HALL EFFECT AND THE OPTICAL ENERGY GAP OF PBS THIN FILMS+

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Abstract

The carrier concentration (N_H) and optical energy gap (E_g^{opt}) of PbS thin films prepared by thermal evaporation have been measured. At room temperature and thickness (2500 A°) , Hall carrier concentration N_H was to be found (2.9×10^{10}) cm^{-3} , when increases the thickness to (3500 A°) , N_H becomes (1.33×10^{12}) cm^{-3} and the Hall mobility decreases from $6.73 \times 10^4 cm^2.V^{-1}.S^{-1}$ to $694 cm^2. V^{-1}.S^{-1}$. E_g^{opt} for indirect transitions were (0.45) eV , but for direct transitions (0.57) eV, i.e when the thickness increases the Hall mobility (μ_H) decreases but the carrier concentration (N_H) increases , and the Hall coefficient (R_H) decreases .

المستخلص

تم قياس تركيز حوامل الشحنات وفجوة الطاقة البصرية لأغشية PbS المحضرة بالتبخير الحراري عند درجة حرارة الغرفة وبسمك ٢٥٠٠ انكستروم ، تركيز حوامل هول (N_H) وجدت ٢,٩×١٠^١٠ سم^-٣ حينما يزداد السمك الـى ٣٥٠٠ انكستروم ، N_H تصبح ١.٣٣×١٠^١٢ سم^-٣ وتحركية هول تقـل مـن ٦,٧٣ سم^٢ .فل^-١.ثا^-١ الى ٦٩٤ سم^٢.فل^-١.ثا^-١ . فجوة الطاقة البصرية E_g^{opt} للانتقالات غير المباشرة وجدت ٠,٤٥ الكترون فولت ولكن للانتقالات المباشرة وجدت 0.57 الكترون فولت بمعنى أخر حينما يزداد السمك فان تحركية هول μ_H تقل بينما تركيز حوامل الشحنات N_H يزداد ، وان معامل هول R_H يقل.

Introduction

When the current passes through the thin film material , electromotive force is created normal to the current that is happen when homogenous magnetic field (B) = 0.257 Tesla applied perpendicular to the current (I) , Hall coefficient (R_H) is calculated from the relation.

$$R_H = (V_H/H)x(t / B) \quad \dots\dots\dots(1)$$

where V_H is the Hall voltage , t is the thin film thickness. The Hall carrier concentration N_H is calculated from the relation

$$N_H = (- r' / (R_H e)) \quad \dots\dots\dots(2)$$

where r′ is the scattering factor ($r \leq 1$) ,e is the electron charge . μ_H is calculated from the relation

$$\mu_H = R_H . \sigma \quad \dots\dots\dots\dots\dots\dots\dots(3)$$

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where σ is the relation expressen of the electrical conductivity of the thin film

$$\sigma = L / (R\ t\ D) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

Where R is the electrical resistance, D is the width of the aluminum pole and L is the length of the film. From Tauc's equation

$$\alpha\ h\ \nu = B^o\ (h\ \nu - E_g^{opt})^r \quad \ldots\ldots\ldots\ldots.(5)$$

where B^o is constant , h is the blank's constant. ν is the frequency of the photon , α is the absorption edge and r =2 for direct transition and r = ½ for indirect transition. Galena, lead sulfide with halite–type structure, is the most important lead mineral in the earth's crust. Apart from the lead content , recoverable amounts of Bi , Ag , Cu , etc. are usually present.

PbS is further interesting because it is a naturally occurring semiconductor [1] . The transistor has been demonstrated in some of the purest specimens [2].

In 1958 , Wayne W . Scanlon [3] studied the intrinsic optical absorption of PbS, and found that the optical energy gap (E_g^{opt}) for direct transitions 0.41 eV at 300 K , and for indirect transitions is 0.37 eV . In 1965 Schoolar and Dixon [4] found the optical energy gap for direction transitions is 0.42 eV .

In 1970, Ravich and Efimova [5] studied the electrical and optical properties if semi-conducting lead Chalcogenides, by studying the Hall effect, the charge carrier concentration and the type of the charge .

In 1989, Thaba [6] studied the optical properties of PbS prepared by the chemical spray pyrolysis method, he found many values for (E_g^{opt}) .

