APPLICATIONS OF TRANSPARENT CONDUCTORS

Sampath Ranasinghe
Board of Study in Chemical Sciences

The term of transparent conductors (TC) is not very familiar to many people although they have dominated human lives in every aspect. Most of the present day electronics devices and various other applications featured with these materials to deliver unimaginable things several decades ago. Touch-screen sensors, low emissivity windows, liquid crystal display (LCD) devices, plasma and organic light emitting diode (OLED) displays, smart windows, and photovoltaic devices are just a few of innumerable technological applications possible for these materials.

Most of these TCs are metal oxides. Thereby they are also known as the transparent conductive oxides or TCOs. It was first discovered by Badeker and he reported the electrical conductivity of the material formed by the oxidation of Cd metal deposited on the inner walls of a glow discharge tube in 1907. The property of these materials should deliver high electrical conductivity as well as transparency to visible light. The light absorption property of a material is directly related with the band gap of the material. Therefore to be considered as a TCO, it should possess a band gap of E_g > 3.0 eV, where they are also called wide band gap semiconductors. The transparency and conductivity are two main properties and which are interrelated features for most of the TCOs when it is doped to achieve high conductivity than its intrinsic TCO. Generally, the TCOs are expected to have more than 85% transparency and conductivity of 10^6 S m^{-1}. Since the first reported TCO, numerous oxides such as Sb- doped SnO_2, F-doped SnO_2, Sn-doped In_2O_3, Cd_2SnO_4, $CdSnO_3$, $CdIn_2O_4$, Al-doped ZnO, Ga-doped ZnO, F-doped ZnO materials have been exploited. These TCOs have different properties like thermal stability and chemical stability, other than their two main properties. For example, the F-doped SnO_2 shows best chemical stability while ZnO based oxides show lowest in chemical stability where their conducting properties show the opposite. Therefore, selectivity of the TCO depends on the final application.

Thin films of these materials are commonly deposited on optically-transparent substrates such as glass. It is important to know some of the fabrication techniques available to fabricate these semiconductor thin films on these substrates. TCO layers can be deposited using many techniques such as chemical vapor deposition (CVD), electron beam evaporation, pulsed laser deposition, RF magnetron sputtering, atomic layer epitaxy, spray pyrolysis and sol-gel processes. Among these techniques, spray pyrolysis is a simple technique which can be used to prepare large-area films with uniform morphology. To obtain high quality TCOs, our research group at University of Peradeniya has also developed a novel spray pyrolysis technique, which is known as Atomized Spray Pyrolysis (ASP) for fabrication of F-doped SnO_2 thin films. Following applications are not possible without these TCOs. Most of these applications use the TCO deposited glass substrates as the main electrode of the relevant device.

1. Touch-Screen Sensors. - Touch screens have now become a part of the human lives which expanded it uses from simple cell phone to sophisticated mechanical instruments. The structure of the device is quite simple as shown in figure 01. The device is constructed using TCO deposited on glass substrate and transparent patterns are made on it using various lithographic techniques. Screen pattern is fed in to a software, where the detection of change in resistivity at where it is touched can be identified through the microprocessors. This is the simplest and earliest device architecture, where all the materials used are transparent, so when it incorporated with any display device user can see through it without any disturbances.

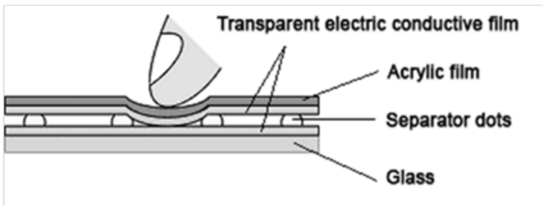

Figure 01. Device architecture of touch screen sensor. (DMC Co., Ltd. 2004)

2. Low Emissivity Windows and Smart Windows. - Smart windows are one step beyond the concept of low emissivity windows. The low emissivity windows are used to block a particular range of wavelengths incident from outside of the window. For instance, most of the low emissivity windows are used to prevent IR radiation transmittance through the window. This helps to reduce the heat inside the building without a reduction of incoming light. Most of the smart windows are also capable of deliver this feature with additional colour controlling property which means a control of incoming light. The TCO is coated with photochromic or electrochromic materials where colour depends on the application. When the window is coated with electrochromic materials and incorporates with electronic control system the window colours and pattern can be varied in seconds giving new dimension to decoration of modern buildings.

