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ANNEALED TIN SELENIDE (SnSe) THIN FILM MATERIAL FOR SOLAR CELL APPLICATION

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The main theme of this work is the synthesis and characterization of SnSe thin film for photovoltaic application. 2-micron Tin Selenide thin film is deposited on clean glass substrate (4cm×4cm) by thermal evaporation technique. The sample is annealed for one hour at a temperature of 350°C· Optical characterization is achieved for the calculation of transmittance, reflection, reflection and absorbance. 1.2 eV band gap is calculated which confirmed the semiconductor nature of thin film. Relatively high resistance (5MΩ) of the sample is calculated using I-V characteristics.

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1. Introduction

The burning and critical issue of all the developed countries is the depletion of energy resources. In the last ten years the energy crises have very badly affected the social and economic life of these countries. Using the idea that if only 10% of the solar radiation is utilized, the energy needs of the whole world will be fulfilled. It is noted that most of the light received from sun is in the range of visible wavelength range and we need to explore such a material which must be useful in converting visible light into electrical energy. The absorption capability of the cell can also be increased by using non-reflective coatings such as textured surfaces and downconversion layers which may split shorter wavelength into visible spectrum that may increase the efficiency. The material for solar cell needs to be cheap and nontoxic[1].

The thin films of compound semiconductors have contributed in photovoltaics for decades. The major developments in thin film solar cell have been driven by the production of cheap photovoltaic modules. The contribution of selenium (Se) based compounds played a major role in terms of $CuIn_xGa_{1-x}Se_2$ (CIGSe) [2], $CuInSe_2$ (CISe) [7] and $Cu_2ZnSnSe_4$ (CZTSe) [3]. The easy fabrication techniques, cheap, highly efficient and stable compound of Se have also been used in other semiconductor fields such as thermoelectric materials and LED.

In these days the technology of conversion of solar energy into electrical energy are not sufficient as the use of elemental semiconductor like silicon in photovoltaics required a large amount of Si and the extraction of silicon is a difficult task. Therefore, compound semiconductors play an important role in such conversion. Different compound semiconductors are already in market for commercial purpose e.g. CdTe, ZnTe, CZTS, CZTSe, etc[2-5]. And all they have some problem either of toxicity or low efficiency. The researchers are efficiently involved in discovering a material which must be non-toxic, cheap and efficient in conversion. Tin selenide (SnSe) is one of the promising and new materials in the field of photovoltaics. SnSe is also used in nonlinear optical devices, flat panel displays, light emitting diodes, lasers, logic gates, transistors, etc. Beside

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these uses, its applications in photovoltaics are tremendous. SnSe has very low thermal conductivity, high thermal transport properties, outstanding electrical properties and high power factor [6].

SnSe is reported to have high chemical stability, suitable and tunable band gap, high absorption coefficient and p-type conductivity [7]. These properties are required for an efficient absorber layer in thin film photovoltaics. Different methods are reported for the fabrication techniques and thermal evaporation is found to be a versatile technique. In the current work, we used thermal evaporation technique for the deposition of SnSe thin films on clean glass substrate followed by annealing at 350°C.

2. Experimental

SnSe thin films were deposited from Sn granules and Se powder having 99.99% purity via dual evaporation technique on clean glass soda lime glass [8]. In thermal evaporation technique, material is heated at a very high temperature in order to increase its vapor pressure. The vapor of material finally condensed on the surface of substrate which form a thin film on it. Thermal evaporation process i.e. the evaporation of basis materials occurs in the empty chamber below 10^{-4}mbar. After fabrication, the thin film is annealed at 350°C for 1 hour in vacuum inside tube furnace.In order to characterize a sample, XRD is used for structural characterization; UV-visible spectroscopy is used to measure the optical properties of SnSe. From optical properties absorption, transmission, and reflection, is measured. For I-V characteristics, four probe techniques are used.

3. Results and discussions

XRD analysis of the as deposited SnSe thin film as well as annealed at 350°C is shown in Fig. 1. The main diffraction peak is matching with standard and it is found that peaks at 33.7° (111) and 44° (411) corresponds to JCPDS 01-089-0233 with orthorhombic structure. The particle size was calculated using Debye Scherer formula and the average particle size of 70nm was obtained. The figure shows that the diffraction peaks get sharper at higher annealing temperature. The large particle size is an indication for better absorbing solar cell material.

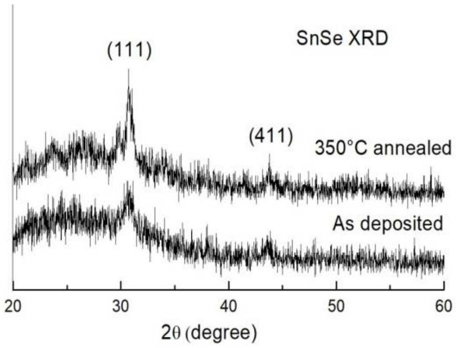

Fig. 1. XRD analysis of SnSe thin film.

The transmittance spectrum for SnSe is shown in Fig. 2. The graph shows that the transmittance is very low in the visible region even for the as deposited sample. However, the transmittance of the annealed sample is zero in the visible range. The edge of the transmission spectra for the annealed sample is 800nm. It means that every photon laying in the visible part of the spectrum is absorbed. This property of SnSe is attributed to the low transmitting layer in solar cell materials.

