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STUDY OF ANNEALING EFFECTS ON THE ELECTRICAL PROPERTIES OF EVAPORATED SnS THIN FILMS FOR PHOTOVOLTAIC APPLICATIONS

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Tin Sulphide (SnS) thin films have been deposited on glass slides by thermal evaporation using SnS powder. The improvements in the electrical and photovoltaic properties of SnS thin films annealed at different temperatures (200°C, 300°C, and 400°C) in vacuum for one hour are presented in this work. The photoconductivity response was improved with annealing SnS thin films in vacuum. Better photoconductivity response around the band gap was observed for annealed samples. By hot probe conductivity type was found p-type.

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1. Introduction

Tin sulphide (SnS) is an IV-VI binary semiconductor compound. Both constituent elements of this compound, Tin (Sn) and Sulphur (S) exist abundant in nature. SnS in its orthorhombic crystalline structure has direct and indirect band gap values between 1.3–1.5 eV and 1.0–1.1 eV, respectively and has p-type conductivity. It has higher absorption coefficient (~10^5 cm^{-1}) like other photovoltaic materials (GaAs and CdTe etc). These properties make it a better alternative absorber material for thin film solar cell (TFS) applications.

SnS thin films can be deposited using different deposition techniques such as chemical spray paralysis (CSP) [1], vacuum evaporation [2-4], chemical bath deposition (CBD) [5, 6], pulsed electrochemical deposition [7], and RF sputtering [8]. Researchers are interested in understanding and engineering the properties of SnS for TFS applications [1-4, 9]. Better understanding of physical properties such as structural, electrical and optical properties is required to the improve efficiency of TFS devices. In the present work we have studied the effects of annealing temperature on the electrical and photovoltaic properties of SnS thin films deposited by thermal evaporation. Usually post-deposition annealing is used to improve the physical properties. Improvement in the physical properties like structural, optical, electrical and photoconductivity plays a major role in enhancing the device efficiency. We have studied the structural and optical properties of SnS thin films earlier [10]. Our present work is mainly concerned with the study of influence of annealing temperature on photoconductive and electrical properties of SnS thin films deposited by thermal evaporation on non conducting glass substrate.

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2. Experimental

SnS thin films used for study were deposited from powder material via thermal evaporation technique onto non conducting glass substrates held at the chamber ambient temperature in vacuum. Prepared SnS thin films were annealed at different annealing temperatures (Ta) as-deposited, 200°C, 300°C, and 400°C for 1 hour encapsulated in evacuated Pyrex glass ampoules having pressure around 10^{-2} Torr. Deposition and preparation of these SnS thin films is discussed earlier in detail [10]. In order to perform determination of photoconductivity response, current-voltage (*I*-*V*) characteristics and conductivity type measurements, the coplanar circular Molybdenum (Mo) metal contacts were deposited on the front face of the films surfaces by DC magnetron sputtering at the chamber ambient temperature shown in Figure 1. Area of each deposited circular contact was 3.14 mm^2 and separation between two adjacent contacts was 3mm.

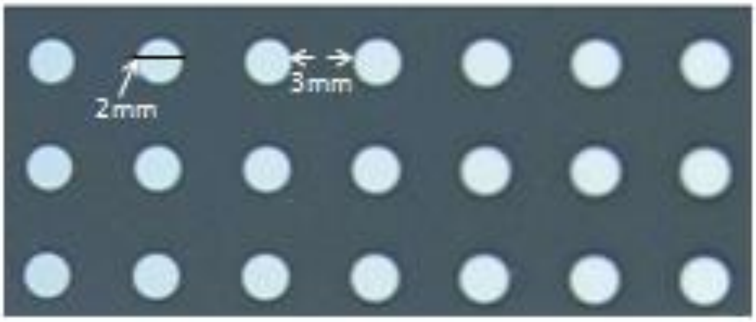

Fig. 1: Molybdenum (Mo) metal contacts on the front face of thin film

3. Characterization

To synthesize and study new photovoltaic materials photoconductivity (PC) is an important characteristic to be determined. Photoconductivity (PC) involves the generation and recombination of charge carriers by incident sun light due to which conductivity of sample changes [11]. The photoconductivity process takes place by photon absorption. A schematic diagram of photoconductivity set up used in the present study is shown in Figure 2.

Typical (*I*-*V*) characteristics of SnS thin films were determined by two-probe technique using tungsten probes. Keithley 4200 semiconductor characterization system was used for the characterization. A box sample holder was used to enable measurements in the dark and these *I*-*V* characteristics were recorded at the room temperature.

For the conductivity type determination of prepared SnS thin films we used hot probe technique. For comparison and reference, we used a standard n-type Si wafer, having a resistivity of 72-98 Ω-cm, which was supplied by the Wacker-Chemitronic GmbH, Germany. One probe was heated and other was kept at room temperature. Obtained response was plotted against the time. Same probe was heated for the samples under study and response was plotted against the time.

