ISSN (e): 2250 – 3005 || Volume, 07 || Issue, 07|| July – 2017 ||
International Journal of Computational Engineering Research (IJCER)

Sputtering Power Dependent Physical Properties of Nanocrystalline Au: SnO_2 Thin Films

T.V.N. Prathyusha[1], T. Srikanth[1], R. Subba Reddy[1], A. Sivasankar Reddy[1*], B. Radha Krishna[2], P. Sreedhara Reddy[3]

[1]*Department of Physics, Vikrama Simhapuri University PG Center, Kavli-524 201, India*
[2]*Department of Physics, NBKR Institute of Science and Technology, Vidyanagar-524413, India*
[3]*Department of Physics, Sri Venkateswara University, Tirupati- 517 502, India*
*Corresponding Author: * A. Sivasankar Reddy*

ABSTRACT

Nanocrystalline gold doped tin oxide (Au:SnO_2) thin films were deposited on glass substrates at different sputtering powers by DC reactive magnetron sputtering. The physical properties of as deposited films were characterized by different analytical techniques. The oxygen content in the films was slightly decreased with increasing of the sputtering power. The Au:SnO_2 films exhibited the SnO_2 phase only and no diffraction peak from Sn and/or Au phase was found. The deposited films were preferentially grown to (101) plane. The optical absorption edge shifted to higher wavelength side with increases of sputtering power. The band gap of the films decreased from 3.41 eV to 3.18 eV with increasing the sputtering power.

Keywords: Tin oxide, Thin films, Sputtering, Sputtering power, Nanocrystalline, Resistivity, Band gap

---

Date of Submission: 10-07-2017 Date of acceptance: 26-07-2017

I. INTRODUCTION

Tin oxide (SnO_2) is n-type semiconductor in nature, wide band gap, high transparence in the visible light region, chemical and thermally stable. These unique properties leads the SnO_2 is a most suitable and promising material for gas sensors, transistors, solar cells, photo-detectors and batteries. High electrical conductivity and nanostructured SnO_2 is more useful for gas sensor applications, this can achieved by additive incorporation into SnO_2 [1-5]. Pure and doped SnO_2 thin films have been prepared by variety of methods such as sputtering [6-8], pulsed laser deposition [9], anodic oxidation technique [10], thermal oxidation [11], atomic layer deposition [12], spin coating [13], and spray pyrolysis [14]. Among these thin films deposition techniques, dc magnetron sputtering is one of the best technique due to its good adhesion to the substrate, high deposition rates, easy to control the chemical composition of the film and maintained in uniform manner over large scale of substrates. In this study, gold doped SnO_2 (Au:SnO_2) thin films were deposited by DC magnetron sputtering technique under various sputtering powers and investigated the compositional, structural, microstructural, morphological, optical and electrical properties.

II. EXPERIMENTAL

Nanocrystalline Au:SnO_2 thin films were deposited on glass substrate by DC reactive magnetron sputtering from the tin and gold mosaic target. The magnetron target assembly was mounted at the top of the sputter chamber such that the sputtering could be done by down configuration. The vacuum system is evacuated to a base pressure of $5x10^{-4}$ Pa with the combination of diffusion pump and rotary pump. Both flow rates of sputter (Ar) and reactive gases (O_2) were controlled individual by Tylan mass flow controllers. Before deposition of each film, the target was sputtered in pure argon atmosphere for 10min to remove oxide layers if any on the surface of the target. The sputtering condition maintained during the deposition of Au:SnO_2 thin films are mentioned in Table 1.

The crystal structure of the films was determined by X-ray diffraction (XRD). The microstructure and surface morphology of the films were analyzed with scanning electron microscope (SEM) and atomic force microscope (AFM). The transmittance spectra of the films were recorded using the Hitachi U-3400 UV-Vis-NIR double

beam spectrometer in the wavelength range of 300 -1000nm. The electrical resistivity of the films was measured by using four-point probe method.

