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Effect of annealing on structural, optical and magnetic properties of Fe doped In_2O_3 thin films

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Abstract: Pure and Iron doped In_2O_3 thin films were deposited onto Corning 7059 glass substrates using an electron beam evaporation technique and then the films were air annealed at 250 ^oC, 350 ^oC and 450 ^oC, respectively for 5 hours. The effect of annealing temperature on structural, optical and magnetic properties of the thin films has been investigated. All the pure and Fe doped In_2O_3 films were found to be ferromagnetic at room temperature. The saturation magnetization of pure and Fe doped In_2O_3 thin films decreased with increase of annealing temperature.
Keywords: Indium oxide; Electron beam evaporation; Room temperature ferromagnetism.

Introduction:

Diluted magnetic semiconductors (DMS) are the semiconductor compounds exhibiting the magnetic property by doping with transition metal ion into the host semiconductor lattice [1]. The feasibility of control in the electron charge and spin characteristic of a DMS, finds a great interest in developing the spintronics devices [2]. Advantages in these oxide DMSs are wide band gap, high carrier concentration, low cost and Tc above the room temperature. Among the various semiconductor oxides In_2O_3 is the most promising candidate due to its wide band gap (3.5 eV) with n-type degeneracy. But few reports are available on Fe doped In_2O_3 thin films prepared by electron beam evaporation technique. Hence an attempt is made here for the growth of Fe doped In_2O_3 thin films using an electron beam evaporation technique and studied the influence of annealing temperature on structural, optical and magnetic properties of the films.

Experimental:

Fe doped In_2O_3 compound was prepared using solid state reaction. Pure In_2O_3 and Fe (5 at.%) doped In_2O_3 thin films were grown onto corning 7059 glass substrates at a substrate temperature of 350 ^oC. The films were characterized for their structural, optical and magnetic properties.

Results and Discussion:

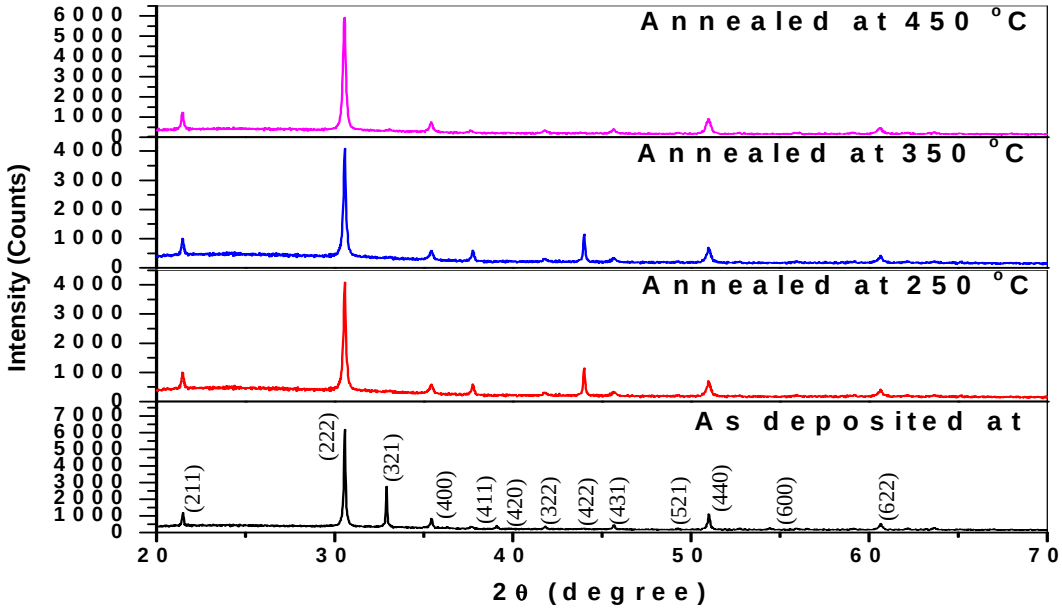

Fig. 1 X-ray diffraction patterns of the Fe (5 at.%) doped In_2O_3 thin films deposited and air annealed at different temperatures.

Fig. 1 shows the X-ray diffraction patterns of the Fe (5 at.%) doped In_2O_3 thin annealed at 250 ^oC, 350 ^oC and 450 ^oC. All the diffracted peaks were exactly coincided with the cubic structure of In_2O_3 and not found any impurity phase in the Fe doped In_2O_3 thin films. The lattice parameter was calculated and observed that it increased from 10.126 Å to 10.132 Å with increase of annealing temperature. In case of annealed Fe (5 at.%) doped In_2O_3 thin films lattice parameter was decreased from 10.159 Å to 10.108 Å. It is decreased when compared with pure In_2O_3, which indicate that the Fe ions occupied the In sites of the In_2O_3. Similar kind of results were also observed in Fe doped In_2O_3 thin films reported by Hong Xu et al. [3]. Moreover, the XRD patterns of Fe and Fe_2O_3 were also taken into consideration from standard JCPDS data to identify the impurity phases related to either Fe or Fe_2O_3 in the Fe doped In_2O_3 thin film. But no phases related to impurities were found. The phases related to indium were observed in XRD patterns of Fe doped In_2O_3 thin films, which may due to insufficient oxygen present in the working chamber during deposition of the films. In order to make the films stoichiometric, the grown films were air annealed at 250 ^oC, 350 ^oC and 450 ^oC for 5 hours, respectively. When the films annealed at higher temperature, complete oxidation of the indium was observed.

