HALL MEASUREMENTS ON THERMALLY EVAPORATED PbSe MULTILAYER THIN FILMS AND EFFECT OF SUBSTRATE TEMPERATURE

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Lead Selenide multilayer thin films were prepared by thermal evaporation technique by successive coatings of Lead and Selenium. The substrate temperature was varied from ambient (28°C), low (0°C) and high (80°C) and the electrical properties were studied using Hall measurement system and the results are presented in this article. The minimum sheet resistance of 2.97×10^3 Ω/sq was obtained for the films prepared at ambient substrate temperature. The carrier concentration for the bulk as well as for the sheet decreases for high and low substrate temperatures. The mobility of low substrate temperature films observed as 2.653×10^2 $cm^2/V.s$ and the ambient temperature film have 1.432×10^2 $cm^2/V.s$. The various electrical properties were calculated and reported in this paper.

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1. Introduction

IV-VI semiconductors are commonly considered to be promising materials for optoelectronic, thermoelectric and other applications in the mid-infrared as optoelectronic emitters, sensors and detectors [2,3]. PbSe is a polar semiconductor, which is a polar semiconductor, which crystallizes in a face center cubic (f.c.c) of NaCl type. It is characterized by high dielectric susceptibility, high carrier mobility [4] and narrow band gap (T=293 K) of 0.27 eV [5,6]. Lead Selenide will not require cooling but performs better at low temperature. Many workers have been investigated the electrical properties of the PbSe thin films at various conditions. In our earlier paper [7] we reported the structural and optical properties of 2 layer and 5 layer PbSe multilayer thin film. In this work, we report the electrical studies on PbSe multilayer thin films with varying the substrate temperature.

2. Experimental

Lead selenide thin films were prepared by thermal evaporation technique at various substrate temperatures onto glass substrates at vacuum pressure of 10^{-6} torr. The successive coating of Lead and Selenium were deposited on the glass plates alternatively. The Pb and Se metals were placed in the molybdenum boat (200 amps) and were heated with current by energizing transformer. The thickness of the films is maintained at≈200A° for Pb and ≈200A° for Se and was monitored by the Quartz Crystal thickness monitor. The constant rate of evaporation ranging 1-3A°/sec is maintained throughout the experiment. For depositing the source material at low temperature on the substrate, an exclusively designed substrate holder is used [7]. The

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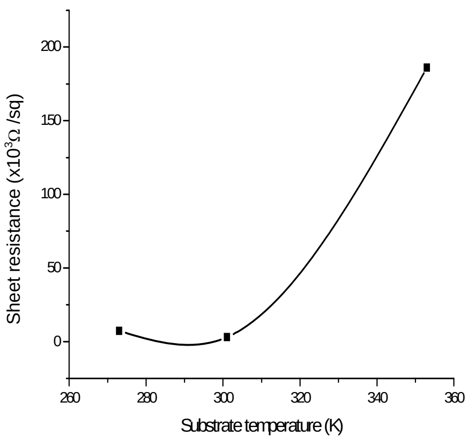
electrical studies of as deposited films carried out using Hall measurement system (Ecopia, HMS-300) at room temperature with varying the current.

3. Result and discussion

3.1 Sheet resistance (R_s) and resistivity (ρ)

The thickness of the films was maintained at 0.15 μm using the quartz crystal thickness monitor. The input current of 0.7μA is given to ambient and elevated substrate temperature samples whereas for low substrate temperature 0.9μA of current source is applied. The magnetic field of 0.570 gauss was applied in all cases. The value of sheet resistance (R_s) and resistivity (ρ) are shown as a function of substrate temperature in Fig.1a & 1b respectively.



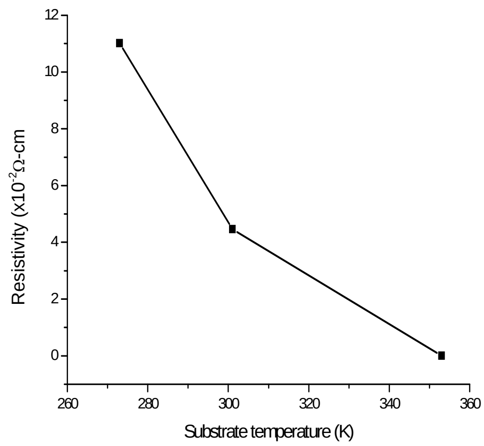


Fig.1. Sheet resistance and electrical resistivity of PbSe multilayer thin films.