In 1990, Kothrly and Ghosh [7] found E_g^{opt} increases from 0307eV to 0.414eV when the annealing temperature increases from 77K to 373K.

In 1996 , Al-Amen [8] studied the optical properties of PbS prepared by chemical spray and found E_g^{opt}=0.45 eV .

In this research we studied the Hall effect and the optical energy gap of PbS. In 2000, Heini Salonierni [9] found the film is p- type.

In 2001, Pentia et.al [10] found E_g^{opt} = 0.4eVfor standard film and 0.6eV for nanocrystalline film which is prepared by Chemical Bath Deposition (CBD).

Experiment

Coating unit E 306 type Edward was used for aluminum poles deposition in vacuum, these thin films were put in Balzer coating unit BA 510 to depose PbS material at room temperature. Molybdenum boat was used to evaporate PbS with 3 x 10^{-6} m bar pressure. Keithly 616 digital electrometer was used for Hall voltage and current measurements . Stabilized power supply model PE 1512 instrument was used as D.C. power supply. Philips PU-8800 spectrophotometer used to determine the optical energy gap.

For Hall effect experiment Fig. (1) the thin film is supplied by D.C voltage, electromotive force is generated normal to the current, we can measure them, and by using equations 1,2and

3, R_H, N_H and μ_H are calculated. E_g^{opt} is found from the extrapolation of the exponential part of the curve (between $(\alpha h\nu)^{1/2}$ or $(\alpha h\nu)^2$ vs. $(h\nu)$) with hν axis which is illustrated in Fig. (4) and (5).

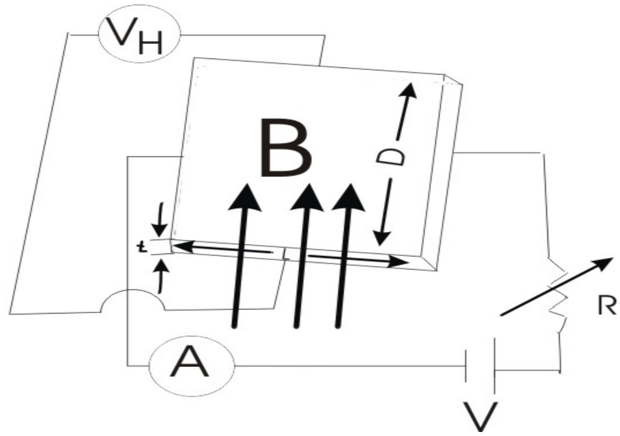

Fig. (1): Hall experiment

Results

From Fig. (2) we find V_H is proportional to I where Hall coefficient (R_H) is 2.15 x 10^8 cm^3/C and charge carrier concentration (N_H) is 2.9×10^{10} cm^{-3} but the Hall mobility (μ_H) is 6.73 x 10^4 $cm^2.V^{-1}.S^{-1}$ when the thickness is 2500A° at room temperature .

From fig.(3) when the thickness was 3500A , R_H decreases to 4.7 x 10^6 cm^3/C and μ_H to 694 $cm^2.V^{-1}.S^{-1}$,but N_H increases to 1.33 x 10^{12} cm^{-3} .

From these figures the type of charge appears n-type . because some defects are embedded within the film. These defects do decrease the charge carrier mobility. The carrier concentration increases because it is inversely proportional to carrier mobility, which is illustrated in equations (2) and (3),and the film appears n-type.

