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Organic Light Emitting Diode Technology: Review

Ms. Diksha Ashokrao Mule **Ms. Kalyani Ravising Rathod**

***Abstract* — OLEDs i.e. Organic light emitting diodes are solid state devices composed of thin films of organic molecules that is 100 to 500 nanometres thick. They emit light with the application of electricity. This light was produced at a very low operating voltage with high efficiency. They are made from carbon and hydrogen. Main principle behind OLED technology is electroluminescence.The first OLED device was developed by Eastman Kodak in 1987. Many developments had take place in the year 2012. The various features of OLED devices are such as flexibility, emissive technology, light weight and thin, low power consumption, high contrast, brighter and perfect display from all angles. Organic Light Emitting Diodes are evolving as the next generation displays.Now more research is being done with the application of OLED on polymer so as to obtain a higher efficiency OLED. As OLED display technology matures, it will be better able to improve upon certain existing limitations of LCD including high power consumption, limited viewing angles, poor contrast ratios.**

***Key Words* — Electroluminescence, Organic light emitting diode, Transparent OLED, White OLED**

I. INTRODUCTION

A. History of OLED

Organic electroluminescence was first discovered by Martin Pope et al. in 1963. They observed luminescence when a voltage of about 400 was applied to an anthracene crystal. However, the development of devices based on organic electroluminescence was very slow, because of the high voltage required and the low efficiency. In 1987, Ching W. Tang and Steve Van Slice developed a novel electroluminescent device at Eastman Kodak Company. This is considered the first organic light-emitting diode. The device was fabricated by vapor deposition using Tries (8-hydroxyquinolinato) aluminum (Alq3) and demines in a double layer structure. This structure made the electron and whole recombination effective. The device had 1% external Quantum efficiency, 1.5 l m/W 10 V. In 1990 Richard Friend’s group at Cambridge University developed luminous efficiency, brightness of more than 1000 cd/m2 and a driving voltage of about a poly (p-phenylenevinylene) (PPV) based OLED, which is called polymer-LED or PLED . The light emission was in the green-yellow part of the spectrum, and the efficiency was about 0.05%. Since then, there have been increasing interests, and research activities in this new field. Enormous progress has been made in the improvements of color gamut, luminance efficiency and device reliability. The growing interest is largely motivated by the promise of the use of this technology in flat panel displays.

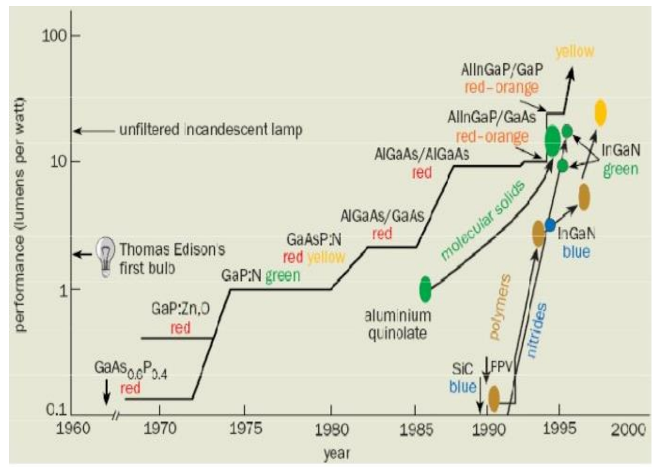

Fig. 1. OLED progress (Originally from Sheats et al. Science 273, 884, 1996)

B. Introduction to OLED

The organic light emitting diode technology uses a device name as OLED i.e. Organic light emitting diode. OLED’s are simple solid-state devices (more of an LED) comprised of very thin films of organic compounds in the electro-luminescent layer. These organic compounds have a special property of creating light when electricity is applied to it. The organic compounds are designed to be in between two electrodes. Out of these one of the electrodes should be transparent. The result is a very bright and crispy display with power consumption lesser than the usual LCD and LED.

