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Preparation and inter-Band Transition of Zno Thin Films by an Evaporation Method

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Abstract:

Transparent zinc oxide (ZnO) thin films have been prepared on a glass substrate at 450 OC by thermal evaporation.
Structural and optical properties were studied. X-ray diffraction studies showed the polycrystalline nature of the films with preferred (002) orientation perpendicular to substrate surface and grain size estimated to be 40 nm. The optical absorption coefficient, Urbach energy, energy gap were determined from transmittance spectrum in the wavelength range (300 - 900) nm.

Introduction :

Zno is an n-type semiconductor and exhibits good piezoelectric, photoelectric and nonlinear optical properties. It is an important material to fabricate acoustic, optic and microelectronic devices, such as surface-acoustic-wave devices, ultrasonic transducer arrays, transparent conducting electrodes used in solar cells, optical wave guides and others (1-5). Several techniques have been used to prepare Zno thin films such as DC-.RF sputtering (5-7|, chemical bath deposition (8), pulsed Laser (9) and spray pyrolysis (10).
There have been extensive studies on the crystalline structure and optical transmittance of Zno thin films prepared by an evaporating method (1 1,121) However, there are few studies on the optical properties such as inter band transition of Zno thin films .

In this article, structure and optical properties; inter-band transition of Zno thin films prepared by an evaporating method have been investigated.

Experimental Part:

Zno films were prepared by evaporating Zinc acetate in Vacuum.

The reaction is :

$$Zn\ (CH_3COO)_2 \longrightarrow ZnO + CO_2 + CH_3COCH_3.$$

A resistivity heated quartz glass boat was used for evaporating zinc acetate. Glass substrates were mounted above the source at a distance of about 18 cm. The substrate temperature was maintained at 450 oC. Zno films were carried out at a base pressure of (2 x 10-3 Pa).
The evaporating power of Zinc acetate was maintained at 30 w. X-Ray diffraction measurements were carried out to examine the crystalline structure of the films. Optical transmission was measured in the wavelength range of (300- 900) nm.

Results and Discussion:

X-Ray diffraction analysis indicated that the prepared film was polycrystalline ZnO, which was oriented perpendicular to the substrate surface ic-axis orientation) as shown in Fig. (1).
T

$$g = \frac{0.94\lambda}{B\cos\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where y is the X-ray wavelength (1.5405 0A) 0 and B are the Bragg diffraction angle of the XRD peak and full width at half maximum (FWHM) of (002) diffraction peak respectively (13,141. The crystallite size is estimated about 40 nm.
The optical transmission through the film was measured using double-beam spectrophotometer. Fig.(2) shows

measured transmission curve for Zno and it is inferred that the average transmission over the visible range exceeds 80 %.

The thickness of the film was measured by using SEM as shown in Fig.(3) and found to be 750 run.
The absorption coefficient a is determined using the relation (15):

$$\alpha = \frac{1}{t}\ln(T) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where t is the thickness of the film and T is the transmittance.
According to Tauc (16) it is possible to separate three distinct regions in the absorption edge spectrum as shown in Fig.(4). The first is the weak absorption tail, which originates from defects and impurities, the second is the exponential edge region, which is strongly related to the structural randomness of the system and the third is the high absorption region that determines the optical energy gap. In the exponent edge where the absorption coefficient (a) lies in the absorption region of the absorption coefficient is governed by the relation (17):

$$\alpha = \alpha_0 e^{\frac{h\nu}{E_u}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

is Urbach energy and it is the width of the band tails of the localized states in the forbidden gap existing in the films.
Urbach energy can be calculated from plotting (lna) vs (hv) as shown in Fig. (5). The value of Eu = 0.3 ev is calculated from the slope of the linear plot.
The optical band gap Eg, was calculated on the basis of the fundamental absorption using the well-known relation:

$$\alpha h\nu = A\left(h\nu - E_g\right)^n \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where A is constant and the exponent n depends on the type of transition. n=1/2, 2, 3/2 and 3 corresponding to the

allowed direct, allowed indirect, forbidden direct and forbidden indirect transitions respectively (18,19).