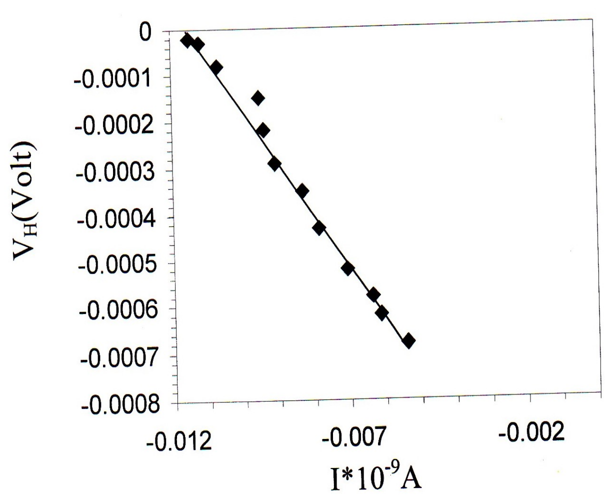

Fig. (2): Hall Voltage V_H vs I for PbS thin films, thickness 2500 A^0

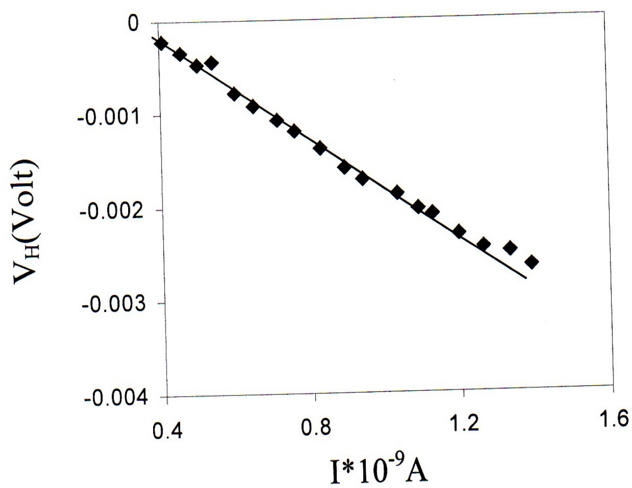

Fig. (3): V_H Vs. I for PbS thin film, thickness 3500A^0

Figure (4) illustrates the relation between $(\alpha\, h\nu)^2$ vs. hν where α is the absorption coefficient, h is blank constant and ν is the photon frequency ,this figure represents direct transition .The optical energy gap E_g^{opt} becomes 0.45 eV, but in Fig. (5) the optical energy gap becomes 0.57eV for indirect transition , where this figure illustrates the relation between $(\alpha h\nu)^{1/2}$ vs. hν . because the electron is in the indirect transition transients.

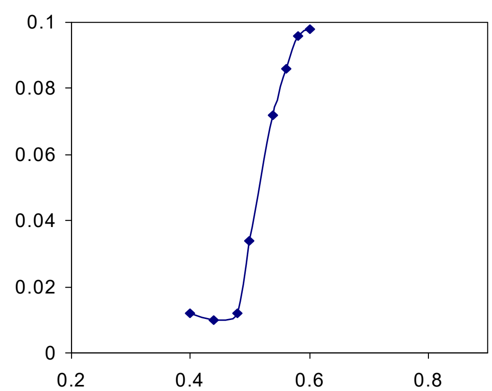

Fig. (4): $(ahv)^2$ vs. hv, direct transition for PbS thin films

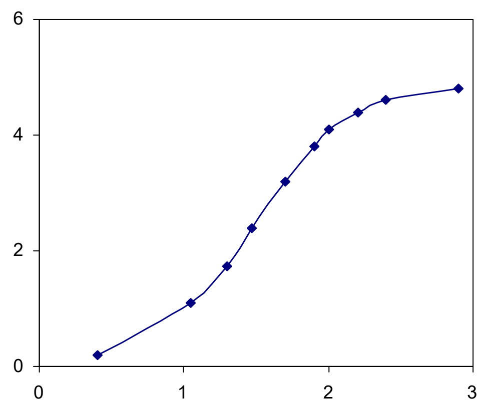

Fig. (5): $(ahv)^{1/2}$ Vs, indirect transition for PbS thim films

From the equivalent band to the conduction band with long time than its transients in the direct transition .

Conclusion

At room temperature when the thickness increases from 2500A° to 3500A° the carrier concentration N_H increases from 2.9 x 10^{10} cm^{-3} to 1.33 x 10^{12} cm^{-3} , R_H decreases from $2.15x10^8 cm^3/C$ to $4.7x10^6 cm^3/C$ and μ_H decreases from $6.73x10^4$ $cm^2.V^{-1}.S^{-1}$ to $694 cm^2.V^{-1}.S^{-1}$.

The type of the charge appearing is (n-type) . The optical energy gap for indirect transitions is found to be 0.45 eV but for direct transition it was 0.57eV.

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