The optical transmittance spectra of the Fe (5 at.%) doped In_2O_3 thin films annealed at 250 ^oC, 350 ^oC and 450 ^oC were recorded in the wavelength range from 200 nm to 2500 nm. The transmittance of the annealed films increased with increase of annealing temperature from 250 ^oC to 450 ^oC in both Fe (5 at.%) doped In_2O_3. A band gap of 3.28 eV was observed for pure In_2O_3 at 450 ^oC, a band gap of 3.05 eV was observed for Fe doped In_2O_3 at 450 ^oC.

Fig. 2 (a) shows the M-H curves of the as deposited and annealed pure In_2O_3 films at 250 ^oC and 350 ^oC showed the ferromagnetic behaviour, after that air annealed at 450 ^oC for 5 hours films changes its behaviour from ferromagnetism to diamagnetism shown in Fig. 2 (a) inset right bottom. Fig. 2 (b) shows the M-H curves of Fe (5 at.%) doped In_2O_3 thin films as deposited and air annealed at different temperatures. Hence the reduction in oxygen vacancies which reduced the magnetization of pure In_2O_3 thin films. This weakly magnetic hysteresis in pure In_2O_3 may come from the defects such as oxygen vacancy and grain boundary defects.

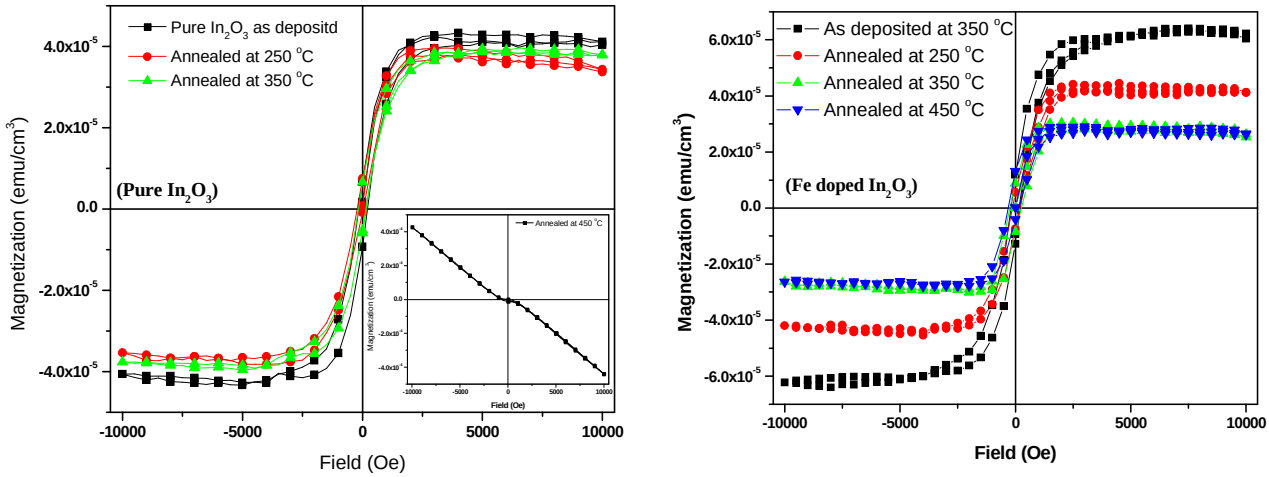

Fig. 2 M-H curves of the (a) pure In_2O_3 thin film as deposited, air annealed at different temperatures and inset shows the annealed at 450 ^oC diamagnetism of In_2O_3. (b) Fe (5 at.%) doped In_2O_3 thin films as deposited and air annealed at different temperatures.

Air annealing at high temperature in the Fe (5 at.%) doped In_2O_3 thin films made astonishingly changed in its magnetic property, and a strong connection linked with parameters like defects such as oxygen vacancies and interstitial positions of the indium in the host lattice. The high temperature air annealing of the films was reduced the effective F-center mediated ferromagnetism couplings and oxygen vacancies. So it can be considered that the remarkable decrease in the saturation magnetization from 64.07 (μ emu/cm^3) to 27.92 (μ emu/cm^3) with increase of annealing temperature to 450 ^oC was due to the existing oxygen vacancies in the films. Present results supports that the observed ferromagnetism may be due to oxygen vacancies that exist in the lattice, and these results are in good agreement with Fe doped In_2O_3 films [4].

Conclusions:

Pure and Fe doped In_2O_3 thin films were deposited using electron beam evaporation technique. The effect of annealing temperature on structural, optical and magnetic properties of the thin films has been studied. All the films were showed ferromagnetic behavior at room temperature. Ferromagnetic state of the Fe (5 at.%) doped In_2O_3 thin film decreased with annealing temperature.

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