*Available online at*www.scholarsresearchlibrary.com

Scholars Research Library

Archives of Applied Science Research, 2015, 7 (4):71-75
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0975-508X
CODEN (USA) AASRC9

Studies on temperature and thickness dependent electrical resistance and conductivity of SnO_2 thin films

***Ugalal P. Shinde[1] and Hiraman S. Aher[2]**

[1]Dept. of Physics and Electronics, L. V. H. College, Panchavati, Nashik, Savitribai Phule Pune University, (M.S.), India
[2]Dept. of Chemistry, L. V. H. College, Panchavati, Nashik, Savitribai Phule Pune University, (M.S.), India

---

ABSTRACT

Thin films of tin (Sn) of varying thicknesses have been deposited on glass substrates in a vacuum. After annealing, thin films of tin were heated in an air forms tin oxide (SnO_2) films. The electrical resistances as well as conductivity of the films have been measured. The electrical resistance and conductivity are the functions of thickness and temperature of films. SnO_2 thin films show effect of annealing temperature and thickness. The activation energy has been calculated as function of thickness for low and high temperature regions. From energy of activation, conduction mechanisms have been predicted.

Keywords: SnO_2, thin films, thickness, temperature, resistance, conductivity, activation energy.

INTRODUCTION

The direct band gap of SnO_2 determined to be 3.76 eV and for SnO_2: Sb is 3.83 eV. Thin films of SnO_2 and SnO_2: Sb prepared on soda glass substrates by photolysis in air at 140 ^{O}C. The crystallinity, transmittance and conductivity of the films were observed with annealing in either air or vacuum and with change in thickness by [1]. The earlier studies of SnO_2 films were mainly on the film structure, resistivity, Hall effect and Optical properties reported by[1,2]. The specimens from crystals of natural Bolivian cassiterite studied the electrical conductance of these samples in the temperature range 100^{O}C to 500 ^{O}C and found the activation energy of 0.72 eV [3]. Polycrystalline bars of stannic oxide, undoped and doped with antimony in the temperature range 100 ^{O}C to 900 ^{O}C were prepared by [4]. He reported the conductance in the range of 10^{-1} to 10^{2} $\Omega^{-1}cm^{-1}$ for doped specimen and 10^{-2} $\Omega^{-1}cm^{-1}$ for the undoped.

The electrical conductivity of compressed power specimens of SnO_2 prepared by the oxidation of SnO ranged from $2.5x10^{-5}$ to $3x10^{-7}$ $\Omega^{-1}cm^{-1}$ as the oxidation temperature was varied from 800 ^{O}C to 1000 ^{O}C. The electrical conductivities of number of stannic oxide polycrystalline bars prepared from Nigerian cassiterite powder were measured in the temperature range 250 ^{O}C to 650 ^{O}C. The activation energy obtained in the high temperature from three samples studied is 0.42, 0.48, and 0.52 eV [5]. The transparent semiconducting thin films of tin oxide involving chemical vapor phase oxidation of tin iodide. X-ray diffraction studies revealed the polycrystalline nature of films; the sheet resistance was greater than 100 Ωcm and an average optical transmission in the visible range exceeding 80% [6].

The temperature coefficient of resistance of tin oxide coated electrically conducting glass between 1 to 300 ^{O}K have been measured by [7] and the results were used for the precision thermometry. The undoped SnO_2 [8] has low electrical resistance and high optical transparency in the visible range of the electromagnetic spectrum. These properties make tin oxide suitable for many applications, particularly as an electrode material in solar cell, light emitting diodes, transparent electromagnetic shielding materials, etc [9]. Numerous works have been reported concerning doped and undoped tin oxide thin films using various preparation techniques such as chemical vapor deposition [10], thermal beam evaporation [11], and spray pyrolysis [12], and sputtering techniques [13]. Sputtering technique has advantages among other methods, since film deposition can be carried out at low temperature, whilst yielding the preferred orientation and uniform properties [14].

Furthermore, sputtering technique is known to reproduce thin films of various types of materials especially the oxides [15]. Studies on effect of substrate type and temperature, deposition rate, oxygen partial pressure and annealing temperature are widely performed by many researchers to improve the structural, electrical and optical properties of the sputtered thin film. The annealing processes, for instance, are usually performed to reduce the intrinsic stress, to improve the lattice mismatch and create longer mean paths for the free electrons in getting better electrical conductivity [16].

