

Structural and optical properties of electron beam evaporated ITO and Ni: ITO thin films

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Abstract - Indium-tin-oxide (ITO) and Ni doped ITO thin films were prepared using electron beam evaporation technique. The prepared thin films were subjected to structural and optical properties. From the XRD it was observed that the films were crystalline in nature with cubic structure. The crystallite size was calculated using Scherrer's relation and found that it was about 25 nm. The optical transmittance and absorbance spectra were recorded using UV-Vis-NIR spectrophotometer. From these the optical band gap of ITO and Ni:ITO thin films were found to be 4.0 eV and 3.97 eV, respectively. The Fourier transform-Infrared spectroscopy studies showed peaks at 292, 519, 804, 957, 1149, 1387 and 2985 cm^{-1} which are characteristic of In-O bonds.

Key Words: Dilute magnetic semiconductors, thin films, electron beam evaporation, shallow donors, direct band gap.

1. INTRODUCTION

Currently much focus is being paid on physical properties of oxide semiconductors such as ZnO, SnO₂, In₂O₃, Cu₂O, CdO, TiO₂, etc [1-3]. These oxide semiconductors exhibit two most important properties such as high optical transmittance in the visible region and high electrical conductivity [4,5]. Among the other oxide semiconductors, indium oxide is one of the best suited materials for most of the optoelectronic applications. It is a wide band gap oxide semiconductor (3.7 eV) with cubic structure. It exhibits conductivity equal to that n-type semiconductor. The electrical conductivity of this material can be controlled by controlling the oxygen vacancies in the host lattice or by doping with suitable element. In this contest tin (Sn) is the most suitable element to be doped into the In₂O₃ lattice to bring the changes in optical and electrical properties. The indium-tin-oxide called as ITO is the promising material for optoelectronic applications such as solar cell, touch screens,

gas sensors, flat panel displays, etc [6-10]. Much interest has been shown on the optical and electrical properties of ITO thin films using different preparation techniques, doping with different impurities. In addition to the optical and electrical properties of ITO, if magnetic properties were also added for this, then it can find new future applications such as spintronics in which one can utilize both charge and spin of electron. Till now few reports are available on magnetic properties of ITO thin films [11,12]. Hence an attempt is made here for the preparation of ITO and Ni doped ITO thin films using electron beam evaporation technique and studied their structural and optical properties.

2. EXPERIMENTAL DETAILS

The ITO and Ni doped ITO source materials were prepared using solid state reaction and studied their physical properties [13]. The same powder samples were taken here as source materials to prepare the ITO and Ni: ITO thin films. The films were prepared using electron beam evaporation technique [12A4D]. A base pressure of 5×10^{-6} mbar was created before coating the films. A pressure of 5×10^{-5} mbar was maintained during the deposition. A well cleaned glass substrates were used here as substrate for coating the films. The substrates were cleaned as per the protocol and fixed onto the substrate holder. The total set up was kept in coating unit and the substrate temperature was raised to 350° C and maintained the same temperature till the end of the coating. The coating was carried out for 30 min. The thicknesses of the films were controlled by quartz crystal thickness monitor (QTM) and it was about 250 nm. X-ray diffraction (X-ray diffractometer, D8 Advance, BRUKER) was used to establish structural aspects. Energy dispersive analysis spectroscopy (EDS) (OXFORD instrument incapenta FET X3) was used to carry out elemental analysis. The diffused reflectance spectra were recorded on UV-Vis-NIR Spectrophotometer (JASCO V-670). Fourier Transform

Infrared (FT-IR) Spectroscopic analysis was carried using FT-IR Spectrophotometer (SHIMADZU).

