

# Electrical Characterization of Tin Oxide Thin Films Prepared by Dip Coating Technique

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**ABSTRACT:** The influence of bath temperature on tin oxide Nano layers on the surface of glass substrate by sol-gel dip coating method was investigated. The bath temperature was varied from 313 K to 373 K in steps of 20 K. The deposited films were annealed at 673 K. These films were characterized by dc conductivity measurements. The dc electrical conductivity was measured in the temperature range of 303-403 K and was found to increase with temperature. The results indicated that the material could be used for solar and laser applications.

**KEYWORDS:** tin oxide thin films, dc conductivity, solar and laser applications.

## I. INTRODUCTION

Transparent conducting tin oxide (SnO<sub>2</sub>) semiconductors are widely used as transparent films in electronic devices such as thin film solar cells, display devices, electro-chromic display, defogging aircraft and automobile windows, gas sensors, light emitting diodes, flat-panel display and other optoelectronic devices, etc., [1-3]. Tin oxide has been prepared as a promising alternative anode material for micro batteries. Recently, many researchers have reported the preparation and properties of SnO<sub>2</sub> films such as chemical precipitation method [4], spray pyrolysis [5], sol-gel dip coating [6], plasma oxidation [7], etc.

Even though several methods have been employed to form a transparent SnO<sub>2</sub> thin film, to the best of the knowledge of the authors, this is the first attempt to prepare SnO<sub>2</sub> thin films annealed at low temperature. Based on these aspects, the authors have presented the work on the growth of SnO<sub>2</sub> films by a cost effective dip technique which becomes very important for their practical applications.

## II. EXPERIMENTAL PROCEDURE

The coating solution used for the experiment was prepared from anhydrous SnCl<sub>4</sub> by process. Pure SnO<sub>2</sub> sols were prepared from SnCl<sub>4</sub>, distilled water, n-propanol (C<sub>3</sub>H<sub>7</sub>OH) and isopropanol (2-C<sub>3</sub>H<sub>7</sub>OH) at a molar ratio SnCl<sub>4</sub>:H<sub>2</sub>O: C<sub>3</sub>H<sub>7</sub>OH:2-C<sub>3</sub>H<sub>7</sub>OH = 1:9:9:6. At first, the SnCl<sub>4</sub> was dropped into two-thirds of the total amount of propanol. One-third of the total distilled water dissolved in the remaining n-propanol (C<sub>3</sub>H<sub>7</sub>OH) was added for prehydrolysis of the tin precursor. It was stirred for 1 hr and after that the previously prepared sol was mixed with the solution of the remaining amount of H<sub>2</sub>O dissolved in the prescribed amount of isopropanol (2-C<sub>3</sub>H<sub>7</sub>OH). It was again stirred for 1 hr. With this procedure, clear and homogeneous sols were prepared. The bath temperature varied from 313 to 373 K in steps of 20 K. The prepared films were annealed at 673 K.

## III. RESULTS AND DISCUSSION

The electrical resistivity of the films was measured using a four probe setup in the temperature range of 303-403 K as shown in Fig 1. The electrical measurement was performed by making four electrical contacts with sample surface. Two of the probes were used to measure the current and the other two probes were used to measure the corresponding voltage.

The electrical conductivity of the samples was calculated from the following equation,

$$\rho = \frac{\pi}{\ln(2)} \times \frac{V}{I} \times t \quad \text{----- (1)}$$

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Where (I) is the current, (V) is the voltage and (t) is the thickness of the sample. In order to investigate the rectifying behaviour of the samples at different temperatures, four probe setup was connected to the Keithley 6517B electrometer by applying voltage of 1 to 10 V in steps of 1V. After the application of each volt increment, current was automatically measured with a delay time of 2 sec. I-V data at each selected temperature was transferred to the computer and stored for further analysis. The current through the sample as function of applied voltage was measured in the temperature range of 303-403 K. I-V measurements for each sample were carried out by reversing the polarity of the contacts several times.

