International Journal of Current Research and Review
DOI: http://dx.doi.org/10.31782/IJCRR.2018.4648

Research Article

IJCRR
Section: General Science
Sci. Journal Impact Factor: 5.385 (2017)
ICV: 71.54 (2015)

Processing and Characterization of Tin Chalcogenide Thin Films by Thermal Evaporation

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ABSTRACT

Due to the limitations of currently used materials like indirect band gap Si and Ge, binary and ternary compounds of high melting point, toxicity and scarcity of elements, there is a significant demand for alternate compound semiconductors towards energy harnessing applications. Tin selenide (SnSe), being a member of the IV-VI chalcogenide family, has gained wide attention due to its favorable physical properties such as direct band gap, high absorption coefficient and optimum melting temperature. Thin film deposition is intrinsically significant, because it offers a low temperature versatile process comprising low material consumption and provides large area module bearing tunable material properties compared to bulk counterparts. Therefore, special emphasis has been paid to prepare two dimensional SnSe thin film structures. In this regard, high pure (99.999%) Sn and Se elements were weighed in stoichiometric proportions and sealed in specially cleaned quartz ampoules. The ampoule containing the materials was heated in a muffle furnace and periodically rotated using a DC motor of 60 rpm, in order to forge the uniform SnSe precursor. Amorphous thin films have been deposited on glass substrates by thermal evaporation under high vacuum in room temperature using the stoichiometric SnSe charge. Optical microscopy (OM) and scanning electron microscopy (SEM) tools were employed to investigate the surface morphology of the prepared thin films. Systematic energy dispersive analysis by X-rays (EDAX) revealed the homogeneity and even distribution of Sn and Se in the samples. X-ray diffraction (XRD) studies were carried out to probe the atomic structure and quality. The grains were found distributed uniformly, without pinholes and the particle size has been enhanced upon controlled thermodynamic conditions.

Key Words: Tin chalcogenide, Thermal evaporation, Substrate temperature and grain size

INTRODUCTION

Compound semiconductors have gained popularity owing to their unique properties when compared with silicon. A great deal of interest has been focused on semiconducting tin chalcogenide compounds. One such compound is tin selenide (SnSe) from the IV-VI family whose constituents is naturally abundant and can be easily synthesized. Although the material is a competitive semiconductor, the structural, optical and other properties of thermally deposited thin film samples have been comparatively less reported. Thin film deposition requires relatively less amount of source material compared to the growth of bulk crystal. Thermal vapour deposition offers high degree of stoichiometry and purity due to the controlled vacuum conditions.

MATERIALS AND METHODS

Thin film technology, due to its versatility has become the core of semiconductor industries and is widely used in practice. Due to high uniformity obtained in the process, physical vapour deposition has been employed to deposit the material on the substrate [1-2]. Tin selenide has been selected in the present study due to its low cost, chemical stability and non hazardous nature coupled with excellent absorption characteristics [3-4]. Growth of stoichiometric SnSe ingot was undertaken in a constant temperature furnace attached with the help of a rotation mechanism. The high pure Sn and Se elements were filled in the designed quartz ampoule according to the desired chemical composition of the compound, SnSe. The ampoule was sealed under high vacuum using rotary

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ISSN: 2231-2196 (Print) **ISSN:** 0975-5241 (Online)
Received: 24.07.2018 **Revised:** 28.08.2018 **Accepted:** 15.10.2018

and diffusion pumps and periodically heated to stabilize the temperature, 880 °C for 48 h. The obtained charge was powdered and introduced in to the molybdenum boat for deposition. Substrate temperature was adjusted precisely with the help of analog and digital arrangements. After loading the glass substrate in the deposition chamber (Hind high vacuum coating unit, model: 12A4D), the distance of separation between source and substrate was adjusted to 15 cm. During the deposition, the rate of evaporation and thickness of the film were measured with help of quartz crystal. The applied current to the molybdenum boat was relatively adjusted to achieve high directionality, stoichiometry and purity of the films. Thin films of SnSe were deposited at various temperatures. The obtained thin film samples were subjected to microscopy (Optical and SEM), EDAX and XRD analysis for further investigation on the structure and properties of tin selenide thin films.