The variation of (ahv2) and (ahv)2\3 with photon energy (hv) are shown in Fig.(6) and Fig.(7). It has been observed that n =1/2, 3/2 gives us linear over a wide of photon energy indicating the allowed direct and forbidden direct transition. The intercept (extrapolation) of these plots (straight line) on the energy axis gives the energy band gap. The direct allowed Eg' and forbidden Eg optical band gaps were determined and it was found equal to 3.1 ev and 2.88 ev respectively. These values are in good agreement with previously reported data of Zno thin films (20)

Conclusion :

Highly transparent Zno thin films were prepared by evaporating method an glass substrate at 450 C. The X-ray diffraction analysis showed that Zno film is polycrystalline with (002) preferential orientation, grain size 40nm, with high optical transmittance of over 80% in the visible range and the optical studies reveal that the film has a direct band gap allowed and forbidden.

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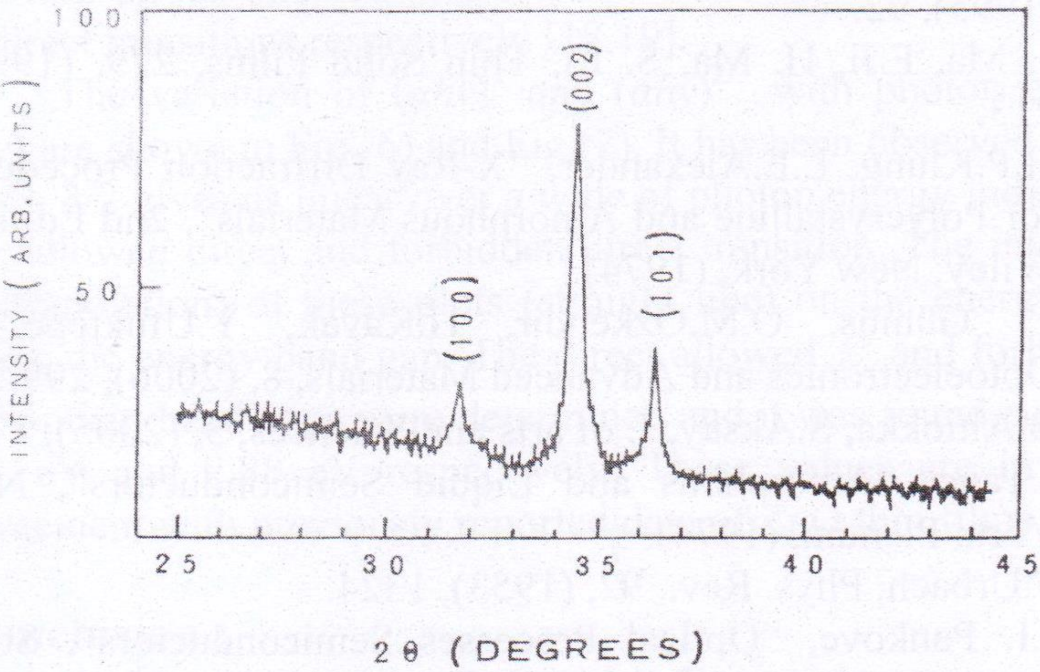

Fig.(1) X-ray diffraction of ZnO thin film .

