DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB103J –Semiconductor Physics

Module 2 Lecture 15

1. ***Introduction to Optoelectronic integrated circuits***
2. ***Organic light emitting diodes – basic concepts***

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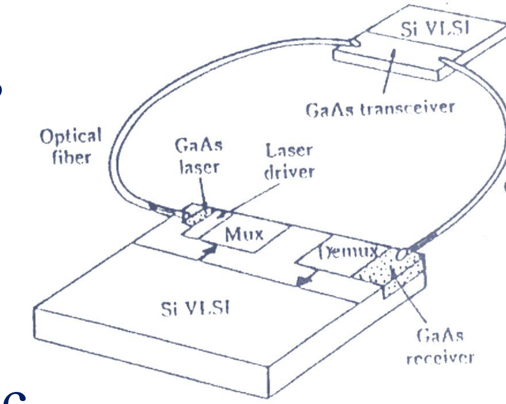
OPTOELECTRONIC INTEGRATED CIRCUITS

- Optoelectronic Integrated Circuits (OEICs) which involves monolithic integration of optical devices (lasers, waveguides) and electronics (transistors, modulators) devices.
- Integrated optoelectronic circuits (OEICs) have numerous applications in the different fields of applied science and engineering due to their advantages such as high data transmission speed, improved reliability, small size, light weight and potential low cost.
- Due to these advantages, it is now widely recognized that monolithic OEICs will play an important role in the field of data processing and transmission.

