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Investigations on the photoconductivity studies of ZnSe, ZnS and PbS thin films

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Zinc selenide (ZnSe), zinc sulphide (ZnS) and lead sulphide (PbS) thin films were prepared by chemical bath deposition (CBD) method. In this paper we report results on the photoconductivity behaviour of ZnSe, ZnS and PbS thin films. Photoconductivity measurements were carried out at room temperature by connecting it in series with a picoammeter (Keithley 480) and a dc power supply. Photoconductivity processes may be the most suitable technique for obtaining information about the states in the gap. The thin films showed a significance rise in photocurrent over dark current. The photoconductive studies reveal the positive photoconductive nature of the thin films. Photoconduction includes generation and recombination of carriers and their transport to the electrodes.

Key words: Thin films, photoconductivity, ZnSe, ZnS, PbS.

INTRODUCTION

Semiconducting thin film materials, which are based on sulfides and selenides, have recently concerned much consideration as materials for optoelectronics technology. Thin films have other useful properties of electrical conduction, optical transmittance, reflectivity, absorption and corrosion resistance. Nanocrystalline semiconducting materials were used in electronic, optoelectronic and solar energy conversion devices. The physical and chemical properties are found to be strongly size dependent (Gray, 2003; Elango et al., 2000). During the recent decades, semiconductor materials are extremely vital in the development of wide range electronic and optoelectronic devices for information applications. A significant property of a semiconductor is its temperature dependence of conductivity, that is, the fact that the conductivity in semiconductors increases with increasing temperature, whereas the conductivity in metals decreases with increasing temperature (Goswami, 2008). One of the key parameters that often determine the range of applications of a given semiconductor is the basic energy bandgap that separates the conduction from the valence bands, which is typically in the range from 0 to 3 eV for semiconductors (Yacobi, 2003). In recent years, research on the preparation and characterization of thin films was developing into a major research area. Thus the electronic industries due to the use of thin films in electronic, opto-electronic and other devices have become the supreme beneficiary of thin film technology.

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The use of thin films in manufacture active and passive electronic components made it possible to produce very large-scale integrated and microcomputer. Studies on thin films have been responsible for the development of active and passive components, different types of sensors, solar energy conversion, magnetic memory devices, superconducting films, optical image storing devices, electromechanical devices like strain gauge, gas detecting transducers, interference filters and reflection and antireflection coatings (Joachim et al., 2002; Kalyanasundaram and Graetzel, 2010; Cavaco et al., 2007; Lita et al., 2005; Shinya et al., 2000; Stephen et al., 2004; Pierre, 2002; Koc et al., 2005). In addition to major role to a diversity of new technologies, the thin film studies have many new areas of research in solid state physics and chemistry and will continue to pave the way for a variety of problems of basic and technological importance. Photodetection technology has become very significant in military applications, particularly in guided weapons and communication through fiber optics. Infrared developments are based on solid state photonic devices. Further developments in these fields demand a good understanding of the basic principles of photoconductivity processes. Smith and Sandland (1923) recorded first the photoconductivity effect in 1873 when he observed the decrease in the resistivity of selinium by the radiation shining on it. When the photons of energy greater than that of the band gap of the material are incident upon a photoconductive material, the electrons and holes are created in the conduction and valence bands respectively, increasing the conductivity of the sample. The basic principle involved in photoconductivity is that when photons of energy greater than that of the band gap of the semiconductors are incident on the material, electrons and holes are created resulting in the enhancement of electrical conductivity. This phenomenon is called intrinsic photoconductivity. It is also possible to observe photoconductivity when the energy of the incident photon is less than that of the band gap. When the energy of the photon matches the ionization energy of the impurity atoms, they are ionized, creating extra carriers and hence an increase in conductivity is observed. This phenomenon is called extrinsic photoconductivity. In the present investigation, we report the photoconductivity studies were carried out on Zinc Selenide (ZnSe), Zinc sulphide (ZnS) and Lead Sulphide (PbS) thin films. The variation in field dependent dark and photoconductivity of thin films were studied.