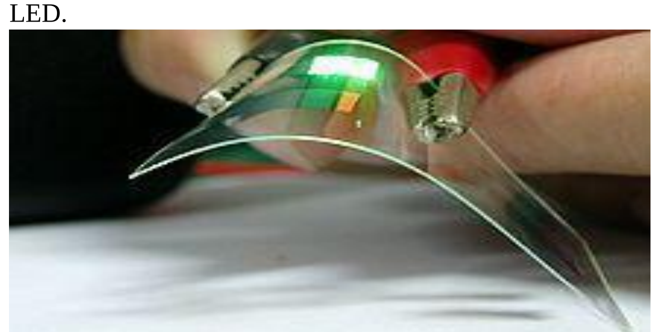

Fig. 2. Demonstration of a flexible OLED device

An organic light emitting diode (OLED) is a light-emitting diode in which the emissive electroluminescent layer is a film of organic compounds which emit light in response to an electric current. This layer of organic semiconductor material is situated between two electrodes. Generally, at least one of these electrodes is transparent. The discovery of the electroluminescence property in organic materials is considered to be the stepping stone of OLED in 1950s. The first proper OLED was manufactured in 1980 by Dr. Ching W Tang and Steven Van Slyke. The OLED had a double layer structure, when the holes and electrons were transported separately and when combined together produces a light in the organic layer centre. This light was produced at a very low operating voltage with high efficiency. More research is being done with the application of OLED on polymer so as to obtain a higher efficiency OLED.

II. Structure Of Oled

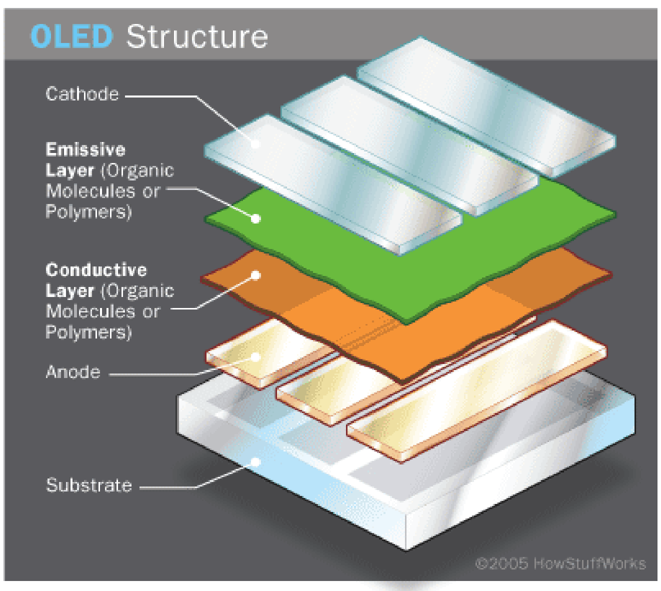

Fig. 3. Structure of OLED

OLED consists of the following parts:

A. Substrate (clear plastic, glass)

The substrate supports the OLED.

B. Anode (transparent)

The anode removes the electrons (adds electron "holes") when a current flows through the device.

C. Organic layers

These layers are made up of organic molecules or polymers.

D. Conducting layer

This layer is made of organic plastic molecules that transport "holes" from the anode. One conducting polymer used in OLEDs is polyaniline.

E. Emissive layer

This layer is made up of organic plastic molecules (different ones from the conducting layer) that transport electrons from the cathode this is where light is made. One polymer used in the emissive layer is polyfluorene.

F. Cathode (may or may not be transparent depending on the type of OLED)

The cathode injects electrons when a current flows through the device.

III. Working Principle

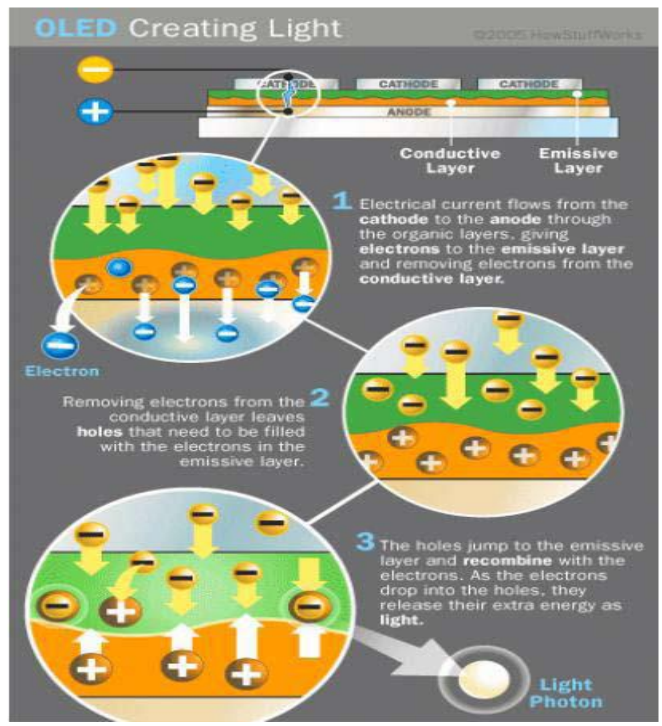

Fig. 4. Working principle of OLED

OLEDs are solid-state devices composed of thin films of organic molecules that create light with the application of electricity. OLEDs can provide brighter, crisper displays on electronic devices and uses less power than conventional light-emitting diodes (LEDs) or liquid crystal displays (LCDs) used today. OLED emits light in a similar manner to LEDs, through a process called **electrophosphorescence**.

