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Preface

The increasing interest in the interaction of light with electricity and electronically active materials made the materials and techniques for producing semitransparent electrically conducting films particularly attractive. Transparent conductors have found major applications in a number of electronic and optoelectronic devices including resistors, transparent heating elements, antistatic and electromagnetic shield coatings, transparent electrode for solar cells, antireflection coatings, heat reflecting mirrors in glass windows and many other. Tin doped indium oxide (indium tin oxide or ITO) is one of the most commonly used transparent conducting oxides. At present and likely well into the future this material offers best available performance in terms of conductivity and transmittivity combined with excellent environmental stability, reproducibility and good surface morphology.

Although partial transparency, with a reduction in conductivity, can be obtained for very thin metallic films, high transparency and simultaneously high conductivity cannot be attained in intrinsic stoichiometric materials. The only way this can be achieved is by creating electron degeneracy in a wide bandgap (\(E_g > 3\)eV or more for visible radiation) material by controllably introducing non-stoichiometry and/or appropriate dopants. These conditions can be conveniently met for ITO as well as a number of other materials like Zinc oxide, Cadmium oxide etc.

ITO shows interesting and technologically important combination of properties viz high luminous transmittance, high IR reflectance, good electrical conductivity, excellent substrate adherence and chemical inertness. ITO is a key part of solar cells, window coatings, energy efficient buildings, and flat panel displays. In solar cells, ITO can be the transparent, conducting top layer that lets light into the cell to shine the junction and lets electricity flow out. Improving the ITO layer can help improve the solar cell efficiency. A transparent
conducting oxide is a material with high transparency in a derived part of the spectrum and high electrical conductivity. Beyond these key properties of transparent conducting oxides (TCOs), ITO has a number of other key characteristics. The structure of ITO can be amorphous, crystalline, or mixed, depending on the deposition temperature and atmosphere. The electro-optical properties are a function of the crystallinity of the material. In general, ITO deposited at room temperature is amorphous, and ITO deposited at higher temperatures is crystalline. Depositing at high temperatures is more expensive than at room temperature, and this method may not be compatible with the underlying devices.

The main objective of this thesis work is to optimise the growth conditions of Indium tin oxide thin films at low processing temperatures. The films are prepared by radio frequency magnetron sputtering under various deposition conditions. The films are also deposited on to flexible substrates by employing bias sputtering technique. The films thus grown were characterised using different tools. A powder x-ray diffractometer was used to analyse the crystalline nature of the films. The energy dispersive x-ray analysis (EDX) and scanning electron microscopy (SEM) were used for evaluating the composition and morphology of the films. Optical properties were investigated using the UV-VIS-NIR spectrophotometer by recording the transmission/absorption spectra. The electrical properties were studied using vander Pauw four probe technique. The plasma generated during the sputtering of the ITO target was analysed using Langmuir probe and optical emission spectral studies.

An overview of the developments in the filed of transparent conducting oxides is briefly presented in Chapter 1. The advantages of semiconducting transparent thin films as a potential candidate over other materials are discussed. The review gives an insight into the developments in the field of transparent conducting oxides and transparent electronics.
Tin doped indium oxide (ITO) thin films are having numerous applications in opto-electronic devices and are widely used as the transparent conducting electrode in solar cells. Chapter 2 presents a detailed literature review on the material.

Chapter 3 deals with the various deposition methods and characterisation tools employed in the present study. The characterisation tools include both material characterisation and plasma characterisation.

Chapter 4 presents the comparative study on the influence of annealing and substrate temperature on the properties of ITO thin films. Indium tin oxide thin films were deposited by RF magnetron sputtering of ITO target. The influence of annealing temperature and substrate temperature on the properties of the films were investigated. The as deposited films showed (222) and (440) peaks of Indium oxide, and an enhancement in the (222) peak intensity were observed with increase in annealing temperature. The films deposited onto preheated substrates showed (400) diffraction peak along with (222) peak. The structural characteristics also showed a dependence on the oxygen partial pressure during sputtering. Oxygen deficient films showed (400) plane texturing while oxygen-incorporated films were preferentially oriented in the [111] direction. An annealing temperature of 250°C resulted in films with maximum bandgap and minimum resistivity whereas a substrate temperature of 150°C was sufficient to get films with low resistivity and high bandgap.

Chapter 5 gives a detailed description on the influence of RF power on the properties of ITO thin films. Highly transparent and conducting ITO thin films were deposited at room temperature by RF magnetron sputtering of ITO target (95wt%In₂O₃ and 5wt% SnO₂) in pure argon atmosphere. Thin films were deposited on glass substrate without any intentional heating at various RF
powers ranging from 20W to 50W and the influence of RF power on the structural, electrical and optical properties of the films were investigated. The influence of fluorine doping on the properties of ITO thin films was also investigated as a function of RF power. Enhancement of crystallinity and conductivity was observed with increase in RF power. Film deposited on glass substrates at an RF power of 50W was oriented in the (100) direction and it showed a minimum resistivity of $1.27 \times 10^{-3}$ $\Omega$ cm. It has been observed that the film properties are greatly influenced by the plasma conditions during sputtering. Radio frequency (RF) plasma during sputtering was analyzed using Langmuir Probe and Optical Emission Spectroscopy (OES). The plasma parameters such as ion density and electron temperature were determined and their dependence on properties of thin film deposited under similar plasma conditions were studied. Plasma parameters were determined for different RF powers keeping the distance from the target a constant.

Chapter 6 presents the influence of bias voltage on the properties of ITO thin films. ITO films were prepared at room temperature by RF bias sputtering on polyimide substrates. The influence of bias voltage on the structural and electrical properties was investigated. The films deposited at negative bias voltages showed a preferred orientation along [111] direction while positive bias voltages resulted in poorly crystalline films. The maximum grain size of about 28nm and a minimum resistivity of $2.24 \times 10^{-2}$ $\Omega$ cm were obtained for the film deposited onto substrates biased at $-20$V. The plasma parameters during the deposition was analyzed using Langmuir probe technique and the observed plasma parameters were correlated with the film characteristics.

Chapter 7 presents the summary and conclusion.
Publications

4. Influence of RF power on the properties of sputtered ITO thin films, M.Nisha, M.K.Jayaraj (To be communicated)
5. Growth of ITO thin films under various processing conditions, M.Nisha, M.K.Jayaraj (to be communicated)
6. Bias sputtered ITO thin films on flexible substrates, M.Nisha, M.K.Jayaraj (to be communicated)

Conference Proceedings