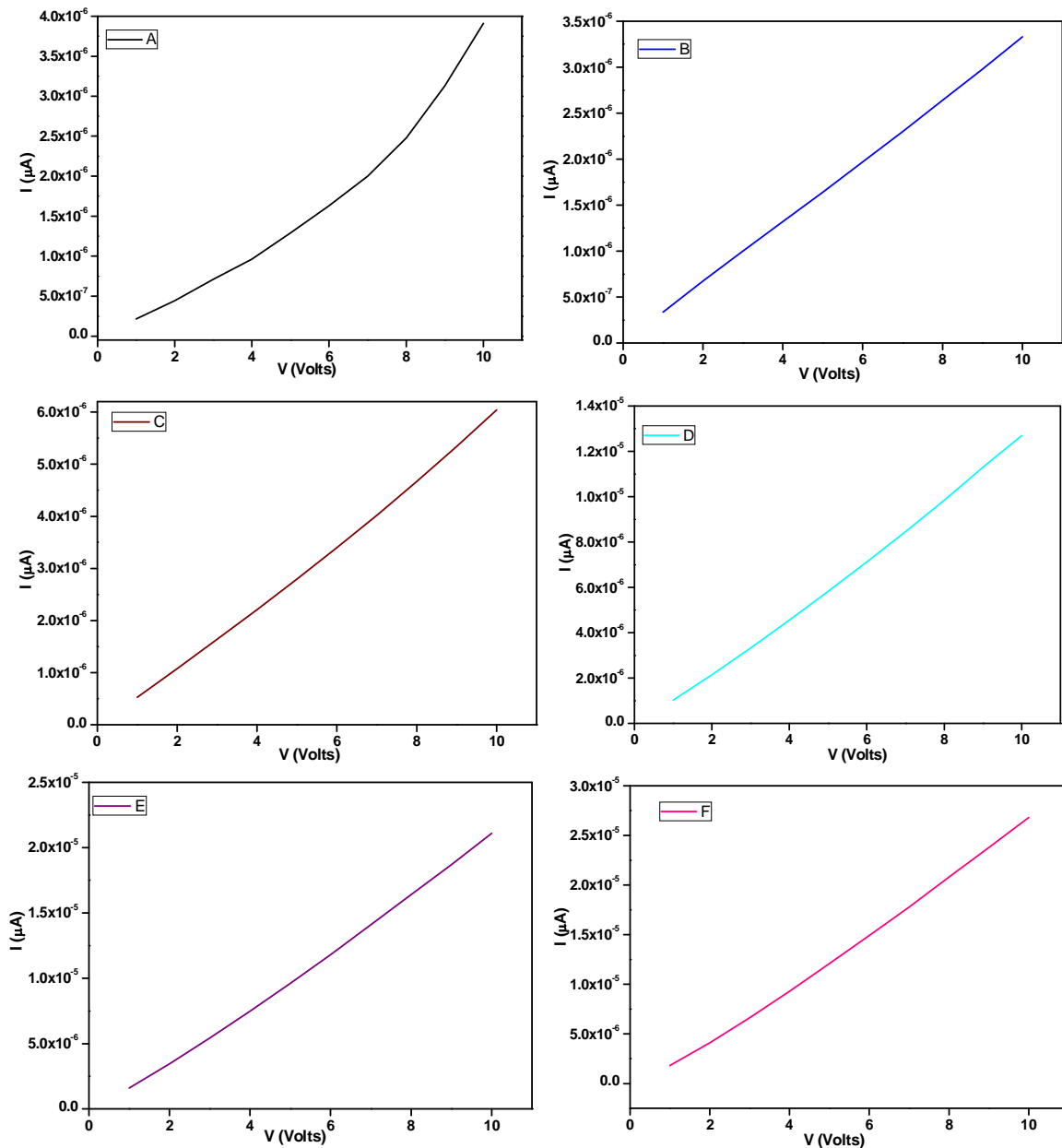


Fig.1 (a-f) I-V characteristics of tin oxide thin film at different bath temperatures

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I-V characteristics of SnO<sub>2</sub> thin films prepared at different bath temperature of 313-373K were annealed at temperature 673 K as shown in fig. 1 (a-f) 313-373 K. The curves are found to be linear, indicating ohmic conduction due to the thermally generated carriers [8].