Photoconduction and dark conduction

Photoconductivity is due to the absorption of photons (either by an intrinsic process or by impurities with or without phonons), leading to the creation of free charge particles in the conduction band and/or in the valence band. Photo-absorption and hence photo-conduction takes place by one of the following mechanisms. (i) Band-to-band transitions, (ii) Impurity levels to band edge transitions, (iii) Ionization of donors, (iv) Deep level (located in the valence band) to conduction band transitions. Photoconduction includes the generation and recombination of charge carriers and their transport to the electrodes. Obviously, the thermal and hot carrier relaxation process, charge carrier statistics, effects of electrodes, and several mechanisms of recombination are involved in photoconduction. It gives valuable information about physical properties of materials and offers applications in photodetection and radiation measurements. Dark current (I_d), is the amount of current that flows through the material or device when no radiation is incident on it. It changes with operating temperature and applied voltage, and therefore these parameters should be always mentioned. Dark current is not a constant background current but also has fluctuations or noise. The average D.C. value of the current is generally mentioned as dark current.

MATERIALS AND METHODS

The chemical bath deposition (CBD) method is used to the deposition of a thin film on a substrate from a reaction occurrence in solution. The procedure wants the substrate to be immersed in a supersaturated solution of aqueous precursors. CBD method possesses many advantages over the others method such as its non-sophisticated instrumentation, convenience for large area deposition, applicable to a wide range of substrates, and generally very simple. In particular, chemical bath, method has been used to deposit thin films for present investigation. In this method the substrate was reserved immobile and the solution has been stirred well with magnetic stirrer and the oil bath was used to heat the chemical bath to get a preferred temperature. The process generally operates under ambient conditions and has the potential to replace expensive energy. In chemical bath deposition, the film forms when the substrate is immersed into the solution. The deposition of sulphide and selenide thin films used chemical bath deposition method on the glass substrates. Zinc Selenide (ZnSe), Zinc Sulphide (ZnS) and Lead Sulphide (PbS) thin films were prepared by chemical bath deposition method. The sample is well-polished and surfaces are cleaned with acetone. This is attached to a microscope slide and two electrodes of thin copper wire (0.14 cm diameter) are fixed onto the specimen at some distance apart using silver paint. A direct-current (D.C.) power supply, a Keithley 485 picoammeter and the prepared sample are connected in series as shown in Figure 1. The sample is covered with a black cloth to avoid exposure to any radiation. The current (dark) is measured. To measure the photoconductivity, light from a 100 W halogen lamp is focused onto the sample. The field-dependent dark and photoconductivity studies were carried out using Keithley picoammeter. The applied field was varied and the corresponding current in the circuit was measured.

RESULTS AND DISCUSSION

Photoconductivity is a useful tool to study the properties of semiconductors. It is also considered to be an important tool for providing information about the nature

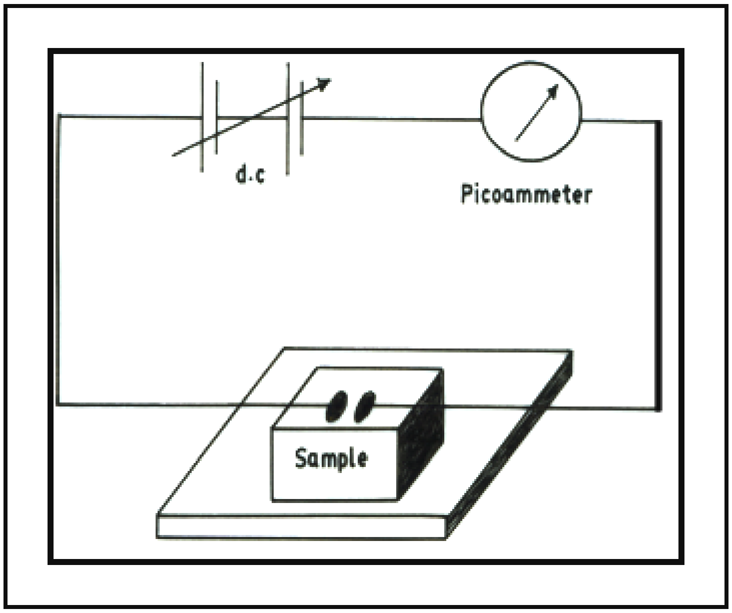

Figure 1. Experimental setup for measuring photoconductivity.

