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Optical Parameters of Nano metric SnO_2 Thin Films Deposited via Sol-Gel Spin Coating Technique

Soumya S S[1]
[1] *Assistant professor, Department of Physics, University College, Thiruvananthapuram, Kerala, India.*
soumyadevanss@gmail.com[1]

Abstract

Thin films of tin oxides were successfully synthesized by using Tin(II)chloride dihydrate and ethanol as precursors. This paper discuss about the optical parameters of the thin films of tin oxide post annealed at 200^0C. UV- Vis spectroscopy study reveals that the prepared tin oxide thin film shows high transparency (87.5%) and low absorbance and low reflectance in the region of visible spectrum. The band gap of the tin oxide thin film was obtained as 3.59 eV. The average value of refractive index of the thin films of tin oxide was 1.909. The real and imaginary values of dielectric constants were 7.1 ans 0.33 respectively.

Keywords: Tin oxide thin films, Sol-gel spin coating, Optical parameters.

1. Introduction

In recent years the studies and applications of thin film technology is entirely entered in to almost all the branches of science and technology[1]. Tin oxide thin films were the mostly investigated materials in literature as having wide optical band gap energy (~3.7 eV) [2] and it is an n-type transparent conducting oxide with high transparency and electrical conductivity. Tin oxide films are widely used as transparent electrodes on glass substrates and as anti reflecting coating materials on solar cells owing to their high electrical conductivity with low absorption in the region of the visible spectrum[3]. It is a potential candidate for gas sensing materials such as carbon monoxide, carbon dioxide and oxygen for better environment[4]. SnO_2 has the tetragonal rutile structure and it belongs to the P42/mnm space group. Tin oxide crystallizes with tetragonal rutile structure with lattice parameters are a = b = 4.7382 Å and c = 3.1871 Å [5]. Tin oxide thin film has so many applications in the field of ceramic glazers, dye sensitizing, photo catalysis, solar cells and in optoelectronics.

Several methods were available for the synthesis of the thin films of tin oxide material. They are Spray pyrolysis [6], Spin coating method[7], Sol-gel dip coating technique[8], Pulsed laser deposition[9], Polyol method[10], etc. From all the above methods, sol-gel spin coating is used in this paper for the preparation of tin oxide thin films. Because this method is very economical and the control of sample preparation parameters is very easy. Sibel Gurakar etal studied about how the Cobalt doping concentration affect the optical parameters of the thin films of tin oxides deposited by spray pyrolysis technique[2]. Manreet Kaur etal studied about the thermistor applications of tin oxide thin films prepared by electron beam evaporation technique[11] and Bhavana etal discuss about the optical, electrical and structural properties of tin oxide thin films deposited by electrostatic spray deposition technique[12]. In this work I discuss about the optical parameters of thin films of tin oxide deposited via sol-gel spin coating technique and post annealed at 200^0C.

2. Experimental

The materials used for producing tin oxide thin films were absolute Ethanol and Tin(II)chloride

dihydrate, $SnCl_2.2H_2O$ (Merck). 1.128 g of $SnCl_2.2H_2O$ and 10 ml of ethanol was mixed with the help of a magnetic stirrer for 1 h at 50 ^{0}C to get a homogenious mixture of the solution of the precursors. This homogenous mixture was put in a closed container for gelation under room temperature for about 24 hs. The glass plates were cleaned using soap solution, acetone, distilled water and isopropyl alcohol. Then the gelated mixture was coated on the cleaned glass substrates using a spin coating machine (SpinNXG-P1A). The machine was allowed to spin for 30 s with a speed of 1600 rpm to get the uniformly coated thin films of tin oxide. This coated tin oxide thin films were kept on a hot oven at 100^0 C for 20 minutes for evaporation of the volatile solvents. Then the deposited tin oxide thin films were heated at 200 ^{0}C in a muffle furnace for 1 h to improve crystallization. The optical study of the film was done by using UV – Vis Double beam spectrophotometer (JASCO V-730).

