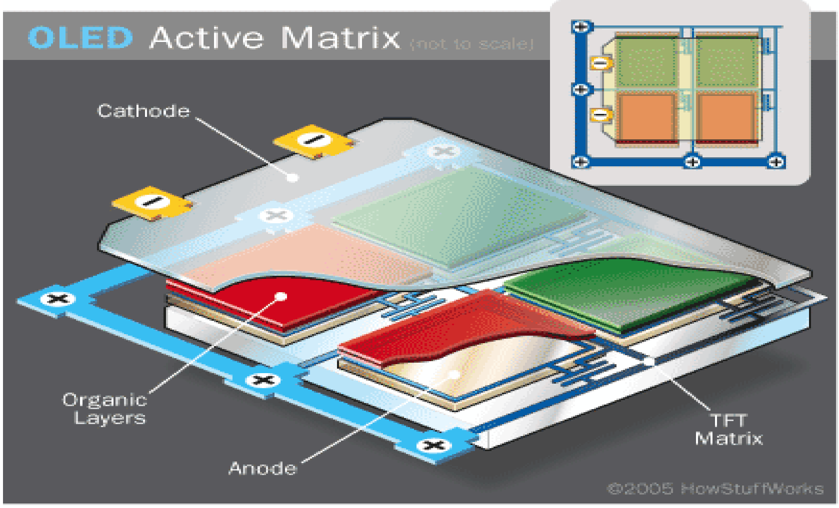

Fig.4: structure of an AMOLED.

AMOLEDs will be similar to passive but will have full layers of cathode, organic molecules, and anode; the anode layer will have a thin film transistor (TFT) back plate that forms a matrix. The TFT controls the brightness and which pixel gets turned on to form an image. In AMOLED there will be two TFT arrays per pixel, one starts and stops the charge and the other keeps a constant electrical current to the pixel. Since there is a TFT array there they will consume less power than the PMOLED since there is that constant current and they have faster refresh rates then the PMOLED. This allows the AMOLEDs to be used for computer monitors, large screen TVs, and even billboards. AMLEDs have an opaque substrate which means it is only top emitting.

IV. FOLDABLE OLED

Fig.5: A device made using foldable OLED.

Foldable OLEDs have substrates made of very flexible metallic foils or plastics. Foldable OLEDs are very lightweight and durable. Their use in devices such as cell phones and PDAs can reduce breakage, a major cause for return or repair. Potentially, foldable OLED displays can be attached to fabrics to create "smart" clothing, such as outdoor survival clothing with an integrated computer chip, cell phone, GPS receiver and OLED display sewn into it.

3. **White OLED**

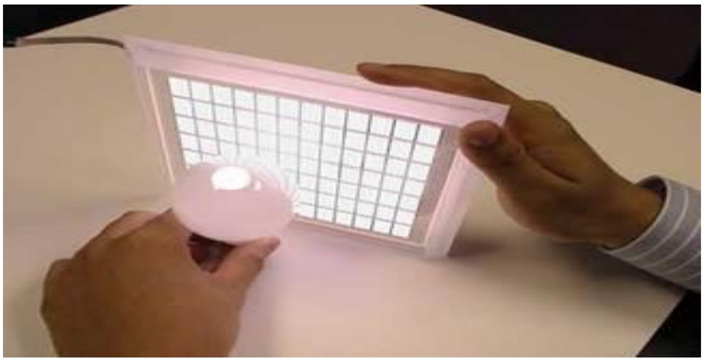

Fig. 6: White OLED used in lighting.

White OLEDs emit white light that is brighter, more uniform and more energy efficient than that emitted by fluorescent lights. White OLEDs also have the true-color qualities of incandescent lighting. Because OLEDs can be made in large sheets, they can replace fluorescent lights that are currently used in homes and buildings. Their use could potentially reduce energy costs for lighting.

V. MERITS AND DEMERITS

The LCD is currently the display of choice in small devices and is also popular in large-screen TVs. Regular LEDs often form the digits on digital clocks and other electronic devices. OLEDs offer many advantages over both LCDs and LEDs:

- Because the light-emitting layers of an OLED are lighter, the substrate of an OLED can be flexible instead of rigid. OLED substrates can be plastic rather than the glass used for LEDs and LCDs.