The minimum sheet resistance of 2.97×10^3 Ω/sq was observed at the film prepared at ambient temperature substrate. The low substrate temperature films have the sheet resistance of 7.34×10^3 Ω/sq was acheived for the very first time and has been reported for PbSe thin films in this paper. The very high sheet resistance of 186×10^3 Ω/sq was observed on ambient temperature substrate which is due to bulk nature of the as deposited films. The electrical resistivity of the PbSe multilayer thin films was found to decrease with increase in the substrate temperature. The very high resistivity of 11.02×10^{-2}Ω-cm was observed on low substrate temperature films and the room and high temperature substrates have the resistivity of 4.46 $\times 10^{-2}$ Ω.cm and 0.002 $\times 10^{-2}$ Ω.cm respectively.

3.2 Carrier concentration(n) and mobility (μ)

The carrier concentration of the bulk and sheet of deposited multilayer Lead Selenide thin films are shown in Fig.2a. The minium bulk concentration of 0.33×10^{12}cm^{-2} was observed at elevated substrate temperature and the sheet concentration has 0.50 $\times 10^{17}$cm^{-2} (fig.2a).

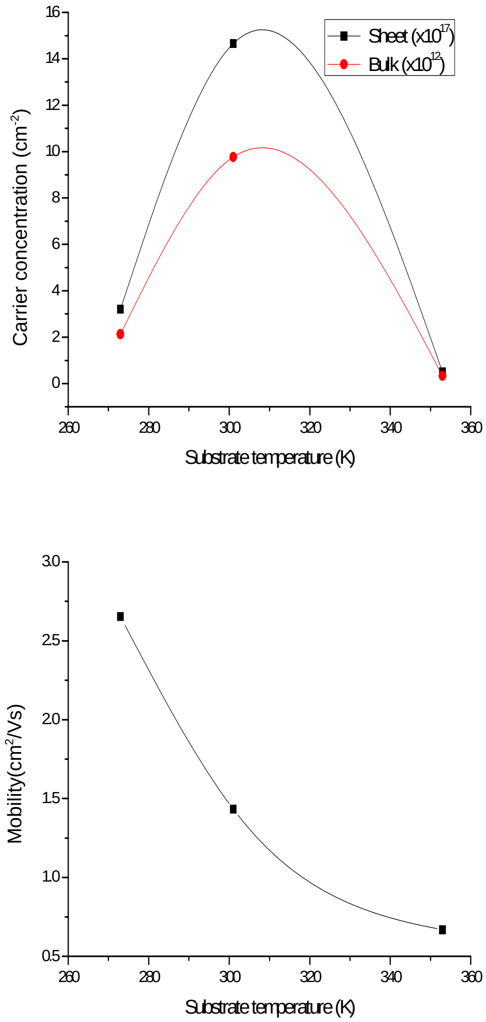


Fig.2. Carrier concentration and Mobility of PbSe multilayer thin films.

The carrier concentration for the bulk and sheet has high value of 14.66 x10^{12}cm^{-2} and 9.77x10^{17}cm^{-2} respectively. The mobility of the deposited PbSe films as a function of substrate temperature is shown in fig.2b. It is found that the Hall mobility of the films decrases with increasing the substrate temperature. The high mobility of 2.65 cm^2/V.sec is observed on low substrate temperature PbSe thin films may be due to un attached carriers freely moving due to Brownian motion.

Table.1. Hall measurements on PbSe thin films at different substrate temperature

Substrate temperature	R_{sh} (10^3 Ω/sq)	ρ (Ω.cm)	σ ($\Omega^{-1}cm^{-1}$)	μ (cm^2/V.sec)	Δ (Ω-1)	N_b (cm^{-2})
Low(0˚C)	7.34	11.02	9.23	2.65	9.23	2.13
Ambient(28˚C)	11.02	4.46	22.41	1.43	0.03	9.77
High (80˚C)	2.97	0.002	23.55	0.66	23.35	0.33