From the above survey it is concluded that SnO_2 films find applications in diverse fields. Dissociation and formation of new species have been observed during the vacuum deposition of several oxides [17]. In order to avoid the formation of amorphous and disordered SnO_2 films and dissociation of SnO_2 films formed by vacuum evaporation method, we obtained SnO_2 films by oxidation of tin films for the measurement of resistance as well as conductivity for various thicknesses in the present investigation**.**

MATERIALS AND METHODS

2.1 Preparation of tin thin Films

Tin metal films of varying thicknesses were obtained on backed and cleaned microscopic glass slides by vacuum evaporation of 99.999 % pure metal with a pressure of ~ 10^{-4} torr using a conventional vacuum system. The films were thermally oxidized in air at a temperature of 410^{O}K with an atmospheric pressure for 36-48 hours, forms tin oxide (SnO_2) films.

The SnO_2 thin films were annealed at 383^{O}K for 6-8 hrs, after annealing the stoichiometric films of SnO_2 were used for measurement purpose. The Large area ohmic contacts of evaporated Al were made at the end of the films.

2.2 Measurement of Thickness

The film thickness (d) of SnO_2 thin films was measured by gravimetric and optical interference methods, reported by [18-20] (±100Å) using the relation

$$d = \frac{M}{g \times A} cm \qquad \text{----------} \qquad (1)$$

Where
A - Surface area of the film
M - Mass of the film material
g - Density of the film material,
Both techniques of thickness measurements agreed within ±10% for very thin films and ± 5% for thick films.

2.3 Electrical properties

The measurement of electrical resistance of varying thicknesses of SnO_2 thin films were carried out at different temperatures from 300 to 500 ^{O}K.

To eliminate the effect of adsorbed moisture, the measurements were made at reduced pressure of ~ 10^{-2} torr keeping the film inside a glass vacuum tube connected to rotary pump. For all these measurements, leads were connected to Al electrode using pressure contacts.

RESULTS AND DISCUSSION

Several investigators [21, 22] have studied the thermal oxidation behavior of tin films. α-SnO is formed [23] as a result of thermal oxidation of vacuum evaporated tin films on air at atmospheric pressure in the temperature range 130-200 ^{O}C and that no higher oxide (SnO_2) is formed in air.

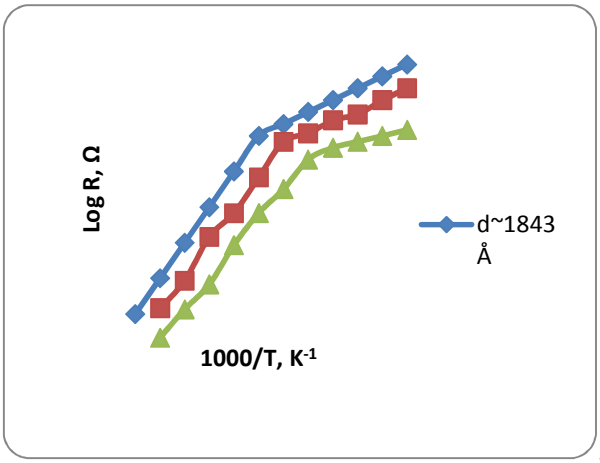

Fig.1: Plot of Log R versus 1000/T of SnO_2 thin films.

The plots of logR as a function of reciprocal absolute temperature (1000/T) at reduced pressure (~ 10^{-2} torr) are found to consist of two linear parts for each thickness shown in above fig.1. The dc dielectric resistance is found to vary as

$$R=R_0 \exp (\Delta E / KT) \quad \text{----------} \quad (2)$$

The presence of two distinct values of ΔE for different samples in different temperature ranges may be attributed to two activation processes namely (1) it is intrinsic conduction at band gap in high temperature region and (2) in low temperature region, conduction is due to hopping of charge carriers in the localized states at Fermi level.