3. Results and Discussions

The room temperature optical properties of the tin oxide thin films deposited by sol-gel spin coating technique and post annealed at 200^0 C was studied using UV-Vis spectroscopy from 300 nm – 900 nm. The variation of the transmittance and absorbance with wavelength of the tin oxide thin films post annealed at 200^0 C was shown in Fig.1 and Fig.2. The transmittance spectra show that the maximum transmittance was 87.5% around 700nm and the average transmittance of the films were greater than 80%. This shows that tin oxide thin films shows high transmittance. The absorbance spectra show that the tin oxide thin films show lowest absorbance in the UV-Visible region.

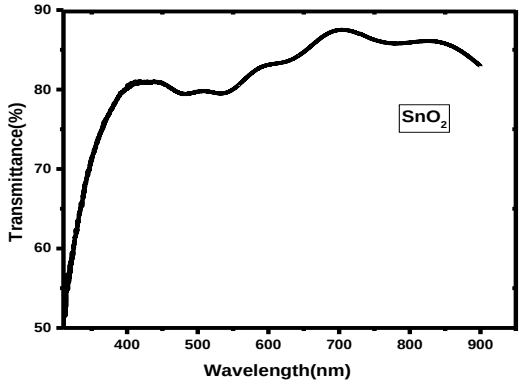

Fig.1. Transmittance spectra of tin oxide thin films post annealed at 200 ^{0}C

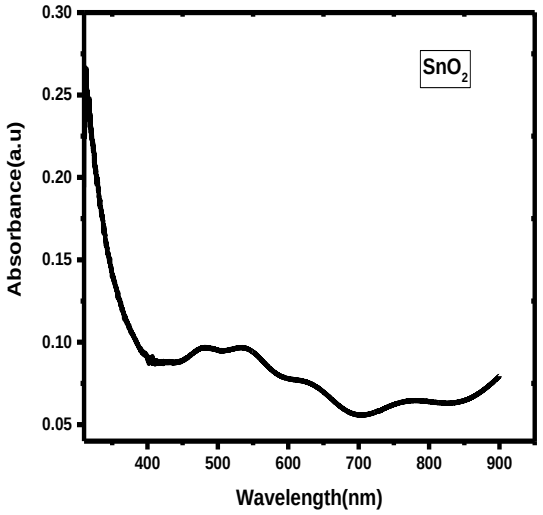

Fig.2. Absorbance spectra of tin oxide thin films post annealed at 200 ^{0}C

The optical band gap, E_g of the thin films were obtained from Tauc plot using the equation[13]

$$(\alpha h\nu) = A(h\nu - E_g)^n \quad (1)$$

Where 'α' represents the coefficient of absorption, 'h' represents the Planck's constant, ν is the transition frequency, A is a constant, E_g is the optical band gap for a particular transition of the tin oxide thin film and n gives transition type. n=1/2 corresponds to direct allowed transition, n=2 corresponds to indirect allowed transition, n=3/2 corresponds to direct forbidden transition and n=3 corresponds to indirect forbidden transition. The fundamental absorption occurring in the materials that corresponds to the excitations of electrons from the valence band to the conduction band is used to determined the value of direct optical band gap calculated from Tauc plot[14]. The absorption coefficient α can be calculated using the relation

$$\alpha = 2.303A/t \quad (2)$$

Where t represents the thickness of the prepared tin oxide thin films post sintered at 200 ^{0}C. Dektak Stylus Profilometer is used to measure the thickness of the thin films of tin oxide and is obtained as 223 nm. The direct optical band gap of the tin oxide thin films were calculated from the Tauc plot of $(\alpha h\nu)^2$ with hν. The linear portion of

the graph is extrapolated to X – axis at α = 0, the obtained band gap value is 3.59 eV and is shown in Fig.3. This value is in comparable with the results obtained by S.Majumder[15], R.Mani etal[16] and E. Elangovan etal[17].