OPTOELECTRONIC INTEGRATED CIRCUITS

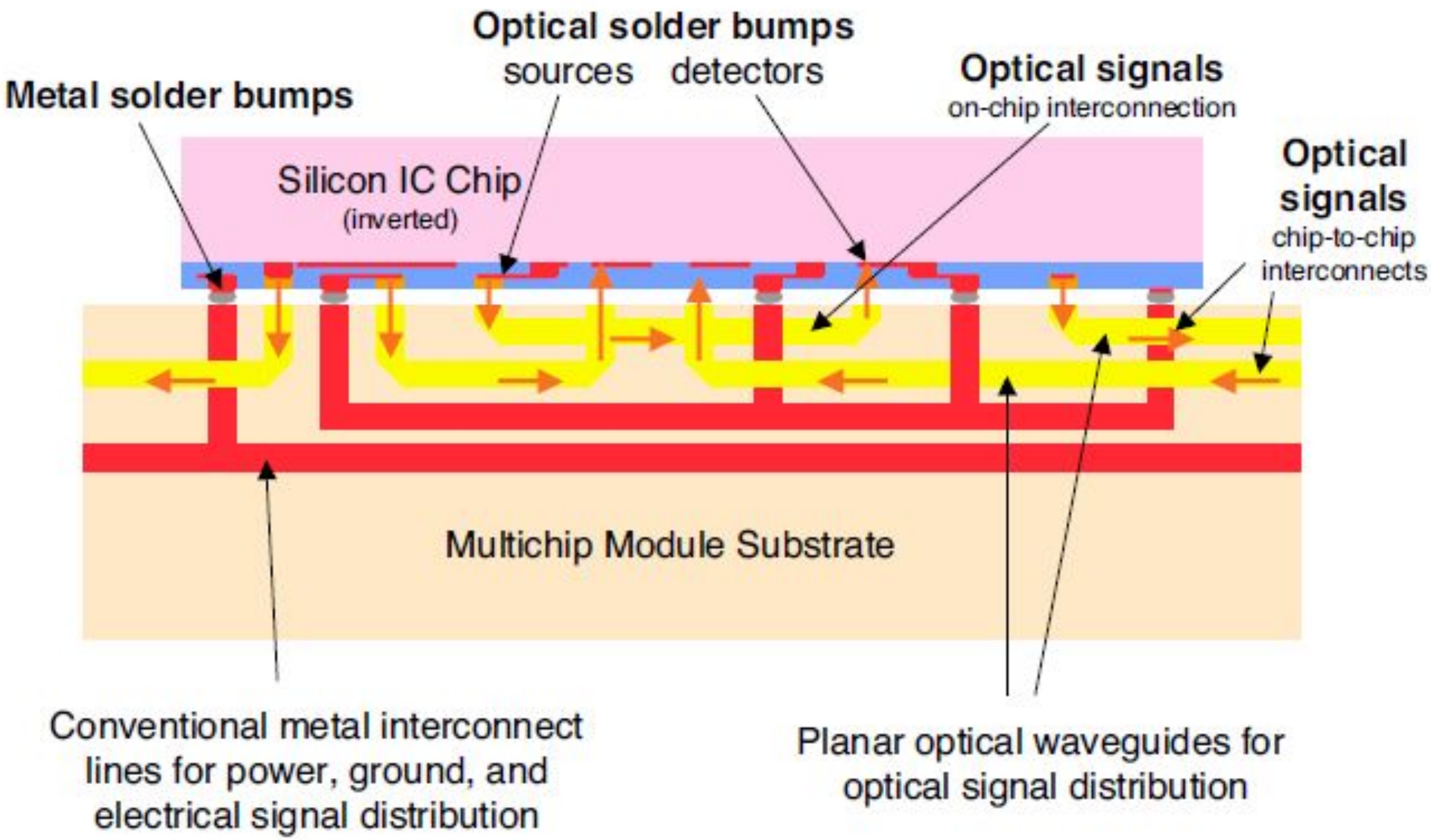


- An OEIC consists of active and passive components, monolithically integrated on the same substrate.
- The active components are those components which require the application of voltage or the passage for current (i.e. they are the components which have to be integrated with electronic circuits).
- The passive components are those components which do not require electric signals for their operation.
- Therefore, the active components are lasers, photo detectors, switches, modulators etc and the passive components are spectral filters, couplers, multiplexers, de-multiplexers, lenses etc.

OPTOELECTRONIC INTEGRATED CIRCUITS

- Most optical elements should be connected with electronic circuitry in an OEIC. It is reasonable to expect that the progress in optoelectronic device technology will follow that of silicon based VLSI technology.
- However, the integration of several optical components on a single substrate is still a technological challenges.
- Since the technology of monolithic integration of electronic components is mature, now the task is to select a suitable material, structure and technology, which can address the challenges, faced by this new technology and can meet the demands of communication and computing systems.

Optical Solder Bumps: IC chip mounted multi-chip module substrate



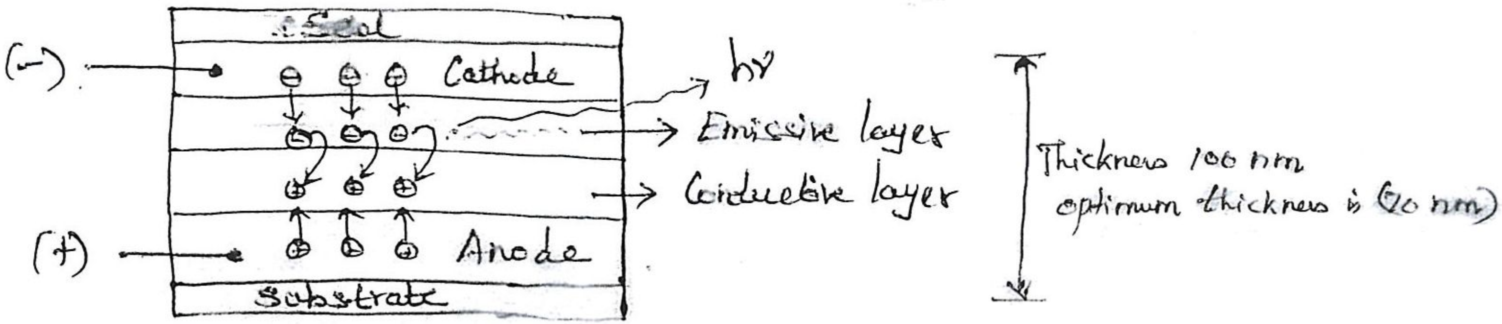
ORGANIC LIGHT EMITTING DIODE (OLED)

A type of LED where emissive electroluminescent layer is a film of organic compound which emit light in response to an electric current.

