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ORIGINAL ARTICLE

Investigation of Optical Properties of Transparent Conducting Oxide Based on Al2ZnO4

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ABSTRACT
In this study, the optical energy gap, refractive index of the films, single oscillator energy and dispersion energy were studied. The effect of changing the condition of preparation on the optical constants was investigated.
Keywords: *Tin Film, Optical Gap, Refractive Index, Dispersion Energy.*

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INTRODUCTION

Transparent conducting oxide coating will support the development of the next generation of photovoltaic components [1-3]. Most transparent conducting oxide are based on SnO2, In2 O3, ZnO and their mixed compounds are formed by different physical and chemical techniques. The properties of transparent electrodes have been improved using sputtering methods, but there methods of deposition have drawback, such as their high cost the longer fabrication time[4]. The electrical and optical properties of transparent conducting oxide films were found to depend on composition, structure, density, surface roughness and dopant concentration [5-7]. The importance of aluminum zinc oxide Al2ZnO4 is due to its wide band gap which gives the uniqueness property where it has been weakly studied for various practical applications such as solar cells [8], flat panel display [9], surface acoustic devices, optical waveguide , gas sensors micro machined actuator [9, 10]. The physical properties of the films depend strongly on the condition of preparation as deposition technique, the growth methods and post deposition treatment. Aluminum zinc oxide AZO is transparent for visible light, making them promising for optical applications. AZO is regarded as a distinguished substitute for indium oxide (ITO) because zinc oxide is a nontoxic, inexpensive and abundant material [11]. A lot of attentions have been paid by industry to develop thin AZO films. Zinc oxide is an n-type II-IV semiconductor with a band gap of 3.2 eV at room temperature [12].

EXPERIMENTAL TECHNIQUE

In this experimental setup, AZO target (from Cathey) with a purity of 99.998 % and 3 inch diameter was used. Aluminum zinc oxide thin layers were prepared by DC sputtering under a base pressure of argon of 18 mTorr. The AZO target with a purity of 99.998 % and 3 inch diameter was used. The distance between the target and substrate was fixed at 12 cm. For homogeneity of the films, periodic motion of 2 rpm of the substrates was adopted. The structural characteristics of AZO thin films were investigated by X-ray diffraction pattern. Philips X-ray diffractometer model X Pert was used for the measurements which utilized monochromatic CuKα = 1.5406 Å radiation operated at 40 kilovolt and 35 mA. Reflectance R and transmittance T measurements at near-normal incidence in the spectral range 20-100 nm were performed by using double beam spectrophotometer (JASCO model V-680 UV-VIS-NIR). The substrate temperature was kept at 27 oC during deposition.

THEORY

In order to obtain the optical energy gap Eop, the following equation was used [13];

$$(\alpha h\upsilon)^b = A(h\upsilon - E_{op}) \quad (1)$$

and the absorption coefficient α can be expressed as [14];

$$\alpha = \frac{1}{d} Ln\left(\frac{(1-R)^2}{T}\right) \quad (2)$$

the correct value of transmittance T is given by [15];

$$T = (\frac{I_{ft}}{I_g})(1 - R_g) \quad (3)$$

$(h\nu)$ is the incident photon energy, R is the reflectance, Rg is the reflectance of glass substrate, Ift is the intensity of light passing through the film-glass system, Ig is the intensity of the light passing through the reference glass and d is the film thickness. The real value of the reflectance R is given by [16];

$$R = [(\frac{I_{fr}}{I_m})R_m(1 + [1 - R_g]^2) - T^2 R_g \quad (4)$$

I_{fr} is the intensity of light reflected from the sample, I_m is the intensity of light reflected from the reference mirror. The refractive index n was calculated from the following equation:

$$n = \frac{1+R}{1-R} + [\frac{4R}{(R-1)^2} - k^2)]^{1/2} \quad (5)$$

Where $k = \alpha\lambda / 4\pi$ is the absorption index, and λ the is incident wavelength. The band tails of the localized states can be estimated to a first approximation by plotting the absorption edge data in terms of an equation originally given by Urbach [17]. It has been reported that hν holds over several decades for a glassy material and takes the formula:

$$\alpha = \alpha_o e^{\frac{h\upsilon}{E_u}} \quad (6)$$

Using Domenico dispersion relationship, the single oscillator energy Eo and dispersion energy Ed can be calculated using the following equation:

$$(n^2 - 1)^{-1} = \frac{E_o}{E_d} - \frac{1}{E_o E_d}(h\upsilon)^2 \quad (7)$$

RESULTS AND DISCUSSION

Thin films of Al2ZnO4 with 10, 15, 20, 25, and 30 nm thick were deposited at the same preparation conditions on glass substrate at room temperature. Figure 1 depicts the changes of the transmittance T(%) with the incident wavelength revealing that the intensity of the transmittance decreased with increasing the thickness of the film in the range of wavelength from 28 nm to 70 nm due to thickness effect.

