Preparation and Characterizations of Bi-Doped Tin Oxide Thin Film Gas Sensor

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ABSTRACT

Bi-doped thin film samples were prepared by physical vapour deposition technique. The Bi-doped tin metal was deposited on pre-cleaned standard glass substrates with above technique. The film samples were then annealed at various temperatures for 2 hrs. and were characterized for studying structural, morphological, electrical and gas sensing properties by XRD, FESEM, static gas sensing system respectively. Preparation of thin film samples, structural, surface morphological and elemental analysis are explained in this paper.

Keywords: Bi-doped tin oxide, physical vapour deposition, XRD, FESEM.

INTRODUCTION:

Since last few decades, among various oxides, SnO2 (tin oxide) semiconductor films have been widely employed in recognition of volatile organic compounds as stable gas sensors. They are also used in monitoring the environment, industries etc. [1], as window layer in solar cells [2], as gas sensors to sense hazardous gases like CH4, CO, NOx, CNG etc. [3-5]. SnO2 and TiO2 are promising gas sensors because [6-9] of their advantages like low cost, simple fabrication methods, and rapid response and recovery times [10].

Doping is one expected method of enhancing the conductivity and stability of the sensor by incorporating an atom or ion into host material [11, 12]. Although numerous studies have been conducted on the electronic and optical properties of different semiconductor oxides doped with metals, only a few theoretical studies exist on metal (M)-doped semiconductors oxides [13-15]. The present study aims to systematically study the effect of Bi doping concentration on the structural properties, conductivity and stability of SnO2 by combining theoretical calculations with our experiments. We have successfully fabricated Bi-doped SnO2 thin solid films by using Physical Vapour Deposition. The prepared film samples were analyzed using X-ray diffraction (XRD), FESEM, EDAX, Static gas sensing system etc.

PREPARATION OF THIN FILM SAMPLES:

Thin film samples were prepared by using Physical Vapour Deposition Technique. Pre-cleaned standard glass substrates were placed on a specially designed mask exactly above the tungsten filament containing tin wire and a lump of Bi. Appropriate amount of current was passed through the filament with the help of dimmerstat for evaporating tin and Bi. The evaporated material got deposited onto the glass substrates mounted on the mask. These samples were then heated at about 125oC for 24 hrs for maximum oxidation of the deposited material. These samples later were annealed at 300, 400 and 500oC for 2hrs. and stored in a desiccator. They were then analyzed for structural, morphological, electrical and gas sensing characterizations by XRD, FESEM and static gas sensing system respectively. Fig.1 shows the vacuum system employed for deposition purpose.

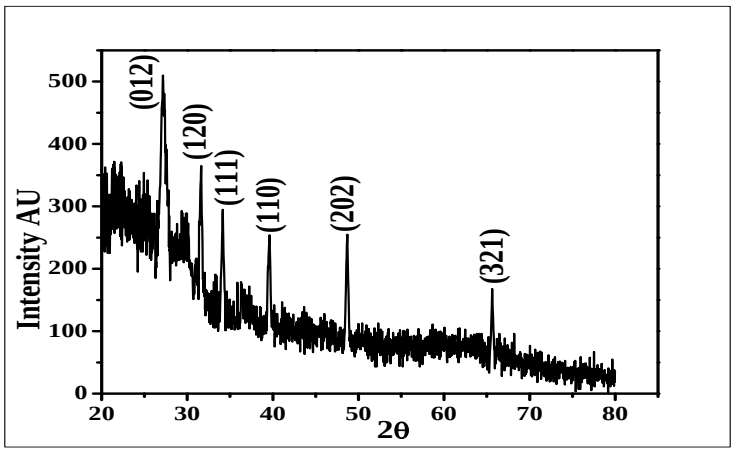
Fig.1: vacuum system

CHARACTERIZATIONS:

Structural Analysis by XRD:

Fig. 2 shows the XRD pattern of Bi-doped SnO2 thin film samples. Samples were scanned over the range of 2θ from 20-80o. The (hkl) planes (120) and (111) correspond to orthorhombic phase.

Fig. 2: XRD patterns of Bi-doped SnO2 thin film sample



The data matched with that from the JCPDS data card [20] and the planes (012) and (110) correspond to rhombohedral phase. The observed data matched with JCPDS card [21]. This data confirmed the material. The crystallite sizes calculated are systematically tabulated in the table 4.1. The structural parameters of Bi-doped SnO2 thin film samples are represented in Table 2. Crystalline nature of the films is clearly seen from the data.