Structure of OLED:

A simple OLED is made of six different layers. On the top and bottom layers of protective glass or plastic. The top layer is called seal and the bottom layer is substrate. In between seal and substrate, a negative terminal (cathode) and positive terminal (anode), and finally between cathode and anode there are two layers made of organic molecules called emissive layer which produces light and the conductive layer.

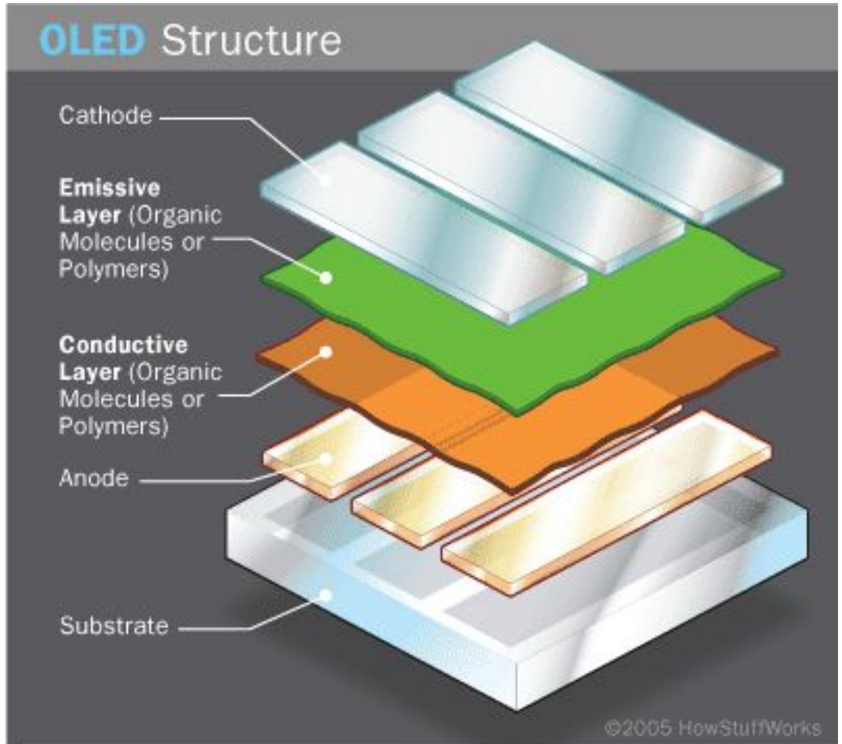
ORGANIC LIGHT EMITTING DIODE (OLED)



1. Substrate – Clean glass / plastic
2. Anode – Positively charged (Indium Tin Oxide) which ejects holes
3. Organic layer –Emissive and Conductive layers –Polyaniline and Polyfluorene
4. Cathode – Negatively charged which injects electrons

Conjugated polymers are having characteristics of LED and having energy gap (Eg) same like semiconductors by doping with p-type/ n-type materials used for light emission

OLED COMPONENTS



Like an LED, an OLED is a solid-state semiconductor device that is 100 to 500 nanometers thick or about 200 times smaller than a human hair. OLEDs can have either two layers or three layers of organic material; in the latter design, the third layer helps transport electrons from the cathode to the emissive layer.