The process is as follows:

1. The battery or power supply of the device containing the OLED applies a voltage across the OLED.
2. An electrical current flows from the cathode to the anode through the organic layers.

- The cathode gives electrons to the emissive layer of organic molecules.
- The anode removes the electrons from the conductive layer of organic molecules. (This is the equivalent to giving electron holes to the conductive layer.)

3. At the boundary between the emissive and the conductive layers, electrons find electron holes.

- When an electron finds an electron hole, the electron fills the hole (it falls into an energy level of the atom that's missing an electron).When this happens, the electron gives up energy in the form of a photon of light.

4. The OLED emits light.
5. The color of the light depends on the type of organic molecule in the emissive layer. Manufacturers place several types of organic films on the same OLED to make color displays.

IV. Color Generation

There are different approaches for fabricating red, green and blue pixels.
- Red, green and blue individual pixels.
- White emitter and colour filters.
- Blue emitter and colour converters.
- Stacked OLED

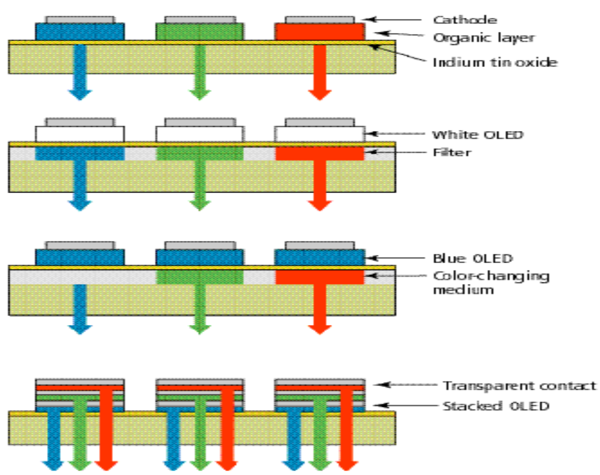

Fig. 5. Colour generation

V. Types Of OLED

A. Small molecule material OLED

In this type of OLED the emissive layer based on small molecule materials. This require vacuum processing. More manufacturing experience already gained in this OLED. This have more mature materials with longer life times. In small molecule material phosphorescent materials are available

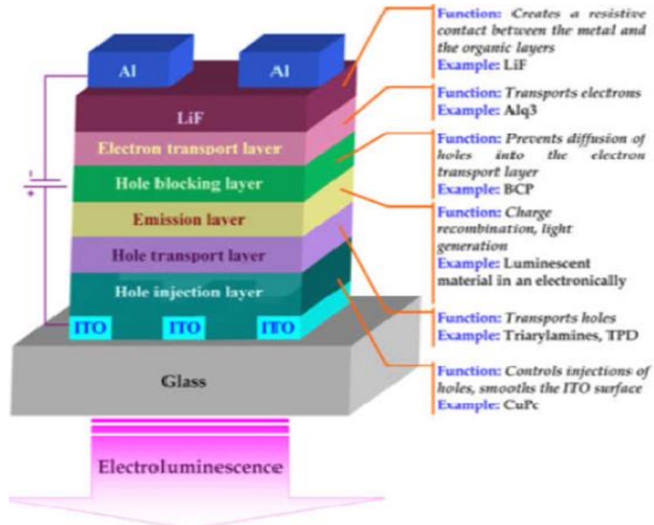

Fig. 6. Small molecule material OLED

B. Polymer material OLED

In this type of OLED emissive layer (EML) based on large molecule/polymer materials. They can be deposited at atmospheric pressure. These are more compatible with roll-to-roll processing. They have lower operating voltage.