In the ohmic region, the electrical conduction is governed only by the resistance of the films and controlled by thermally activated carriers. This power continues until the injected free carrier density becomes comparable with thermally created carrier density and at sufficiently higher fields the conduction current is mainly due to the injected space charge [9].

It is observed that for the same applied field, the current increases with increasing temperature in ohmic region for all samples. As the temperature increases, the probability of thermal ionization of the trapping centres increases too. Hence a shift in the quasi Fermi level occurs and this causes the lowering of the barrier across which the electrons are transported and the conduction becomes nearly ohmic [10].

The temperature dependence of DC conductivity ( $\sigma_{dc}$ ) for SnO<sub>2</sub> thin films prepared at different bath temperatures (313-373 K) were annealed temperature 400°C as shown in fig 2. In all cases conductivity increased with the increase in temperature for the entire range of 303 to 403 K. This is the characteristic of semiconducting behaviour.

$$\rho = \rho_o \exp(E_a / KT) \quad \text{----- (2)}$$

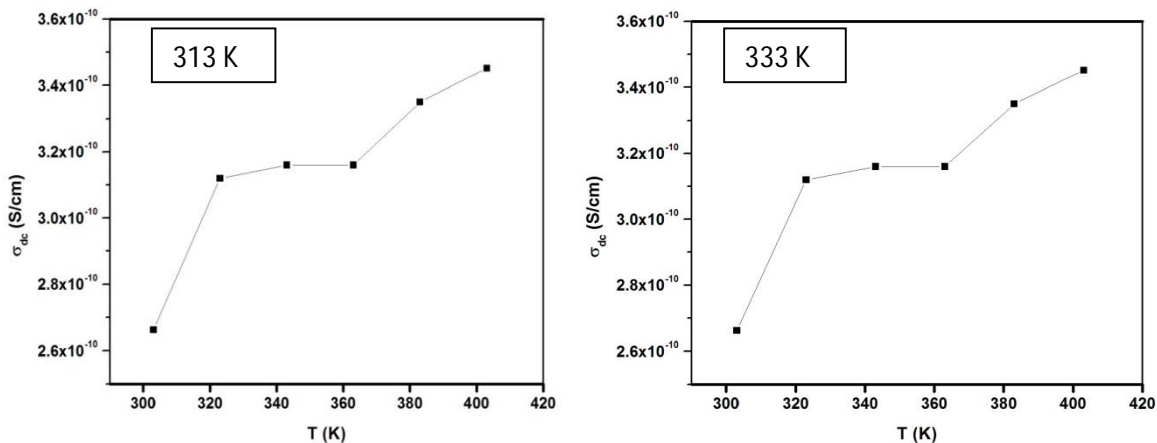


Fig 2 Temperature Vs Conductivity of tin oxide thin films at different bath temperatures

