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Transport Properties of PbS Thin Films

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ABSTRACT

Thin films of PbS were obtained by chemical bath deposition method onto the glass substrates. To obtain the PbS thin films the reactive substances lead acetate, thiourea, sodium hydroxide, ammonia, triethanolamine and distilled water were used. The effect of pH of reactive mixtures on the film growth and quality has been studied. The temperature dependence of dark electrical conductivity was studied using two-probe method. The transport characteristic such as thermo-electric power shows that deposited films were p-type in nature.

Keywords: PbS thin film, Chemical bath deposition, Electrical conductivity, TEP.

INTRODUCTION

Lead sulphide is a unique direct bad gap material which has developed a lot research interest, especially in the fabrication of infrared detection and solar cell applications [1], Semiconductor materials are always in focus due to their outstanding electronic and optical properties. Due to the non-linear optical properties PbS nanoparticles has found an extensive application in optical devices such as optical switch [2]. These properties have been correlated with the growth conditions and the nature of the substrate. In addition, PbS has been utilized as photo resistance, diode lasers, humidity and temperature sensors, decorative and solar control coating [3]. The preparation of the thin film of.

PbS explored by a number of methods such as electro deposition [4], spray paralysis [5], photo accelerated chemical deposition [6], microwave heating [7] and chemical bath deposition [8]. CBD is relatively inexpensive, simple and convenient method for large area deposition and a variety of substrates can be used to grow thin films. It does not require complicated instrumentation [9]. We have selected chemical bath deposition method owing to its many advantages.

MATERIAL AND METHOD

The deposition was carried out using commercial glass slides of dimensions 25 mm X 30mm X 1.2mm. All the chemicals used for the deposition were analytical grade reagents. It includes lead acetate, thiourea, sodium hydroxide, ammonia, triethanol-amine (TEA). The deposition was done in a reactive solution prepared in a 250 ml beaker containing equimolar solutions of lead acetate and thiourea. TEA was used as a complexing agent and pH of the reaction mixture was adjusted to about 10.5 with the help of sodium hydroxide and ammonia solution. The bath temperature was fixed at an appropriate temperature, pre-treated substrates were inserted vertically into the beaker. After deposition for 2 hours, the substrates were taken out, washed with distilled water and dried in air.

RESULTS

The deposition rate process was studied by monitoring the variations of film thickness with pH. The growth rate and quality of the film was found to be a stringent function of the pH of the reaction mixture. Fig.1 shows the variation of film thickness with a pH of reaction mixture. pH below 10.5 was found to consist of non-adherent powder like precipitates indicating poor quality of deposition. The reaction mixture also tends to lose stability for pH<10.5. However, above pH value of 10.5, the growth rate decreases abruptly. The film thickness increased with increase in pH up to 10.5 and then it decreases for further increase in pH of the reaction mixture so the optimized pH value of the reaction mixture is 10.5. The dark electrical conductivity of the PbS thin film was studied in the temperature range 383 to 498°K using dc two- point probe method.

Conductivity is an important factor, which reveals important information about the transport phenomenon of the material. The dc electrical conductivity of a semiconductor at temperature T is given by,

$$\sigma_{DC} = \sigma_0 \exp(-\Delta E / KT) \quad (1)$$

Where ΔE is activation energy and K is the Boltzmann constant. When we plot a graph between lnσ and 1000/ T a straight line is obtained having slope ΔE/1000k, we may calculate the activation energy as follows.

$$\Delta E = 1000k \text{ X slope of straight line} \quad (2)$$

The variation of lnσ with reciprocal temperature ($(1/T) X10^3$) is shown in Fig.2. It can be observed that electrical conductivity has two linear portions. First in the lower temperature range (383-473°K) has activation energy 0.143 eV and second in the higher temperature range (473-498°K) having activation energy 0.794 eV. The increase in conductivity with increase in temperature indicating the semiconducting nature of films The thermally generated voltage at the cold end is positive, indicating the films are p-type. Fig.3 shows variation of thermo-emf with temperature, which shows that thermo-emf increases with increase in temperature. The carrier concentration of semiconductor at temperature T is given by

$$\text{Log}(n) = 3/2 \log(T) - 0.005p + 15.7198 \quad (3)$$

Where T is the temperature and P is T.E.P.

