Transparent Electronics

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***Abstract* – Transparent electronics is an emerging science and technology field concentrates on producing 'invisible' electronics circuit and optoelectronics devices. The application contains consumer electronics such as automobile windshield, transparent solar panel, transparent display and real time wearable display. In the conventional Si/III-V based electronics, the structure is based on semiconductor junction & transistor. However, the basic building material for transparent electronic devices which is to be transparent and in visible range is a true challenge! .Therefore to understand and implement such technology there are two scientific goals, to have a material which are optically transparent and electrically conductive and to implement an invisible circuitry. Development of such invisible transparent electronic devices needs expertise together from pure and applied science, material science, chemistry, physics &electronic science.**

I. INTRODUCTION

The classes of material available for transparent electronics have grown dramatically in the last decade. The TCO is widely used as oxide material as it is both electrically conductive and optically transparent. Transparent conductors are neither 100% optically transparent nor metallically conductive. From the band structure point of view, the combination of the two properties in the same material is a contradictory.

A transparent material is an insulator which posses completely field valance & empty conduction band while conductive material has Fermi level of completely field conduction and valance band.

The most commonly used TCO in transparent electronics are In2O3, SnO2, ZnO and CdO. Transparent conducting oxide such as Sn doped In2O3; Al doped ZnO & Sb doped SnO2 are widely used as transparent LCD, Organic light emitting diode & solar cell. In addition TCO are applied to transparent optoelectronics because it has unique feature of optically transparent in visible region [1][2].

II. FABRICATION

Generally, epitaxial films of semiconductors are fabricated by conventional vapor phase epitaxy (VPE) techniques such as RF sputtering, vacuum evaporation, chemical vapor deposition (CVD), molecular beam epitaxy (MBE), and pulsed-laser deposition (PLD). However, such VPE methods cannot be applied directly to the growth of TOSs because it becomes dominant at temperatures higher than nearly 60% of the melting point of the compound. Therefore such a high-temperature deposition process in turn induces an intrinsic problem for the growth of complex oxides [1][4].

To overcome this difficulty in conventional VPE, new technique is developed called reactive solid-phase epitaxy (R-SPE). The solid-state reaction at high temperature leads to the formation of a thin, single crystalline layer on the substrate InGaO3 (ZnO) with a layered natural super lattice structure which would have been impossible by conventional VPE [1][4].

Several types of transparent optoelectronic devices have been demonstrated, such as p-type SrCu2O2 and n-type ZnO, UV-detectors composed of single crystalline p-type NiO and n-type ZnO, and transparent thin-film transistors (TTFTs) fabricated from single-crystalline InGaO3(ZnO).

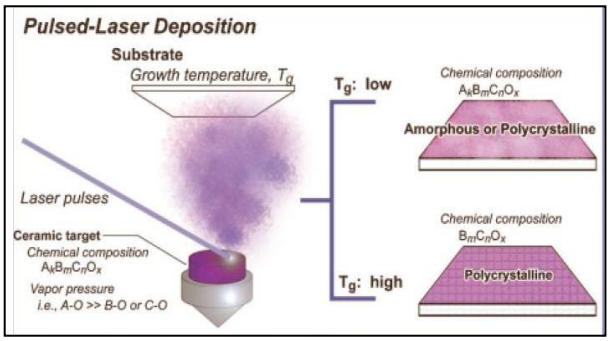

Fig. 1 : Pulsed laser deposition process [1]

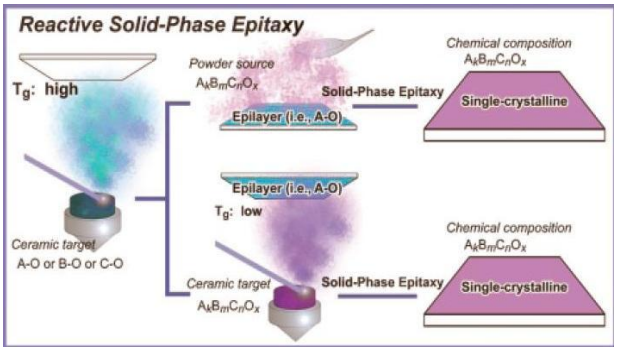

Fig. 2 : Reactive solid phase Epitaxy [1]

Reactive solid phase epitaxy involved three steps that are i) Bilinear Fabrication, ii) surface clapping & iii) thermal annealing. In bilinear fabrication, the laser deposition process is used. All these three steps are as shown in figure 1 and figure 2. [1][4]

III. TRANSPARENT OPTOELECTRONICS DEVICES

A. Transparent thin film transistor:

It is a special kind of field-effect transistor made by depositing thin films of a semiconductor active layer as well as the dielectric layer and metallic contacts over a supporting substrate. A common substrate is glass, since the primary application of TFTs is in liquid crystal displays. This differs from the conventional transistor where the semiconductor material typically is the substrate, such as a silicon wafer[1][4].

