Temperature Dependence of Hall Mobility And Carrier Concentration of $pb_{0.55}S_{0.45}$ Films

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Abstract

Measurements of Hall effect properties at different of annealing temperature have been made on polycrystalline $Pb_{0.55}S_{0.45}$ films were prepared at room temperature by thermal evaporation technique under high vacuum $4*10^{-5}$ torr . The thickness of the film was 2μm .The carrier concentration (n) was observed to decrease with increasing the annealing temperature. The Hall measurements showed that the charge carriers are electrons (i.e n-type conduction). From the observed dependence on the temperature, it is found that the Hall mobility (μH), drift velocity (ν d) carrier life time (τ), mean free path (λ) were increased with increasing annealing temperature

Key words: Thin film, Hall Mobility, $pb_{0.55}S_{0.45}$

Introduction

A good general picture of the physical behavior of semiconductor can be obtained by measuring the electrical conductivity and Hall coefficient

The electrical properties of semiconductors are primarily interested and are dependent on the availability of holes in the valence band and electrons in the conduction band to facilitate the flow of charge under applied potential[1].The analysis of the measurement of the Hall and conductivity are relatively simple only in the case of a uniform semiconductor and they are much more difficult in the case of heterogeneous sample with gradients of an energy gap carrier concentration and mobility[2,3] .

Polycrystalline lead sulfide films an important group of semiconducting, it has been study in recent year mainly because of its easy to fabricate and applications in optoelectronic technology .It is crystallized in the rock salt structure and characterized by low – energy gap and large dielectric constant .therefore from the among owing to their high sensitive and high speed response ,we consider PbS compound is of wider interest than other lead salts (PbSe & PbTe) and the most important infrared detectors which is extremely available in every form of infrared work over range (1-3) μ m[4].

Numbers of studies have been prepared pbS films by varies technique: chemical vapor technique (CVD)[5], spray pyrolysis technique[6], and thermal vacuum evaporation (TVE) in a stoichumatric from[7,8].

The Hall effect measurements of pbS compound have been studied only in a single crystal by many authors[9,10,11].

The Hall coefficient can be determined from:

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$$RH = \frac{V_H t}{I.B} \text{ -------- (1)}$$

Where VH is Hall voltage , I is the current through the sample , t is the thickness and B is the applied magnetic field equal to 0.256 T.

Very simply theory predicts that RH as defined in eq. (1) is given by[12]:

$$RH = \frac{1}{nq} \text{ or } \frac{1}{pq} \text{ -------- (2)}$$

Where q is the electronic charge and n or p is the concentration of electrons or holes.

Thus from Hall coefficient, can be determined the carrier concentration as well as concentration, since RH is negative for n-type and positive for p-type.

The Hall mobility can be simply determined from product of the conductivity (σ) and the Hall coefficient [13].

$$\mu = RH\sigma = \left(\frac{1}{nq}\right)\left(\frac{nq^2\tau}{m*}\right) = \frac{q\tau}{m*} \text{ ----- (3)}$$

where m* is the effective mass , and τ is the life time of the carriers.

$$\sigma = \frac{nq^2\lambda}{m^* v_d} \text{ =------ (4)}$$

Where v_d is the drift velocity and ℓ is the mean free path which are given as[14]

$v_d = \mu E$ -------- (5)

$\lambda = V_d \ \tau$ ------- (6)

Where E is the electric field.

In the present work, we study the effect of annealing temperature on the Hall measurements of $p_{0.55}bS_{0.45}$ films.

Experiment

$Pb_{0.55}S_{0.45}$ compound was synthesized as alloy by using purity material (99.999%) of lead and sulfide and then weighted in proportion to their atomic percentage. Than we put the lead and sulfide in an evacuated quartz tube to 10^{-3} tore and kept in furnaces whose temperature was raised to 1400K. The ampoule is kept at this temperature about three days and than the melt is quenched in cold water.

Thin films of alloy were prepared on glass substrate by thermal evaporation method at RT(**room temperature**) in the pressure$4*10^{-5}$ torr .The thickness of the films was 2 μm which is measured using tolonsky method. The crystalline structure of PbS films sample has been examind by X-ray diffraction type (Philips) .

Hall measurements which include (RH , μH , υ_d , τ , and λ) were determined(used instruments :power supply, keithely meter , maskes) (used magnetic field B=0.254T)as a function of annealing temperature.

Results and Discussion

Fig.(1) shows the x-ray diffraction (XRD) patterns obtained for $Pb_{55}S_{45}$ thin films deposited by thermal evaporation method .According to (ASTM) cards ,the structure of the thin films have polycrystalline cubic structure,and the films have crystallized with a strong peak at (200) direction, this means that this plane is suitable for crystal growth. This results are similar to those obtained by Helsink[14] and Judita[15].