3. RESULTS AND DISCUSSION

3.1 STRUCTURAL PROPERTIES

Fig.1 shows the XRD profiles of ITO and Ni doped ITO thin films. The ITO thin films exhibited only two diffraction peaks at 31° and 51°. The Ni doped ITO thin films exhibited two more diffraction peaks in addition to pure ITO thin films. The diffraction peaks such as (222), (440), (400) and (622) were observed for Ni:ITO thin films which are characteristic of cubic structure of indium oxide [JCPDS 06-0416]. No other diffraction peaks other than indium oxide were observed in the XRD patterns. No significant change in the diffraction peak toward higher or lower diffraction angles was found as shown in Fig.2. It may be due to limited doping concentration of Ni. The crystallite size was calculated using Scherrer's relation and found to be 25 nm. A slight decrease in lattice parameter was observed by adding Nickel into the ITO lattice.

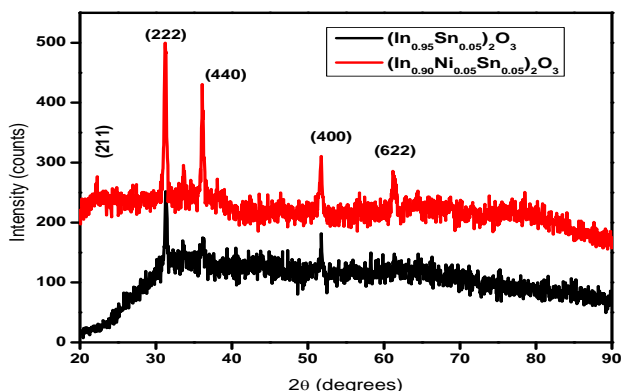


Fig -1: XRD profile of ITO and Ni: ITO thin films

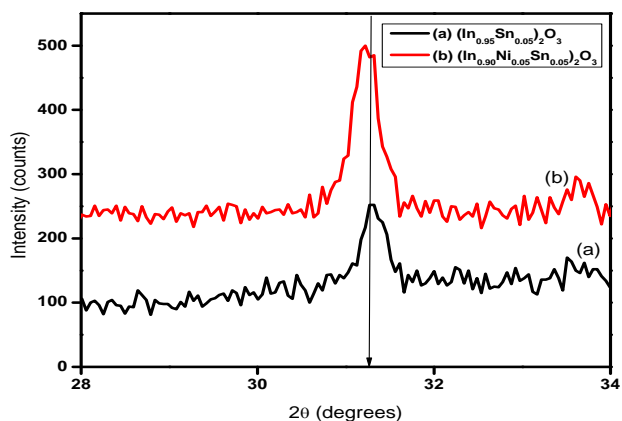


Fig -2: XRD profile of of ITO and Ni: ITO thin films in the 2θ range of 28° to 34°

3.2 OPTICAL PROPERTIES

Fig. 3 shows the optical transmittance spectra of ITO and Ni: ITO thin films prepared on glass substrates. From the figure it can be seen that the ITO thin films exhibited good optical transmittance about 70% in the visible region. The transmittance of the films decreased to large extent by doping nickel into the ITO lattice. Fig. 4 shows the absorbance spectra of ITO and Ni: ITO thin films prepared onto glass substrates. A clear absorption peak was found at 350 nm which indicate the band gap of In₂O₃. The absorbance increased with substitution of Ni into the ITO lattice.

The optical band gap (E_g) of the films was determined from the optical transmittance data using Tauc's relation [14],

$$\alpha h\nu = A(E_g - h\nu)^n \text{-----(3)}$$

where, n depend on the kind of optical transition that prevails. Here $n = 1/2$, as In₂O₃ is directly allowed n-type degenerate semiconductor. The optical band gap is obtained by plotting $(\alpha h\nu)^2$ versus the photon energy ($h\nu$) and by extrapolating of the linear region of the plots to zero absorption ($\alpha = 0$). The optical band gap E_g is obtained by plotting $(\alpha h\nu)^2$ versus the photon energy ($h\nu$) and by extrapolating the linear region of the plots to zero absorption ($\alpha = 0$). Fig.5 shows the optical band gaps of ITO and Ni: ITO thin films. The pure ITO thin films exhibited a band gap of 4.0 eV and Ni: ITO thin films exhibited a band gap of 3.97 eV. The observed band gap is almost equal to that of band gap of bulk ITO [15].