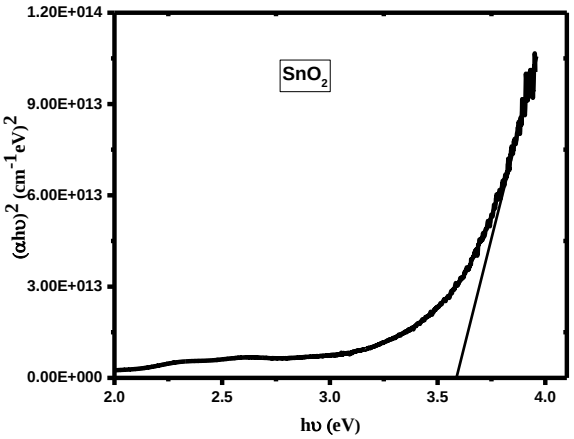

Fig.3. Direct optical band gap of tin oxide thin films post annealed at 200 ^{0}C

The optical conductivity of the tin oxide thin films was found out using the expression[18]

$$\sigma = \alpha nc/4\pi \quad (6)$$

Where n represents the refractive index of tin oxide material and c is the velocity of light. The calculated values of optical conductivity were plotted against photon energy and were shown in the Fig.4. The optical conductivity of the tin oxide thin films increases around 3.5eV due to the increase in the value of absorbance of the SnO2 thin films reported by N.B.Ibrahim etat[18]. The optical conductivity of as prepared tin oxide thin films increases sharply at 3.51eV in this work.

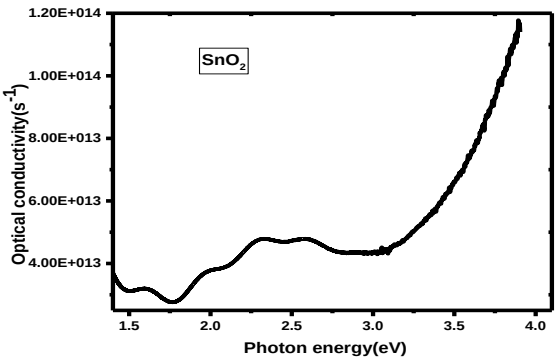

Fig.4. Optical conductivity versus photon energy of tin oxide thin films post annealed at 200 ^{0}C

Reflectance, R of the thin film was calculated using the expression[13]

$$R = 1 - (A+T) \quad (3)$$

Where R is the reflectance, A is the absorbance and T is the transmittance.
The refractive index of tin oxide thin film was obtained using expression[13,19]

$$n = (1 + \sqrt{R})/(1 - \sqrt{R}) \quad (4)$$

Extinction co-efficient is obtained using equation [13,20]

$$k = \alpha\lambda/4\pi \quad (5)$$

Where α corresponds to the absorbance of the tin oxide thin films and λ is the wavelength used for the UV-Visible spectra recording. The change in reflectance of the tin oxide thin film post annealed at 200^0 C with wavelength was shown in Fig.5. This shows that the reflectance was high at lower wavelength region and it was lower in the higher wavelength region. High transmittance and low absorbance and low reflectance makes the tin oxide thin films good for used as transparent coating materials in the solar cells, used in the display of the electronic gadgets and touch screens[21].

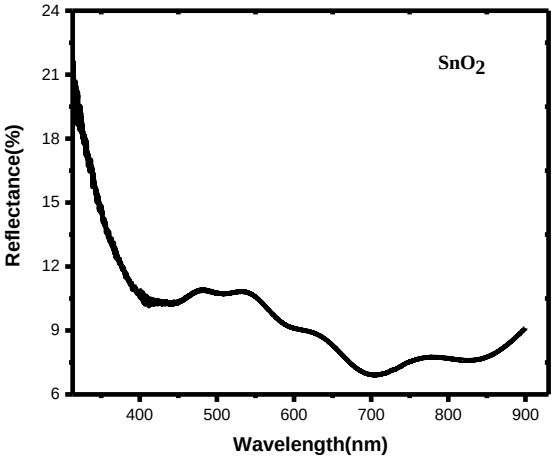

Fig.5. Variation of Refractive index with wavelength plot of tin oxide thin films post annealed at 200^0 C.