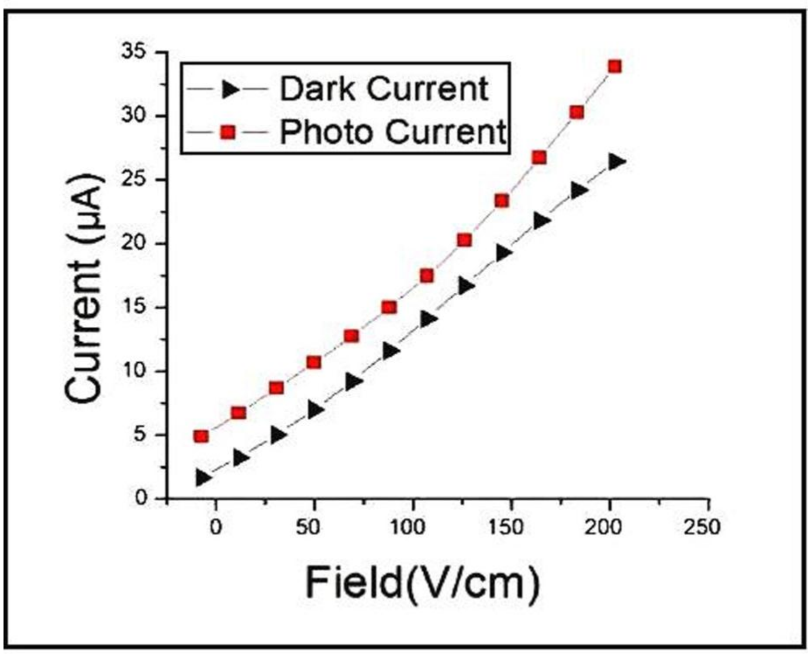

Figure 2. Photoconductivity study of ZnSe Thin films.

of the photo-excitations. A good photoconductive device requires efficient charge separation and efficient transport of charge carriers to electrode. The conductivity of the material depends upon the carrier density and complex process of carrier generation, trapping and recombination. It is also a function of temperature, applied field, intensity of light and energy of radiation. Field dependent dark and photoconductivity plots of ZnSe, ZnS and PbS thin films are shown in Figures 2 to 4 respectively. It is observed that both dark and photo currents increase linearly with the applied electric field with the dark lesser than the photocurrent current which is termed as positive photoconductivity. The plots indicate a linear increase of current in the dark and visible light

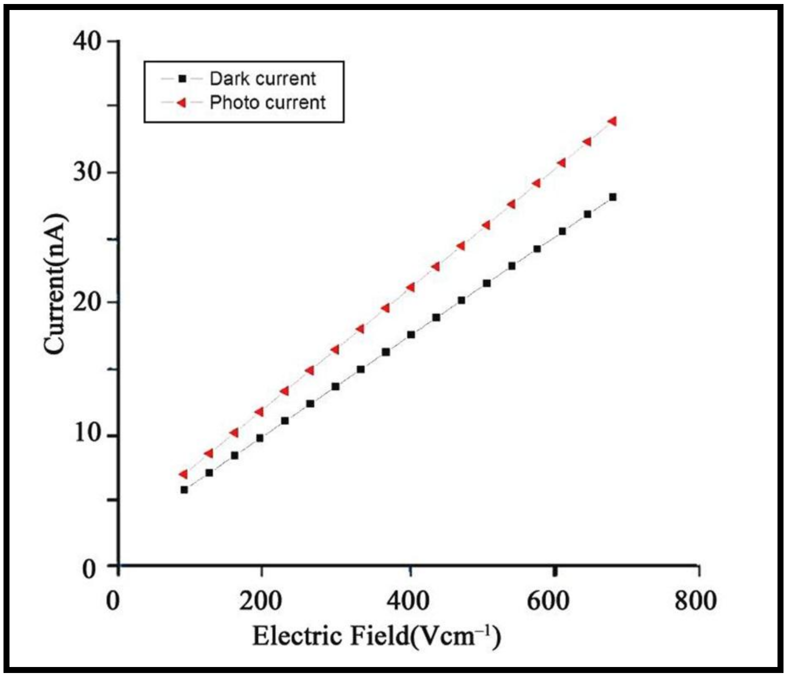

Figure 3. Photoconductivity study of ZnS thin films.