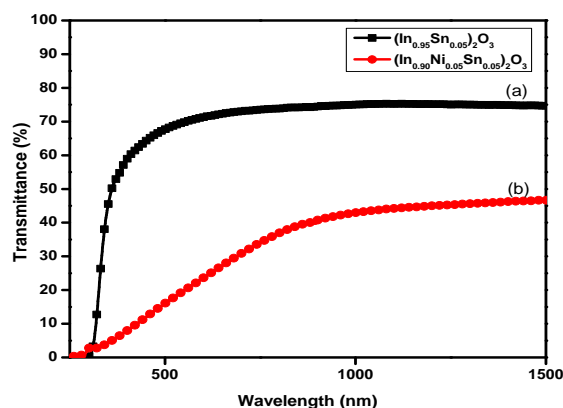


Fig -3: Optical transmittance spectra of ITO and Ni:ITO

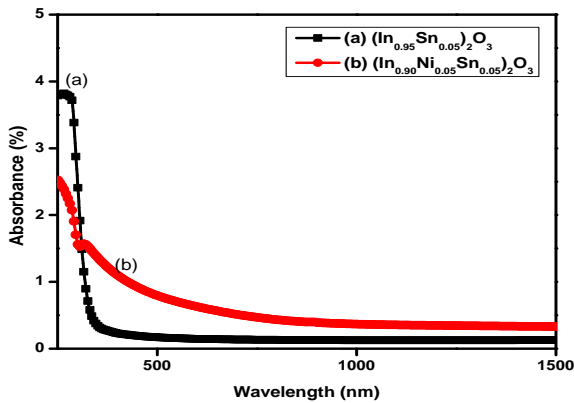


Fig -4: Optical absorbance spectra of ITO and Ni: ITO thin films

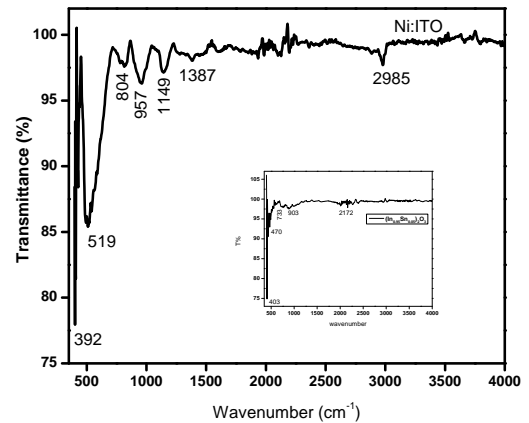


Fig -6: FT-IR spectra of ITO and Ni: ITO thin films

Fig. 6 shows the FTIR spectra of the ITO and Ni: ITO thin films recorded at room temperature. In₂O₃ exhibits intense bands around 419 and 440 cm⁻¹ attributed to In-O lattice stretching vibrations [16].

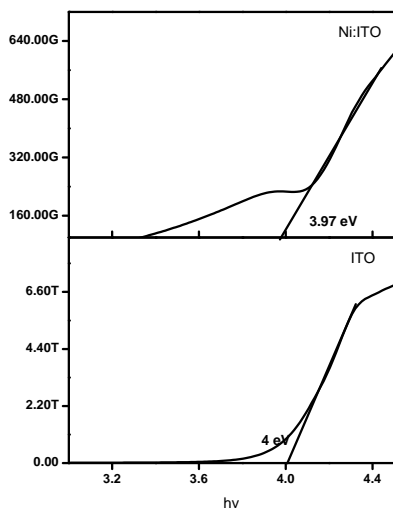


Fig -5: Optical band gaps of ITO and Ni:ITO thin films

3. CONCLUSIONS

ITO and Ni: ITO thin films were prepared using electron beam evaporation technique and studied for their structural and optical properties. Both ITO and Ni: ITO thin films were in cubic structure with crystallite size of 24 nm. No new diffraction peaks related to nickel was found in XRD. A band gap of 4.0 eV was observed for ITO thin films and it decreased to 3.97 eV by doping Ni into the ITO lattice. The FT-IR studies revealed the characteristics of In₂O₃ lattice.

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