Impact of Deposition Temperature on Amorphous Zinc Oxide Thin Film Characteristics.

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Abstract:

In this paper, we discuss the deposition of amorphous zinc oxide (a: ZnO) thin film at two different temperatures by spray pyrolysis unit for Thin Film Transistor (TFT) application. The a: ZnO films were studied for its structural, morphology, composition, optical and electrical properties by means of XRD, SEM, EDAX, UV-Visible spectroscopy and I-V measurement system respectively. The film thickness characterized by optical Profilometer. The SEM images exhibit the variation in temperature leads to the crystallinity of the film. The XRD spectrum confirmed the films were amorphous in nature. The rise in deposition temperature there is one order difference in the film resistance is found. The film deposited at higher temperature exhibited high transmittance value in the visible region. The transmission spectrum is used to calculate the optical constants such as bandgap and extinction coefficient. The films deposited at higher temperature has lower bandgap and higher extinction coefficient which are best suited for electronic devices application like TFT.

Keywords: Spray Pyrolysis; amorphous ZnO; thin film; TFT;

Introduction

Thin film technology is gaining more attention in the modern era. The thin films are being used in almost all fields to name few the agriculture[1][2], automobile[3], bio medical[4][5], food processing, electronics[6], household[7] etc. The thin film coatings are becoming more necessary these days as they improve the stability, noncorrosive, making biocompatible, and ease the cost of the materials. The thin films like ZrO_2 and TiO_2 coated on stainless steel helps to make materials biocompatible that can be used for implants in medical fields[8]. Materials like Tio_2/SiO is used as Antireflection coating[9]. Metal oxides semiconductor thin films have been widely researched and have received considerable attention in recent years due to their optoelectronic properties because they are good candidates for transparent conducting oxides (TCO). There is a number of metal oxides[10] such as ZnO, GZO, IZO, IGZO, ITO, TZO, FTO etc. Among them, Zinc oxide materials have received increased interest in recent years due to their wide range of technological applications such as TFTs[11], sensors[12], photodetectors, solar cells and other devices.

ZnO is a material with large direct bandgap varying between 2.8 to 3.3eV [13]and having excellent chemical stability, thermal stability and being non-toxic in nature. ZnO has higher electron mobility compared with other oxide materials[14]. This property of ZnO thin films was also investigated for their potential applications in Nanosystem. Pure ZnO films can by vacuum and non-vacuum process. Some of the vacuum process such as pulsed laser deposition, sputtering[15] and chemical vapour deposition. Liquid phase synthesis, wet chemical process, spin coating, laser pyrolysis, sol-gel technique[16], flame assisted spray pyrolysis, spray pyrolysis[17] is some of the non-vacuum[18]. Among these techniques spray pyrolysis offers low cost, simplicity, good electrical performance compared to others. The other advantage of spray pyrolysis is easy adaptability for the production of large-area uniform films.

The work presented in the paper focusses on the deposition of ZnO thin films two temperatures i.e. 170℃ and 250℃ on a glass substrate by self-fabricated Spray pyrolysis, we have also studied the characteristics of the films using XRD, optical profilometer, SEM, EDAX, UV-Visible spectroscopy and I-V measurement system respectively.

Materials and Methods

Synthesis

The solution of 0.3M Zinc acetate dehydrated is used as a precursor prepared by double distilled water, acetic acid and methanol (48:4:48) as a solvent. Few drops of acetic acid are used as a stabilizer and to get clear the solution. The solution was stirred for 30 minutes at room temperatures.

Thin Films Deposition

Zinc oxide films were deposited on a cleaned glass substrate at a different temperature of 170℃ and 250℃ with an accuracy of ±5℃ by custom design and developed spin spray pyrolysis equipment[19].

The film was deposited by spin-spray pyrolysis method using the synthesized solution on a plain glass substrate which was preheated. The carrier gas pressure was kept constant at 1 bar and the nozzle to substrate distance was 24cm. The 0.3 M solution was sprayed with a flow rate of ~1.5ml/ min was fixed. The coatings were carried out keeping all other parameters constant with the exception of temperature.