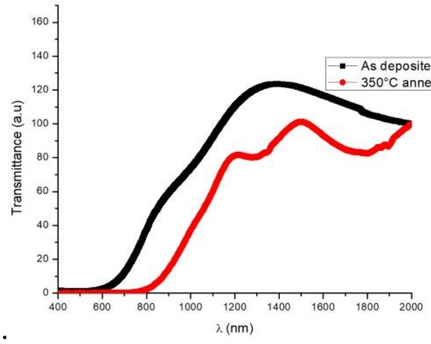

Fig. 2. Transmittance curve for SnSe thin film.

The absorption coefficient of SnSe thin films is calculated from the graph plotted between coefficients α in cm^{-1} and wave length λ in nm. "α" represents the absorption coefficient which is equal to

$$\alpha = 4\pi k/\lambda$$

here "k" the extinction coefficient for the material and λ is the wave length measured in nanometers. From the curve in Fig. 3 it is observed that the material in the form of thin films have maximum absorbance in the visible and near infrared (NIR) region. The absorption coefficient of the annealed SnSe thin film is very high (5×10^4/cm) in the vis-NIR region. The reduction in stacking faults and crystal defects are responsible for such high absorption coefficient. Due to the low band gap of SnSe, the material have high absorption coefficient [9, 10].

This is because of reduction in stacking faults and lattice defects as film thickness increased; thus, an improvement in film crystallinity [12]. High absorption coefficient is achieved when the photon energy is higher than the energy gaps of a semiconductor material.

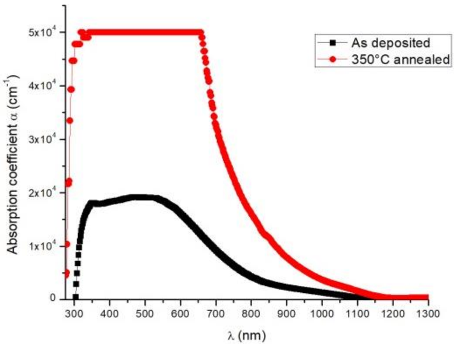

Fig. 3. Spectra for absorption coefficient.

3.1. Band gap Calculation

Band gap of SnSe is calculated by plotting αhν against hν by using the following formula

$$\alpha h\nu = A\,(h\nu - E_g)^n$$

where "α" is the absorption coefficient which are related with energy band gap [11]. "h" is plank's constant and "A" is also a constant. The value of n for direct band gap is ½ and for indirect band gap the value of n is 2 [12].

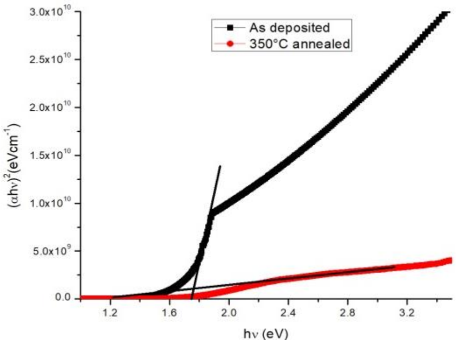

Fig. 4. Band gap calculation curves.

Annealing temperature 350°C is helpful in reducing the band gap due to grain growth and reduction in impurity and increase in the crystalline size. The band gap is calculated by extrapolating the linear part of the curve on horizontal axis as shown in Fig. 4 and a moderate band gap 1.2 eV is calculated for SnSe annealed at 350°C. It has been seen from Fig. 4 that the decrease in the band gap occurred (1.75 eV to 1.2 eV) with annealing temperature which might be due to high crystalline size.

3.2. I-V Characteristics

The current voltage characteristic for the as deposited as annealed film at 350°C is shown in Fig. 5. The graph shows linear relationship between voltage and current. Current increases linearly with increasing voltage. Resistivity of SnSe decreased with annealing temperature and resistivity obtained from the I-V characteristics graph. The electrical conductivity of the film increased at high temperature. When the potential barrier reduces, the grain growth occurs [13-15]. The resistance of the film was calculated from the slope of the curve in Fig. 5. It can be seen from the graph in fig.5 that 5 mega ohm resistance is resulted for the annealed sample.

$$R=\frac{V}{I}=\frac{4}{8\times10^{-7}}=5M\Omega$$

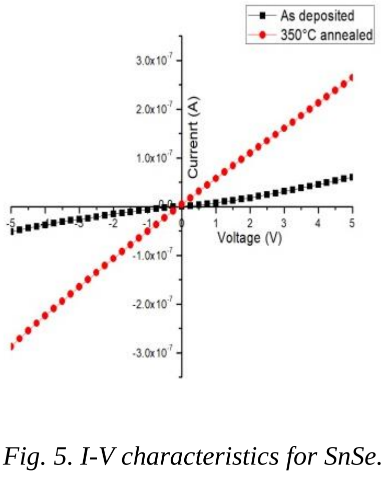

Fig. 5. I-V characteristics for SnSe.

4. Conclusions

The Optoelectronic and structural properties of as deposited and annealed at 350°C tin selenide semiconductor compound is studied for photovoltaic applications. SnSe is prepared by thermal co-evaporation techniques on clean soda lime glass substrate from SnSe powder.

Annealing at moderate temperature extracts the maximum output properties of this semiconductor compound. The absorption coefficient was found to be 5×10^4/cm at the annealing temperature.

The transmittance is very low and all the photons in the visible range are almost absorbed. It is found that the optical property of the semiconductor compound has excellent output properties at 350°C annealing temperature. The band gap and electrical properties are in the range of photovoltaic materials already reported in the literature. The band gap found at this annealing temperature has an optimum value of 1.2 eV.

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