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Study of Light Induced Defects in Thin Films of Se-Sb-Ag Glassy System

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Abstract

A well known space charge analysis is employed for the analysis of defect density at various light illumination time and quantitatively found light induced defects in a-$Se_{90}Sb_6Ag_4$ thin films. The outcomes show that density of defect states (DOS) raises with illumination time. A suitable explanation is given for light induced defects creation in this sample.

Keywords: Light induced defects; thin films; Fermi level; density of defect state

1. Introduction

The amorphous chalcogenide materials are suitable candidates for high field conduction studies due to low conductivity and negligible small joule heating [1-4]. Last few decades, various research groups motivated towards the electrical properties of these materials and interpreted their experimental results on the basis of heating effects, Poole-Frankel effect and Space Charge Limited Conduction (SCLC) [3,4]. For photoconductive and photovoltaic applications, there is requirement of materials of less defect density, for estimation of defect density quantitatively, SCLC technique is one of most important analysis due to insufficient knowledge of electronic structures of chalcogenide materials and less experimental limitations [2,4].

The study of addition of Ag in Se-Sb binary system is very interesting in research point of view. The Ag doped amorphous chalcogenide materials have numerous potential applications [5-7] in optoelectronic, basic science point of views, cell based device applications, optical components, optical memories, microlenses, waveguides, electrochemical and natural sensors, solid electrolytes and batteries etc. [8-10]. Numerous past studies have demonstrated that Ag-based amorphous chalcogenide materials indicate most prominent applications in optoelectronic and assortment of photoinduced impacts are seen in these technological important materials [11-13].

To obtain DOS in amorphous chalcogenide materials, various techniques have been pre-owned which have completely precedence and their respective confinements. As a result of the trouble in manifestation of p-n junction, spectroscopical techniques couldn't be utilized for DOS estimation in these materials. Space charge limited conduction (SCLC) technique [14, 15] has been generally utilized for quantitatively experimentally estimations of DOS.

In perspective of above mentioned, this study announces the quantitative estimation of light induced defects (LID) in thin films of a-$Se_{90}Sb_6Ag_4$ by using SCLC analysis. Thus for this reason, white light of intensity 1500 lux exposed to the above mentioned thin films from 0 to 6 hours. The DOS increment with exposure time demonstrates that additional defects are made as increment of light illumination time. Section 2 depicts the experimental points of interest. The outcomes are mentioned and discussed in section 3. Last section explains the conclusions of this research work.

2. Experimental Methods

Glassy alloy of $Se_{90}Sb_6Ag_4$ was prepared by well known quenching approach. The best possible measure of every material is weighted as per their atomic percentages and kept into ultra-cleaned quartz ampoules containing the vacuum of 10^{-5} Torr, for avoiding the oxidation of these materials. The filled ampoule was put in furnace and the temperature increasing rate of 3-4 K/min. up to a maximum temperature 900°C, for almost 16 hrs with persistent rocking to the guarantee of homogeneous melt. The ampoule containing identical melt was then passed

through in ice-cooled water for quenching. This sample was expelled from the respective ampoules by shattering. The amorphous character of quenched sample was affirmed by the X-ray diffraction pattern.

Vacuum evaporation technique with appropriate experimental setup was used for deposition of indium electrodes & thin films of $Se_{90}Sb_6Ag_4$ sample. The vacuum evaporated thin films were placed in deposition chamber for 24 hrs [16].

For the measurements of SCLC, the thin films of $Se_{90}Sb_6Ag_4$ were arranged in a uniquely composed high temperature metallic sample holder containing vacuum of 10^{-3} Torr. First annealed for one hour then I-V characteristics under d. c. voltage (0-440V) at various fixed temperatures (300K - 450K) were studied for all thin films of above mentioned sample. For exposure of white light, sample holder containing transparent window was used.

