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Optical studies of Zinc Oxide Thin Films Grown at different Substrate Temperature

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***Abstract*— To date most, ZnO thin films have drawn a lot of attention because of their variety of applications. ZnO has unique properties such as its wide range of band gap, high binding energy, high melting point, and boiling point. So in this paper we have taken the ZnO target and using PLD we have deposited thin film on a substrate of silicon and corning glass at different temperatures. After deposition of the thin films the optical properties of these films were characterized by UV-visible spectroscopy and FTIR spectroscopy. The parameters such as the band gap of these thin films with the help of TAUC's plot and also calculated the refractive index with the help of reflectance and transmittance. We have used FTIR for the calculation of the bond position (peak) of zinc and oxygen at different wavelengths. This method exhibits the unique properties of ZnO thin films and provides a better understanding of experimental as well as phenomenological techniques.**

***Keywords*— ZNO, PLD, UV-visible spectroscopy and FTIR spectroscopy**

I.INTRODUCTION

Over the last few years, ZnO films have drawn the attention of many researchers because of the possibilities to be used in valuable applications, such as optoelectronics devices, and not the least, due to its highly preferential orientation along the c-axis. ZnO films show high piezoelectric properties and can therefore be used for surface acoustic wave devices [1]. The extensive investigations on its structure, morphology, and optical properties would lead to the development of novel and high-quality devices and may increase the number of applications. Many techniques have been used to fabricate ZnO thin films, including laser molecular beam epitaxial, metal-organic chemical vapor deposition [2], sputtering [3], thermal evaporation [4], chemical vapor deposition [5], sole gel [6], and pulsed laser deposition (PLD) [7]. Amongst these techniques, PLD is a popular research technique because of its potential to achieve high-quality films at low temperatures, even at room temperature, as well as the stoichiometry transfer between the target material and the film [7]. The advancement in the field of thin film technology paved the road for the development of various semiconductor-based devices [8-10]. Moreover, ZnO-based nanomaterials can be considered promising candidates for solar cells, gas sensors, laser diodes, and so on. ZnO films can be grown by several physical and chemical methods such as sputtering, chemical vapor deposition, sol–gel method, molecular beam epistaxis, and pulsed laser deposition on a wide range of substrates [11–15]. PLD also offers the deposition in reactive and inert background gases which allows a sufficient control of the film composition and properties. It is also well known that different deposition pressures can influence the surface roughness of the PLD thin films with a direct effect on the light emission of the thin films [16-18]. Well-known UV emission was observed from undoped ZnO films with the films deposited in vacuum and oxygen giving respectively the least and highest PL intensity. The particle size and emission intensity were dependent on the growth atmosphere and stress [19]. Many works have been done that include materials in which the target material was undoped ZnO [20-22]. Pulsed laser deposition (PLD) has been studied and employed as a relatively simple and reliable technique for depositing a wide range of materials for novel applications [23-27].

In the present investigation, undoped ZnO thin films were deposited on glass at different substrate temperatures by the PLD technique. The influences of substrate temperature and reactive gas pressure (O2) on the optical and electrical properties of the deposited films were investigated.

II.EXPERIMENTAL PROCEDURE

The oxide layer of ZnO is deposited on silicon and corning glass substrate using a pulsed laser deposition technique with variation of temperature at 100 mT pressure. Before pulse laser deposition we made a target of ZnO oxide. After the deposition of the film, we study the structural properties of the deposited film via XRD pattern. We can calculate crystallize size, stress, inter-planer distance, and lattice constant from XRD analysis. For the deposition of the thin film of zinc oxide at various temperatures of O_2 at 100 mt pressure, we put two different substrates one was corning glass and the other one was silicon at the substrate holder and a ceramic target of zinc oxide put on the target holder. We take some parameters during depositions which are tabulated below in table no.1.

Table 1: Parameter at deposition of PLD

Substrate	Temperature	Pressure	Pulse energy	Repetition rate	No. of shots
Corning glass	R.T.	100mT	175mJ	10	15000
Corning glass	100°c	100mT	175mJ	10	15000
Corning glass	200°c	100mT	175mJ	10	15000
Silicon	R.T.	100mT	175mJ	10	15000
Silicon	100°c	100mT	175mJ	10	15000
Silicon	200°c	100mT	175mJ	10	15000

III. RESULT AND DISCUSSION

(A) ***UV-SPECTROSCOPY*****:** The transmittance spectra of zinc oxide film are taken at corning glass substrate and reflectance spectra of same film is taken on silicon substrate.