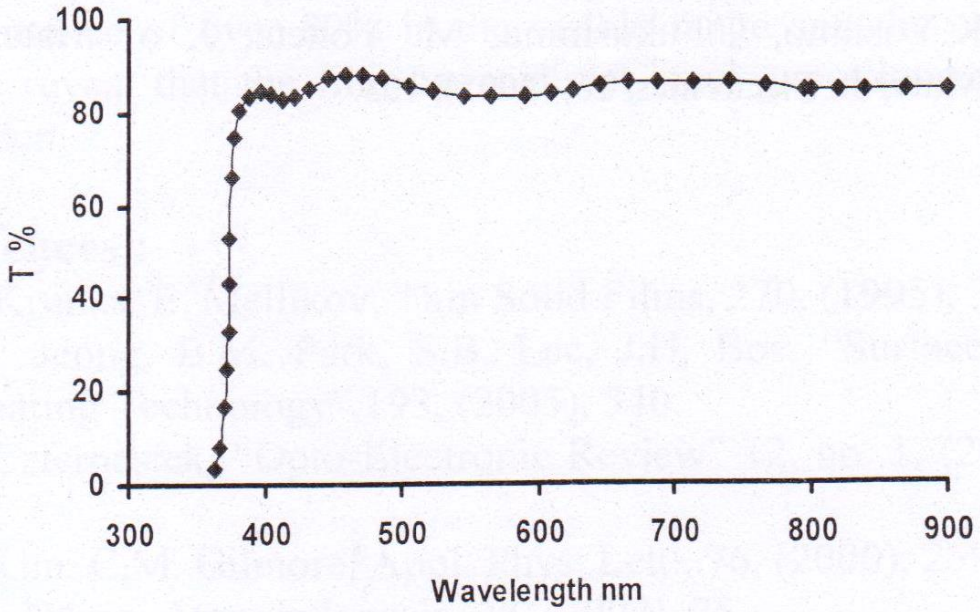

Fig.(2) The transmittance spectra for ZnO film.

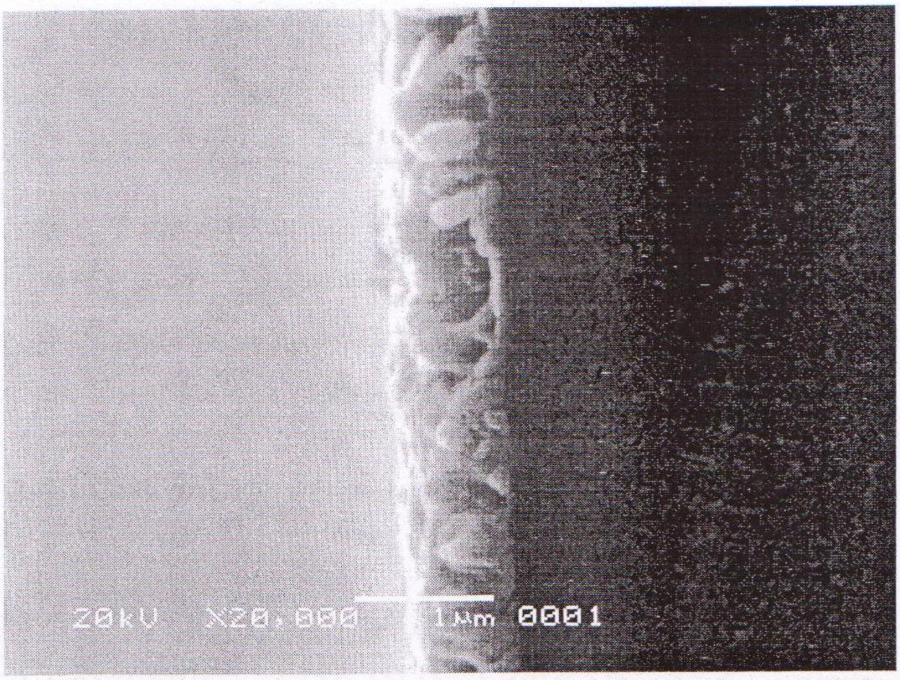

Fig. (3) SEM image of ZnO thickness.

