Effect of Growth Conditions on Conductivity of Indium Tin Oxide Films

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Indium tin oxide (ITO) films were grown using radio frequency (RF) sputtering technique. Conductivity or sheet resistance of the ITO films grown by this technique depends on various conditions such as the post annealing temperature, substrate temperature and the composition of the gas used for the deposition. Current work presents the study on the variation of sheet resistance by varying the conditions of growth. All the parameters such as post annealing temperature, substrate temperature and composition of gas used were found to affect the sheet resistance of ITO films.

Keywords: Indium tin oxide (ITO) films, Radio Frequency (RF) sputtering technique.

1. INTRODUCTION

Transparent conducting oxide films plays a significant role in a variety of technologies such as solar cells, flat panel displays, flat transparent heaters, electro chromic windows etc. [1-6]. Indium Tin Oxide is the most used transparent conducting oxide as one of the electrodes. Indium Tin Oxide (ITO) is an n-type wide band gap semiconductor (3.3-4.3 eV) shows high transmission in the visible and near IR regions of the spectrum. Depending on the deposition method, ITO films can have different conductivity, transparency and surface structures [7,8]. The most common of all these methods are sputtering, chemical vapor deposition, vacuum evaporation and e-beam evaporation [9,10].

In this study, ITO films were deposited by reactive RF sputtering in an Ar an Ar/O_2 plasma. This deposition technique is widely used for its excellent uniformity, high conductivity and high transparency. It was reported that the properties of the films were generally changed at high temperature, and therefore annealing could be an important step to modify the films properties. The objective of this study was to investigate the influence of in situ heating and to study the change in conductivity, transparency with heating temperature.

2. EXPERIMENTAL PROCEDURE

ITO films were deposited on glass substrate by RF sputtering using an ITO target. Before loading into the chamber, glass substrate was cleaned in an ultrasonic cleaner with distilled water, acetone and propanol. The sputtering chamber was first pumped down to a base pressure of $5x10^{-7}$ Torr. Ar and O_2 were introduced into the sputtering chamber through the separate mass flow controllers (MFC). The deposition process was carried out in pure Ar and Ar/O_2 plasma. During deposition the substrate was heated at 250^0C. The ITO films of varying thickness were prepared at deposition pressure of 7mTorr. The ITO films were deposited at a fixed power density of 1.6 W/cm^2. The ITO films were then heated in a vacuum of the order of $7x10^{-3}$ Torr and $1x10^{-6}$ Torr at temperature between 200-600^0C for a constant time of half an hour and then they are allowed to cool down to room temperature in vacuum before taking out from the chamber. The sheet resistance of the films was determined using two probe measurement. The transparency of ITO films was recorded using UV/VIS spectrometer.

3. RESULTS AND DISCUSSIONS

3.1. Electrical Properties

Sputtering depends on many variables, like RF power, sputtering pressure, substrate temperature and gas composition. To see the effect of heating on the sputtered ITO we fixed the parameter of sputtering as power 140 W, thickness of deposited ITO as 300 nm, target height as 6 cm. we heated ITO at pressures -7×10^{-3} Torr and 10^{-6} Torr. Figure 1 shows the plot of sheet resistivity vs. heating temperature. From the figure it is clear that sheet resistivity is lower for heating in lower pressure. A minimum of 4 ohm/sq sheet resistance was achieved for annealing of ITO thin films at 600^0C at a pressure of $1x10^{-6}$ torr. This specifies that the grown films were dependent on the post annealing temperature.

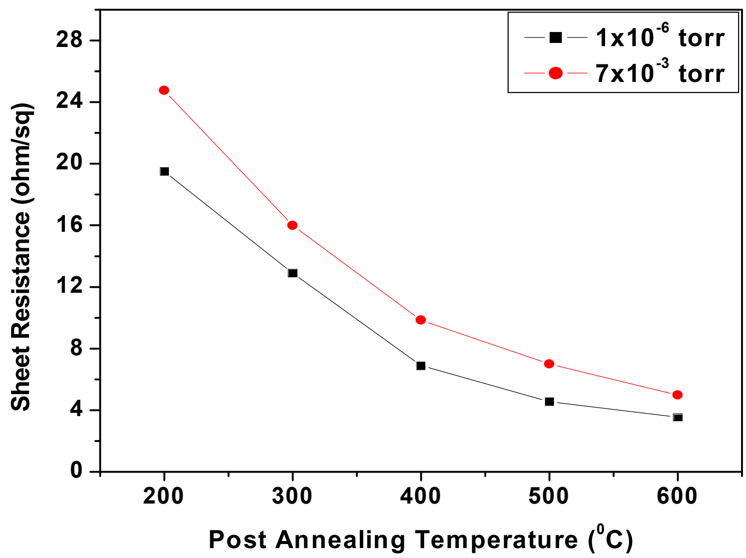

Fig. 1: Sheet resistance of indium tin oxide thin films grown using RF-sputtering as a function of post annealing temperature at different pressure conditions.