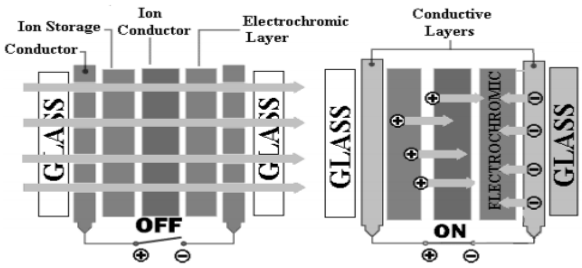

Figure 02. Device architecture of an electrochromic window. (Guangxi 2010)

3. Display devices. - There are several displays devices have been developed using TCO electrodes. Among these, Liquid Crystal Display (LCD) is one of the most common. The device is constructed on a TCO which has patterns constructed using lithographic techniques and liquid crystals have placed in between two TCOs. The crystals orient as the electrical signals received through the two TCO electrodes and colour is generated. Several other transparent layers also include in the device to optimize the display features to the user.

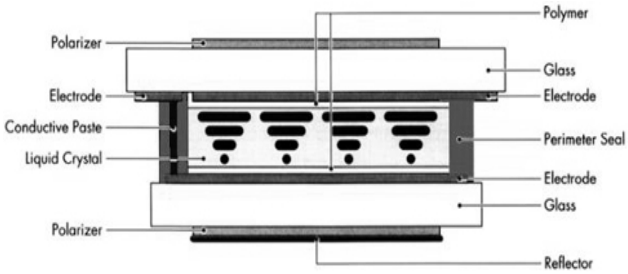

Figure 03. Device architecture of LCE display. (Blaze Display Technology Co., Ltd. 2014)

4. **Photovoltaic devices. –** Photovoltic devices are the devices which can generate electrical power in the presence of light which are commonly known as solar cells. Most of the available solar cells are constructed on TCO coated glass substrates. The Dye-Sensitized solar cells, tandem cells, and organic solar cells are well known among the researchers. Organic or inorganic semiconductors are deposited on the TCO to create p-n multi-junction or heterojunction according to their band gaps and band. These devices are most promising candidate to replace the conventional silicon solar cells which can deliver high efficiencies in harvesting solar energy.

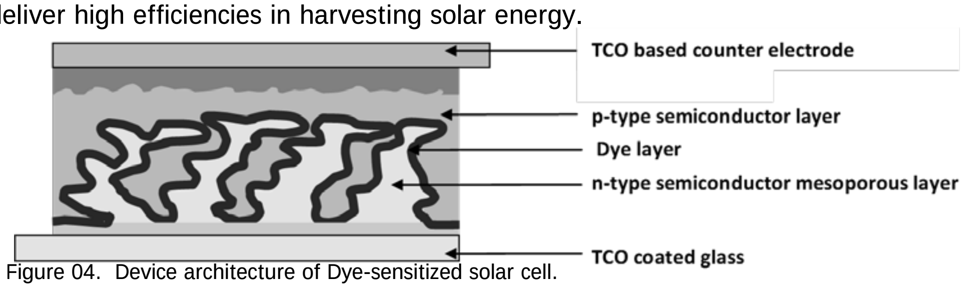

Figure 04. Device architecture of Dye-sensitized solar cell.

References:

Blaze Display Technology Co., Ltd. (2014). Basics of LCD Operation. http://www.blazedisplay.com/Basics_of_LCD_Operation.html (March 02, 2014).

DMC Co., Ltd. (2004). Fundamental Structure of Resistive Touch Screen. http://www.dmccoltd.com/english/tecnical/logs/tec20041126_a.asp (March 02, 2014).

Guangxi Wu (2010) Smart Window. https://filer.case.edu/gxw94/research_smart_window.html (March 02, 2014).