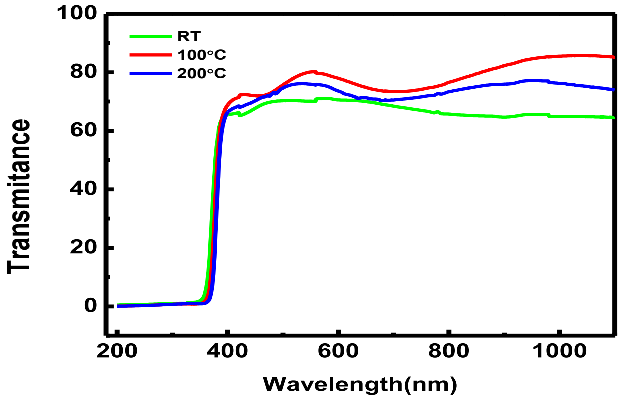

Figure 1 (a): Transmission plot of ZnO thin films grown with various temperatures (a) RT (b) 100℃ (c)200℃

With the help of the data of both spectra, we calculate the band gap using Tauc's equation:

$$\alpha h\nu = A(h\nu - E_g)^2$$

The optical band gap is obtained by plotting $(\alpha h\nu)^2$ vs. $h\nu$ and extrapolating the linear portion of it. From the below graph, it is clear that as increasing temperature the value of the optical band gap of a thin film of zinc oxide decreases. The decrease in the band gap may be due to the improved crystalline structure of the ZnO thin films. The maximum value of the optical band gap at room temperature is 3.3eV.

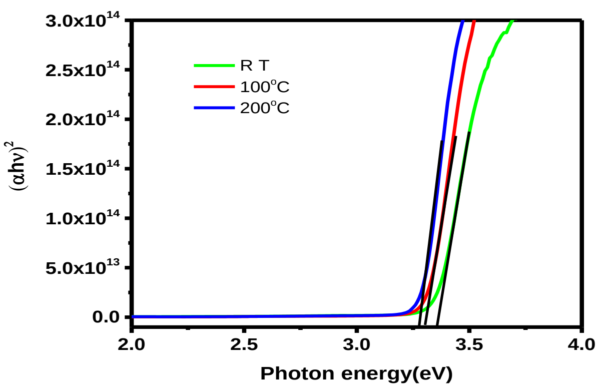

Figure 1(b): Band gap of ZnO thin films grown with various temperatures

Table 2: Calculated band gap of thin film of zinc oxide at temp.Variation

S.No.	Temperature(^{O}C)	Band gap (eV)
1.	R.T.	3.35Ev
2.	100^{O}C	3.30Ev
3.	200^{O}C	3.27Ev

For the samples prepared on Silicon, reflectance studies were carried out. Fringes were obtained in the case of reflectance of Silicon samples. With the increase in temperature, a decrease in the value of reflectance was found which leads to opacity of samples.

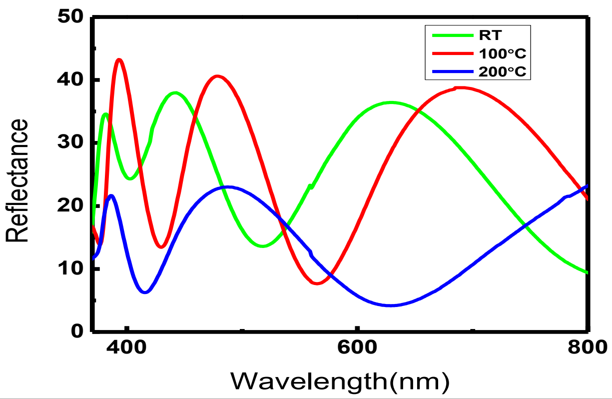

Figure 2: Reflectance spectra of ZnO thin films grown with various temperatures (a) RT (b) 100℃

The value of refractive index n(k) [28] of the ZnO thin film was determined at different wavelengths from both the reflectance and transmittance spectra using equation:

$$n(\lambda) = \frac{(1+R)}{(1-R)} + \sqrt{\frac{4R}{1-R^2} - k^2}$$

Where R is the reflectance and k (k = αλ/4π) is the extinction coefficient, α (α =[ln($\frac{1}{T}$)]/t) is the absorption coefficient, λ is the wavelength, t is the thickness, T is the transmittance.

