

Structural, morphological and optical properties of Al/SnO₂/p-Si (MIS) Schottky diodes

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An absorption-wavelength ($\alpha\lambda$) and basis absorption spectrum $[(\alpha h\nu)^2 - h\nu]$ of Al / SnO₂ / p-Si (MIS) Schottky Diodes prepared by means of spray Pyrolysis technique have been investigated at constant temperature, 300 K. From the obtained results barrier height and ideality factor have calculated. Optical properties which are absorptions, transmittance and band-gap of these diodes were also investigated. To understand the surface morphologies of them, X-Ray spectroscopy and diffraction techniques have been used. The experimental results showed that in this type of diodes the crystal size was found to be a few angstroms in size. Also the preferred directions of these crystals are in the [110] crystallographic directions. These findings indicated that the Schottky diodes can be used in the photovoltaic solar cell applications.

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1. Introduction

SnO₂ films may be find application in areas such as sensors, solar sells, thin-film transistors and so on. Many techniques have been used to prepare SnO₂ films such as spray pyrolysis [1], spin coating [2], electron beam [3], sputtering [4], chemical vapour deposition [5], sol-gel [6] and vacuum evaporation [7]. We have used spray pyrolysis technique to prepare films due to simplicity and commercial viability Because of technical importance of metal-insulator-semiconductor (MIS) Schottky diodes is very useful tool in studying electrical and optical properties of semiconductors. Though MIS Schottky Diodes have been studied extensively, understanding all details has still not been achieved. In this study, Structural, morphological and optical properties of Al / SnO₂ / p-Si (MIS) Schottky Diodes by Spray Pyrolysis is investigated..

2. Experimental

The SnO₂ films were grown on Si (2.5 cm × 1 cm), using spray pyrolysis technique. The SnO₂ was obtained from a solution containing tin chloride (0.1 M) dissolved in a mixture of deionised water [8]. The substrate temperature was maintained at a constant temperature of 350 °C. The variation of the substrates temperature during spray was controlled within ± 5 °C with the help of temperature controller. 180 cm³ solutions were sprayed onto the Si substrates during 30 min.

Structural analysis of the films was carried out using Philips X-Ray diffraction equipment model PW-3710 and Cu K_α radiation ($\lambda = 1.5406 \text{ \AA}$) at 40 kV and 30 mA [9]. The surface properties of the SnO₂ film were investigated using scanning electron microscope (SEM).

3. Results and discussion

The structural properties of SnO₂ film were investigated using X-Ray diffraction (XRD) patterns. SnO₂ films have a polycrystalline structure of a tetragonal form, with a (110) preferred orientation and other orientations are given in Table 1.

Table 1. The Bragg angle, preferred orientation and crystal system for the tested films.

2θ	$d(\text{\AA})$	(hkl)	Crystal System
26.58	3.35	(110)	Tetragonal SnO ₂
33.88	2.64	(101)	Tetragonal SnO ₂
51.78	1.76	(211)	Tetragonal SnO ₂

The half-peak widths, dislocation density (δ) diameters for the preferential orientations of SnO₂ films were calculated. The rough grain diameter (D) is calculated by the simple Scherrer equation (1),

$$D = \frac{0.9 \lambda}{\beta \cos \theta} \quad (1)$$

where β is the half-peak width, D is the grain diameter as \AA , θ is the Bragg angle and λ is the wavelength of light used [10,11]. n is a constant which has been taken 1. The dislocation density (δ) is also calculated after (2) and these values are given Table 2.

$$\delta = \frac{n}{D^2} \quad (2)$$

Table 2. The half-peak width, grain diameter, Bragg angle and dislocation density for the SnO₂ film.

Material	2θ(°)	d(Å)	β×10 ⁻³ (rad)	D(Å)	δ×10 ⁻⁶ (line/nm ²)
SnO ₂	26.58	3.34	2.36	603	2.75

The surface morphologies of the SnO₂ film were investigated by the scanning electron microscopy (SEM). The SEM Photographs of the samples are shown in Fig. 1.