Table 1: Crystallite size

Peak Position 2θ	(hkl) plane	FWHM (radians)	Crystallite size (nm)
27.16	012	0.03349	4.2588
31.63	120	0.01308	11.0148
34.15	111	0.01413	10.2654
39.61	110	0.01361	10.8308
48.70	202	0.00785	19.3885

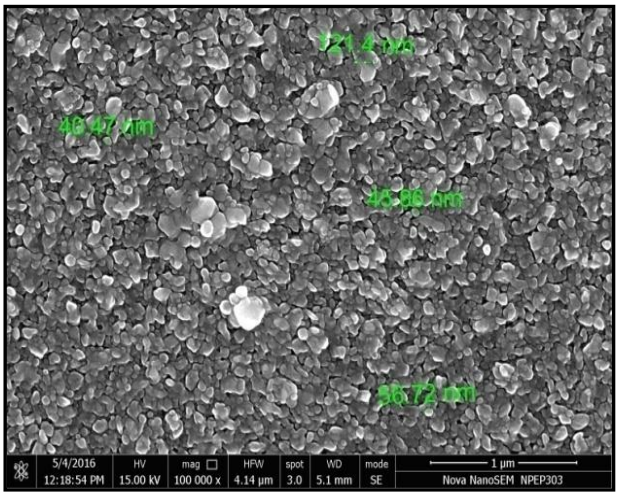
Table 2: Structural parameters of Bi-doped SnO2 thin film samples

Annealing Temp. °C	Dislocation density x 10^{16}	Crystallite Size D nm	Interplanar Distance d A°	Degree of Crystallinity DC (%)	Average Texture Coefficient	Lattice Strain g (%) x 10^{-2}
400	1.429	11.152	5.4959	92.98	0.99987	4.7936

Surface Morphology using FESEM:

The surface morphology of Bi-doped SnO2 thin film samples obtained by using FESEM are shown in Fig. 3. Average grain size for Bi-doped film samples, was observed to be 65.61 nm respectively. The compactness and agglomeration of the grains is clearly seen from the FESEM images of doped film samples. This is possibly due to annealing of the samples.

Fig.3: FESEM image of Bi-doped SnO2 thin film samples annealed at 400oC



Elemental Analysis by EDAX:

Fig. 4 shows the EDAX spectra of Bi-doped SnO2 thin film samples. Elemental composition of the film samples are summarized in Table 3.

Fig.4: EDAX spectra of Bi-doped SnO2 annealed at 400oC

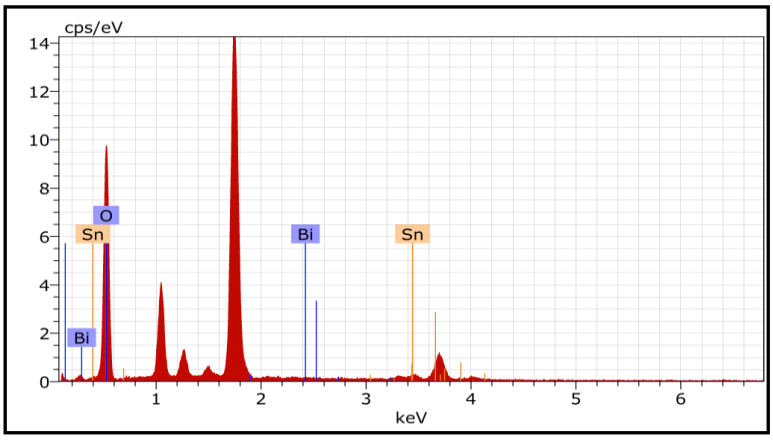


Table 3: Elemental composition of Bi-doped SnO2 thin film samples

Type of sample	Atomic Number	Element	Weight %	Atomic %
Bi-doped SnO_2	50	Sn	12.48	1.89
	8	O	87.43	98.11
	83	Bi	0.09	0.01
		Total	100.00	100.00

CONCLUSIONS:

1. The Physical Vapour Deposition method can be used to fabricate SnO2 thin film samples doped with Bismuth.
2. Once the appropriate vacuum is obtained, a large number of uniform samples can be fabricated at room temperature by this method. In addition, the samples are free from any contamination.
3. Grains formed are irregular shaped and uniformly distributed. Average grain size for Bi-doped film samples was 66.11 nm.
4. EDAX studies confirmed the nonstoichimetry of the samples.

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