3. Results and Related Discussions

I-V properties are investigated with respected to temperatures in thin films of $Se_{90}Sb_6Ag_4$ prior and after prolonged illumination of white light as shown in Fig. 1(a-d). An Ohmic and superohmic conduction are observed at low electric fields ($E < 10^3$ V/cm) and high electric fields ($E \sim 10^4$ V/cm) respectively. In high field conduction region, ln I/V versus V curves are plotted and observed like straight lines prior and after prolonged illumination of white light as appeared in Fig. 2 (a-d) for a-$Se_{90}Sb_6Ag_4$. This figure demonstrates that the slopes S of ln I/V versus V curves are such that temperature dependent curves.

At small voltage the infused density of charge carriers is lower than the density of thermally generated charge carriers which prompts the ohmic conduction. At giant voltages, infused charge carrier thickness prevails and the conduction in view of this region might be overwhelmed by a trap limited SCLC technique. Lampert and Mark [17] demonstrated the SCLC mechanism, on account of a uniform distribution of localized states of density g_0, the current (I) at specific voltage (V) is written by:

$$I = (2\ e\ A\ \mu\ n_0\ V/\ d)\quad [\exp\ (SV)] \qquad (1)$$

S is also given by:

$$S = 2\ \varepsilon_r\ \varepsilon_0\ /\ e\ g_0\ k\ T\ d^2 \qquad (2)$$

Here symbols used in eqs. (1) & (2) have their usual meanings as per above mentioned communication [17].

By. eqs. (1) and (2), ln I/V versus V curves should be straight lines and the slope S of these curves diminish with rise in temperature. The estimations of these slopes, in the current manifestation, are plotted as temperature function prior and then afterward prolonged illumination of white light in Fig. 3(a-d) for a-$Se_{90}Sb_6Ag_4$. It is intelligible from this figure that the slope (S) of ln I/V versus V curves is reversed relative to the temperature of present sample. The particular outcomes show the existence of SCLC in all these samples.

Thin films of the given accommodate a giant defects states that offer ascent to extensive numeral of localized defect states. These giant localized defect states worked as carrier trappers and behind trapping the inoculated charge from electrodes, they get to be charged and accordingly anticipated that would develop a space charge. These developments of space charge then assume the crucial part in the resolution of SCLC mechanism.

DOS are calculated quantitatively from the slope of S versus 1/T plots. Here, the relative dielectric constant (ε_r) is taken for calculation 70 for the present sample. The calculated values of DOS at various illumination times are given in Tables 1 and plotted in Fig. 4 as a function of illumination time for thin films of a-$Se_{90}Sb_6Ag_4$. It is intelligible from the present figures that the DOS (g_0) raises with the rise of time white light illumination.

The results are explained as, on long illumination of band gap light, Staebler-Wronski showed that hydrogenated amorphous silicon debases upon light absorbing and passes to a metastable state [18] which was described because on the basis of formation of light induced metastable defects states in such type of specific materials. Biegelsen and Street [19] have detected light induced ESR signal, extrinsic absorption below the band gap energy and non radiative recombination in amorphous materials and clarified these outcomes in terms of the creation of giant DOS.

Shimakawa and coworkers [20, 21] have detected time dependent decreasing photocurrent during illumination of light in thin film of amorphous chalcogenide materials and clarified these specific outcomes in respect of light induced metastable defects. A model has been suggested by Shimakawa et al. [21] and Elliott and Shimakawa [22] for light induced metastable defects in these material, self trapped exciton played an important role for light induced metastable defects creation in the form of an intimate valence alternation pairs (IPs), that are stout at little temperatures i.e. below 200 K temperatures. As per research of Biegelsen and Street [19], light induced ESR can be identified with above mentioned IPs and these experimental outcomes are completely removed by annealing at 300 K. Shimakawa and coworkers[21] further researched that defect conserved bond switching mechanism inflated by white light exposure prompts defect relocation and partition deriving into the formation of metastable fine disunited charge defects (random pairs), which are just evacuated by annealing phenomena bordering the temperature of glass transition state. These researchers clarified their outcomes in terms of random pairs and responsible for dominate photoconductivity in amorphous chalcogenide material as a recombination centers and the number of traps intricate in photocurrent kinetics phenomena may be the number of random pairs. For our case, it has been found that increment in density of defects on light illumination at room temperature and basically these defects may play as traps and consequently influences the current of space charge. The light induced defects of the present sample of Se-Sb-Ag can be random pairs as recommended by Shimakawa and coworkers [20].