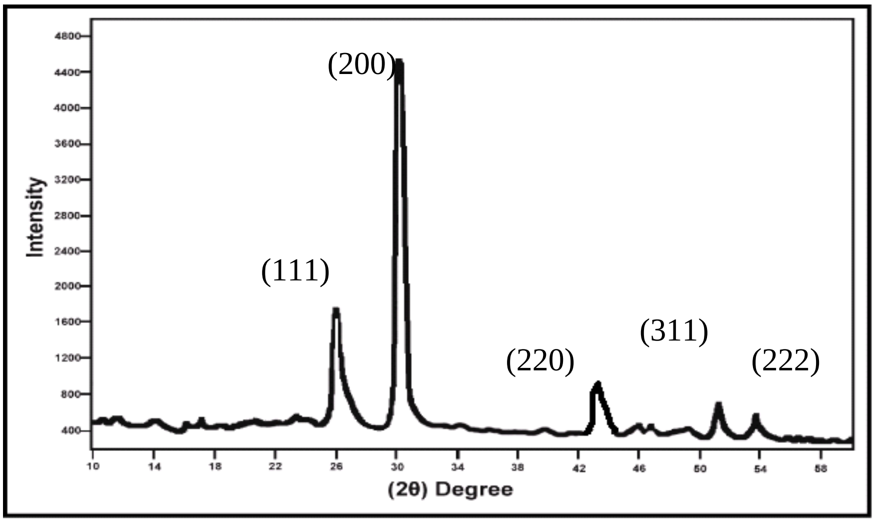


Fig.1 : X-ray diffraction pattern for PbS

Fig.(2) shows the variation of Hall voltage with the current in pb0.55S0.45 films deposited at RT and heat treatment in different annealing temperature (373-523)K .It is observed that Hall measurements show that the film of pb $_{0.55}S_{0.45}$ at thickness of 2 μm are n-type ,this mean that the conduction is dominated by the electron, the explanation of exhibits the films as n-type conduction is the excess in Pb atoms in pbS compounds act as donor atoms and this is agreement with Al-Fawadi[12].

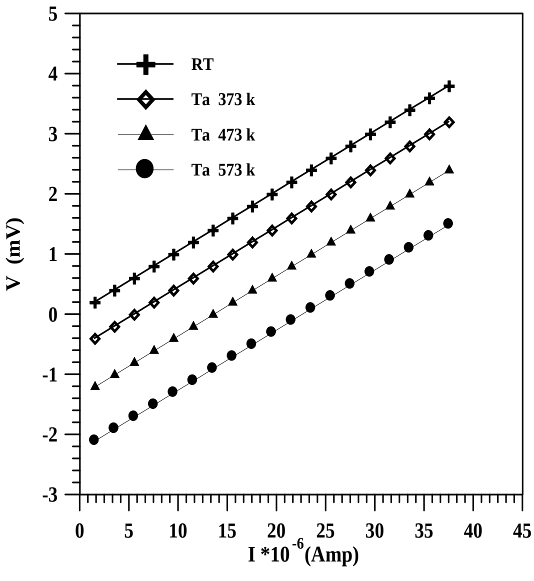
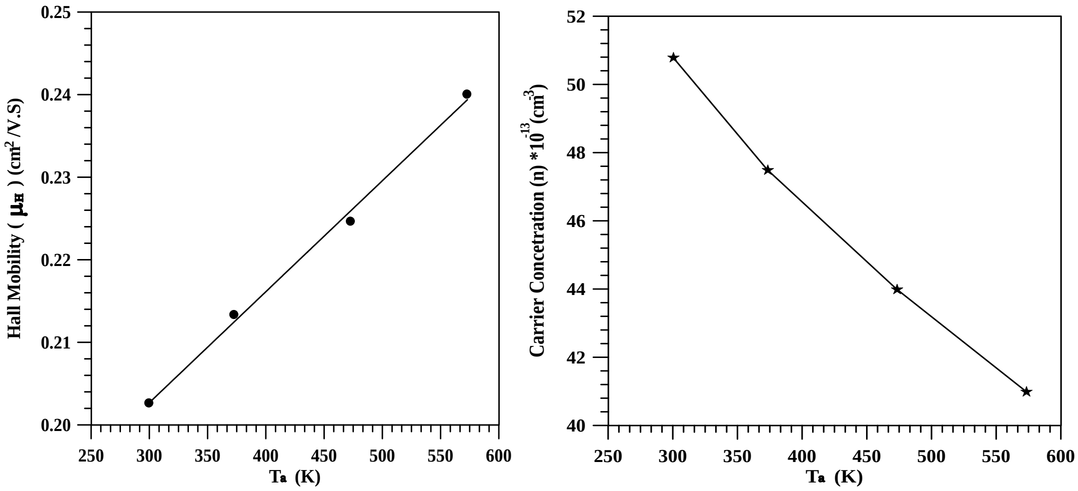


Fig.(2) The variation of Hall voltage with the current for $pb_{0.55}S_{0.45}$ films.

The variation of Hall mobility (μH) and carrier concentration with annelling temperature(Ta)of $pb_{0.55}S_{0.45}$ films are shown in Fig.(3 a&b) .It is shown in this figure that the carrier concentration decreases while the mobility increases as the film temperature is increased from room temperature R.T. to 573 k. This is the typical of many polycrystalline films due to the existence of potential barriers in the grain boundaries and this is in agreement with Petritz.[10].