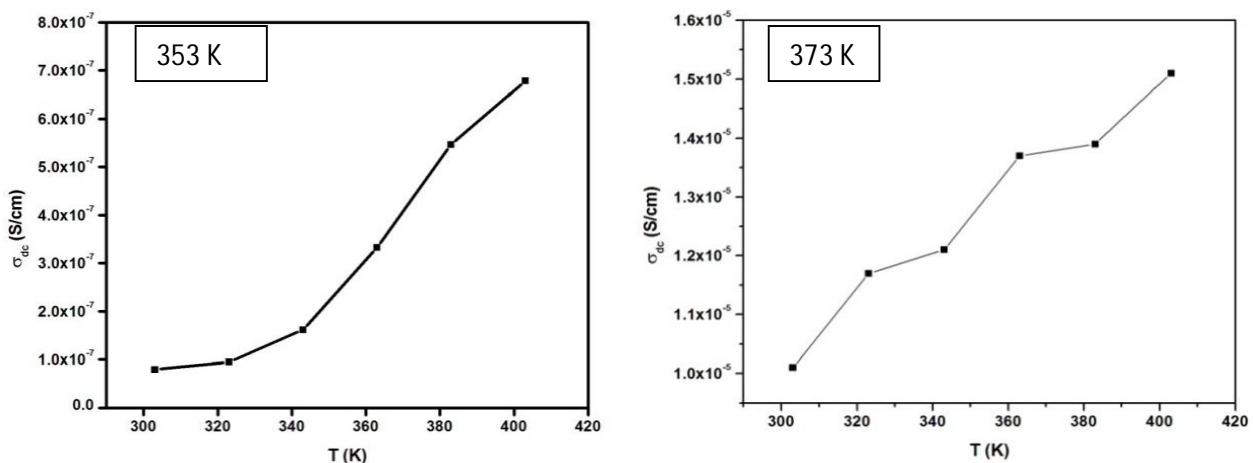


Fig3 Temperature Vs Conductivity of tin oxide thin films at different bath temperatures

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The activation energy ( $E_a$ ) determined, at different constant applied voltages using the relation  $\rho = \rho_0 \exp(-E_a/KT)$ , by plotting  $\ln \sigma$  against  $1000/T$  (fig 3). Jonscher and Anasari suggested that  $\nabla E$  values less than 0.8 eV would indicate that the dominant charge transport is through the motion of electrons, as where  $\nabla E$  values higher than 0.8 eV reflect that the dominant charge transport is ionic. Therefore the values of  $\nabla E$  for all samples indicate that the electronic conduction is dominated in these samples, which provides support to the proposed analysis [11-12].

The activation energies for the charge transport mechanics were calculated using the initial rise method of Perlman [13] by isolating the individual peak from the composite curves. The slopes of  $\log 1$  Vs  $1/T$  plots from the initial rising portion of the individual peaks were used to calculate the activation energies as shown in fig 3.

The DC conductivity of SnO<sub>2</sub> thin film prepared at bath temperature (313 K) was  $0.2327 \times 10^{-3}$  S/cm. As the bath temperature increased the conductivity was found to change from  $0.2327 \times 10^{-3}$  s/cm. After the bath temperature increase, the conductivity was found to change from  $0.2327 \times 10^{-3}$  –  $0.56737 \times 10^{-3}$  S/cm. The conductivity of the SnO<sub>2</sub> thin films increases slowly by a few orders of magnitude with the increase of bath temperature. The slight increase in the conductivity of SnO<sub>2</sub> thin films with the increase of bath temperature may be not only due to the mobility of the charge carriers at the Fermi level, but also due to the presence of high amount of conducting species in all the samples [14-16].