TTFTs using TOSs as the channel layer have several merits compared with conventional Si-TFTs when applied to flat panel displays. These include the efficient use of backlight in LCDs or emitted light in OLEDs and insensitivity of device performance to visible light illumination. In addition, oxide TFTs has potential advantages over semiconductor-based TFTs in terms of their high voltage gain, heat dissipation, and radiation tolerances. The TTFTs fabricated to date using conventional TOSs are SnO2 and ZnO [1][4][6].

A single-crystalline film of the TOS InGaO3(ZnO) is used for the active channel layer to realize high-performance TTFT devices. This material has advantages over conventional TOSs, including the efficient growth of high quality, single-crystalline films and good control of carrier concentration. The crystal structure of InGaO3(ZnO)m consists of an alternating stack of InO2- layers and GaO+(ZnO) m blocks make up a super lattice structure. For fabricating TTFT the R-SPE method is used and producing high quality single crystalline films of InGaO3 (ZNO)5 and R-SPE is a unique and practical growth method for this compound. Indinium tin oxide &ZnO are used as interconnection. In traansparent displays, the device exhibits an on-to-off current ratio of nearly 10^6 and a field-effect mobility of nearly 80 square centimeters per volt per second at room temperature [1][4][6].

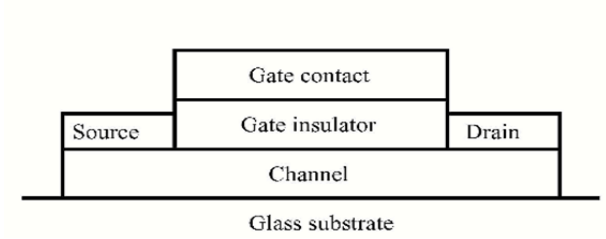

Fig. 3 : TTFT[4]

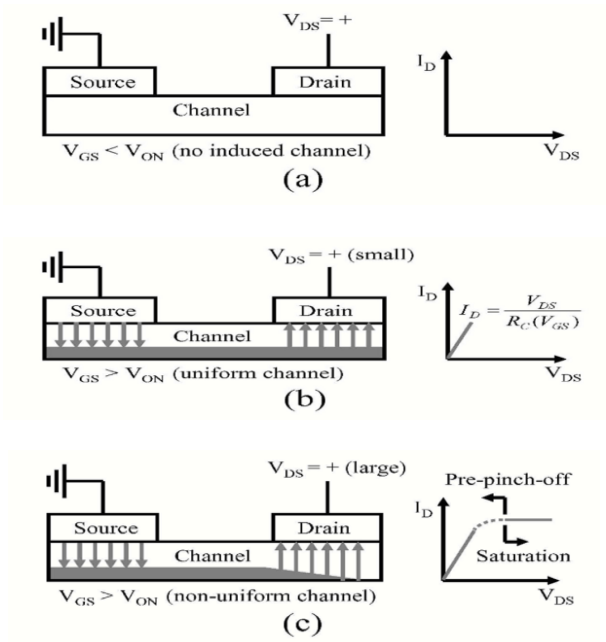

Fig. 4 : I_D V/s V_{DS} Charecterstics of TTFT[4]

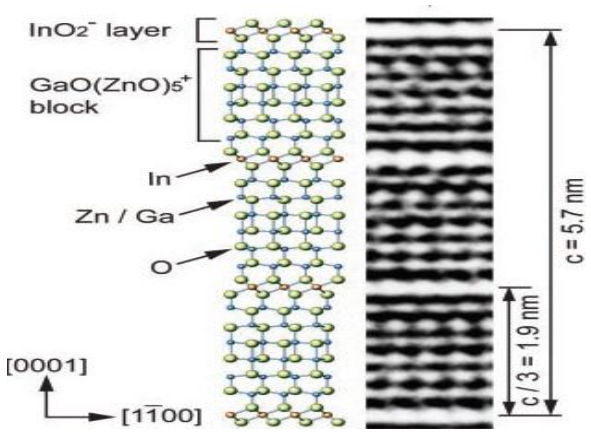

Fig. 5 : Microscopic image of TTFT [1][4]