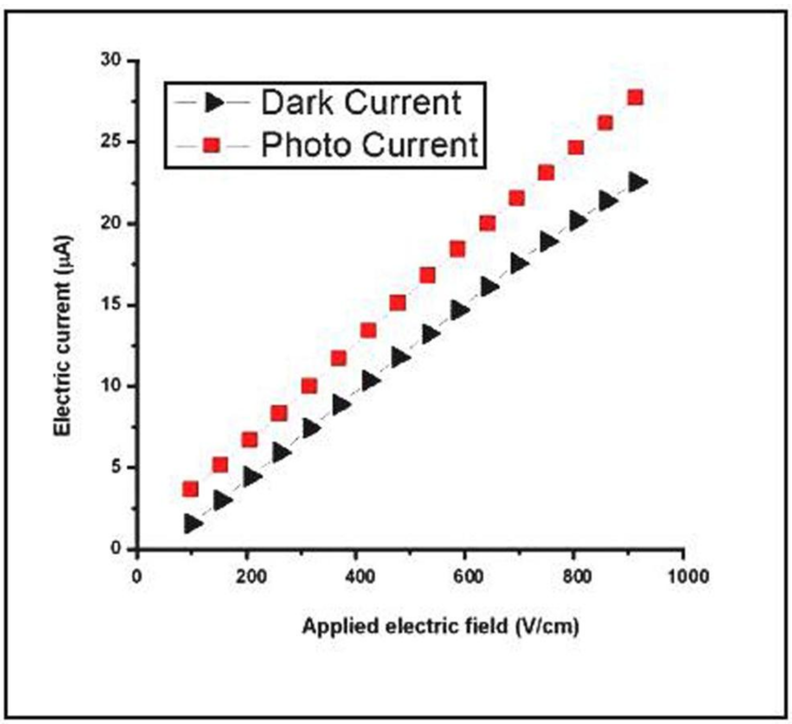

Figure 4. Photoconductivity study of PbS thin films.

illuminated thin films cases with an increase in applied field depicting the ohmic nature of the contacts (Armelao et al., 2003). The low values of dark current and insignificant rise in photocurrent upon the visible light illumination are as expected. But the photocurrent is found to be more than the dark current. Hence, it can be said that the material exhibits positive photo conductivity. This is caused by the generation of mobile charge carriers caused by the absorption of photons. This is because of an increase in the number of charge carriers or their life time in the presence of radiation (Bube, 1981). The start of a charge transfer process where in the photon absorbed and it gives rise to electron injection into the conduction band of the semiconductor films is responsible for the increase in photocurrent. The forbidden gap in the material contains two energy levels in which one is located between the Fermi level and the conduction band while the other is located close to the valence band. The second state has high liberate electrons and holes. As it liberate electrons from the conduction band and holes from the valence band, the number of charge carriers in the conduction band gets complete and the current increase in the presence of radiation. Thus the films is said to exhibit positive photoconducting effect. The positive photoconductivity of the films may be due to the increase in the number of charge carriers to reveal the conducting nature of the material. The dark current was lesser than the photocurrent, signifying positive photoconductivity nature confirmed by the reported results (Thirumavalavan et al., 2015).

Conclusion

The objective of the work is to analysis photoconductivity behaviour of ZnSe, ZnS and PbS thin films. The ZnSe, ZnS and PbS thin films were obtained by chemical bath deposition (CBD) technique. Photoconductivity studies on these films were done. Photoconductivity test is a simple and powerful technique to study energy levels in the band gap of semiconducting material.The photoconductivity studies determine the positive photoconductivity nature of the thin films. The thin films recorded low values of dark and an insignificant rise in photocurrent upon visible light illumination whereas the thin films showed better photocurrent.

Conflict of Interest

The authors have not declared any conflict of interest.

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