Material characterization

The nature of the film was investigated by X-Ray diffractometer in MIT Manipal. The morphology of the film was investigated using SEM. The composition of the film was studied using EDAX. The thickness of the film was investigated by Optical Profilometer at IISc, Bangalore. The optical transmission spectroscopic measurement of these films was carried out by UV-Vis spectrophotometer in the wavelength range of 300-700nm**.** The electrical characterization of the films was carried using B1500A Agilent semiconductor parametric analyzer at MIT Manipal.

Results and Discussions

Thickness measurement

The two films A and B are deposited at 170℃ and 250℃ temperature respectively. The thickness of the ZnO thin film was measured using Optical Profilometer. The film was coated on a glass substrate by spin-spray pyrolysis equipment and tested for uniformity, thickness by the use of optical Profilometer. The thickness of the samples A and B was 416nm and 482nm respectively.

XRD analysis

The films A and B were tested for crystallinity using XRD and results confirm that they are amorphous in nature. The scan was performed in the range of 10^0C to 90^0C The graph is as plotted in Figure *1*.

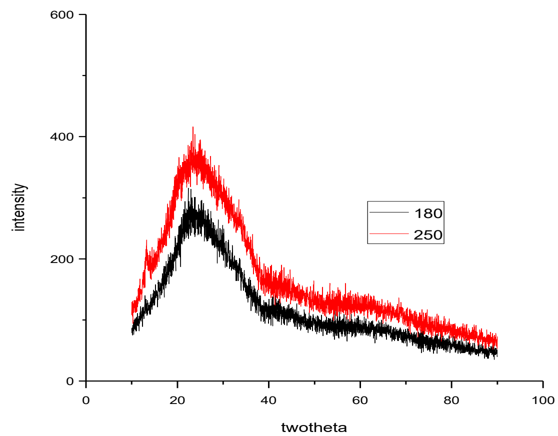

Figure 1 X-ray diffraction pattern of a: ZnO thin film deposited on a glass substrate.

EDAX

The ZnO thin film coated on the glass substrate was subjected to compositional analysis using EDAX and the result are as shown in Table 1 and

Table 2 which confirms that the film is Zinc Oxide with less contamination of carbon.

Table 1 EDAX of the thin film Deposited at 180℃

Element	**Weight %**	**Atomic %**	**compound %**	**Formula**
O K	31.31	46.02	43.06	O2C
Si K	11.90	9.96	0.00	
Zn L	58.43	21.02	0.00	
C	11.75	23.01		
Totals	113.39			

Table 2 EDAX of the thin film Deposited at 250℃

Element	**Weight %**	**Atomic %**	**compound %**	**Formula**
O K	28.89	46.39	39.73	O2C
Si K	11.74	10.74	0.00	
Zn L	50.05	19.67	0.00	
C	10.84	23.20		
Totals	101.51			

SEM

In

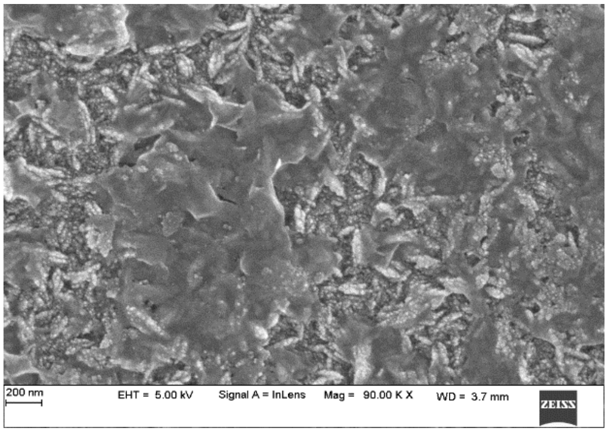

Figure 2 and Figure 3 shows the morphology of ZnO thin films deposited at different temperature. The rise in temperature of the film shows the change in the morphology of the film. The film deposited at 250℃ started agglomeration.