B. Transparent UV detector

The UV radiation that reaches the surface of the Earth has a Wavelength of 280-400 nm (UV-A and UV-B), and plays an important role in skin aging and cancer. Portable UV-detectors, which contain a pn-junction of a wide band gap semiconductor, would be useful for monitoring UV radiation intensity. Although several UV-detectors have recently been developed using pn- or Schottky-junction diodes of wide band gap semiconductors such as GaN, ZnSe, ZnS, and diamond, TOSs are preferable because they are optically transparent in visible and near-UV regions, environmentally friendly, and thermally and chemically stable[1][4].

A transparent UV-detector was fabricated using a high quality pn-heterojunction diode composed of p-type NiO: Li and n-type ZnO and its UV response measured at room temperature[4][1].A p-type NiO n-type ZnO heterojunction diode measured in dark (UV-OFF) and UV (300-400 nm wavelength) illumination (UV-ON, total power density ~0.33 W/cm2) at room temperature [1][4].

IV. APPLICATIONS

Now days there is vast used of transparent electronics application such as OLED display &transparent solar panel

A. OLED Display

Types of OLED

A. Transparent OLED

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 [5].

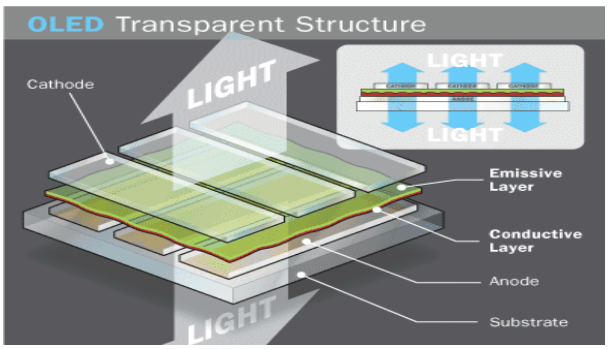

Fig. 6 : Transparent OLED[5]

B. 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 smart cards [5].

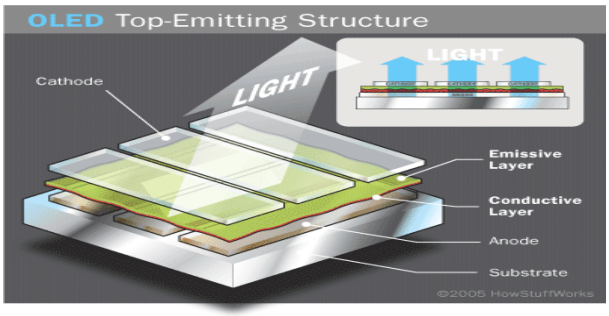

Fig. 7 : Top Emitting OLED[5]

C. 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[5].

Fig. 8 : Foldable OLED[5]

D. White OLED

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 [5].

E. 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 [5].

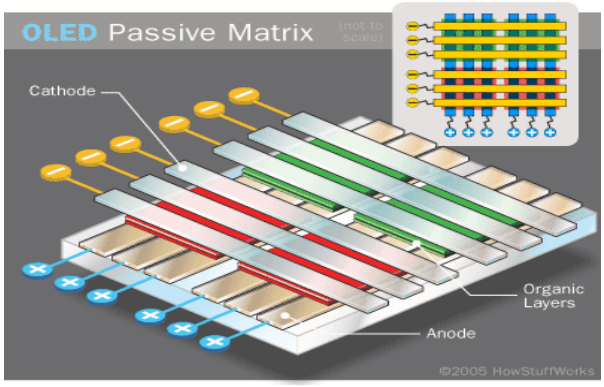

Fig. 9 : Passive Matrix OLED[5]

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, PDAs and MP3 players. Even with the external circuitry, passive-matrix OLEDs consume less battery power than the LCDs that currently power these devices [5].