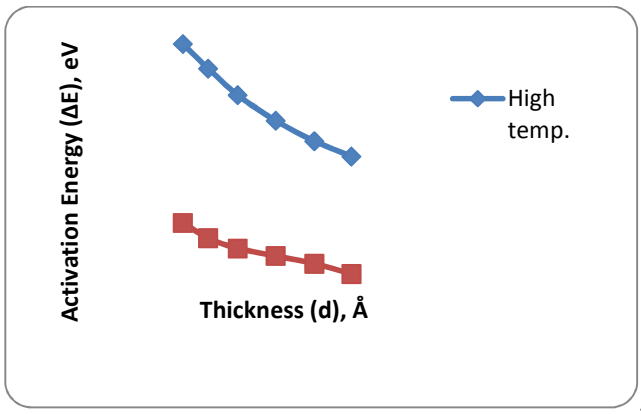

Fig.2: Plot of activation energy (ΔE) versus thickness (d) of SnO_2 thin films.

Fig.2 shows higher values of ΔE for thinner samples may be explained qualitatively on the basis of Island structure theory of Neugebauer and others [24-26].

On the basis of this theory, ΔE is given by [27]

$\Delta E = e^2/K.D + \Delta Eg / 2$ ---------- (3)

Where
e = is the electronic charge
Eg = semiconductor energy band gap
D = the average linear dimension of the Island,
K = the dielectric constant of the material

Even though the films studied by us were much thicker and more or less continuous, the variation of ΔE has the same trend as that of very thin films.

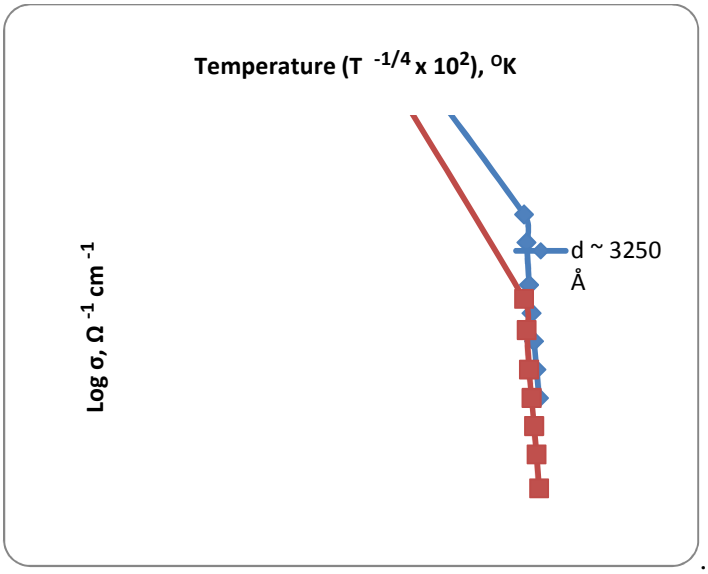

Fig.3: Plot of conductivity (Log σ) versus temperature ($T^{-1/4}$) of SnO_2 thin films

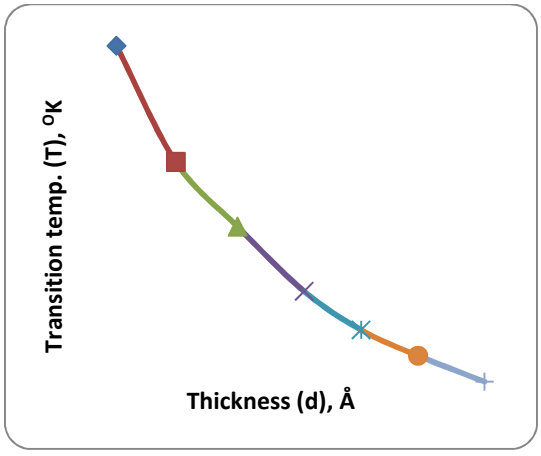

Fig.4: Plot of transition temperature versus thickness (d) of SnO_2 thin films

As revealed by linear plots of Log σ verses $T^{-1/4}$ in lower temperature region shown in fig. 3. It may be mentioned that the break in graph shown in fig.1 does not occur at one constant temperature for all the films; hence it cannot be attributed [27] to any change of structure or phase of the oxide.