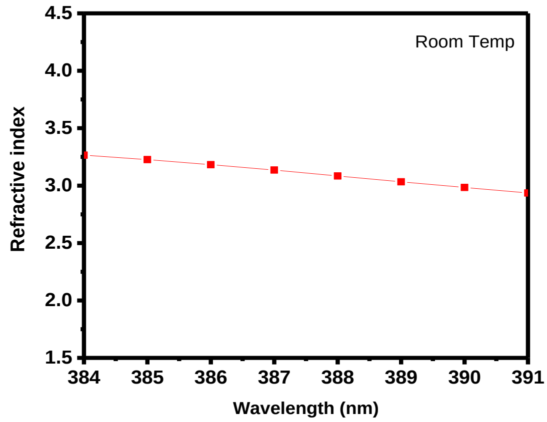

Figure:3(a)

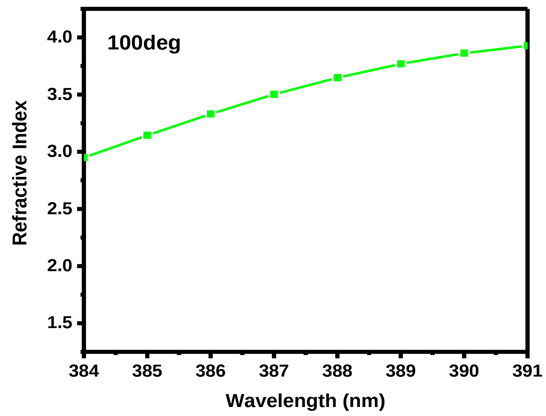

Figure:3(b)

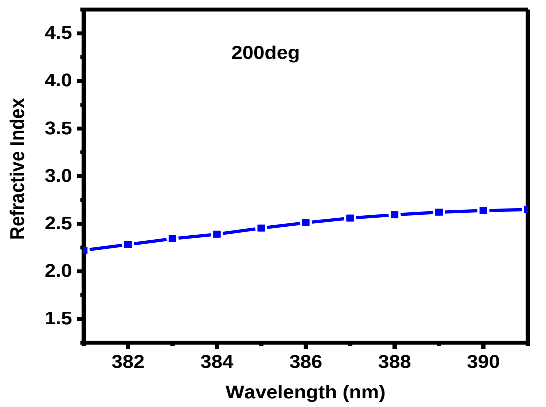

Figure 3: Refractive index of ZnO thin films grown with various temperatures (a) RT (b) 100℃

It may be observed that the refractive index of ZnO film grown at 100^{0}C temperature was found to be relatively higher as compared to those deposited at

Room Temperature and 200^{0}C. This can be correlated with the stress generated across the film i.e. the film with minimum stress was found to exhibit maximum refractive index.

(B) *FTIR ANALYSIS*:

FTIR[29]spectroscopy is an important technique to checking the vibrational spectrum and properties of thin films. Fourier transform infrared(FTIR) spectroscopy is the spectroscopy that deals with the infrared region of the electromagnetic spectrum which is light with a longer wavelength and lower frequency than visible light. The surface-to-volume ratio (i.e. aspect ratio) for nanoparticles is higher than their bulk counterpart. As more atoms/molecules are arranged on the surface of nanoparticles, the surface chemistry of these nanomaterials is of immense interest. To quickly establish the presence or absence of the various vibrational modes present in ZnO nanoparticles, we performed FTIR spectroscopy of ZnO nanoparticles. To analyze spectrum peaks are correlated with FTIR spectroscopy correlation wave number. we have FTIR spectra of as-prepared nanoparticles. The absorption and transmittance bands peak obtained of Zn–O bond and also authenticates the presence of ZnO.

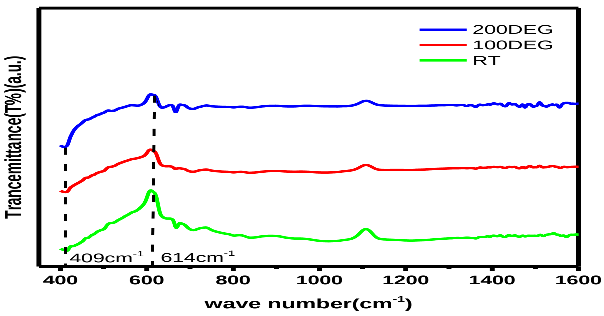

Figure 4: FTIR spectra of ZnO thin films grown with various temp.

The absorption bands at around 409cm^{-1} and 614cm^{-1} are attributed to the E1 (TO) and A1 (LO) bending vibration of ZnO respectively. The observed absorption bands confirm the deposition of ZnO thin films with good structural properties.

IV CONCLUSION

Highly crystalline ZnO thin films were deposited on corning and Si (100) substrate using the Pulsed laser deposition(PLD) technique at varying substrate temperatures (RT, 100^{0}C, 200^{0}C). The films were found to be c-axis oriented with good crystal quality. The structural analysis of films was performed using the FTIR technique. The ZnO films deposited at varying substrate temperatures exhibit high optical transmittance, which was confirmed using the UV-visible Technique. The band gap of films was found to decrease with an increase in substrate temperature. Furthermore, it was observed that the films with minimum stress exhibited maximum refractive index in the absorbing wavelength range.

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