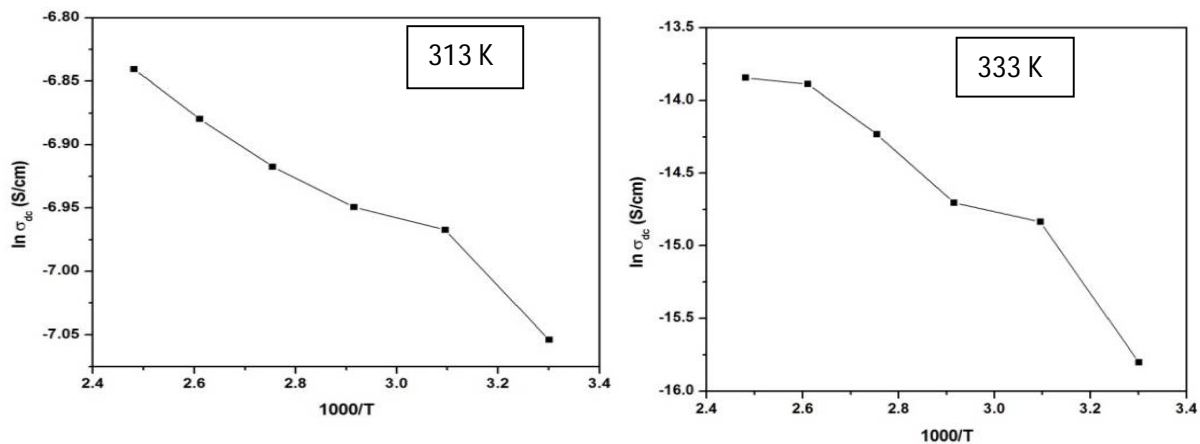


Fig 3 1000/T Vs  $\ln \sigma$  of tin oxide thin films at different bath temperatures

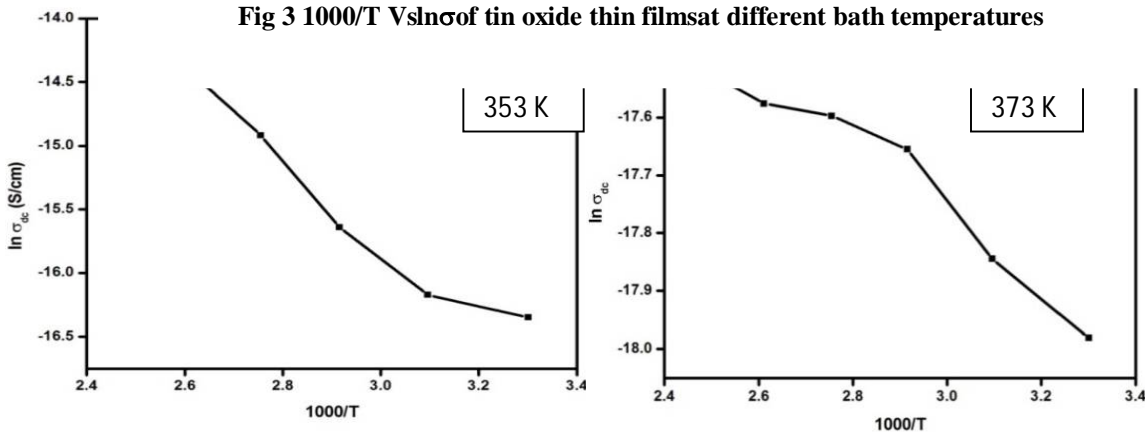


Fig3 1000/T Vs  $\ln \sigma$  of tin oxide thin films at different bath temperatures

The activation energy values for tin oxide thin films can be calculated from the slope of the Arrhenius plot over the entire temperature range (313-373 K). The calculated activation energy was found to be 0.875-0.116 eV. It is clear from the table that, as film temperature of the sample increased, conductivity also increased. The decrease in activation energy with temperature was shown in Table 1.

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**Table:1 DC Conductivity, Activation Energy and different bath temperature of tin oxide thin films**

Bath Temperature (K)	Conductivity $\sigma \times 10^{-3} \Omega\text{-cm}^{-1}$	Activation energy, $E_g(\text{eV})$
313	$0.2327 \times 10^{-3}$	0.800
333	$0.2390 \times 10^{-3}$	0.622
353	$0.2902 \times 10^{-3}$	0.161
373	$0.5673 \times 10^{-3}$	0.116