- The plastic, organic layers of an OLED are thinner, lighter and more flexible than the crystalline layers in an LED or LCD.

- OLEDs are **brighter** than LEDs. Because the organic layers of an OLED are much thinner than the corresponding inorganic crystal layers of an LED, the conductive and emissive layers of an OLED can be multi-layered. Also, LEDs and LCDs require glass for support, and glass absorbs some light. OLEDs do not require glass.

- OLEDs do not require backlighting like LCDs. LCDs work by selectively blocking areas of the backlight to make the images that you sees, while OLEDs generate light themselves. Because OLEDs do not require backlighting, they consume much less power than LCDs (most of the LCD power goes to the backlighting). This is especially important for battery-operated devices such as cell phones.

- OLEDs are easier to produce and can be made to larger sizes. Because OLEDs are essentially plastics, they can be made into large, thin sheets. It is much more difficult to grow and lay down so many liquid crystals.

- OLEDs have **large fields of view**, about 170 degrees. Because LCDs work by blocking light, they have an inherent viewing obstacle from certain angles. OLEDs produce their own light, so they have a much wider viewing range.

OLED seems to be the perfect technology for all types of displays, but it also has some problems:

- **Lifetime** - While red and green OLED films have longer lifetimes (46,000 to 230,000 hours), blue organics currently have much shorter lifetimes (up to around 14,000 hours (about 1.6 years).

- **Manufacturing** - Manufacturing processes are expensive right now.

- **Water** - Water can easily damage OLEDs.

VI. CURRENT AND FUTURE OLED APPLICATIONS

Currently, OLEDs are used in small-screen devices such as cell phones, PDAs and digital cameras. In September 2004, Sony Corporation announced that it was beginning mass production of OLED screens for its CLIE PEG-VZ90 model of personal-entertainment handhelds.

Kodak was the first to release a digital camera with an OLED display in March 2003, the EasyShare LS633.

Fig. 7: Kodak LS633 EasyShare with OLED display.

Several companies have already built prototype computer monitors and large-screen TVs that use OLED technology. In May 2014, LG Electronics announced that it had developed a prototype super-thin-OLED-wallpaper-TV., the first of its size.

Fig. 8: LG super-thin-OLED-wallpaper-TV.

Research and development in the field of OLEDs is proceeding rapidly and may lead to future applications in heads-up displays, automotive dashboards, billboard-type displays, home and office lighting and flexible displays. Because OLEDs refresh faster than LCDs -- almost 1,000 times faster -- a device with an OLED display could change information almost in real time. Video images could be much more realistic and constantly updated. The newspaper of the future might be an OLED display that refreshes with breaking news -- and like a regular newspaper, you could fold it up when you're done reading it and stick it in your backpack or briefcase.

OLED technology is still relatively new and unused compared to similar, long-established technologies such as LCD. Broadly speaking, you can use OLED displays wherever you can use LCDs, in such things as TV and computer screens and MP3 and cell phone displays. Their thinness, greater brightness, and better color reproduction suggests they'll find many other exciting applications in future. They might be used to make inexpensive, animated billboards, for example or super-thin pages for electronic books and magazines. Or paintings on your wall you can update from your computer. Or even clothes with constantly changing colors and patterns wired to visualize software running from your iPhone.

VII. CONCLUSION

OLED technology has advanced rapidly in recent years, with high-performing products now beginning to enter the marketplace for certain niche lighting applications. The thin, flexible structure of OLED panels provides new opportunities for innovative lighting products, and steady OLED efficiency improvements are expected to make OLEDs a viable, cost-competitive option for many lighting applications within the next five years. However, because of its high cost, it is advisable for students and non-blue-chip companies to the other alternatives such as LCD and LED which has comparative cost advantage.

Despite its numerous advantages, it’s not advisable to be employed by students and non-blue-chip electronics companies because of its high cost of manufacture and implementation. However, I recommend that:

1. Nigerian technological institutions should partner with OLED manufacturing companies and related institutes in the training of Nigerian students in the field of electronics displays.
2. The NBTE and NUC should enrich their curriculum for electronics engineering students by including emerging technologies such as electronic displays.

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