RESULTS AND DISCUSSION

Figure 1(a) depicts the X-ray diffraction pattern of as-deposited SnSe thin films at room temperature (27 °C), which revealed that the film is amorphous nature as per the literature [5]. The temperature of the substrate was varied from 27-250 °C, in order to enhance the periodicity into long range atomic arrangement. The films deposited at a substrate temperature, 250 °C showed peaks emerged only from the SnSe phase. Figure 1(b) justifies the absence of peaks corresponding to any other phases. Thus, the deposition at 250 °C was found to be optimum for achieving crystallization. Diffraction peaks representing (111), (311) and (411) planes substantiate the progress in crystallinity.

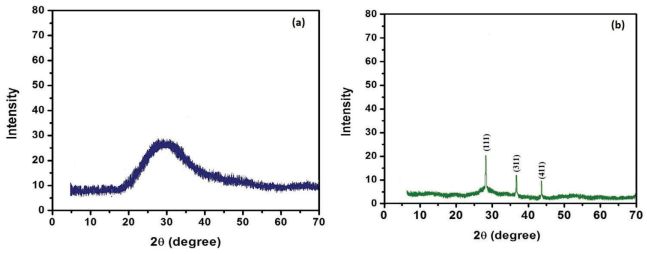

Figure 1: XRD profiles of SnSe thin films deposited at (a) room temperature and (b) 250 °C.

Compositional analysis of the SnSe thin films revealed uniform elemental spread throughout the surface. Figure 2 shows the typical EDAX profile of SnSe thin films deposited at 250 °C, which exhibits sharp peaks of Sn and Se devoid of impurity elements. Elemental atomic ratio of Sn:Se (49.93:50.07 at.%) was maintained close to the ideal stoichiometry (50:50) of SnSe [6].

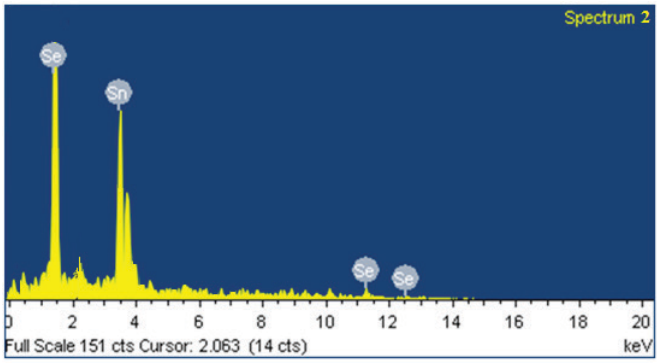

Figure 2: EDAX profile of SnSe thin film deposited at 250 °C.

Figure 3(a & b) shows SEM micrograph of SnSe thin films deposited at two different substrate temperatures, 27 °C and 250 °C, respectively. SEM images revealed the growth of uniformly oriented crystallites at room temperature and uniformly distributed worm-like grains at higher substrate temperature (250 °C). From the images, it is clearly evident that the grain size is enhanced with substrate temperature. The formation of bigger grains is due to coalescence of smaller grains.

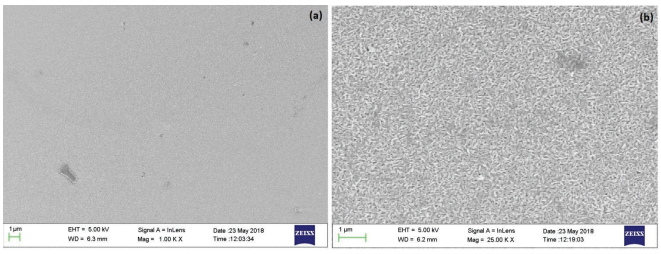

Figure 3: SEM images of SnSe thin films deposited at (a) 27 °C and (b) 250 °C.

CONCLUSIONS

Tin monoselenide thin films, free of pinholes, were grown by thermal evaporation technique at different substrate temperature on pre-cleaned glass substrates. Crystallinity and grain size was progressed significantly with increase in substrate temperature. Increment in surface roughness is marginal as evident from the X-ray diffractogram and SEM images. The films deposited at 250 °C were found to be highly crystalline and stoichiometric, as it showed only SnSe phase.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the Management of CHRIST (Deemed to be University), Bengaluru and Dr D N S Kumar, Associate Director, Centre for Research for the financial support and encouragement. The researchers are also thankful to Center for Nanoscience and Engineering, Indian Institute of Science, Bengaluru and Cochin Univer-

sity of Science and Technology, Kochi for the timely help to perform characterization of the samples.

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