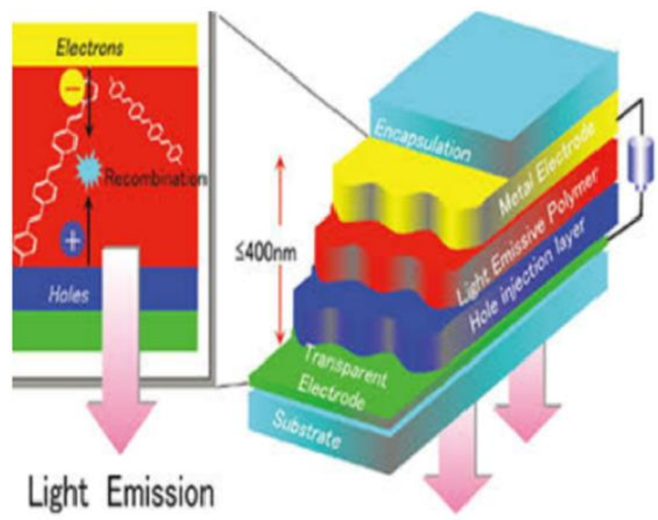

Fig. 7. Polymer material OLED

C. Passive-matrix OLED

PMOLEDs have strips of cathode, organic layers and strip of anode. The anode strips are arranged perpendicular to the cathode strips. As it shown in Fig., the intersections of the cathode and anode make up the pixels where light is emitted. External circuitry applies current to selected strips of anode and cathode, determining which pixels get turned on and which pixels remain off. Again, the brightness of each pixel is proportional to the amount of applied current. This type of

OLED is easy to make but consumes more energy than the alternative system, for this reason are ideal for small displays (1 to 3 inch) such as those you find in cell phones, PDAs andMP3 players. Even with the external circuitry, passive-matrix OLEDs consume less battery power than the LCDs that currently power these devices.

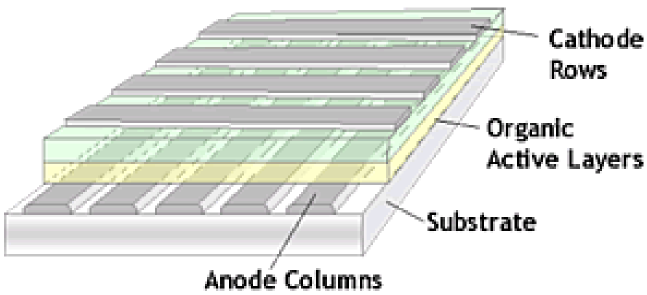

Fig. 8. Passive Matrix OLED (PMOLED)

D. Active-matrix OLED

AMOLEDs consume less power than PMOLEDs because the TFT array requires less power than external circuitry, so they are efficient for large displays. AMOLEDs also have faster refresh rates suitable for video. The best uses for AMOLEDs are computer monitors, large screen TVs and electronic signs or billboards. Active matrix displays, instead of having current distributed row by row, use thin film transistors (TFTs) that act like switches to control the amount of current, hence brightness, of each pixel, as it shown on Fig. Typically, two TFTs control the current flow to each pixel. One transistor is switched to charge a storage capacitor for each pixel and the other creates a constant current source from the capacitor to illuminate the pixel. Therefore, the top emission structure offers more efficient light emission than is typical with bottom emission structures where TFT layers are placed on the front side of the panel, limiting the light-emission aperture. This technology has a micro-cavity structure which incorporates color filters. This cavity structure uses an optical resonance effect to enhance color purity and improve light-emission efficiency. In addition, the color filter of each RGB also enhances the color purity of emitted light, and reduces ambient light reflection.

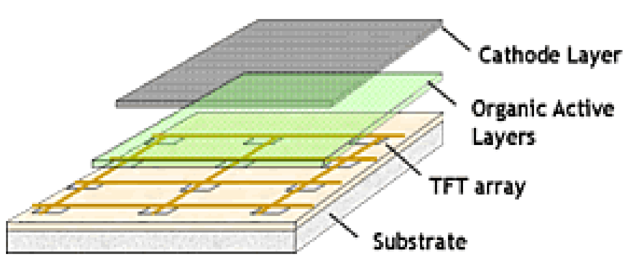

Fig. 9. Active Matrix OLED (AMOLED)

E. Transparent OLED

Transparent OLEDs have only transparent components (substrate, cathode and anode) and, when turned off, are up to85 percent as transparent as their substrate. When a transparent OLED display is turned on, it allows light to passing both directions as it shown in Fig. A transparent OLED display can be either active or passive matrix.