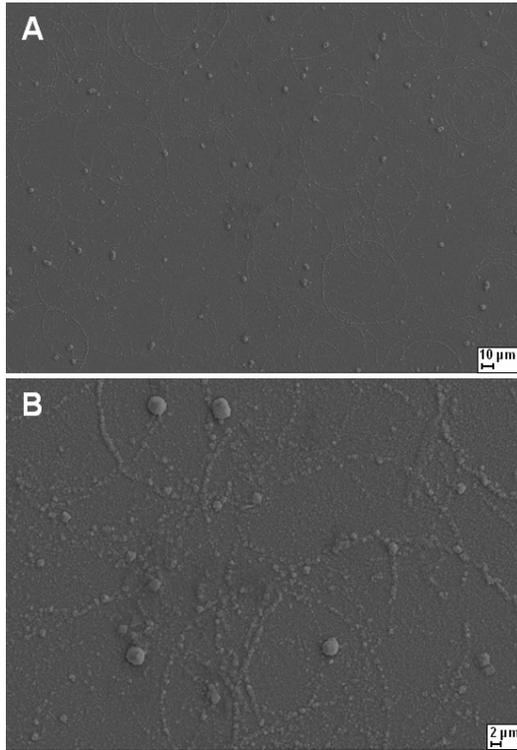


Fig. 1. The Scanning Electron Microscope (SEM) photographs of the SnO₂ films

It is observed that the surface morphologies of SnO₂ films were likely homogeneous, but they have some white regions. The undesired formation may probably take place during deposition itself [12].

The optical band-gap and Urbach parameter were found to be $E_g=2.72$ eV, $E_0=0.98$ eV respectively with extrapolation of data in Fig. 2. Fig. 3 shows the $\ln\alpha$ versus $h\nu$ variations for the film. The Urbach parameter value was also calculated from the slopes of the linear relationship $\ln\alpha$ against $h\nu$, using (3) [9,13].

$$E_0 = \left[\frac{d(\ln \alpha)}{d(h\nu)} \right]^{-1} = \frac{1}{tg \alpha} \quad (3)$$

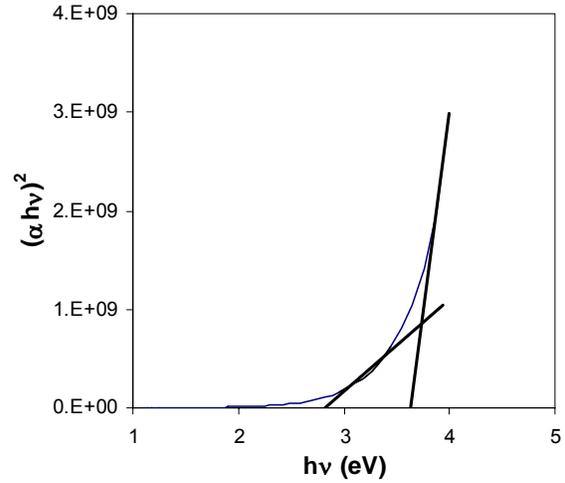


Fig. 2. The basis absorption spectrum of the films.

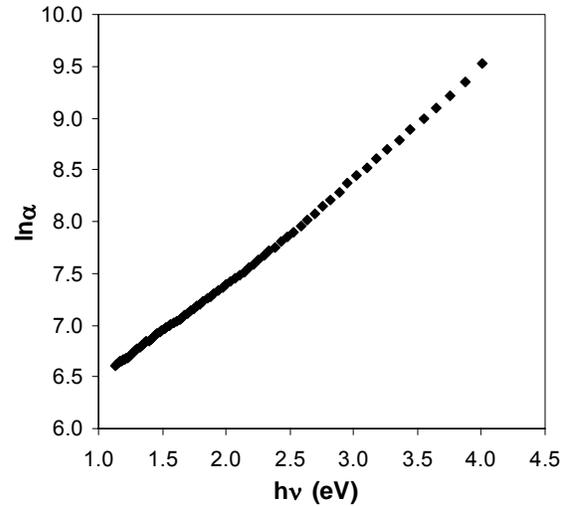


Fig. 3. The variation of $\ln\alpha$ as a function of $h\nu$.

An optical transmission and reflection spectra for the SnO₂ films are shown in Fig. 4. The optical transmission and optical reflection values were obtained from Fig. 4. The films have normally high transmission (%70-90) and low reflection (%10-30) in visible region. Since the SnO₂ films have high thickness and smooth surface, these values are obtained different from expected values and they are %30 and %34.49, respectively. The SnO₂ films used in this study have a low transmission and a high reflection in visible region.