Illumination time (hrs)	Slope of S vs. 1/T curves	g_o (eV^{-1} cm^{-3}) x10^{14}
0	2.083	2.23
2	1.688	2.75
4	1.372	3.38
6	1.230	3.77

4. Conclusions

Light induced defects have studied by well known SCLC analysis in present Ag doped Se-Sb samples. A microscopic model suggested by Shimakawa and collaborators have been used to explain the formation of light induced metastable defects due to prolonged illumination of white light.

Table 1. g_o in thin films of $Se_{90}Sb_6Ag_4$ glassy alloy before and after prolonged illumination of white light

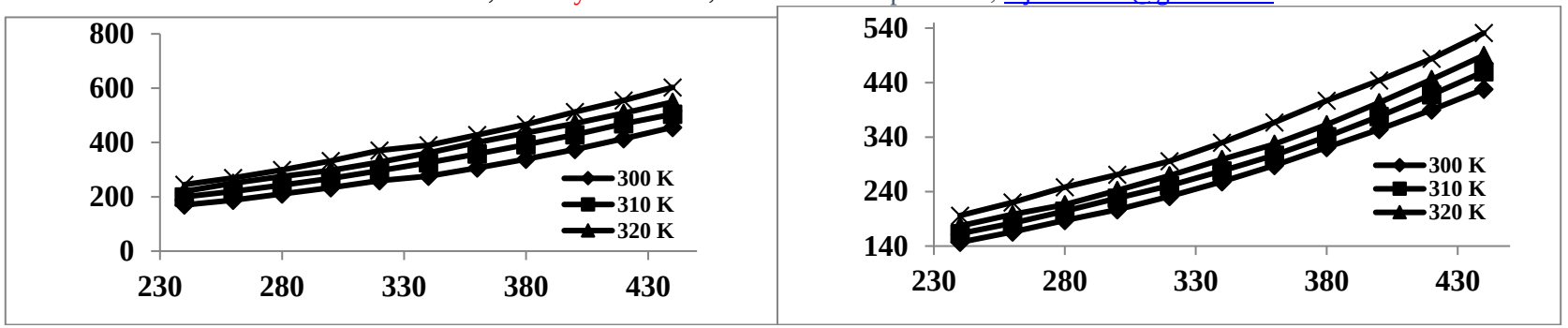

Fig. 1. I vs. V in thin-films of a-$Se_{90}Sb_6Ag_4$ before and after illumination of white light at (a) 0 hour, (b) 2 hours, (c) 4 hours, (d) 6 hours

