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Structural, optical and magnetic properties of Ni- doped SnO_2 thin films prepared by flash evaporation technique

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Abstract: Nickel doped SnO_2 thin films at different Ni doping concentrations were prepared using flash evaporation technique.The effect of Ni doping concentration on structural, optical and magnetic properties of thethin films was studied. X- ray diffraction studies revealed that all the Ni doped SnO_2 thin films were in tetragonal structure. No traces of impurities were found even at higher Ni (15 at.%) doping level. Theoptical band gap of the filmsincreased withthe increase of Ni doping levelfrom 3 at.% to 15 at.%. All the Ni doped SnO_2 thin films exhibited ferromagnetism at room temperature. The saturation magnetic moment (Ms) increased with increase of Ni doping level from 3 at.% to 7 at.% and then it decreased by further increase of Ni doping levels.
Keywords: Oxide thin film, Flash evaporation, Ferromagnetism**.**

Introduction

Recently transparent conducting Oxides (TCO's) have drawn much interest in the field of optoelectronics [1]. Transparent conducting oxides are the material which exhibit higher optical transmittance in visible region, low sheet resistance and higher electrical conductivity. Among the various TCO's such as ZnO, In_2O_3, CdO, TiO_2 and SnO_2[2], SnO_2 is the most promising candidate for the development of transparent conductive ferromagnetic material. SnO_2 is an rutile tetragonal structure with oxygen deficient n- type degenerate semiconductor with wide band gap of 3.6eV. Its high optical transparency and electrical conductivity leads to very appealing applications in spintronics devices. In the present work, $Sn_{1-x}Ni_xO_2$ thin films were prepared using flash evaporation method. The influence of doping level on structural, optical and magnetic properties of Ni doped SnO_2 thin films had been studied.

Experimental procedure:

Ni doped SnO_2thin films were prepared on glass substrate by convenient flash evaporation technique using the 12" vacuum coating unit (model:12A4D). Through which the target materials NiO and SnO_2 are loaded systematically.The source materials were prepared using standard solid state reaction method. Molybdenum

boats was used to vaporize the material. The base and working pressure inside the chamber was $1x10^{-6}$ mbar and $3x10^{-6}$ mbar which could be measured using pirani and penning gauges. The substrate temperature set to be as 573 K. And the as deposited films were annealed at 773 K in air ambience for 2 hrs. The structural, optical and magnetic properties of the annealedthin films were characterized by Bruker D-8 Advance X- ray diffractometer(Cu Kα=1.5406 Å), optical transmittance spectra were recorded using UV-Vis spectrophotometer (JASCO-V-670) and the magnetic hysteresis studies were done by using vibrating sample magnetometer respectively.

Results and Discussion

Structural property of un doped and Ni doped SnO_2 thin films

Fig.1 shows the XRD diffraction patterns $Sn_{1-x}Ni_xO_2$ thin films (x = 0 to 0.15 at.%). The films annealed at 773 K were polycrystalline in nature. The diffraction peaks of (110), (101) and (211) were exactly coinciding with rutile structure of SnO_2. No traces of impurity of NiO, Ni peaks were not found even with higher doping concentrations.

