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- Short communication

INFLUENCE OF THICKNESS ON THE OPTICAL PROPERTIES OF Sb DOPED ZnO THIN FILMS

E. HOQ, M.R.A. BHUIYAN* AND J. BEGUM[1]

Department of Applied Physics, Electronics and Communication Engineering, Islamic University, Kushtia 7003, Bangladesh

ABSTRACT

Sb doped ZnO thin films having various thicknesses have been prepared onto glass substrate by using thermal evaporation method. The atomic compositions of the grown films have been determined by Energy Dispersive Analysis of X-ray (EDAX) method. The optical properties were measured by using a UV-VIS-NIR spectrophotometer (300 to 2500 nm). The EDAX analysis revealed that Sb is doped into the ZnO films. Optical properties showed high absorption coefficient (~10^5/cm) that direct allowed transition band gap. The optical band gap of the ZnO thin films became reduced due to the doping of Sb.

Key words: Sb doped ZnO thin films, Thickness, Composition, Optical properties

ZnO is one of the most promising materials that exhibit a large exciton binding energy and direct band gap of 3.3 eV. It is undoubtedly a good candidate to produce light emission in the visible and UV ranges but due to the doping of Sb into the ZnO the optical band gap and light emission range is changed to visible and near inferred region (Benelmadjat *et al*. 2010). The carrier recombination process in ZnO and its doped form increases the interest for optoelectronics applications (Fay *et al.* 2007, Zeng *et al*. 2003). Due to the doping of Sb into ZnO different properties of ZnO thin films are changed like compositional, band gap energy, reflectance, absorption range with photon energy etc. (Look 2001). In the present study, the influence of thickness on the optical properties of Sb doped ZnO thin films were investigated.

Preliminary (10%) black Sb powder of 1.425 gm and (90%) white ZnO powder of 8.575 gm was taken by using electronic balance. The composition of Sb doped ZnO thin films have been prepared by using the solid-state reaction technique.

The EDAX spectrum of Sb doped ZnO thin films are shown in Fig. 1. These show reasonably identical values (± 0.02 at. %) that ascertains the compositional homogeneity of the films. In our observation the peaks of O-Ka, Zn-La, Sb-La, Sb-Lb, Zn-Ka and Zn-

* Corresponding author: <mrab_iu@yahoo.com>.
[1] Experimental Physics Division, Atomic Energy Centre, GPO Box 164, Dhaka 1000, Bangladesh.

Kb were present at 0.55, 1.00, 3.64, 4.00, 8.71 and 9.62 KeV, respectively. Other peaks of Zn-L1, Sb-L1 and Sb-Lg were present at 0.8, 3.3 and 4.2 KeV, respectively. Additional peaks of C-Ka, Mg-Ka, Mo-L1, Mo-La, Mo-Lg and Al-Ka were also present at 0.196, 1.284, 2.051, 2.421 and 2.815 KeV, respectively. It is confirmed that Sb is doped into ZnO thin films. Similar results were also reported by other researchers (Wang *et al.* 2006, Zhao *et al.* 2008)

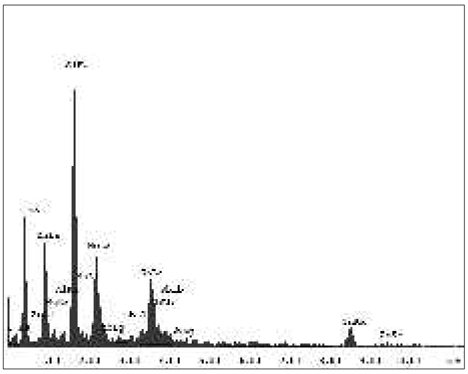

Fig. 1. Typical EDAX spectrum of Sb doped ZnO thin films.