Table 1 Deposition conditions during the preparation of Au:SnO_2 films

Deposition method	: DC reactive magnetron sputtering
Power source	: DC power supply (1000 V and 1 Amp)
Sputtering target (Mosaic)	: Pure tin (99.9%), gold strips (99%)
Target to substrate distance	: 60 mm
Oxygen partial pressure	: $7x10^{-4}$ mbar
Substrate temperature	: 473 K
Sputtering power	: 30-60 W
Sputtering pressure	: $2x10^{-2}$ mbar
Deposition time	: 7-15 min
Substrate rotation	: 20 rpm

III. RESULTS AND DISCUSSION

The chemical composition of films was analyzed by electron probe microanalysis (EPMA). From the EPMA results, The gold incorporation is around 1 at.% in the Au:SnO_2 films. At lower sputtering power Sn content was low and it increases with increasing of the sputtering power. The films deposited at sputtering power of 50W, Sn/O ratio was close to the stoichiometric compound of SnO_2.

Table 2 Chemical composition of Au-SnO_2 films at different sputtering powers

Sputtering power (W)	Atomic percentage Sn	O	Au
30	31.4	67.7	0.9
50	34.2	64.9	0.9

Structural properties

The XRD patterns of Au:SnO_2 films at different sputtering powers are shown in Fig.1. From the XRD patterns, the films exhibited SnO_2 phase only and no diffraction peak from Sn and/or Au phase was found. The deposited films were preferentially grown to (101) plane. The films deposited at low sputtering power exhibited poor crystallinity. As increasing the sputtering power to 50 W, crystallinity of the films increases. Beyond, this sputtering power the crystallinity of the films was decreased. With increasing sputtering power, the sputtering yield is high and the sputtered particles are ejected with higher energy and the growth of a more crystallized phase. Whereas, the high sputtering power induces faster reaction rate and it damages the surface, resulting to a poor crystalline quality. Montero et al. [15] observed similar behavior in DC reactive magnetron sputtered antimony doped tin oxide films.

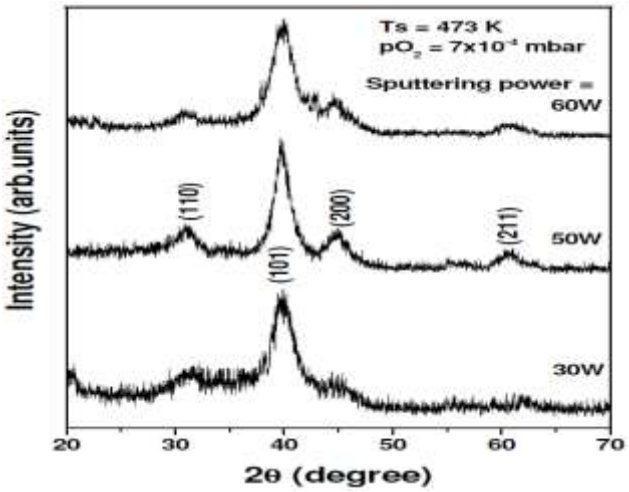

Fig.1. XRD patterns of Au:SnO_2 films deposited at different sputtering powers

The average crystallite size of films was calculated by using Scherrer's equation [16]. The obtained crystallite size are 4.3 nm, 6.9 nm and 5.7 nm for sputtering power of 30 W, 50 W and 60 W respectively. Increase of sputtering power may cause the increase of the rate of gas phase nucleation with corresponding increase in the cluster growth rate, hence, increase in the crystallite size.

Microstructure and Surface morphology

Fig.2. shows the SEM images of Au: SnO_2 films at different sputtering powers. It can be seen that the surface grain size tends to be bigger when the DC sputtering power increases from 30 W to 50 W. The increase in the grain size was due to increase in sputtering yield as a result of bombardment of high energetic particles. The temperature elevation at higher sputtering power helps to obtain the larger grain structure than the lower sputtering power.