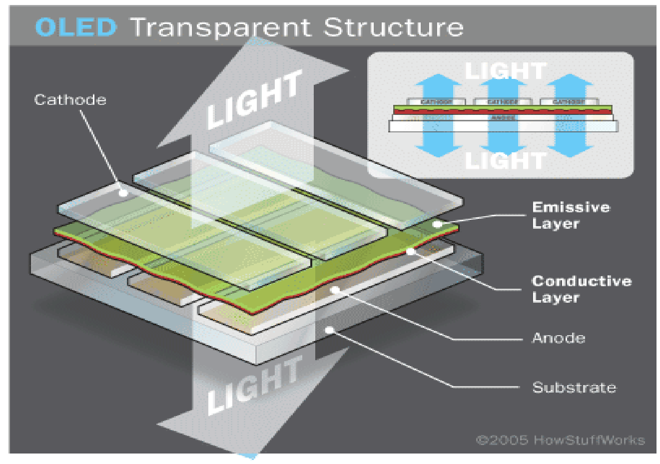

Fig. 10. Transparent OLED

This technology can be used for tablets, heads-up displays, in the car, for window wall big screen and in many other devices.

F. Top-emitting OLED

Top-emitting OLEDs have a substrate that is either opaque or reflective. They are best suited to active-matrix design. Manufacturers may use top-emitting OLED displays in smartcards as it shown in Fig.

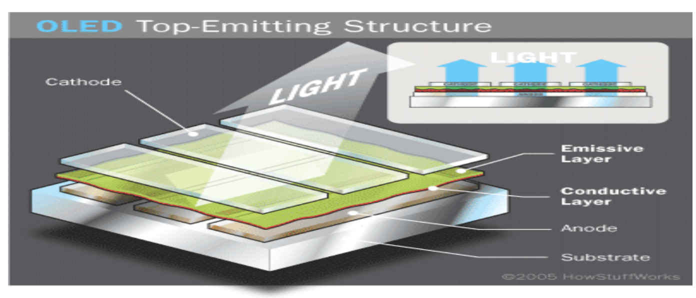

Fig. 11. Top emitting OLED

G. Flexible or Foldable OLED (FLED)

Flexible OLEDs have substrates made of very flexible metallic foils or plastics. They are very light weight and durable. Their use in devices such as cell phones and PDAs can reduce breakage, a major cause for return or repair. Potentially, flexible 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. Fig. shows flexible display.

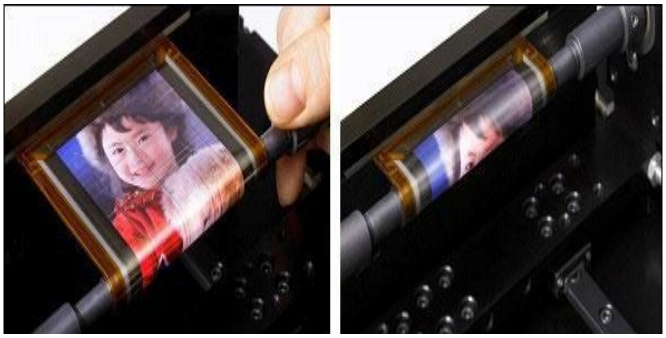

Fig. 12. Flexible OLED

H. White OLED

White OLEDs emits white light that is brighter, more uniform and more energy efficient than that emitted by fluorescent lights.

Fig. 13. White OLED

White OLEDs also have the true-color qualities of incandescent lighting. As it shown in Fig., 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.

VI. CHALLENGES FACED BY OLED

Many obstacles must be overcome before the potential of this technology can be fully realized. These include:

A. Device Stability

OLEDs have relatively short lifetime. Exposure to humidity and heat can be particularly damaging to these devices. Although encapsulation can reduce the impact of hostile environments, it is still difficult to preserves the advantages of low weight, thin profile and flexibility. The performance of the device must not deteriorate markedly with age, either through extended storage or operation. Differential aging between the RGB pixels, or between pixels that are used at different frequencies, must be kept low.

B. Voltage

The voltage needed to provide adequate current in direct drive pulsed mode is too high for inexpensive CMOS electronics and efficient operation. For active-matrix devices, drift in threshold voltages can lead to loss of control in operation, and so must be minimized or compensated for.

C. Fine patterns with vivid colors

Human perception of luminous intensity peaks sharply in the green, making blue and red devices much more difficult to create at the same efficiency. Although great progress has been made with respect to the active organic materials, better blue, green and red emitters are needed to establish clear superiority over the competing technologies.