F. 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 [5].

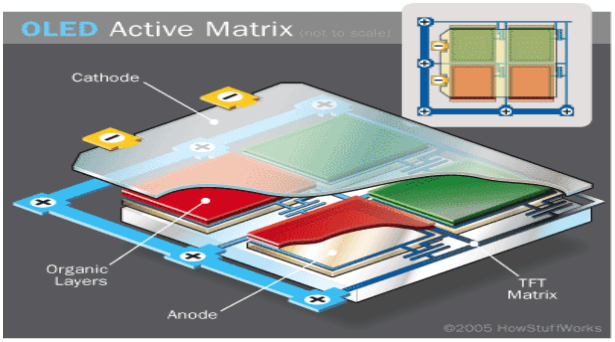

Fig. 10 : Active Matrix OLED[5]

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.[5]

G. Working of OLED

OLEDs emit light in a similar manner to LEDs, through a process called electro phosphorescence[5].

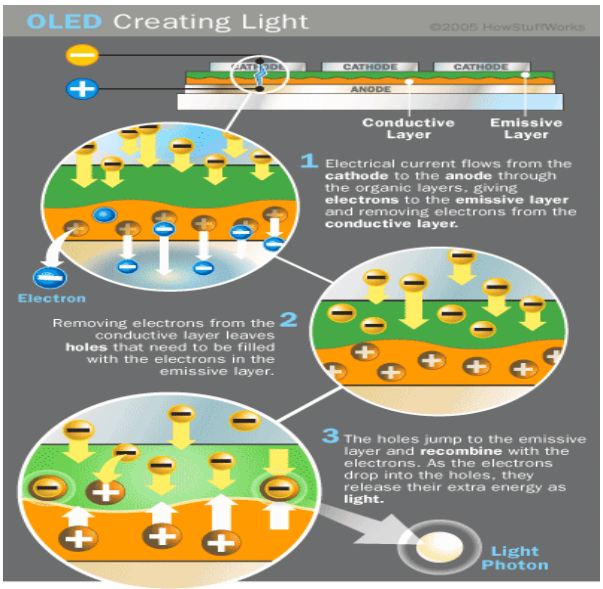

Fig. 11: Working of OLED [5]

The process is elaborate as:

i. The battery or power supply of the device containing the OLED applies a voltage across the OLED [5].

ii. 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.)[5]

iii. 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 [5].

iv. 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 [5].

v. The intensity or brightness of the light depends on the amount of electrical current applied: the more current, the brighter the light [5].

H. OLED Advantages and Disadvantages

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:

i. The plastic, organic layers of an OLED are thinner, lighter, and more flexible than the crystalline layers in an LED or LCD[5][7][8].

ii. 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[5][7][8].

iii. 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[5][7][8].

iv. 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[5][7][8].

v. OLEDs have large fields of view, about 170 degrees. Because LCDs work by blocking light, OLEDs produce their own light, so they have a much wider viewing range[5][7][8].

I. Problems with OLED

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

i) 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) Manufacturing processes are expensive right now[5][7][8].

ii) Water - Water can easily damage OLEDs[5][7][8].

B. Transparent solar panel

The view from garden and adjacent field it look like ordinary window glass, but this window offers an additional feature i.e. it also produces an electricity. This is what the domestic power supply for future could look like. The surface areas used for producing energy are decreases due to transparent solar panel. [3]

Fig. 12 : Transparent Solar Panel[3]

To design transparent solar panel two different transparent coating would be required, one to conduct electricity via electron i.e. n-type. While another electron hole that enables electricity flow i.e. p-type [3].

The n-type transparent material can be fabricated but p-type material is problematic to design. [3] At present, indium tin oxide is mainly used for the n-conductors, but this is costly. Indium has become a rare commodity and its price has increased ten times since 2002. The search for substitute materials is therefore in full swing. At the same time, various questions need to be answered, such as which materials would be best suitable, what they should be doped with to obtain good conductivity, and how good their transparency is.

If transparent p-conductors with adequate conductivity could be produced, it would be possible to realize completely transparent electronics. [3]

V. CONCLUSION

Transparent electronics are relatively new class of material which is applied to active devices such as TFT and UV detector. Combining of two properties that are optically transparent and electrically conductive gives lots of advantages such as high mobility, low processing temperature, high performance and flexibility. The use of OLED as a display gives a high advantage such as more brightness and less power consumption. Transparent solar cell gives a tremendous advantage over conventional solar cell as it required less space, produces more energy, eco-friendly and replaces the ordinary window glass and become a domestic electricity generator. so this new class of electronic is more advantageous than conventional electronics.

VI. REFERENCE

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