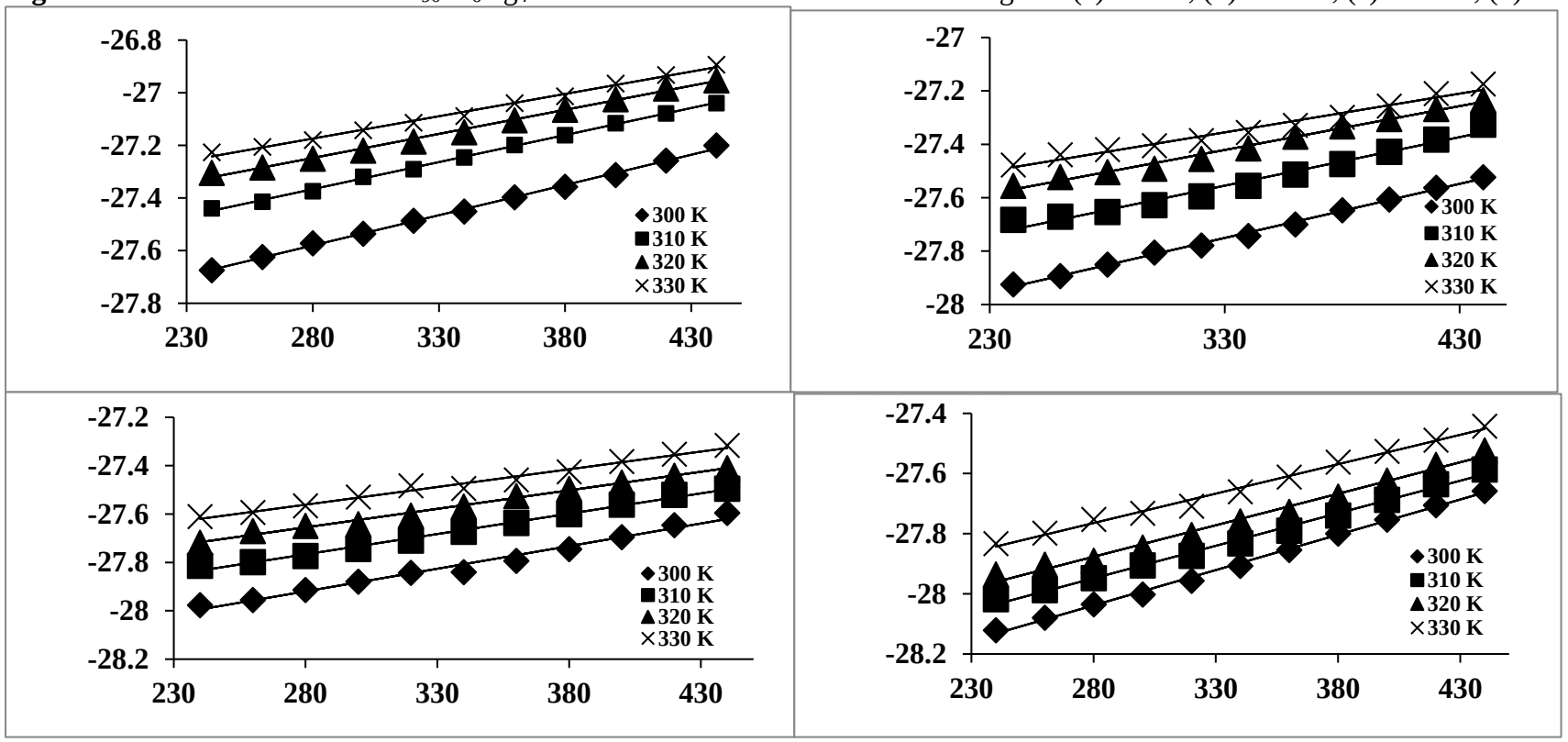

Fig. 2. ln (I / V) vs. V in thin-films of a-$Se_{90}Sb_6Ag_4$ before and after illumination of white light at (a) 0 hour, (b) 2 hours, (c) 4 hours, (d) 6 hours.