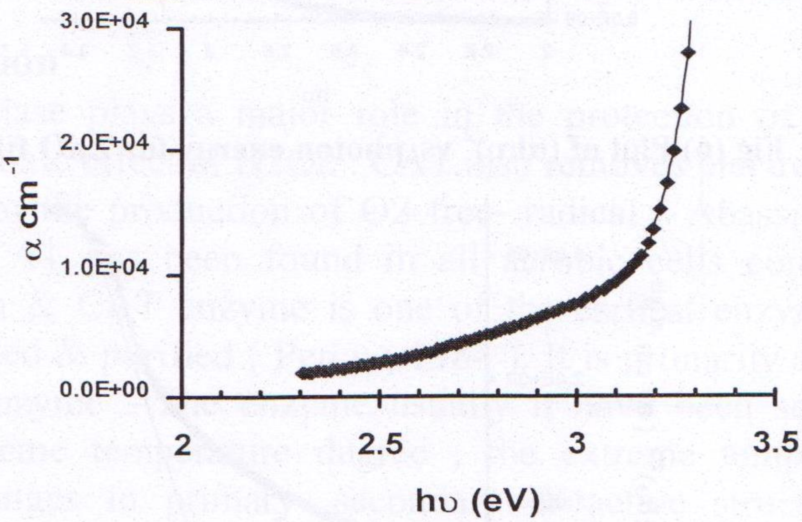

Fig.(4) Absorption coefficient as function of photon energy for ZnO film.

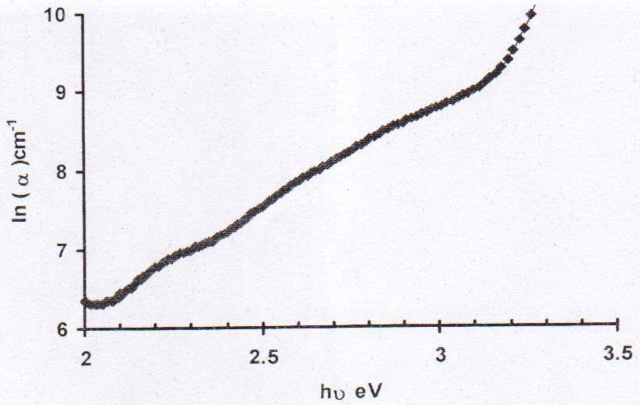

Fig. (5) Plot of ln(α) vs. photon energy for ZnO film.

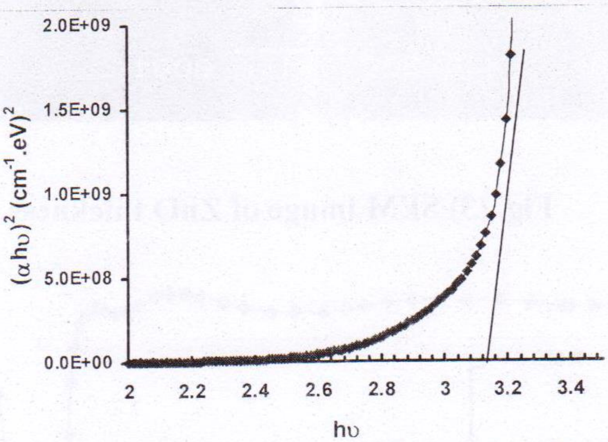

Fig (6) Plot of $(\alpha h\upsilon)^2$ vs. photon energy for ZnO film.

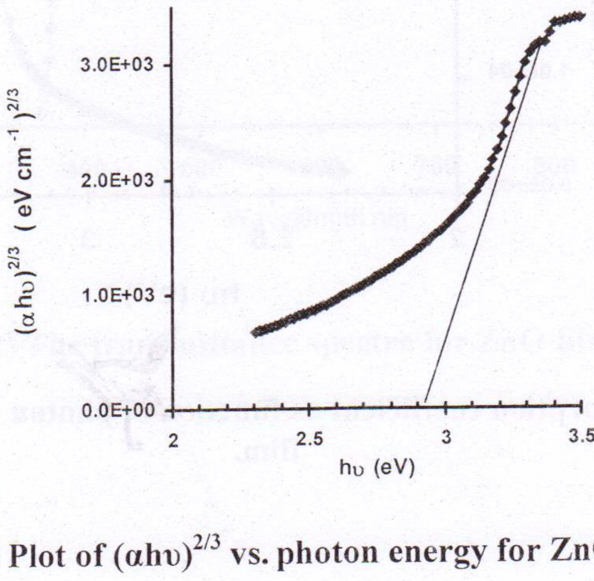

Fig. (7) Plot of $(\alpha h\upsilon)^{2/3}$ vs. photon energy for ZnO film.