The variation of log (n) with 1000/T is shown in Fig.4. The mobility is given by $\mu = \sigma / ne$ where σ is conductivity, n is carrier concentration and e is electron charge (1.6 X 10^{-19}C). A graph between ln (μ T) $^{1\backslash 2}$ and 1000/T is as shown in Fig.5. From which we can calculate barrier height in the lower temperature range (383-473°K) is 0.17 eV and in the higher temperature range (473-498 °K) is 0.99 eV.

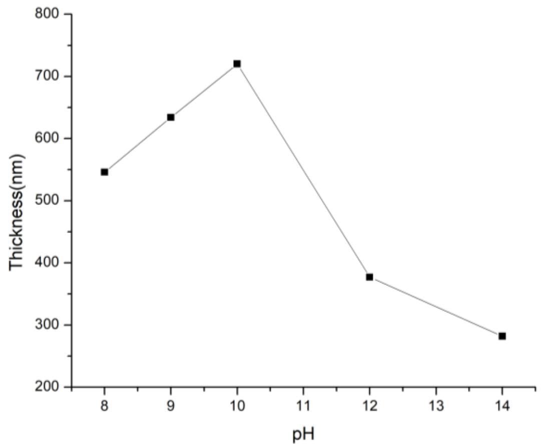

Fig.1. Thickness variation with pH

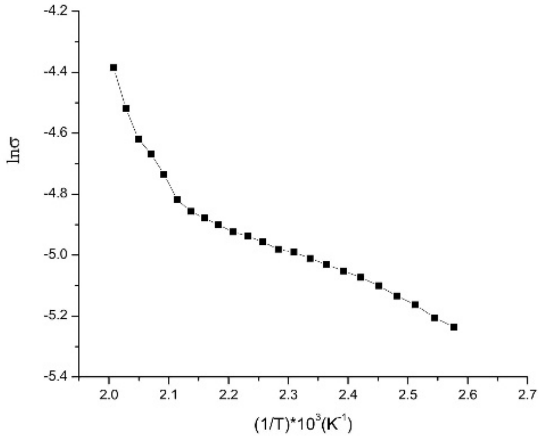

Fig.2.Variation of lnσ with function of temperature

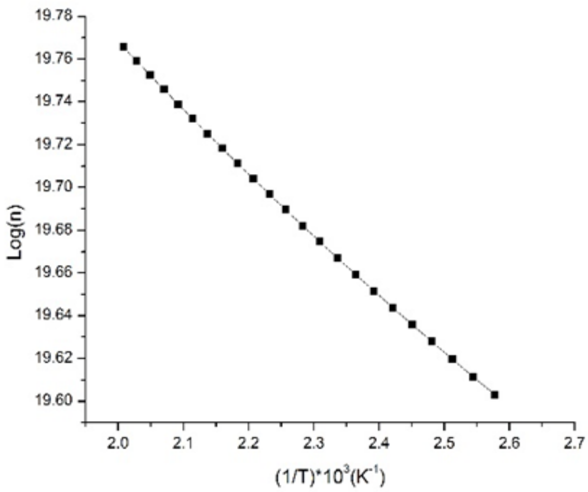

Fig.4. Carrier concentration variation with 1/T

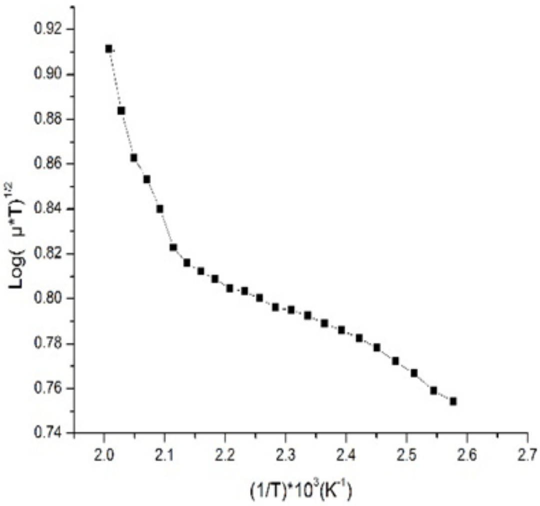

Fig.5. Variation of mobility with 1/T

CONCLUSION

We have deposited PbS thin film on glass substrate. The dc electrical conductivity indicating the semiconducting nature of thin film and thermo-emf measurements confirms the p-type nature of PbS thin films.

Conflicts of interest: The authors stated that no conflicts of interest.

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