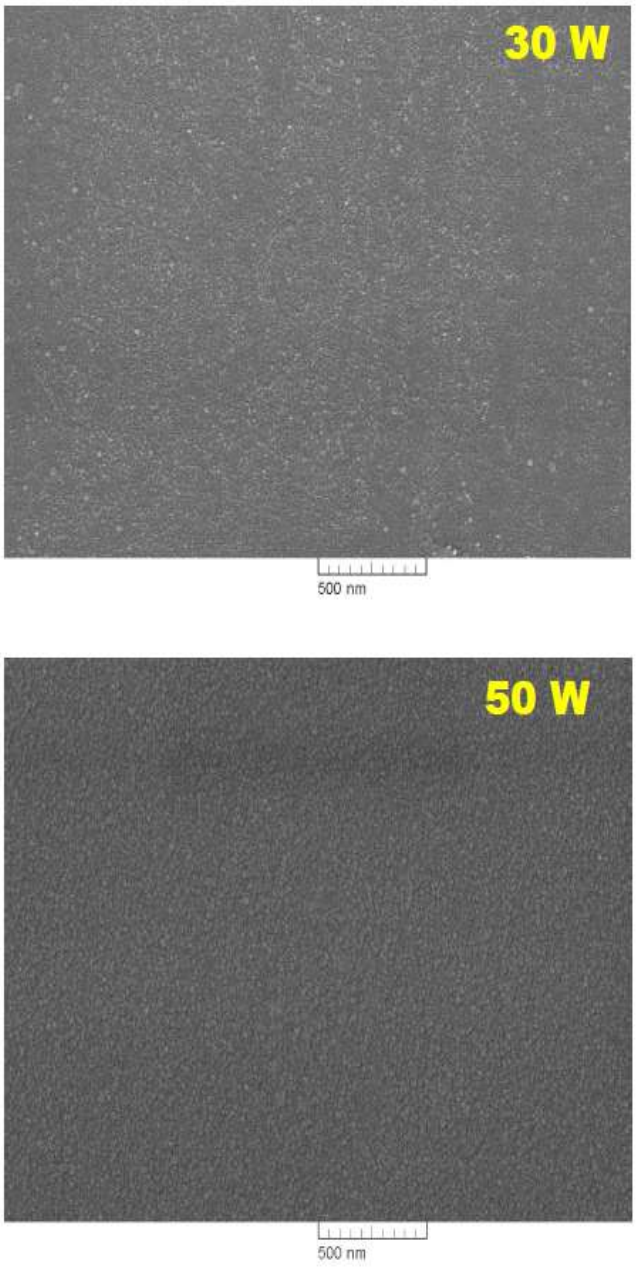

Fig.2. SEM images of Au:SnO_2 films deposited at different sputtering powers

The two-dimensional AFM images of Au:SnO_2 films deposited at different sputtering powers are shown Fig.3. The surface of the films becomes smooth and the grains size increases with increasing the sputtering power. The RMS roughness of the films was 2.9 nm, 2.1 nm and 2.4 nm for films deposited at 30W, 50W and 60W, respectively. However, the increasing of the grain size and surface roughness of films with sputtering power was observed in DC magnetron sputtered NiO thin films [17].