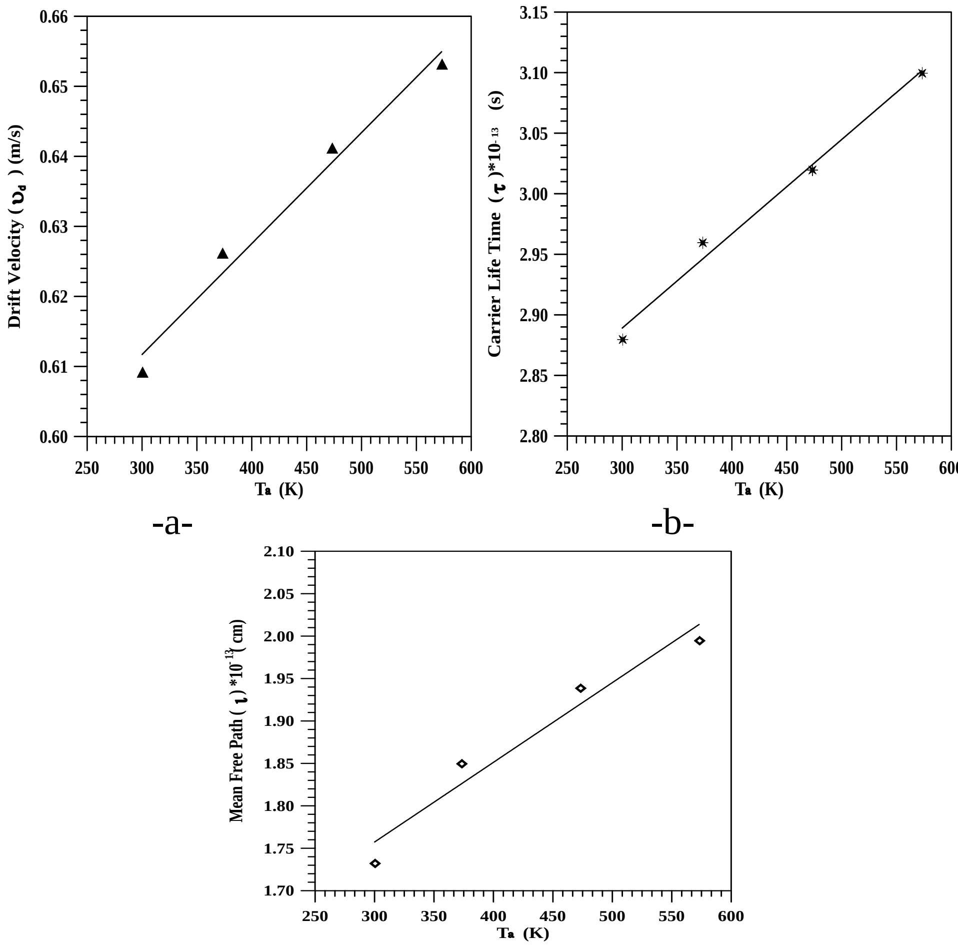
The explanation of increasing of Hall mobility with annealing temperature Ta is due to reduction of the scattering of the carrier from the surface as well as due to the elimination of the defects in the films leads to increase in crystallinty size that decreasing the number of the grain boundaries[12,13] .



-a- -b-

Fig.(3) The variation of –a- Hall mobility &-b- carrier concentration with annealing temperature Ta for $pb_{0.55}S_{0.45}$films

From the Hall mobility data, we can determined the carrier life time ,drift velocity ,mean free path parameters and the results are shown in fig.(4 a,b,c). It is observed that these parameters are increased with increasing of annealing temperature and this is in good agreement with the Ptial et.al.[16].



-a- -b-

-c-

Fig.(4) the variation of –a-drift velocity –b-carrier life time-c-mean free path with annealing temperature Ta for pb0.55S0.45 films.

conclusion

Hall measurement include (Hall mobility, carrier concentration, drift velocity carrier life time and mean free path) of pb0.55S0,45 films were measured as function of annealing temperature .Hall measurements show that the type of the conduction was n-type (i.e. electron charge) .That carriers concentration have been observed to decrease with increasing annealing temperature while μH , υ_d , τ ,and λ were increase with increasing the annealing temperature.

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اعتمادية درجة الحرارة لتحركية هول وتركيز الحاملات لاغشية $P_{0.55}bS_{045}$

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الخلاصة:

تم دراسة خواص تاثير هول عند درجات تلدين مختلفةلاغشية كبريتيد الرصاص المحضرة بدرجة حرارة الغرفة بطريقة التبخير الحراري في الفراغ تحت ضغط $4*10^{-5}$ تور سمك الغشاء كان 2 مايكرو متر ولوحظ ان تركيز الحاملات n يتناقص مع تزايد درجة حرارة التلدين . اظهرت قياسات هول ان حاملات الشحنة هي الالكترونات (أي ان التوصيلية نوع –n) . من ملاحظة الاعتمادية على درجة الحرارة، وجد ان تحركية هول ، وسرعة الانجراف، وزمن عمر الحاملات ، ومتوسط المسار الحر تزداد مع زيادة درجة حرارة التلدين.