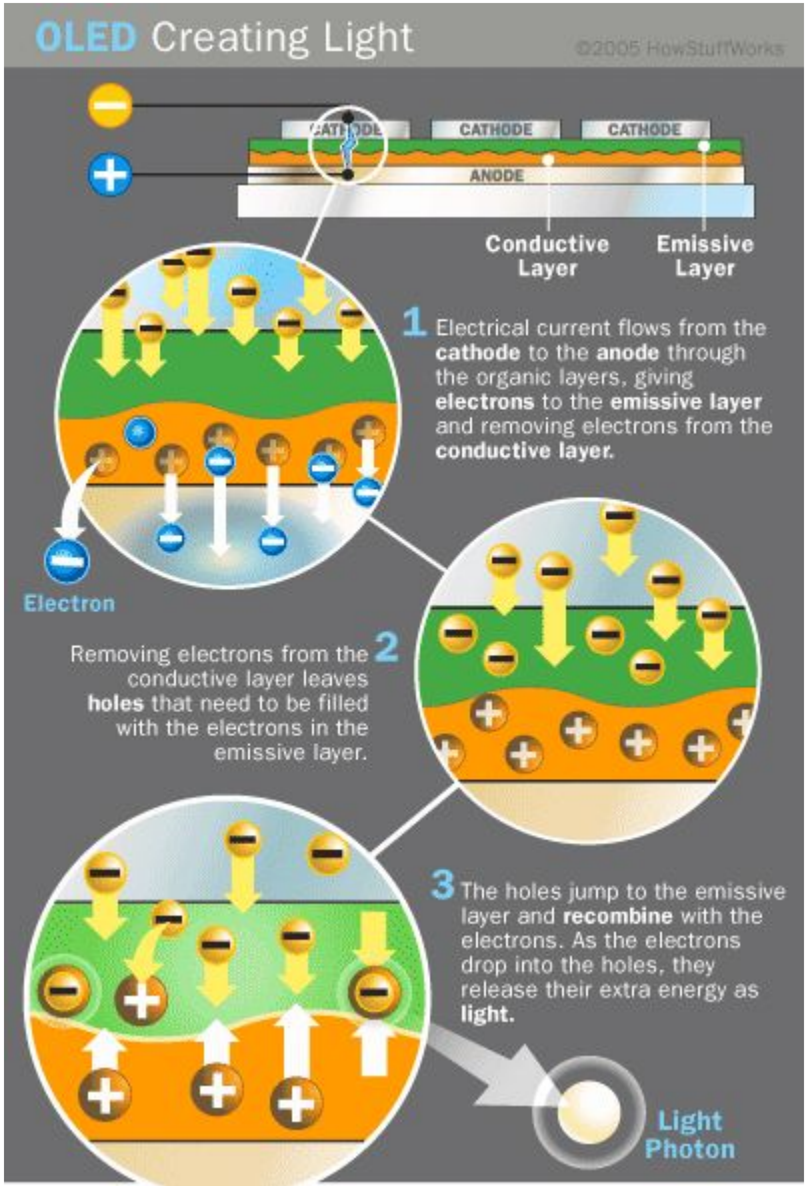
HOW DO OLEDS EMIT LIGHT?

OLEDs emit light in a similar manner to LEDs, through a process called **electro phosphorescence**.

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

HOW DO OLEDS EMIT LIGHT?



HOW DO OLEDS EMIT LIGHT?

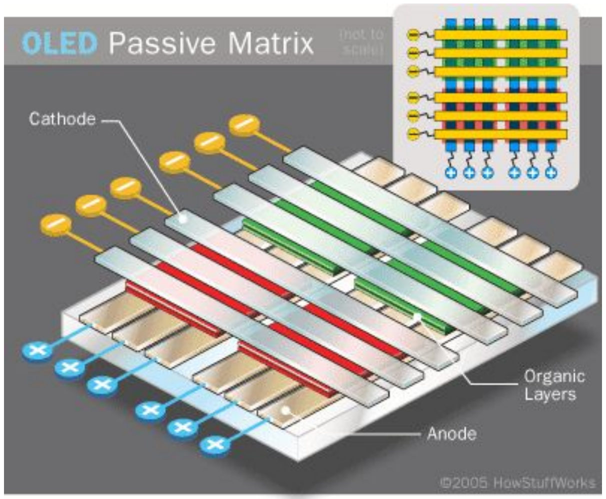
3. At the boundary between the emissive and the conductive layers, electrons find electron holes. When an electron finds an electron hole, the electron fills the hole (it falls into an energy level of the atom that's missing an electron). When this happens, the electron gives up energy in the form of 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.
6. The intensity or brightness of the light depends on the amount of electrical current applied: the more current, the brighter the light.