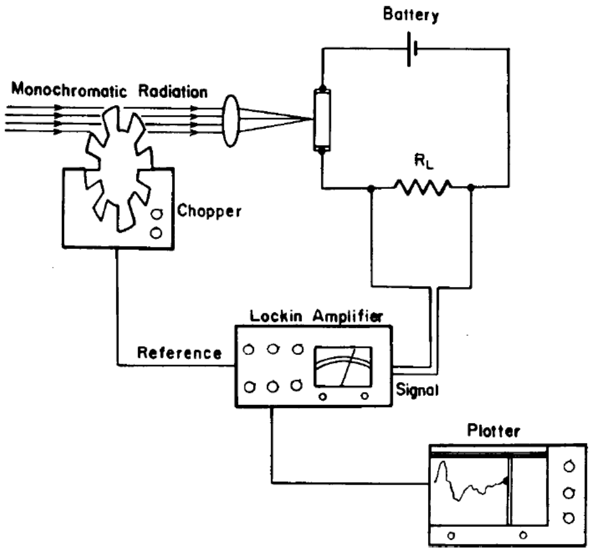

Fig. 2: Schematic diagram of a system for photoconductivity measurement [12]

4. Results and discussion

4.1 Photoconductivity characteristics

During photoconductivity characteristics of SnS thin films spectral response was determined by photoconductivity measurements. These measurements were carried out at room temperature using incident wavelength 300nm-1100nm. Incident photons having energy greater than the band gap of samples will be absorbed and create the free electrons and holes in the conduction and valance bands respectively. The generation of these charge carriers is responsible of photoconductive response. As-deposited samples showed very poor photoconductive response. The photoconductive response was improved after annealing these samples and these annealed samples posses more photosensitivity. The spectral response showed a peak corresponding to band gap shown in Figure 3. This improvement in response may be due to improvement in crystal structure as discussed earlier in [10].

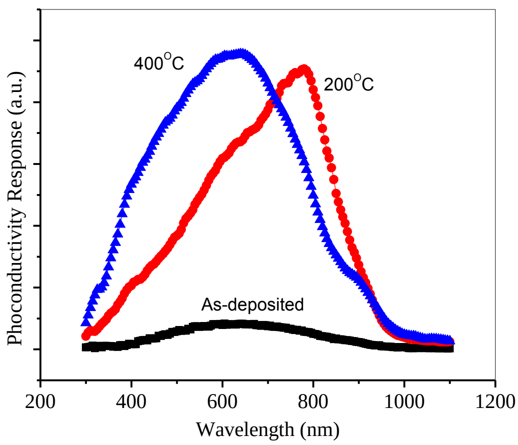

Fig. 3: Photoconductive response of SnS thin films

4.2 *I-V* characteristics

The electrical properties of thin films for photovoltaic applications are important. The *I-V* characteristics of SnS thin film samples deposited on non conducting glass slides were determined for Mo contacts by the 'DC' two probe method. These *I-V* characteristics were examined within the applied voltage -5 to +5V and found to be ohmic. The annealing temperature dependence of the *I-V* characteristics of as-deposited and annealed SnS thin films is shown in Fig. 4.

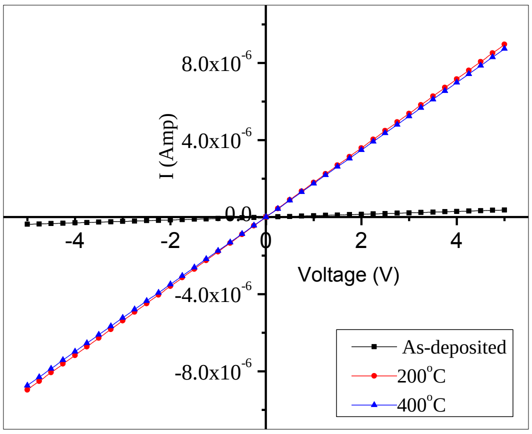

Fig. 4: I-V characteristics of SnS thin film samples

From these plots the observed electrical resistivity of SnS thin films was decreased for the as-deposited to the annealed samples. In general, the resistivity of thin films depends on film thickness, composition and/or crystallite size. Here, the film thickness and composition is constant but the change in crystallite size was obtained from 21 nm – 29 nm on annealing [10]. The decrease in resistivity with the increase in *T*a may be due to increase in crystallite size.

4.3 Conductivity type

The conductivity type of SnS thin films was investigated by hot probe method by observing the potential difference between a hot and cold contact. For comparison and reference, we used a n-type Si substrate/wafer. Keeping one probe hot compare to the other of a voltmeter, thermal gradient generated current in the wafer and the electron current in n-type Si wafer produced a potential [13]. If samples have the same direction of potential, the conductivity will be n-type and the corresponding reasoning leads to the opposite potential for p-type conductivity as shown in Figure 5. For present SnS thin film samples we obtained response of potential difference in opposite direction which confirmed the conductivity type as p-type for these samples under test.