### IV. CONCLUSION

The tin oxide ( $\text{SnO}_2$ ) thin films were prepared by sol-gel at different bath temperatures annealed at 673 K. The linear I-V characteristics may be due to semiconducting nature of the films. The curves were found to be linear, indicating ohmic conduction due to the presence of thermally generated carriers. The estimated electrical conductivity of  $\text{SnO}_2$  films was found to be in the range of  $0.2327 \times 10^{-3} (\Omega\text{-cm})$  at lower temperature (313K) and  $0.5673 \times 10^{-3} \Omega\text{-cm}$  at higher temperature (373K). It is also observed that the conductivity of  $\text{SnO}_2$  thin films increased with increasing bath temperature. It is not only due to the mobility of the charge carriers at the Fermi level, but also due to the presence of high amount of conductivity species in the material. It is observed from electrical conductivity measurements that, the sample with highest conductivity possess the lowest activation energy and the value is found to be in the semiconducting range.

### REFERENCES

- [1] S. B. Deshmukh , R. H. Bari , G. E. Patil , D. D. Kajale , G. H. Jain , L. A. Patil "Preparation and characterization of zirconia based thick film resistor as an ammonia gassensor", International journal on smart sensing and intelligent systems, Vol. 5, no. 3, 2012pp.540–558.
- [2] S. Chappel, A. Zaban, "Nano porous  $\text{SnO}_2$  electrodes for dye-sensitized solar cells: improved cell performance by the synthesis of 18nm  $\text{SnO}_2$  colloids", Solar Energy Materials a Solar Cells", Vol.71, 2002, pp.141–152,.
- [3] S. Gnanam, V. Rajendran, "Luminence properties of EG- assisted  $\text{SnO}_2$  nanoparticles by sol-gel process", Digest Journal of Nano materials and Bio structures, 5, 2010, pp.699704.
- [4] Asama. N. Naje, Azhar S. Norry, Abdulla. M. Suhail "Preparation and Characterization of  $\text{SnO}_2$  Nanoparticles" International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 12, December 2013.
- [5] Ganesh E Patil, D DKajale, D N Chavan, N K Pawar, P T Ahire, S D Shinde, V B Gaikwad and G H Jain "Synthesis, characterization and gas sensing performance of  $\text{SnO}_2$  thin films prepared by spray pyrolysis", Bull. Mater. Sci., Vol. 34, No. 1, pp. 1–9. February 2011.
- [6] S. Gnanam, V. Rajendran" luminescence properties of eg-assisted  $\text{SnO}_2$  nanoparticles by sol-gel process", Digest Journal of Nanomaterials and Biostructures, Vol. 5, No 3, pp.699-704, July-September 2010.
- [7] Stryhal Z, Pavlik J, Novak S, Mackova A, Perina V, Veltruska K. Investigations of  $\text{SnO}_2$  thin films prepared by plasma oxidation [J]. Vacuum, 2002, 67(3/4): 665–671.
- [8] N.A.Hegab, H.A.Atyia, J. of. Ovonic. Res., 2 (2006) 21.
- [9] A.Verma, P.K.Khare, R.K.Srivastava, Indian J. Pure Appl. Phys., 47 (2009) 737.
- [10] C.Ramu, Y.R.V.Naidu, A.K.Sharma, Ferroelectrics., 159 (1994) 275. F.H.Abd-El Kader, W.H.Osman, R.S.Hafez, Physica B., 408 (2013) 140.
- [11] F.H.Abd-El Kader, W.H.Osman, R.S.Hafez, Physica B., 408 (2013) 140.
- [12] A.K.Jonscher, A.A.Ansari, Phil. Mag., 23 (1971) 205.
- [13] M.M. Perlam. J.appl. Pys., (1971)42, 2645.
- [14] A. Tiwari, V. Singh, Exp. Polym. Lett., 1 (2007) 308.
- [15] G.B.V.S.Lakshmi, Vazid Ali, PawanKulriya, AzherM.Siddiqui, M.Husain, M.Zulfeqar, Physica B., 392 (2007) 259.
- [16] SadiaAmeen, Vazid Ali, M.Zulfeqar, M.MazharulHaq, M.Husain, Physica B., 403 (2008) 2861.