TYPES OF OLED

1. **Passive-matrix OLED (PMOLED)** – PMOLEDs have strips of cathode, organic layers and strips of anode. The anode strips are arranged perpendicular to the cathode strips. 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.

TYPES OF OLEDS

PMOLEDs are easy to make, but they consume more power than other types of OLED, mainly due to the power needed for the external circuitry. PMOLEDs are most efficient for text and icons and are best suited for small screens (2- to 3-inch diagonal) such as those you find in cell phones, Personal Digital Assistants (PDAs) and MP3 players. Even with the external circuitry, passive-matrix OLEDs consume less battery power than the LCDs that currently power these devices.



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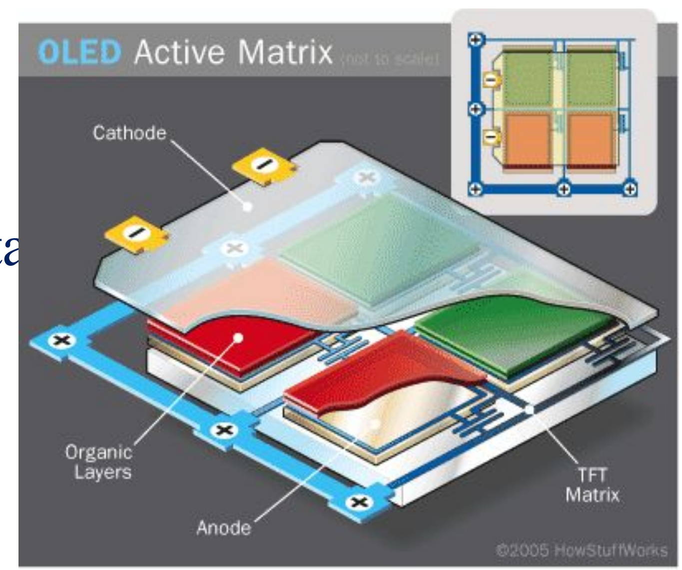
TYPES OF OLEDS

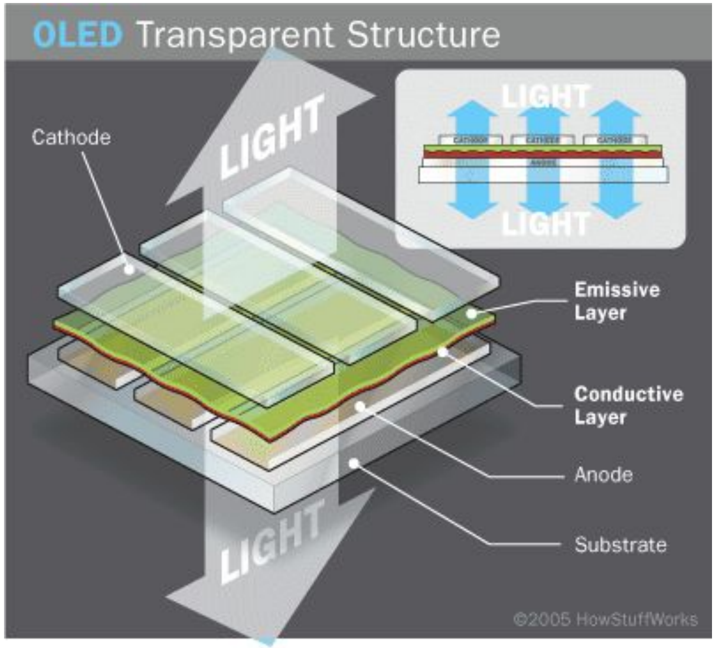
2. Active-matrix OLED (AMOLED) – AMOLEDs have full layers of cathode, organic molecules and anode, but the anode layer overlays a thin film transistor (TFT) array that forms a matrix. The TFT array itself is the circuitry that determines which pixels get turned on to form an image.