Fig.4 reveals that as the thickness of the deposits increases the transition temperature decreases. This decrease of transition temperature of SnO_2 thin films is attributed to decrease of defects with increase of thickness.

CONCLUSION

Thin films of tin (Sn) have been well prepared in vacuum by evaporation method and oxidized in air. Measurement of electrical resistance and conductivity of SnO_2 thin films are the functions of thickness and temperature. The SnO_2 thin films for any thickness show semiconducting nature of two conduction mechanisms showing two different sets of activation energy values. Thickness dependent change of transition temperature of SnO_2 thin films shows increase of thickness decreases the transition temperature.

Acknowledgement
The authors greatly thanks to the Management authorities of M.G.Vidyamandir, Principal of M.S.G. College, Malegaon Camp and the Principal of L.V.H. College, Panchavati, Nashik for giving valuable support to do this work.

REFERENCES

[1] Z. M. Jarzebski, J. P. Marton, *J. Electrochem. Soc.*, **1976**, 123C, 333.
[2] J. C. Manifacier, L. Szepessy, J. F. Bresse, M. Perotin, R. Stuck, *Mater. Res. Bull.*, **1979**, 109, 163.
[3] E. E. Kohnke, *J. Phy. Chem. Solids*, **1962,** 23, 1557.
[4] L. D. Luck, *J. Electrochem. Soc.*, **1963,** 110, 1081.
[5] S. C. Mitra, *Ind. J. Phys.*, **1967**, 41, 448.
[6] R. D. Tarey, T. A. Raju, *Thin Solid Films*, **1985**, 128, 181.
[7] D. N. Lyon, T. H. Geballe, *Rev. Sci. Instrum.*, **1950**, 21,769.
[8] J. C. Manifacier, M. D. Murcia, J. P. Fillard, E. Vicario, *Thin Solid Films*, **1977**, 41, 127.
[9] H. L. Hartnagel, *Semi. Transp. Thin Films, Instit. of Phy. Pub., Philadelphia*, **1995**, 1A
[10] S. Geetha, R. Rup, A. Mansingh, *J. of Phy. Review B*, **1991**, 44, 5672.
[11] D. Das , R. Banerjee, *Thin Solid Films*, **1987**, 149, 291.
[12] K.S. Shamala, L.C.S. Murthy, K. N. Rao, *Bull. Mater. Sci.*, **2004,** 27, 295.
[13] S. Hamzaoui, M. Adnane, *Applied Energy* , **2000**, 65, 19.
[14] S. U. Lee, J. H. Boo, B. Hong, *Jap. J. of App. Phy.*, **2011**, 50
[15] S. Saipriya, M. Sultan, R. Singh, *Physica B*, **2011**,406, 812.
[16] A. F. Khan, M. Mehmood, A. M. Rana, M.T. Bhatti, *App. Surf. Sci.* , **2009**, 255, 8562.
[17] A. Goswami, Y. N. Treham, *Proc. Phys. Soc. London*, **1957**, 70, 1006.
[18] P. S. Nikam, H. S. Aher, *Ind. J. Pure and Appl. Phys.*, **1993**, 31,79.
[19] P. S. Nikam, R. Y. Borse, R. R. Pawar, *Bull. Mater. Sci.*, **1997**, 20, 1015.
[20] U. P. Shinde, *Inter. J. of Engg. & Sci. Inv.*, **2013**, 12, 28.
[21] T. N. Agarwal, R. N. Saxena, *Ind. J. Pure and Appl. Phys.*, **1981**, 19,1057.
[22] T. N. Agarwal, R. N. Saxena, *Ind. J. Pure and Appl. Phys.*, **1982**, 20, 780.
[23] A. R. Patel, D. V. Mysorewala, *Mater. Res. Bull.*, **1970**, 5, 1031.
[24] C. A. Neugebauer, M. B. Webb, *J. Appl. Phys.*, **1962**, 33, 74.
[25] C. A. Neugebauer, *Phy. of Thin Films*, **1964**, 2, 25.
[26] C. J. Gorter, *Physica*, **1951**,17, 778.
[27] D. C. Barua, K. Barua, *Ind. J. Phys.*, **1974**, 48, 332.