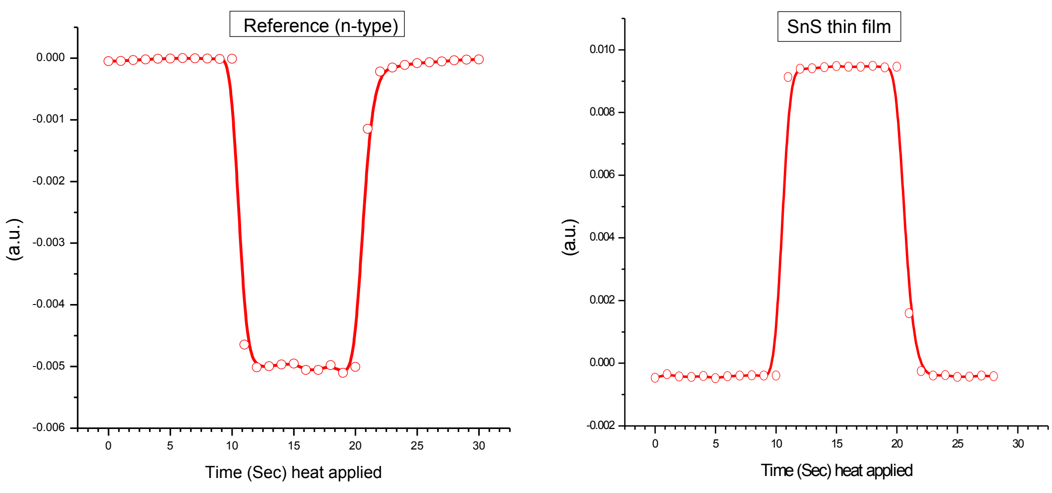

Fig. 5: Conductivity type determination of SnS thin films

5. Conclusions

In this paper we have reported the influence of annealing temperature on photoconductivity and electrical properties of SnS thin films deposited on non conducting; prepared by thermal evaporation and annealed at various temperatures range as-deposited, 200°C, 300°C and 400°C in vacuum environment by encapsulating in Pyrex glass ampoules. Photoconductivity studies showed an improvement in photoconductivity response of SnS thin films on annealing. All prepared SnS thin film samples showed p-type conductivity. On the basis of these results, it can be accepted that SnS thin layers absorb much of the radiation and that they are adequate to be used as an absorber layer in thin film solar cells.

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References

[1] T.H. Sajeesh, A.S. Cherian, C.S. Kartha, K.P. Vijayakumar, Energy Procedia**, 15,** 325 (2012).
[2] O.E. Ogah, K.R. Reddy, G. Zoppi, I. Forbes and R.W. Miles, Thin Solid Films, **519,** 7425 (2011).
[3] P.A. Nwofe, K.T. Ramakrishna Reddy, G. Sreedevi, J.K. Tan, I. Forbes, R.W. Miles, Energy Procedia, **15,** 354 (2012).
[4] P.A. Nwofe, K.T. Ramakrishna Reddy, J.K. Tan, I. Forbes, R.W. Miles, Physics Procedia, **25,** 150 (2012).
[5] C. Gao, H. Shen, Thin Solid Films, **520,** 3523 (2012).
[6] E. Guneri, C. Ulutas, F. Kirmizigul, G. Altindemir, F. Gode, C. Gumus, Applied Surface Science, **257,** 1189 (2010).
[7] M. Gunasekaran and M. Ichimura, Solar Energy Materials & Solar Cells, **91,** 774 (2007).
[8] K. Hartman , J.L. Johnson , M.I. Bertoni , D. Recht , M.J. Aziz, M.A. Scarpulla, T. Buonassisi, “SnS thin-films by RF sputtering at room temperature”, Thin Solid Films, **519,** 7421 (2011).
[9] T.H. Sajeesh, K.B. Jinesh, M. Rao, C.S. Kartha, K.P. Vijayakumar, Phys. Status Solidi A, **209**(7), 1274 (2012).
[10] G.H. Tariq, K. Hutchings, Ghulam Asghar, D.W. Lane, M. Anis-ur-Rehman, J. of Ovonic Res., **10**(6), 247 (2014).
[11] T.S. Moss, “Photoconductivity in the Elements”, Academic Press, London, 1952
[12] V.A. Stoica, “Optical characterization of compound semiconductors using photoconductivity and photoreflectance”, MS Thesis, Morgantown, West Virginia, 2000
[13] S. Prabahar, M. Dhanam, Journal of Crystal Growth, **285,** 41 (2005).