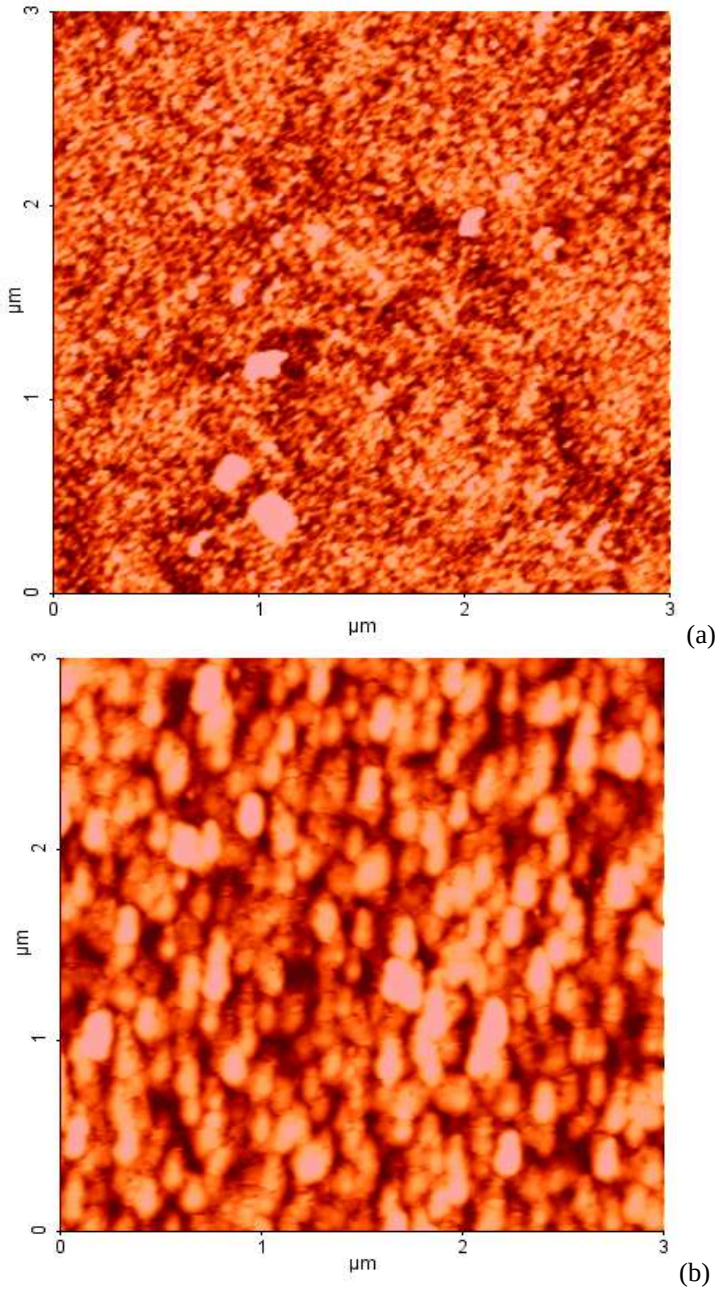

Fig.3. Two-dimensional AFM images Au:SnO_2 films at different sputtering powers: (a) 30 W and (b) 50 W

Optical and Electrical Properties

The wavelength dependence of optical transmittance spectra of Au:SnO_2 films deposited at different sputter powers is shown in Fig.4. The optical transmittance of the films was recorded in the wavelength range of 300 - 1000nm. The optical transmittance of the films increased with increase of sputter power from 30 W to 50 W thereafter it decreased at higher sputtering powers. The increasing of the optical transmittance with sputtering power was due to improvement in the structural properties of the films. At higher sputtering power the degrading of structural properties and increasing of the metal content may reduce the transmittance of the films. The optical absorption edge shifted to higher wavelength side with increases of sputtering power. The band gap of the films decreased from 3.41 eV to 3.18 eV with increasing the sputtering power.

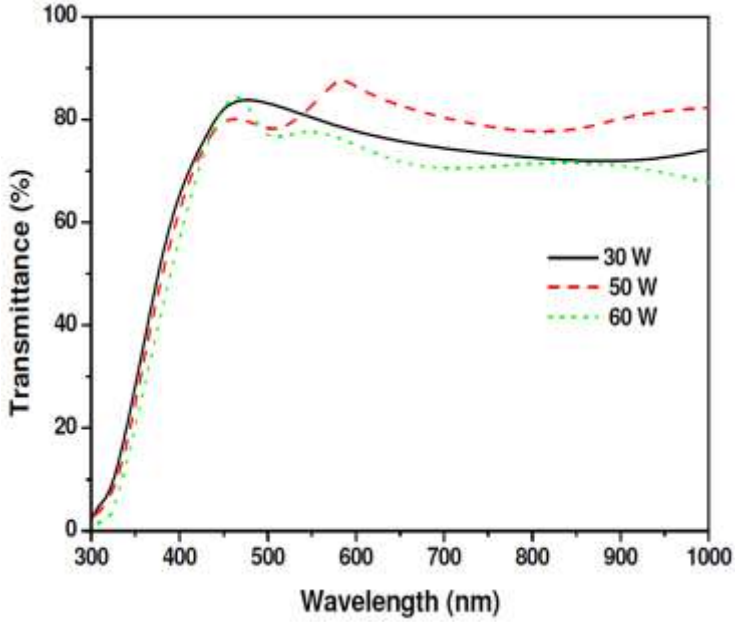

Fig.4. Optical transmittance spectra of Au:SnO_2 films at different sputtering powers

The sputtering power was strongly affected the electrical resistivity of the films. The sputtering power dependence of the electrical resistivity of Au:SnO_2 films is listed in Table.3. The electrical resistivity of the films decreased with increases of sputtering power. The similar behavior was observed by Lee et al. [18] in rf magnetron sputtered ZnO:Al films. The variation of electrical resistivity with sputtering power originate from improved crystallinity, reduced grain boundary scattering to charge carriers, increased substitutional doping and decreased interstitial atoms as sputtering power increased.