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 suita for video. The best uses for AMOLEDs are computer monitors, large-screen TVs and electronic signs or billboards.

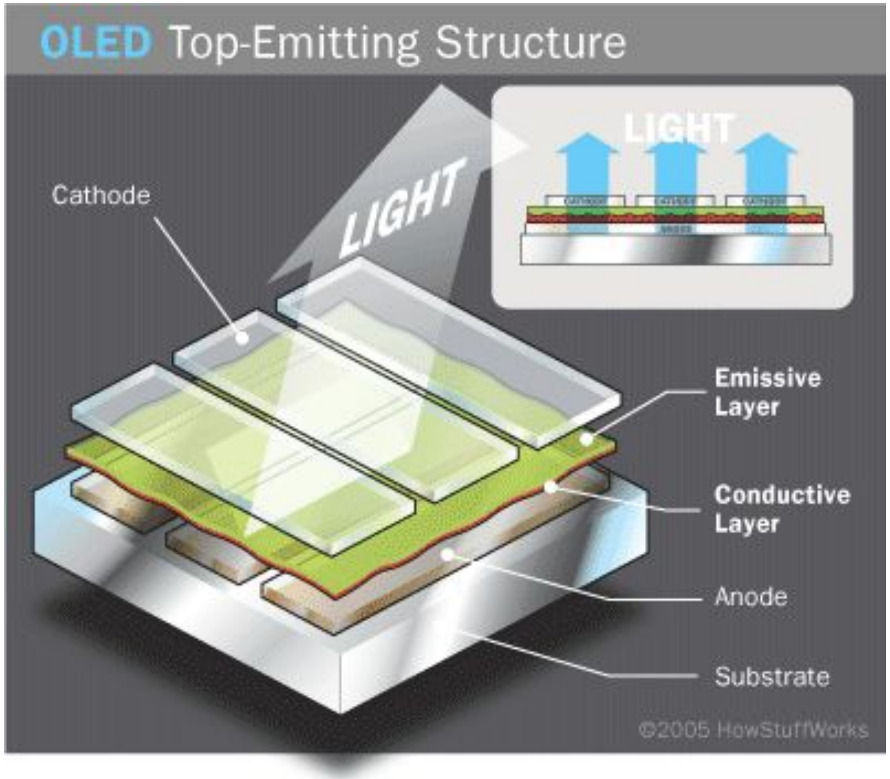


TYPES OF OLEDS

3. Transparent OLED (TOLED) - Transparent OLEDs have only transparent components (substrate, cathode and anode) and, when turned off, are up to 85 percent as transparent as their substrate. When a transparent OLED display is turned on, it allows light to pass in both directions. A transparent OLED display can be either active- or passive-matrix. This technology can be used for heads-up displays.



4. Top-emitting OLED (TEOLED) - 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 smart cards.



TYPES OF OLEDS

5. Foldable OLED (FOLED) - 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.

TYPES OF OLEDS

6. White OLED (WOLED) - 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.

OLED 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. 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.

OLED ADVANTAGES

3. OLEDs do not require backlighting like LCDs and hence they consume much less power than LCDs. This is especially important for battery-operated devices such as cell phones.
4. 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.
5. OLEDs have large fields of view, about 170 degrees. OLEDs produce their own light, so they have a much wider viewing range.

OLED DISADVANTAGES

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

1. Lifetime - While red and green OLED films have longer lifetimes (46,000 to 230,000 hours), blue organics currently have much shorter lifetimes.
2. Manufacturing - Manufacturing processes are expensive right now.
3. Water - Water can easily damage OLEDs

OLED APPLICATIONS

1. OLEDs are used in small-screen devices such as cell phones, PDAs and digital cameras.
2. Because OLEDs refresh faster than LCDs -- almost 1,000 times faster -- a device with an OLED display could change information almost in real time.
3. Several companies have already built prototype computer monitors and large-screen TVs that use OLED technology.