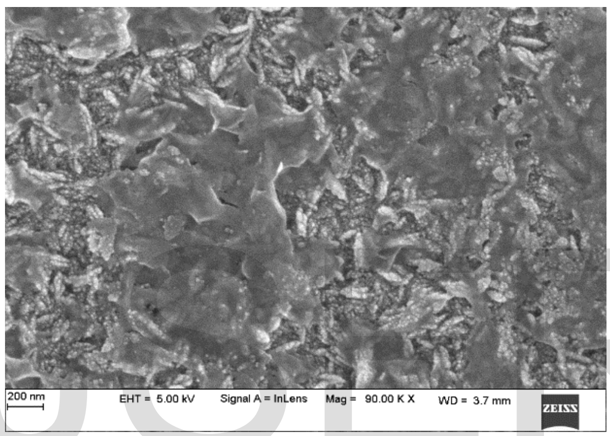

Figure 2 SEM image of the thin film Deposited at 180℃

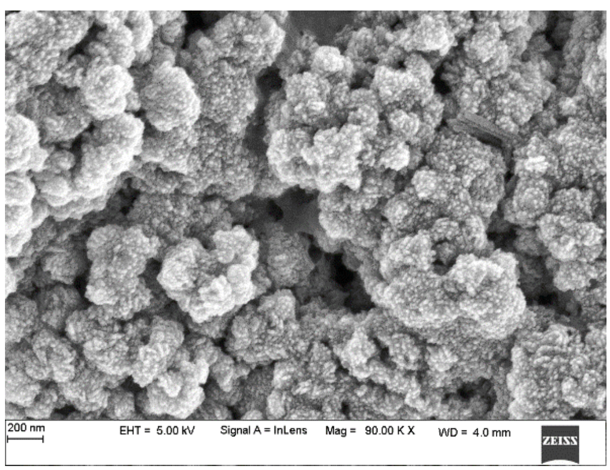

Figure 3 SEM of the thin film Deposited at 250℃

Electrical Characteristics

The samples were electrically characterized using B1500A semiconductor device parameter analyzer. A voltage sweep was carried out in the range of -5V to +5V. The resistance of the film A and B were 0.5MΩ and 5MΩ respectively. The graph is as shown in Figure 4.

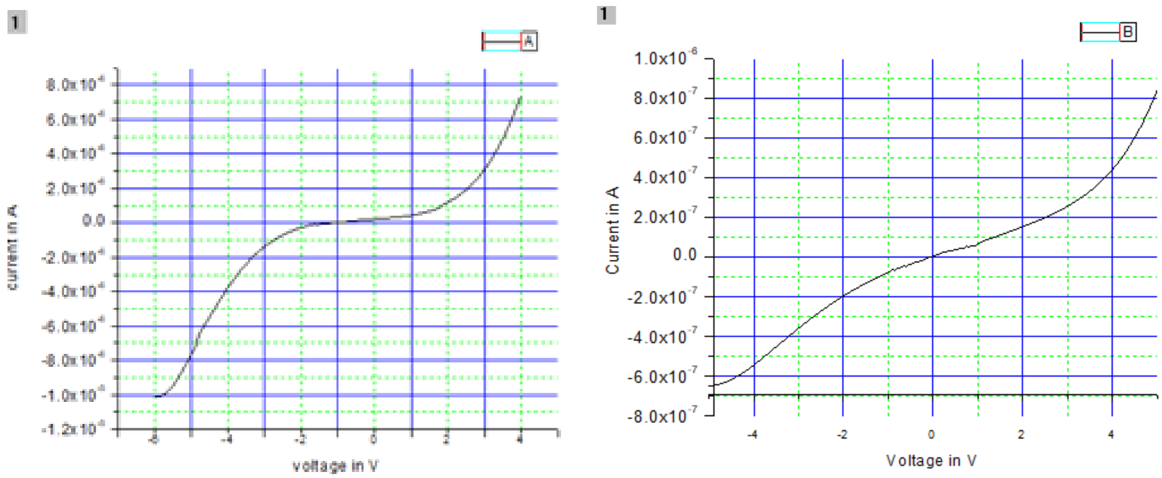

Figure 4 a) Sample A b) Sample B I -V graph of a: ZnO thin film deposited on the glass substrate.

