Electrodeposition Of Semiconducting Bi_2Se_3 Thin Films And Characterization

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Abstract

Thin films of Bi_2Se_3 have been electrodeposited from an aqueous acidic bath at room temperature. The electrodeposition potentials for different bath compositions and concentrations of solution are estimated from the polarization curves. It has been found that $Bi(No_3)_3 \cdot 5H_2O$ and SeO_2 in the volumetric proportion as 7:3 and their equimolar solutions of 0.025 M form good quality films. As-deposited Bi_2Se_3 thin films are characterized by scanning electron microscopy, X-ray diffraction, optical transmittance and reflectance techniques. Studies reveal that as-deposited thin films are continuous and polycrystalline in nature.

Keyword : Electrodeposition, Thin films , $\mathbf{Bi_2Se_3}$

INTRODUCTION

The thin film technology is the basis of outstanding developments in solid state electronics. The studies on thin film formation are being pursued with increasing interest on it proven and potential applications in various fields. Over the last two decades, many experimental data have been gathered on electrical, optical and thermoelectric properties of group V – VI binary compounds [1], owing to their applications such as precise temperature control of laser diodes [2], electromechanical devices [3] and thermoelectric devices [4 – 6]. Bismuth and antimony based semiconductors are commonly used for thermoelectric devices such as thermoelectric generators and coolers [7] and for optical storage system.

The thin films can be prepared either by physical or chemical methods. Among these methods, an electrodeposition method is a simple and inexpensive for the preparation of thin films. The growth rate can be easily controlled through electrical quantities such as current density and deposition potential. In the present investigation, we report the electrodeposition of Bi_2Se_3 thin films from aqueous acidic bath on the stainless steel and fluorine doped tin oxide (FTO) coated glass substrates. The films have been studied for their structural and optical properties.

1. EXPERIMENTAL

1.1 Preparation Of Thin Films

Bismuth selenide (Bi_2Se_3) thin films were deposited on stainless steel and fluorine doped tin oxide (FTO) coated glass substrates [area 4x2 cm^2] by an electrodeposition method. The stainless steel substrates were mirror polished by zero number polish paper, washed with laboline and double distilled water and finally cleaned in an ultrasonic cleaner. The back of the substrate was covered with an insulating tape. The FTO coated glass substrates were cleaned by diluted HCl and then by double distilled water. The polished graphite plate was used as a counter electrode. A three electrode system was used and the potentials were measured with respect to saturated calomel electrode (SCE). The deposition was carried out at room temperature in a potentiostatic mode of conditions.

$Bi(No_3)_3 \cdot 5H_2O$ was dissolved in concentrated nitric acid and then diluted by double distilled water to a desired normality. Selenium dioxide (SeO_2) was dissolved in double distilled water. The equimolar (0.1M) solutions of $Bi(No_3)_3 \cdot 5H_2O$ and SeO_2 in different volumetric proportions were used as electrolytes for determining the deposition potentials. The electrical and optical studies of the films reveal that a good quality film formation occurs at 7:3 composition of Bi:Se. By keeping the composition fixed the equimolar concentration of the bath of $Bi(No_3)_3 \cdot 5H_2O$ and SeO_2 was varied from 0.005M to 0.01M at the interval of 0.025M. At 0.025M equimolar concentration a good quality film formation occurs. The deposition time and deposition potential are kept constant at 1 h and – 0.09V /SCE respectively.

The Bi_2Se_3 thin films deposited on stainless steel substrates were dark gray in colour, well adherent to the substrates and continuous in appearance.

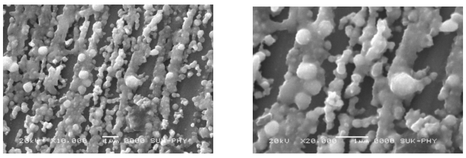
1.2 Characterization

The electrodeposited films were characterized by scanning electron microscopy (SEM) to study the film morphology. The XRD patterns of the as – deposited Bi_2Se_3 thin films for various volumetric proportions and concentrations were investigated using a Philips PW1710 with $C_uK\alpha$ target.The optical measurements were carried out using Spectroscopic Reflectometer, Steller NET INC ·,USA.

2.Results and discussion

The deposition potentials of different compositions of Bi:Se, deposited on stainless steel and FTO coated glass substrates were estimated from the polarization curves. The electrodeposition of Bi_2Se_3 had been carried out from an aqueous acidic bath containing bismuth and selenium ions. The deposition process begins as a result of the application of suitable deposition potential.

The SEM photographs of the as – deposited Bi_2Se_3 thin films at the magnifications 10,000X and 20,000X are as shown in Fig. 1(a) and (b) respectively. The images clearly demonstrate the porous surface morphology with spherical grains. Some overgrowth is observed in the micrographs.



(a) (b)

Figure 1. Scanning electron micrographs of as – deposited Bi_2Se_3 thin film : (a) Magnification 10,000X (b) Magnification 20,000X

The XRD results indicate that Bi_2Se_3 thin film formation is possible at composition and concentration of bismuth nitrate and selenium dioxide to be 7:3 and 0.025M, respectively. The typical XRD pattern of as – deposited Bi_2Se_3 thin film deposited at bath composition (7:3) and bath concentration (0.025M) is shown in Fig.2. The observed and standard values of interplaner distances 'd' are found to be in good agreement[8].

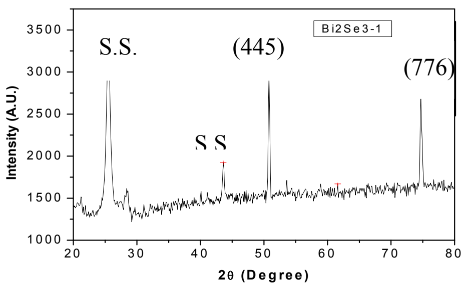
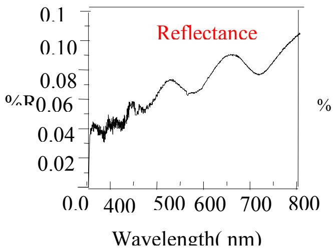


Figure 2. XRD pattern of as – deposited Bi_2Se_3 thin film deposited onto stainless steel (S.S.) substrate.

The planes (445) and (776) appear with maximum intensities. There is less probability of impurity compound deposition because in the electrodeposition, the deposition of a particular compound takes place at a specific deposition potential [9, 10].

The reflectance spectrum of as-deposited Bi_2Se_3 thin film is shown in Fig.3. It is seen that films have well developed interference pattern confirming specular to great extent. Observed average reflectance in the visible region is about 4-10%.

Fig.4 shows the transmittance spectrum of as-deposited Bi_2Se_3 thin film. Average transparency in the visible region is about 50%.



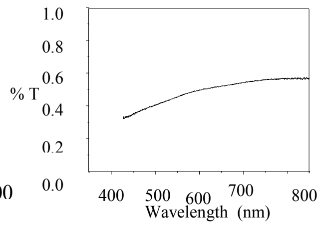


Figure 3. Optical reflectance of as -deposited Bi_2Se_3 thin film.

Figure 4. Optical transmittance of as – deposited Bi_2Se_3 thin film.

Conclusions

A good quality Bi_2Se_3 thin film deposition is possible using the electrodeposition method. The films are polycrystalline. Average reflectance and transmittance in the visible region are about 4-10% and 50% respectively.

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