ELECTRICAL AND PHOTOCONDUCTIVITY STUDIES ON AgSbSe$_2$ THIN FILMS

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Abstract. Silver antimony selenide thin films have been deposited on ultrasonically cleaned glass substrate at a vacuum of $10^{-5}$ torr using reactive evaporation technique. The preparative parameters like substrate temperature and incident fluxes have been properly controlled in order to get highly reproducible compound films. The polycrystalline nature of the sample is confirmed using XRD. The dependence of the electrical conductivity on the temperature has also been studied. The prepared AgSbSe$_2$ samples show p-type conductivity. The samples show a little photoresponse.

1. INTRODUCTION

The investigations on I-III-VI chalcopyrites have been done extensively because of their strong absorbing properties that make these materials good for photovoltaic applications [1]. The compound silver antimony selenide thin film exists in two phases: cubic AgSbSe$_2$ and orthorhombic Ag$_5$SbSe$_4$. Garza et al [2] prepared AgSbSe$_2$ thin films by heating sequentially deposited Sb$_2$S$_3$, Ag$_2$Se and Ag thin films in close contact with Se thin film. In this work, using the reactive evaporation technique AgSbSe$_2$ thin films have been deposited successfully by optimizing the deposition parameters such as impingement rates and substrate temperature. The as-deposited samples are structurally and electrically characterized.

2. EXPERIMENTAL DETAILS

Silver antimony selenide thin films were deposited onto ultrasonically cleaned glass substrates using 12” vacuum coating unit. For the preparation of ternary AgSbSe$_2$, two separate glass crucibles kept in molybdenum baskets were used as sources for the evaporation of 99.999% pure elemental Sb and Se. A molybdenum boat was used for the evaporation of 99.999% pure elemental Ag. The impingement rate of the elements and the deposition temperature used for the preparation of stoichiometric silver antimony selenide thin film was given below [3].
Impingement rate of Silver $\approx 3 \times 10^{15}$ atoms cm$^{-2}$ s$^{-1}$
Impingement rate of Antimony $\approx 2 \times 10^{15}$ atoms cm$^{-2}$ s$^{-1}$
Impingement rate of Selenium $\approx 1 \times 10^{14}$ atoms cm$^{-2}$ s$^{-1}$
Substrate temperature $= 398 \pm 5$K

3. RESULT AND DISCUSSION

3.1. Structural analysis

In order to see the structural properties, the X-ray diffraction pattern was taken using Rigaku D-Max diffractometer. Figure 1 shows XRD pattern of a typical AgSbSe$_2$ thin film. The indexing of the pattern was done with the standard ASTM card no.12-379 [4].

![X-ray diffraction pattern](image)

Figure 1. X-ray diffraction of as prepared AgSbSe$_2$ thin film.

The peaks at 2$\theta$=31.15, 44.45, 64.7 and the corresponding planes (200), (220) (400) indicates the films are polycrystalline in nature. The most reported structure is FCC. The average particle size was calculated using the Debye Scherrer’s equation [5]:

$$D = \frac{0.9 \lambda}{\beta \cos \theta}$$

where $\lambda$ is the wavelength of X-ray used, $\beta$ the full width at half maximum in radian, and $\theta$ the glancing angle in degree. The average particle size calculated using above equation is 22nm. The lattice constant calculated is 5.74Å.

The dislocation density ($\rho$) is calculated using the relation [6]:

$$\rho = \frac{1}{D^2}$$

and it is $2.066 \times 10^{15}$ lines/m$^2$.

The number of crystallite per unit area ($N$) calculated as $3.757 \times 10^{15}$ m$^{-2}$ using the relation [6]:

$$N = \frac{t}{D^3}$$

where $t$ is the thickness of the film.

3.2. Electrical studies

With regards to electrical properties, variations in the conductivity with respect to temperature were studied inside a conductivity cell at a vacuum of $10^{-2}$ torr. It is shown in figure 2 for three continuous cycles. From the figure it is clear that the film is stabilized after under first heating and cooling. The monotonous increase of current with increasing temperature exhibits the semiconducting nature. All the AgSbSe$_2$ samples showed p-type conductivity. The activation energy calculated is 0.08eV. Patel et al [7] studied growth and electrical characterization of AgSbSe$_2$ thin films. They reported the activation energy as 0.45eV in the high temperature region and 0.091eV in the low temperature region respectively.
Figure 2. Variation of ln(I) vs inverse of temperature for AgSbSe$_2$ films

Figure 3. The photoconductivity response of a typical AgSbSe$_2$ with time.

Figure 3 shows the photoconductivity response of a typical AgSbSe$_2$ thin film. The sample is exposed to white light from tungsten halogen lamp of power 100W. At illumination the photocurrent rises gradually with time and attains constant value. It falls down gradually when the illumination is cut off. The AgSbSe$_2$ samples prepared using the reactive evaporation technique showed a little photoresponse and can be used as absorber layer in solar cell [8].

4. CONCLUSION

Silver antimony selenide thin films are successfully deposited on glass substrates using reactive evaporation technique. The deposited thin films are structurally characterized by XRD. The average particle sizes, lattice constant, dislocation density and number of crystallite per unit area are calculated. The activation energy calculated is 0.08eV. AgSbSe$_2$ samples show p-type conductivity and all the samples shown a little photoconductivity.

ACKNOWLEDGEMENT

One of the authors (TNA) would like to thank University Grants Commission for the financial assistance in the form of Research Fellowship in Science for Meritorious Students (RFSMS). Second author (KSU) would like to thank Cochin University of Science and Technology for the financial assistance in the form of Research Fellowship.

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