The plot of refractive index versus wavelength of the thin films of tin oxide post annealed at 200^{0}C was shown in Fig.6. The maximum value of

refractive index was 2.65 and is obtained in the UV region of wavelength around 300 nm. Then the refractive index value decreases and shows the minimum value of 1.7 at 700 nm. These values are comparable with the previously reported values[20,21]. The average value of refractive index was 1.909. High refractive index and low value reflectance of tin oxide thin films was good for used as the anti - reflection coating material. The extinction co – efficient was plotted against wavelength was shown in Fig.6. The k value of the tin oxide thin films shows high value at lower and higher wavelength regions. In the visible region of the spectrum it shows low value.

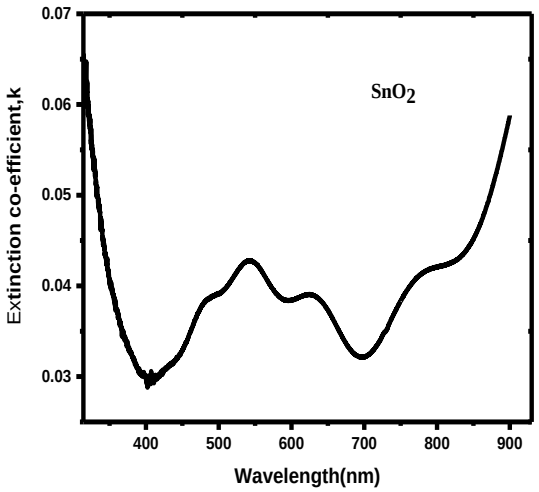

Fig.6. The change in extinction co – efficient with wavelength of the tin oxide thin films post annealed at 200^0 C.

The fundamental spectrum of electron excitation of the tin oxide thin films was explained by means of a complex dielectric constant[20]. The real and imaginary values of dielectric constants are varied according to the refractive index and extinction co – efficient. The real part of dielectric constant is originated due to the presence of free carrier electric susceptibility[19]. The real (ε_1) and imaginary (ε_2) values of dielectric constants were obtained using the expressions[19,20]

$$\varepsilon_1 = n^2 - k^2 \quad (7)$$

$$\varepsilon_2 = 2nk \quad (8)$$

Dielectric constants depend on wavelength. The variation of dielectric constant values with wavelength were shown in Fig.7. The real value of dielectric constant was greater than the imaginary value of dielectric constant. The highest value of real dielectric constant was 7.1 and the imaginary part was 0.33. These values are in agreement with the previously obtained values[22].

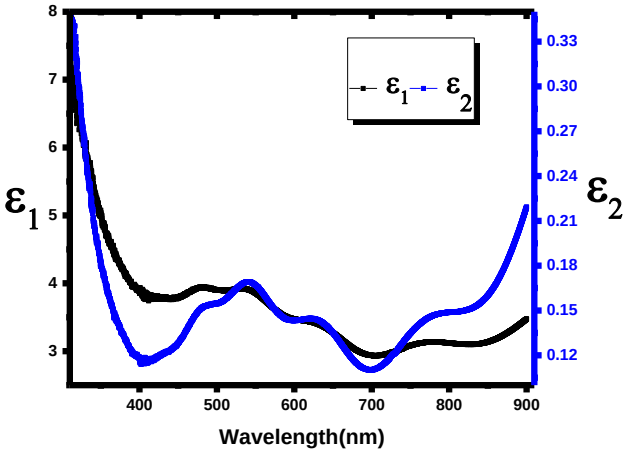

Fig.7. Variation of real and imaginary values of dielectric constants with wavelength of the tin oxide thin films post annealed at 200^0 C.

Conclusions

Tin oxide thin films were successfully prepared by sol-gel spin-coating technique and post annealed at 200 ^{0}C. These films show high transparency and low reflectance and absorbance. The optical band gap of the film was 3.59 eV. The optical conductivity of the films increases sharply at 3.51 eV. The average refractive index of the material was 1.909. The highest values of real and imaginary parts of dielectric constants were 7.1 and 0.33. Due to these properties tin oxide thin films are the promising candidates for used in solar cells and optoelectronic applications.

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