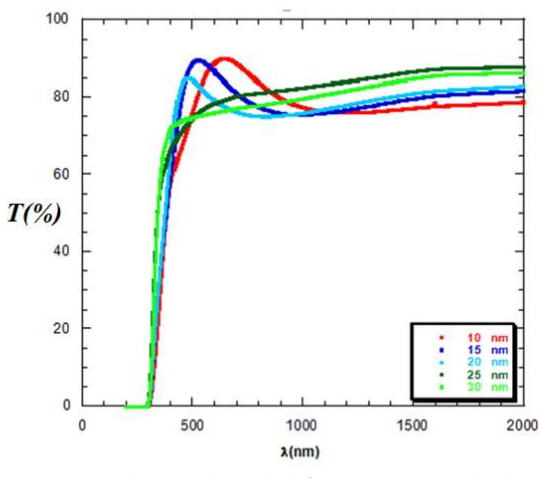

Fig 1: Variation of transmittance T with wavelength λ for as-prepared Al2ZnO4 thin films of different thicknesses.

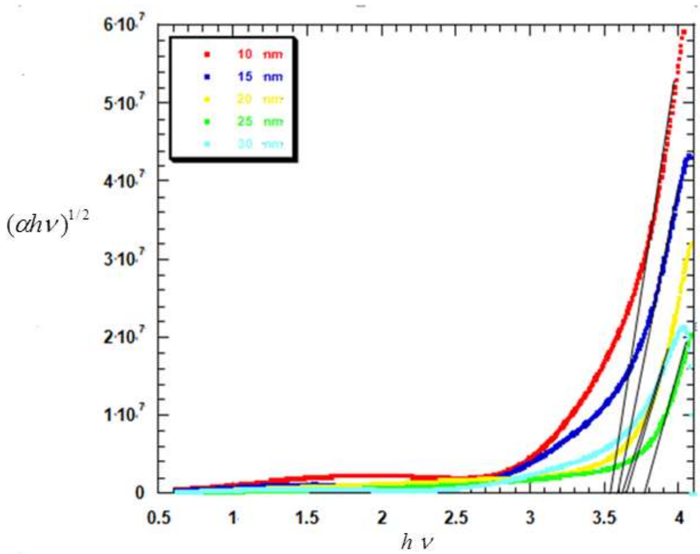

Fig2: plots of $(\alpha h\nu)^{1/2}$ versus $h\nu$ for as-prepared Alzno4 thin film different thicknesses.

To obtain the optical energy gap, the plots $(\alpha h\nu)^{1/2}$ versus $h\vartheta$ to $(\alpha h\nu)^{1/2}$ = 0.0 were found to be the best fitting as shown in Fig. 2 indicating indirect optical energy gap. The calculated values of the optical energy gap were 3.53, 3.6, 3.62, 3.65, and 3.78 eV for the thicknesses, 10, 15, 20, 25, and 30 nm respectively revealing increasing the optical gap with thickness. This can be attributed to improvement in the crystals, in morphological changes of the films, in changes of atomic distances and grain size and structural defects in the films.
Four thin films of Al2ZnO4 of thickness 25 nm were prepared under the same condition, one of them was left as-prepared, each one of the three films was annealed at certain temperature, 300, 400 and 500oC for two hours. The variations of the transmittance T with wavelength λ were plotted in Fig. 3 revealing decreasing of the transmittance with increasing the annealing temperature. The decrease of transmittance with increasing annealing temperature may interpreted as due to improvement of the degree of crystallinity of the films and/or increase of the grain size which is confirmed by the X-ray analysis.

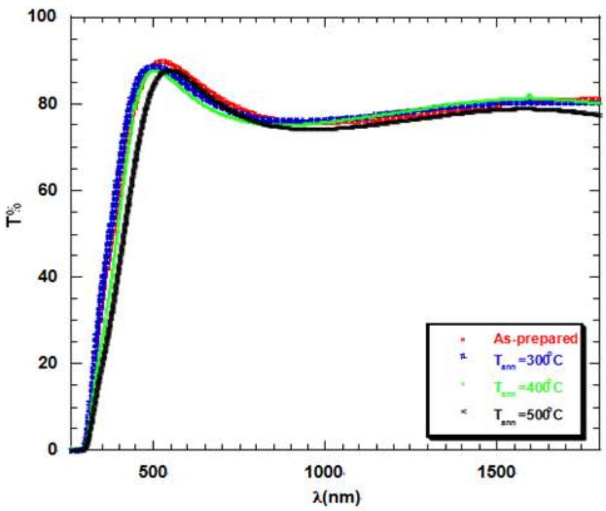

Fig3 plots of transmittance T versus wavelength for as-prepared at different temperature.

The single oscillator energy and dispersion energy were calculated for the films of different thicknesses and others annealed at different temperatures are recorded. The single oscillator energy increase with increasing both of thickness of the film and annealing temperature, whereas, the dispersion energy has a tendency of decreasing with both thickness and annealing temperature.

CONCLUSION

The results show the optical energy gap increases with both the film thickness and the annealing temperature, whereas both the rate and pressure of the gas has not affect the optical gap. Our results showed that the refractive index has normal dispersion in case of changing both the thickness of the films and annealing temperature. Single oscillator energy found to increase with thickness and annealing temperature. Dispersion energy has a tendency to decrease with both of thickness and annealing temperature.

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