Structural Analysis of SnO_2 Thin Films at Various Temperatures (313, 333, 353 and 373 K)

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Abstract: The present paper which deals with thin oxide thin films were prepared by dip coating technique at different bath temperatures (313, 333, 353 and 373 K) and annealed at 400°C and then subjected to structural study.

Keywords: SnO_2 thin films, Dip coating technique, annealing, structural Study.

I. INTRODUCTION

In recent years, semiconductor metal oxide have received significant attention due to its possible application in gas sensor, solar cells, liquid crystal display, gas discharge display, and so on [1-3]. Among the various sensors which have been developed to detect gases, resistive sensors based on semiconductor oxides have a good potential for use in electronic detectors because of various reasons like low price, environmental compatibility, stability and tolerance to high temperature work. The tin oxide (SnO_2) is a special kind case in the category of oxide material due to low electrical resistance with high optical transparency in the visible range. Tin oxide thin films have many other applications like electrode materials in solar cells, light-emitting diodes, flat-panel displays, and other optoelectronic devices [4]. SnO_2 has been considered for its high sensor response to oxidizing and reducing gases simultaneously and its thermal stability [5-7]. It is concerned with an attempt to understand the effect of film thickness. Hence, growing these films by a cost effective technique becomes very important for their practical application.

There is much interest of researchers and engineers especially gas sensitive materials to grow substantially due to the progress in thin film technology in modern days. Many semiconducting metal oxides have been used as gas sensors. Among them, SnO_2 is the most important material used in gas sensing applications in domestic, commercial and industrial sectors. The tin oxide gas sensors are presently the right choice of researchers due to their various properties like high electron mobility, low operating temperature, high sensitivities, high chemical stability, mechanical simplicity of sensor design and low industrialized cost. It is a wide band- gap (3.7 eV) [8, 9] semiconductor and is a part of the family of binary transparent conducting oxides (TCOs) such as ZnO, In_2O_3 and CdO.

In solar-energy conversion, fabrication of sensors and various other electrode applications the tin oxide thin films are of great attention. The most commonly used oxide film resistors are composed of SnO_2 [10]. In the present study, we made an attempt for preparation and characterization of SnO_2 thin films deposited on glass substrate using dip coating technique. Films were studied at different bath temperatures (313, 333, 353 and 373 K) and annealed at 400°C and then subjected to structural study.

TABLE I. PHYSICAL PROPERTIES OF SnO_2

Color	White or gray
Type	n-type
Band gap	Direct, 3.7 eV
Structure	Tetragonal rutile
Spacegroup	D_4th^{14} ($P4_2$/mnm)
Lattice parameters	a = b=4.737 Å C=3.185 Å
Electrical conductivity	1200 –1400 $ohm^{-1}c^{-1}$
Electron mobility	10 –50 $cm^2 V^{-1} s^{-1}$
Carrier concentration	10^{17} - 10^{19} cm^{-3}
Effective mass of electron	0.17 mo
Melting Point	1630°C
Boiling Point	1900 C
Density	6.95 gm cm^{-3}
Dielectric constant (ε)) Parallel to c-axis Perpendicular to c-axis	 9.0 14.5
Thermal expansion coefficient 4.0 x 10^6 C^{-1}	6°C
Electron affinity (χ) 4.85eV	4.85 eV

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II. EXPERIMENTAL PROCEDURE

A. Preparation Technique

In the present study, dip coating technique was chosen for the preparation of tin oxide (SnO_2) thin films. The chemicals used for the preparation were A.R grade (99.5% purity procured from Nice chemicals, India) stannous chloride, n-Propanol and Iso Propanol. The properties of the materials prepared by the dip coating techniques critically depend on various preparative parameters such as the sources and concentration of metal and deposition time, temperature etc., and subsequent heat treatments like annealing in air etc. Tin oxide thin films were deposited on well cleaned glass substrate.

B. Choice of the Substrate

Thin film requires a substrate to support itself. Substrates are chosen according to the type of properties and applications they intended for the method of deposition and materials to be deposited. The properties of substrates used to grow defect free film include surface smoothness matched co-efficient of thermal expansion, good mechanical strength, high thermal conductivity, inertness or chemical stability, low cost, high electrical resistance, good uniformity and high dielectric strength.

Commonly used substrate materials are alumina, glass, metals, silicon and semiconductors available for thin film fabrication of all this glass is found to possess good smoothness that is why used and moreover because of economical and hence widely used. It has the stability to withstand high temperature processing above 375°C. In the present study, micro glass slides of 75 mm x 25 mm x 1 mm has used and for convenience each slide is cut into four equal parts of dimension ~ 37.5 mm x 12.5 mm x 1 mm and then used for further deposition.

C. Cleaning of the Substrate

The cleanliness of the substrate surface is a significant parameter for the film formation. The following steps were performed for substrate cleaning.

