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Study of Magnetic Field Shielded Sputtering Process as a Room Temperature High Quality ITO Thin Film Deposition Process

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Indium Tin Oxide (ITO) is a typical highly Transparent Conductive Oxide (TCO) currently used as a transparent electrode material. Most widely used deposition method is the sputtering process for ITO film deposition because it has a high deposition rate, allows accurate control of the film thickness and easy deposition process and high electrical/optical properties. However, to apply high quality ITO thin film in a flexible microelectronic device using a plastic substrate, conventional DC magnetron sputtering (DMS) processed ITO thin film is not suitable because it needs a high temperature thermal annealing process to obtain high optical transmittance and low resistivity, while the generally plastic substrates has low glass transition temperatures. In the room temperature sputtering process, the electrical property degradation of ITO thin film is caused by negative oxygen ions effect. This high energy negative oxygen ions(about over 100eV) can be critical physical bombardment damages against the formation of the ITO thin film, and this damage does not recover in the room temperature process that does not offer thermal annealing. Hence new ITO deposition process that can provide the high electrical/optical properties of the ITO film at room temperature is needed. To solve these limitations we develop the Magnetic Field Shielded Sputtering (MFSS) system.

The MFSS is based on DMS and it has the plasma limiter, which compose the permanent magnet array (Fig.1). During the ITO thin film deposition in the MFSS process, the electrons in the plasma are trapped by the magnetic field at the plasma limiters. The plasma limiter, which has a negative potential in the MFSS process, prevents to the damage by negative oxygen ions bombardment, and increases the heat(−) up effect by the Ar ions in the bulk plasma.

Fig. 2. shows the electrical properties of the MFSS ITO thin film and DMS ITO thin film at room temperature. With the increase of the sputtering pressure, the resistivity of DMS ITO increases. On the other hand, the resistivity of the MFSS ITO slightly increases and becomes lower than that of the DMS ITO at all sputtering pressures.

The lowest resistivity of the DMS ITO is 1.0×10−3Ω・cm and that of the MFSS ITO is 4.5×10

$-4\Omega\cdot$cm. This resistivity difference is caused by the carrier mobility. The carrier mobility of the MFSS ITO is 40 $cm^2/V\cdot s$, which is significantly higher than that of the DMS ITO (10 $cm^2/V\cdot s$). The low resistivity and high carrier mobility of the MFSS ITO are due to the magnetic field shielded effect. In addition, although not shown in this paper, the roughness of the MFSS ITO thin film is lower than that of the DMS ITO thin film, and TEM, XRD and XPS analysis of the MFSS ITO show the nano-crystalline structure.

As a result, the MFSS process can effectively prevent to the high energy negative oxygen ions bombardment and supply activation energies by accelerating Ar ions in the plasma; therefore, high quality ITO can be deposited at room temperature.

Keywords: ITO, TCO, Low Temperature ITO, ITO Sputtering, Plastic Substrate Electrode