D. Light extraction

With the present planar structures, most of the light emitted by the organic molecules remains trapped in the diode and does not reach the viewer. An easily manufacturable structure is needed that directs more light forward without increasing the reflection of ambient light.

E. Fabrication costs

Fabrication cost must be reduced so that OLED technology can compete with more mature and well developed technologies.

VII. ADVANTAGES

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:

1. The plastic, organic layers of an OLED are **thinner, lighter and more flexible** than the crystalline layers in an LED or LCD.
2. 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.
3. OLEDs are **brighter** than LEDs.
4. OLEDs do not require backlighting like LCDs.
5. 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.
6. Self-luminous: OLEDs are self-luminous and thus do not require backlight, diffusers, or polarizers.

7. Low Power: 2-10 Volts (DC)
8. Low cost and easy fabrication: Roll-to-roll manufacturing process, such as inkjet printing and screen printing, are possible for polymer OLEDs.
9. Color selectivity: There are abundant organic materials to produce a whole spectrum of visible light.
10. Flexibility: OLEDs can be easily fabricated on plastic substrates paving the way for flexible electronics.
11. High brightness and high resolution: OLEDs are very bright at low operating voltage e.g. white OLEDs can be as bright as 150,000 cd/m2.
12. Wide viewing angle: OLED emission is lambertian and so the viewing angle is as high as 160 degrees.
13. Fast response: OLEDs electroluminescence decay time is less than one microsecond.

A. Impact / Benefits

1. Enormous energy saving for the society
2. Environmental impact associated with the reduction of the need for electricity (less air pollution, depletion of non-renewable sources of energy, less greenhouse effect)
3. Creation of new lighting (fixture) industry. New methods of power distribution and conduits.
4. New architectural designs enabled (lower ceilings, contour lighting, wall / ceiling panel lighting, space saving in airplanes, and tall buildings, etc.).
5. Enormous design flexibility
6. They provides images, graphics, video
7. It has long battery life

VIII. Applications

Readily achieved by OLEDs (2002 – 2005)

• **Monochrome applications:** Small monochrome displays for hand held electronic devices (cell phones, PDAs, digital cameras, GPS devices etc.).

• **Two or multicolor applications:** Car electronics (radios, GPS displays, maps, warning lights, etc.), instrument electronics, heads-up instrumentation for aircraft and automobiles, and rugged PDAs.

• **Full color application:** LCD backlights, small full color displays such as high-resolution personal communicators.

Nearly-readily achieved by OLEDs (2005 -2010)

• **Large Displays:** Wall-hanging TV monitors, large screen computer monitors

Applications Convertible to OLEDs

• General White light applications (to replace incandescent / halogen, fluorescent)
• Lighting panels for illumination of residential and commercial buildings.
• Lighting panels for advertising boards, large signs, etc.
• Ultra-lightweight, wall-size television monitors.
• Office windows, walls and partitions.
• Color-changing lighting panels and light walls for home and office, etc.
• Large displays, "smart panels".

New Applications that could be enabled by OLEDs

• Applications benefiting from programmable performance (intensity, color, direction)
• Applications capitalizing on integration with displays, vehicles, architecture, military equipment, etc.
• Smart lights

CONCLUSION

OLED technology is the future. It is a new display technology used to create thin, efficient and bright displays and lighting panels. OLED display is without doubt superior to both LCD display and plasma display. Its not only raises that upper bar but also the lower bar, enabling even cheap manufacturers to create great picture quality because of the stunning OLED picture characteristics. The only downside of the OLED technology at the moment is the price and lifetime. OLED technology has great potential and suggests a very wide range of applications. In terms of technology OLED technology has a significant cost advantage compared with the production technology of liquid crystal matrices. OLED devices is much less rich in materials, they require a significantly smaller number of manufacturing operations.

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AUTHOR'S PROFILE

Ms. Diksha Ashokrao Mule
Final year student of Electrical Engineering, J.D.I.E.T. Yavatmal, Maharashtra.
Published and Presented paper on "Recent development of solar energy in India: Perspective, strategies and future goals"

Ms. Kalyani Ravising Rathod
Final year student of Electrical Engineering, J.D.I.E.T. Yavatmal, Maharashtra.
Published and Presented paper on "Various MPPT techniques used in PV system:Review"
Sport: Basket Ball Winner