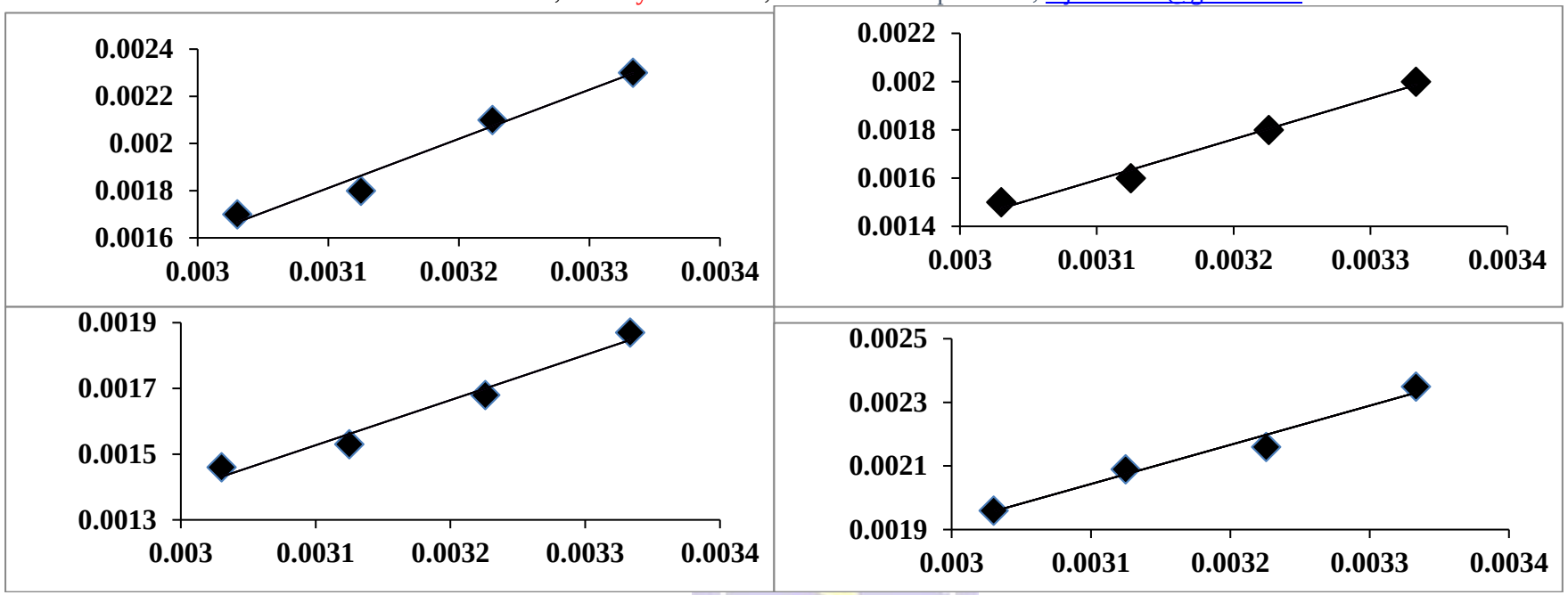

Fig. 3. Slope (S) vs. 1/T in thin-films of a-$Se_{90}Sb_6Ag_4$ before and after prolonged illumination of white light at (a) 0 hour, (b) 2 hours, (c) 4 hours, (d) 6 hours.

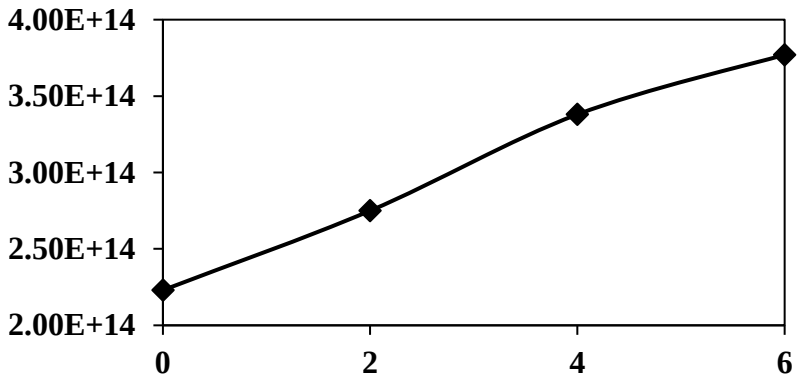

Fig. 4. Variation of g_o with illumination time in thin-films of $Se_{90}Sb_6Ag_4$.

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