Table 3. Optical and electrical properties of Au:SnO_2 films at different sputtering powers

Sputtering power (W)	Transmittance (%) at λ=590 nm	Band gap (eV)	Resistivity (Ωcm)
30	77	3.41	0.9
50	88	3.30	0.005
60	74	3.18	0.0008

IV. CONCLUSION

Nanocrystalline Au:SnO_2 thin films have been prepared on glass substrates by dc reactive magnetron sputtering at different sputtering powers. The deposited films were preferentially grown to (101) plane. The crystallinity of films increased with increasing of the sputtering power and the films deposited at sputtering power of 50 W exhibited better crystallinity with average crystallite size of 6.9 nm. The surface of the films becomes smooth and the grains size increases with increasing the sputtering power. The films deposited at sputtering power of 50 W shows the high optical transmittance of 88% with electrical resistivity of 0.005 Ωcm.

REFERENCES

[1]. Y. Jiang, W. Sun, M. Yan and N. Bahlawane, J. Alloys and Compounds 509 (2011) 7798.
[2]. V.D.L. da Silva, A. de Andrade, L.V.A. Scalvi, E.A. Floriano, J.L.B. Maciel Jr., L.P. Ravaro and J.C. Santos, Materials Chemistry and Physics 134 (2012) 994.
[3]. Y. Jiang, W. Sun, B. Xu, M. Yan. and N. Bahlawane, J. Phys. Chem. 13 (2011) 5760.
[4]. M. Ajili, M. Castagnéb and N.K. Turki, Optik 126 (2015) 708.
[5]. C-Y. Tsay and S-C. Liang, J. Alloys and Compounds 622 (2015) 644.
[6]. B.L. Zhu, X. Zhao, W.C. Hu, T.T. Li, J. Wu, Z.H. Gan, J. Liu, D.W. Zeng and C.S. Xie, J. Alloys and Compounds 719 (2017) 429.
[7]. E. Yu. Sevast'yanov, N. K. Maksimova and E. V. Chernikov, A. A. Firsov, Russian Physics Journal 55 (2012) 602.
[8]. T. Prathyusha, T. Srikanth, A. Sivasankar Reddy, P.Sreedhara Reddy and Ch.S. Reddy, Optik 127 (2016) 9457.

[9]. Jing Li, Guohua Bai, Yinzhu Jiang, Youwei Du, Chen Wu and Mi Yan, J. Magnetism and Magnetic Materials 426 (2017) 545.
[10]. L. Jianhua, W. Jian, Z. Letao and Z. Shengdong, J. Vac. Sci. Technol. A 33 (2015) 031508.
[11]. D. Boulainine, A. Kabir, I. Bouanane, B. Boudjema and G. Schmerber, J. Electronic Materials 45 (2016) 4357.
[12]. D-K Lee, Z. Wan, J-S Bae, H-Bo-Ram Lee, Ji-H. Ahn, S-D Kim, J. Kim and Se-H Kwon, Materials Letters 166 (2016) 163.
[13]. D.M. Priyadarshini, M. Ramanjaneyulu, M.S.R. Rao and N.D. Gupta, Appl. Surf. Science 418 (2017) 414.
[14]. A. Chen, S. Xia, Z. Ji, J. Xi, H. Qin and Q. Mao, Surf. Coat. Technology 322 (2017) 120.
[15]. J. Montero, C. Guillen and J. Herrero, Solar Energy Materials & Solar Cells 95 (2011) 2113.
[16]. B.D. Cullity, Elements of X-ray Diffraction, 2nd Ed., Addison Wesley, London (1978).
[17]. A. Mallikarjuna Reddy, A. Sivasankar Reddy, K-S Lee and P.S. Reddy, Solid State Sciences 13 (2011) 314.
[18]. J. Lee, D. Lee, D. Lim and K. Yang, Thin Solid Films 515 (2007) 6094.

International Journal of Computational Engineering Research (IJCER) is UGC approved Journal with Sl. No. 4627, Journal no. 47631.

T.V.N. Prathyusha. "Sputtering Power Dependent Physical Properties of Nanocrystalline Au: SnO2 Thin Films." International Journal of Computational Engineering Research (IJCER) 7.7 (2017): 36-41.