Optical Characteristics

The absorption and transmittance spectrum was taken between 290 -810nm. The maximum transmittances were above 55% and above 45% for A and B respectively. The maximum absorption peak was found to be at 318 nm for both the samples. If the thickness (t) of the film is found. The absorption coefficient (α) can be determined from the following relations (1)

$$\alpha = \ln\left(\frac{1}{T}\right)/t \quad (1)$$

The absorption spectrum and transmittance graphs are as shown in Figure 5 and Figure 6.

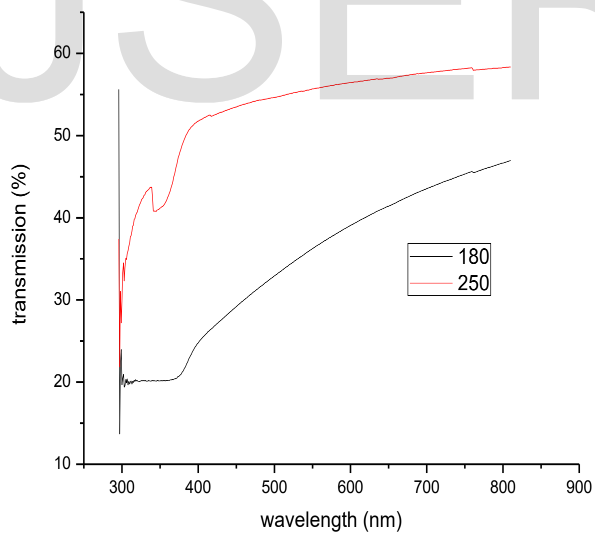

Figure 5 Transmission spectrum of a: ZnO samples

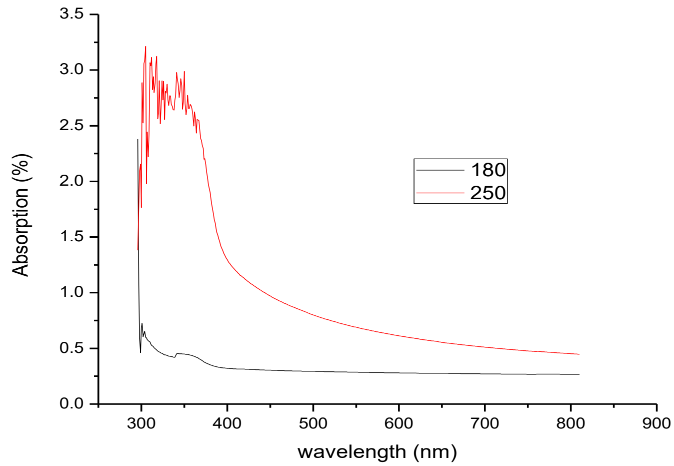

Figure 6 Absorption spectrum of a: ZnO samples

The energy gap was determined by using the absorption coefficient values.

Figure *7* and Figure 8 shows the plot of $(\alpha h\nu)^2$ versus hν, where α is the optical absorption coefficient and hν is the incident photon energy. The optical band gap is found to decrease from 3.04 to 2.87 eV as the temperature of deposition is affecting the morphology of the film formed.