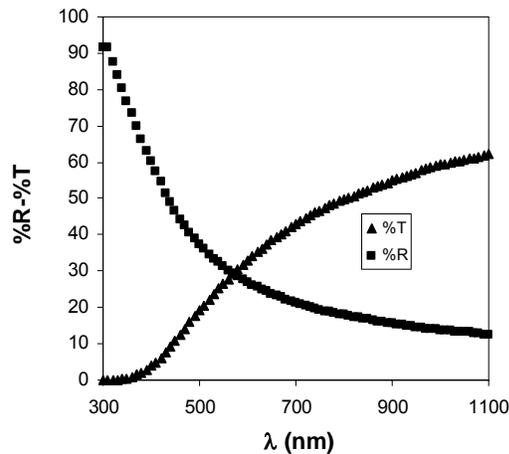


Fig. 4. The transmission and reflection spectra for the films.

An absorption-wavelength (α - λ) and a refractiveness-wavelength (n - λ) spectra for the films are shown in Fig. 5. It is shown that these films have also high refractiveness and low absorption in visible region.

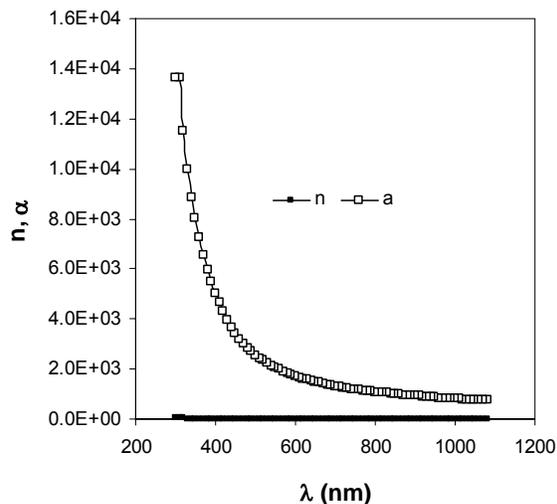


Fig. 5. The variation of (α - λ) and (n - λ) spectra with wavelength for the films.

4. Conclusions

The SnO₂ film was prepared on Si substrates by the spray pyrolysis technique and structural, optical and morphological properties of the SnO₂ film were investigated. The Al/SnO₂/p-Si (MIS) Schottky diode ideality factor and barrier height was also calculated from the semilog-forward bias I-V characteristics at 300 K. The

values of ideality factor n indicated that the current transport mechanism of the Schottky diode is the tunneling. The XRD patterns showed the SnO₂ film is the polycrystal form. The optical band-gap and the Urbach parameter were also calculated. The optical transmission, reflection, absorption and refractiveness spectrums were obtained. It is found to be the SnO₂ films have electrical and optical properties such as high optical transmittance, low optical reflection and wide band-gap, they are suitable materials for the photovoltaic solar cell applications.

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References

- [1] T. Y. Ma, S. C. Lee, J. Mater. Sci. Mater. Electron. **11**, 305 (2000).
- [2] R. S. Niranjana, I. S. Mulla, Mater. Sci. Eng. B, Solid-State Mater. Adv. Technol. **103** (2003).
- [3] Y. Mo, Y. Okawa, T. Nakai, M. Tajima, K. Natukawa, Thin Solid Films **416**, 248 (2002).
- [4] J. L. Brousseau, H. Bourque, A. Tessier, R. M. Leblanc, Appl. Surf. Sci. **108**, 351 (1997).
- [5] P. Rajaram, Y. C. Goswami, S. Rajagopalan, V. K. Gupta, Mater. Lett. **54**, 158 (2002).
- [6] J. P. Chatelon, C. Terrier, J. A. Roger, Semicond. Sci. Technol. **14**, 642 (1999).
- [7] M. Mizuhashi, J. Non-Cryst. Solids **38**, 329 (1980).
- [8] O. Vigil, F. Cruz, A. Morales-Acevedo, G. Conteras-Puente, L. Vaillant, G. Santana, Structural and Optical Properties of Annealed CdO Thin Films Prepared by Spray Pyrolysis, Mater. Chemistry and Physics **68**, 249-252 (2001).
- [9] V. Bilgin, S. Kose, F. Atay, I. Akyuz, Mater. Chemistry and Physics **94**, 103-108 (2005).
- [10] A. G. Valyomona, K. P. Vijayakumar, C. Puruhothaman, J. Mater. Sci. Lett. **9**, 1025 (1990).
- [11] J. Kester, Golden Photon, Photovoltaic Insider Report **XV**(12), December 1996.
- [12] F. Atay, S. Kose, V. Bilgin, I. Akyuz, Mater. Lett. **57**, 3461-3472 (2003).
- [13] J. I. Pankove, Solid State Physical Electronics Series, Prentice-Hall, NJ, 1971, p. 422.

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