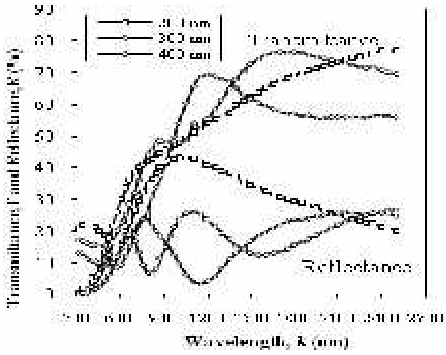

Fig. 2. Dependence of optical transmittance and reflectance on wavelength for Sb doped ZnO thin films having different thicknesses.

The transmittance and reflectance spectra of Sb doped ZnO thin films with different thicknesses having 50°C substrate temperature are shown in Fig. 2. The transmittance spectra show two distinct regions: one for long wavelength with high transmittance and another for short wavelength where transmittance decreases abruptly down to almost zero. The maximum transmittance of the films was ~85% in the near inferred region and ~50% in the visible region. It was observed that the transmittance decreased at short wavelength and increased at long wavelength with the increase in the film thickness. This happened due to lattice disorder, internal stress, discontinuity of the films, refractive index difference between Sb and ZnO and interstice radius difference between Sb^{3+} and ZnO (Zeng *et al.* 2003). It is observed that the reflectance spectra shows interference pattern with distinct peaks and valleys that small in the UV region.

Fig. 3 shows a significantly high absorption coefficient ($\approx 10^5$/cm) above 2.6 eV for Sb doped ZnO thin films. The analysis of the absorption coefficient, α above the fundamental edge shows that the rise of α in the photon energy range $2.8 \leq h\nu \leq 4.00$ eV follows a relation for an allowed direct interband transition (Patel *et al.* 1987) described by

$$\alpha = \frac{A_1}{h\nu}\left[h\nu - E_{g_1}\right]^{1/2} \qquad (1)$$

where, E_{g1} is the band gap energy of the interband transition and A_1 is a parameter that depends on the probability of transition and the refractive index of the material.

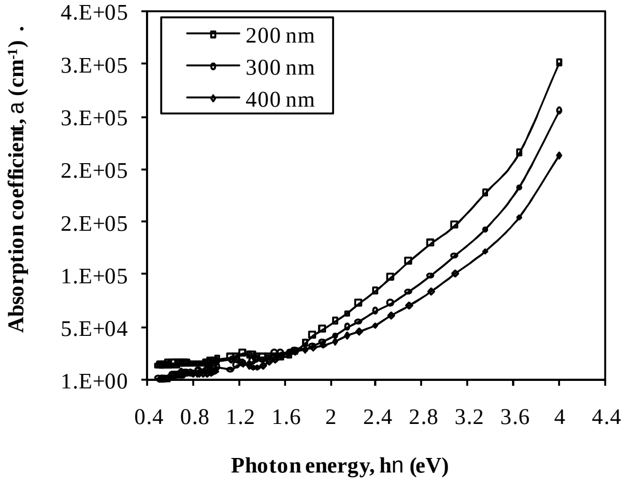

Fig. 3. Dependence of absorption coefficients on photon energy for Sb doped ZnO thin films having different thicknesses.

It was observed that the values of absorption coefficient decreasd with the increase in the film thickness which conforms reasonably well (Nadeem *et al.* 2000). The band gap energy and the value of A_1 were found out from the plot of $(\alpha h\nu)^2$ versus $h\nu$. Extrapolation of the linear portion of the curve to $(\alpha h\nu)^2 = 0$ gives the optical band gap. This indicates direct allowed band gap because the obtained straight line in the photon energy range ($2.695 \leq h\nu \leq 4$ eV). It was found that the band gap energy decreased from 2.989 to 2.779 eV as the film thickness increased from 200 to 400 nm. The calculated optical parameters are summarized in Table 1.

Table 1. Optical parameters of Sb doped ZnO thin films.

Thickness (nm)	Eg (eV)	A ($cm/eV^{1/2}$)
200	2.989	9.29×10^5
300	2.929	9.08×10^5
400	2.779	8.41×10^5

It is concluded that thickness may produce a desired band gap of Sb doped ZnO material having an energy band gap between 2.779 and 2.989 eV.

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