- Firstly, glass substrates were thoroughly cleaned with liquid soap and rinsed in deionized water.
- Secondly, the as-cleaned substrates were kept in dilute H_2SO_4 for 24 hours. This is because cleaning effect of acids leads to the conversion of some oxides and greases into water soluble compounds.
- Thirdly, the substrates were rinsed with distilled water and treated with sodium hydroxide solution.
- Fourthly, the acid-alkaline reacted substrates were then immersed vertically in hot isopropyl alcohol for 30 minutes and dried by blowing hot air.

X-ray diffraction data of the dip coated SnO_2 samples were recorded with the help of X-ray diffractometer (Model-D 5000 using with CuKα) having wavelength (λ=0.1540 nm).

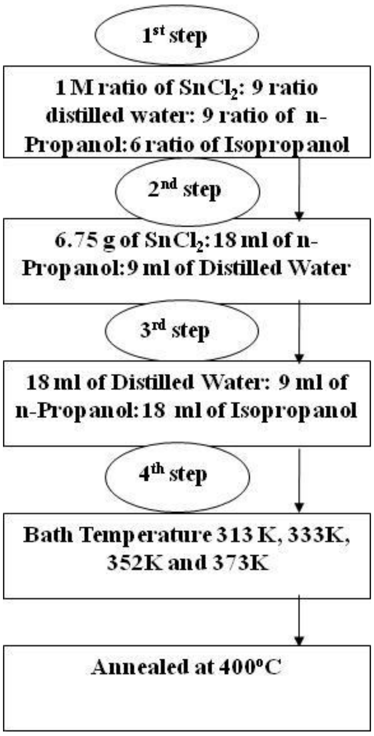

Fig. 1.Schematic representation of SnO_2 by dip coating technique

III. RESULTS AND DISCUSSION

X-Ray powder diffraction (XRD) spectrum is used to identify the crystalline phase resent in materials and to measure the structural properties of different phases. The structural characterization of dip coated tin oxide thin film was carried out by using Simens Diffractometer Model wave length range l=0.1540 nm. Fig. 2 shows the diffractions pattern of dip coated tin oxide thin films prepared at different bath temperatures 313, 333, 353 and 373 K. From the results of XRD the deposited films are found tetragonal rutile crystalline structure and agree well the earlier reported structure. The observed diffraction peaks of SnO_2 films are found 2θ values of 33.41, 26.4, 23.6, 23, 17.6, 16.7 and 15.9 and it is very well matching hkl planes (110), (101), (200), (111), (211), (220) and (200), respectively [11,12].

The different peaks were indexed and the resultant values of interplanar spacing d were calculated and compared with standard values [13]. XRD pattern of the dip coated tin oxide thin film prepared at bath temperatures 313 K and 333 K (fig.2 a, b) shown a low intensity peak indicate that these films are almost entirely non-crystalline i.e the material is amorphous. Moreover, it is also noticed that the films prepared at bath temperatures 353 K and 373 K have increased intensity along with additional peaks (fig.2 c,d). The tin oxide films deposited at 353 and 373 K are found to have good crystalline nature. It is observed that in as the bath temperature an increase the crystalline nature is also increases, this is clearly shown in fig.2. Since we did not find any reflection peaks from the impurities in the XRD spectra, it may be concluded the high purity of the product [13].

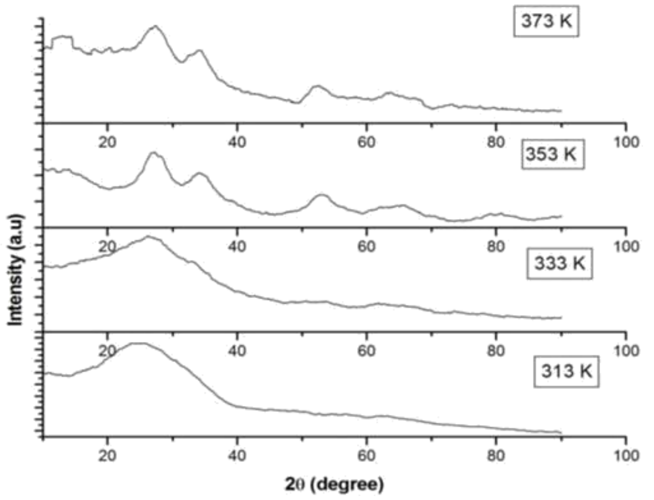

Fig.2. X-ray diffraction patterns of SnO2 thin film prepared at different bath temperatures: (a) 313, (b) 333, (C) 353 and (d) 373 K

IV. CONCLUSION

In conclusions, the tin oxide (SnO2) thin films have prepared by dip coating method. Films were prepared at different bath temperature (313-373 K) were annealed at 400°C. These films are tetragonal rutile structure of SnO2 which was confirmed from the XRD peaks.

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Dr. K. Gurushankar is working as Assistant Professor, Department of Physics, Kalasalingam Academy of Research and Education, Krishnankoil, Tamilnadu, India. He has Five years experience in Teaching filed and 11 years in Research field. Due to his research contribution he has published 14 research international papers. His main area of research is Biophysics.

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