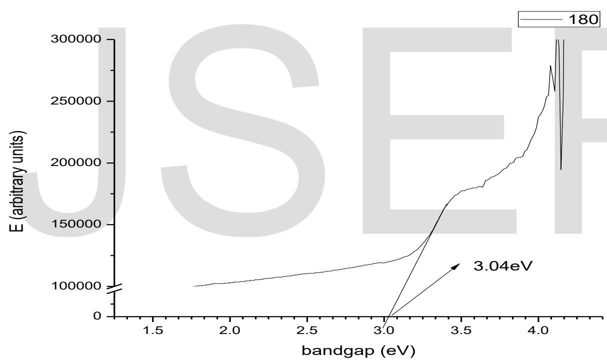

Figure 7 Tauc plot of a: ZnO sample A.

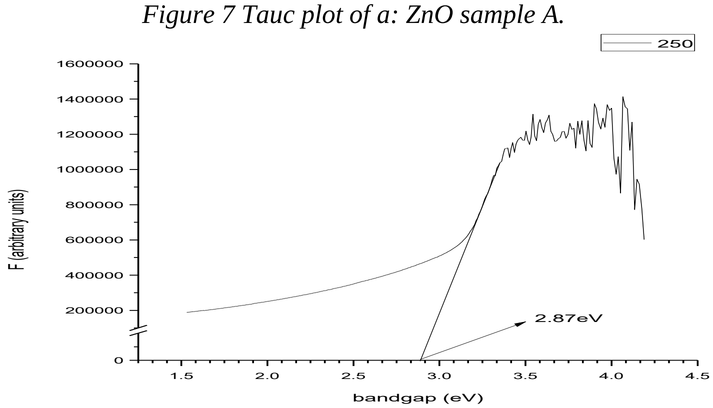

Figure 8 Tauc plot of a: ZnO sample B.

The excitation coefficients of the samples A and B are calculated using the formula 2.

$$K=\alpha \lambda / 4 \pi \qquad (2)$$

Where α is the absorption coefficient and λ is the wavelength. Figure 9 suggests that thin film deposited at 250 is better suited for an electronic application.

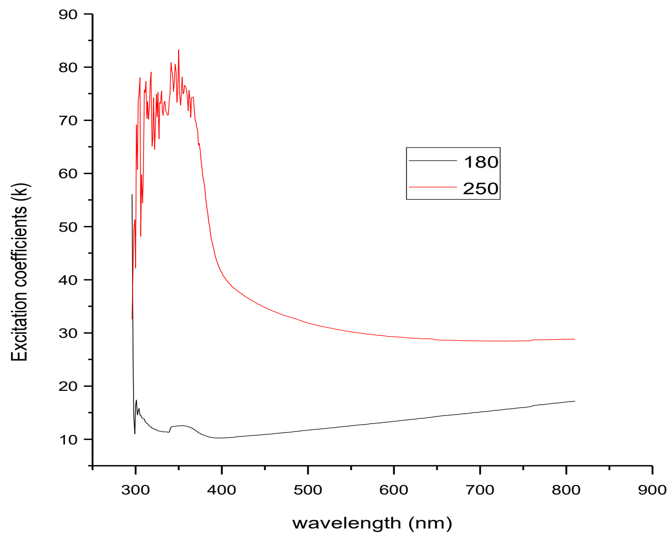

Figure 9 Excitation coefficients of the samples A and B

Conclusion

The present work reports the successful preparation and the characterization of transparent amorphous Zinc oxide thin films on the glass substrate at 180℃ and 250℃ using spray pyrolysis technique. The result of XRD clearly reveals that both films are amorphous nature. The SEM images conclude that a further increase in temperature leads to the formation of crystalline material. The increase in the deposition temperature the transparency of the film also increases from 35% to 55%. The films deposited at higher temperature exhibit good optical properties with transmittance (about 55%), low absorbance and reflectance in the visible region. The data extracted from optical spectroscopy were used to determine various optical constants such as extinction coefficient and energy Bandgap. The deposition temperature also influences the bandgap value. The bandgap value increase from 2.87eV to 3.04eV with the decrease in temperature. The film with higher excitation coefficient is more suitable for electronic device manufacturing. The characterization studies confirm ZnO thin films deposited at 250℃ is best suited for fabrication of TFT devices.

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