To see the effect of gas composition on the sheet resistivity, the deposition power and pressure were kept at 140 W and 7 mTorr respectively. Figure 2 shows the variation of sheet resistivity with O_2 percentage in Ar.

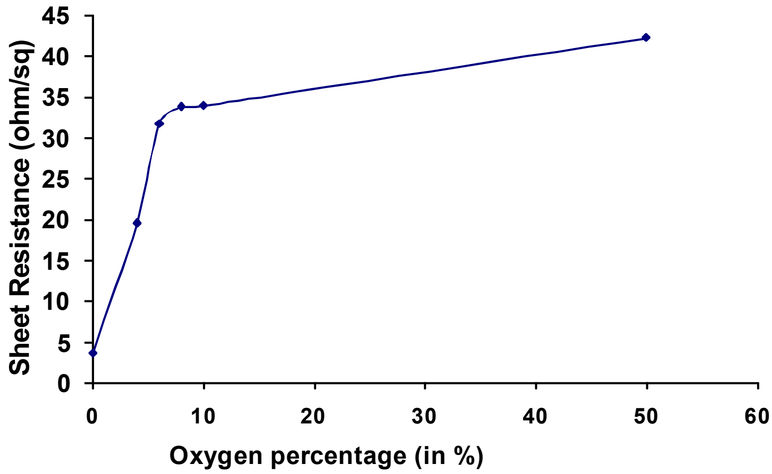

Fig. 2: Sheet resistance of ITO films as a function of oxygen percentage used for the sputtering of ITO.

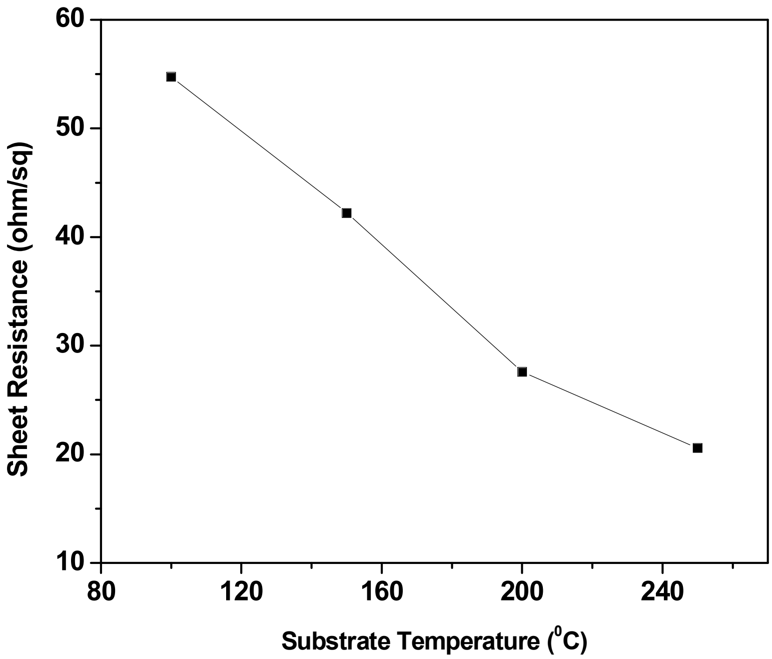

Fig. 3: Sheet resistance of ITO films as a function of substrate temperature.

Electrical resistivity of ITO films varies with substrate temperature. To see the effect of substrate temperature on electrical resistivity deposition power and pressure were kept at 140 W and 7 mTorr and ITO was deposited in pure Ar plasma. Figure 3 shows the variation of electrical resistivity with substrate temperature. Electrical resistivity decreases with the increase in substrate temperature. This can be explained by the fact that the grain size increases significantly with the increase in deposition temperature, thus reducing grain boundary scattering and increasing conductivity.

4. CONCLUSION

ITO films were deposited using RF-sputtering technique at different deposition conditions. All the parameters were varied during the growth of these films and the sheet resistance was measured using two probe measurements. Current work reveals the dependence of the sheet resistance of the films on these parameters.

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