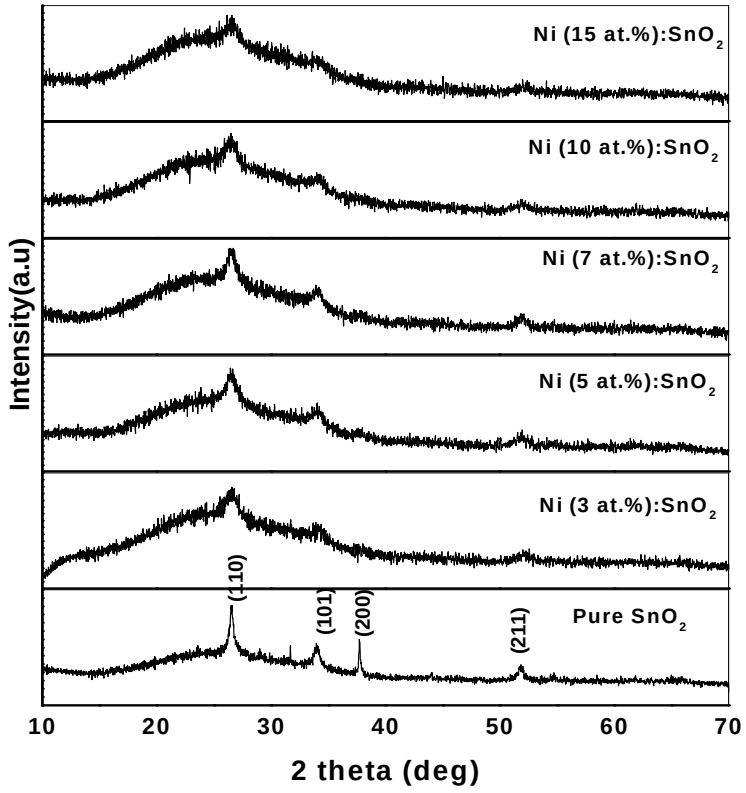

Fig.1 XRD diffraction patterns of $Sn_{1-x}Ni_xO_2$ thin films (x = 0 to15 at.%)

The crystallite size of $Sn_{1-x}Ni_xO_2$ thin films (x = 0 to 0.15 at.%) was calculated using Scherer's relation. The crystallite size of films varied from 21 to 10 nm with increase of doping concentration similar to Dalui et al [4]. The lattice parameter of these films was also varied. This implies that Ni has incorporated in to host SnO_2 lattice.

Optical properties of Ni doped SnO_2 thinfilms

The optical transmittance spectra of the Ni doped SnO_2 thin films were recorded from 200 nm to 2500 nm wavelength, which is not shown here. From the figure it was noticeable that optical transmittance was higher for pure SnO_2 annealed films (72%) where asafter doping with Ni impurity in to the host exhibited poor in transparency. The optical band gap (Eg) of the films were determined by plotting $(\alpha h\nu)^2$ versus the photon energy ($h\nu$) and extrapolating the linear region of the plots to zero(α=0). The band gap decreased (3.95 -3.11 eV) with Ni doping concentration which is not shown here, similar to Ahmed et.al [5]. The increase or decrease in the band gap energy may be due to accumulation of donor or narrowing effects, energy levels of transition metal ions in the actual band gap of SnO_2.

Magnetic property of Ni doped SnO_2 thinfilms

Fig.2 shows the M-H curves for $Sn_{1-x}Ni_xO_2$ thin films with different Ni doping concentrations from x = 3 to 15 at.%. The diamagnetic nature becomes ferromagnetic by adding a little amount of oxide magnetic impurity. This may be due to oxygen vacancy and substitution of Sn atom by Ni atom interstitially. In other words the oxygen vacancy near the impurity plays vital role in mediating the ferromagnetism in this system at room temperature. The saturation magnetization increased with increase of Ni doping concentration. However on continually increase of Ni doping for higher concentration the saturation magnetization turns to decreases gradually. Thus we strongly feels that the oxygen vacancy and or defects in the Ni doped SnO_2sytem, which are in good agreement with the model proposed by Coey et al.[3] The maximum magnetic saturation (ms) $113.76x10^{-6}$emu, magnetic retentivity (mr) 9.501 and coercivity (Hci) 97.715 were obtained for Ni (5 at.%) doped SnO_2thin films.

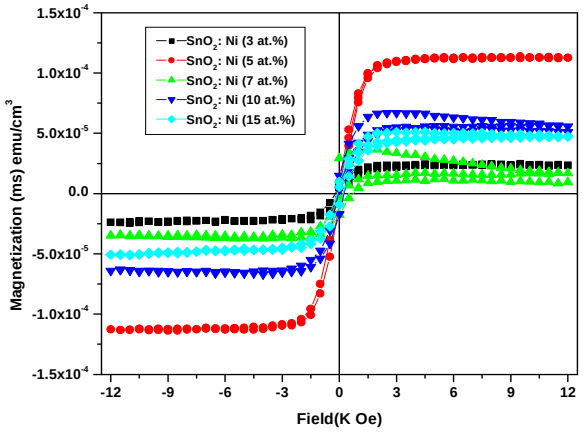

Fig. 2 M-H curves for $Sn_{1-x}Ni_xO_2$ thin films (x = 3 to 15 at.%).

Conclusion

Ni doped SnO_2 thin films were successfully deposited on glass substrates using flash evaporation technique. The films annealed at 773 K exhibited tetragonal rutile structure of SnO_2. From the optical transmittance it was revealed that the transparency and band gap decreased with doping concentration. Ferromagnetic behavior of Ni doped SnO_2 thin films were obtained at room temperature.The maximum magnetic saturation (ms) were obtained for Ni (5% at.%) doped SnO_2 thin films.

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