3.3 Conductivity (σ) and Magneto resistance (Δ)

The electrical conductivity (σ) and the magneto resistance (Δ) of as deposited films are shown in fig.3a and 3b respectively. The conductivity of a material depends directly both on the number 'n' of free electrons per unit volume and on the average time 'τ' between collisions. As we increase temperature, average speed of the electrons, which act as the carriers of current, increases resulting in more frequent collisions. The average time of

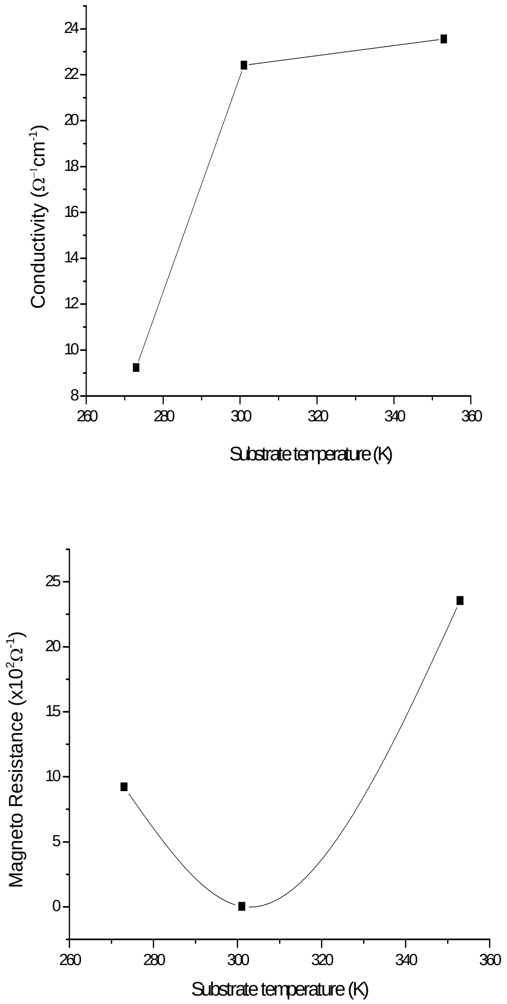


Fig..3. Electrical conductivity and magneto resistance of PbSe multilayer thin films

collisions τ, thus decreases with temperature which decreases conductivity of metals. In Semiconductors the number of free electrons increases with increasing temperature, thus increasing conductivity. In this case the electrical conductivity of low substrate temperature films found to be less (9.23 $\Omega^{-1}cm^{-1}$) than that of the conductivity of ambient (22.41 $\Omega^{-1}cm^{-1}$) and high temperature substrates (23.55 $\Omega^{-1}cm^{-1}$) shown in fig.2a. The magneto resistance is the property of a material to change the value of its electrical resistance when an external magnetic field is applied to it. Here it is observed that the magneto resistance on low substrate temperature (9.23x10^2 Ω^{-1}) and high temperature substrate (23.35 x10^2 Ω^{-1}) is more than that of the ambient temperature substrate. The increase in the magneto resistance on low substrate temperature films is due to applied voltage (0.9 μA) that is more (0.7μA) than other two substrate temperature.

3.4 Hall coefficient (R_H) on PbSe multilayer thin films

The Hall coefficient on semiconductor used to characterise the materials from which the material is made, as its value depends on the type, number, and properties of the charge carriers that constitute the current. All as deposited PbSe multilayer thin films shows the positive value of $0.34 x 10^2$ m^2-c^{-1}, 9.23×10^2 m^2-c^{-1} and 23.55 $x 10^2$ m^2-c^{-1} for ambient, low and elevated substrate temperature respectively. These positive values of Hall coefficient yields to the deposited films are of p-type in nature. Some of the previous workers also identified that the Lead Selenide thin films have p-type in nature using various deposition method.

4. Conclusions

Lead Selenide multilayer thin films were deposited by successive coatings of Lead and Selenium. The Hall coefficient of all as deposited films showed the p-type semiconducting nature observed from its positive values. The electrical conductivity on low substrate temperature observed as 9.23 $\Omega^{-1}cm^{-1}$ and this yield to even at low temperature PbSe multilayer thin films with suitable electrical properties for application towards single electron transistor devices. The mobility of the films observed as linearly decreases with increasing substrate temperature. The minimum sheet resistance of 2.97×10^3 Ω/sq was observed at ambient temperature substrate. The carrier concentration of low and high temperature substrate is found to be decrease than that of the ambient temperature substrate.

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