Effect of Tin Impurity on PbS Thin Film Grown By CBD Method

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Abstract: *Polycrystalline alloy semiconductor as an emerging as an important material for electric and optoelectronics devices. It is an interesting narrow band gap compound semiconductor, which is used in photo-detectors and photo-resistors. Polycrystalline alloy semiconductors PbSnS thin film is deposited on glass substrate by chemical bath deposition method. We have take lead acetate and Thiourea in the presence of an alkaline medium NaOH and added $SnCl_2$ as an impurity. The electrical properties of the grown film were characterized. Hall coefficient, Hall mobility, carrier concentration, and effect of energy band gap with different concentrations were measured.*
Keywords: **Hall coefficient, Hall mobility, Carrier concentration, Chemical bath deposition.**

INTRODUCTION:

Alloy Semiconductor materials are of current interest due to their unique optical and electrical properties, which are different from that of the materials in bulk form. A variety of physical properties of semiconductors have been reported in the literature [1-4]. Lead sulphide thin film is used as a target material in infrared sensor, grating, lenses and various optoelectronic devices. Thin solid films of lead chalcogenide have been a subject of interest for many years mainly because of their possible application to the manufacture of large-area photodiode arrays, solar selective coatings, solar cells, photoconductors, sensors and pollution monitor etc. PbS is an interesting narrow band-gap IV–VI compound semiconductor (Eg = 0.41eV at room temperature), which is used in photo-detectors, photo-resistors and photo-emitters in the infrared region (I.R)[5-7]. Lead sulphide thin film has been grown by various methods, including chemical bath deposition, vacuum deposition, sputtering, spray pyrolysis, electro-deposition and microwave heating. Chemical bath method has also been found to be a very suitable method for deposition of poly crystalline PbS thin film [8-10] . It does not require sophisticated and expensive instruments. Electro-deposition has been used to prepare high-quality metal sulphide thin films, with advantages such as low-temperature deposition and relatively low-cost hardware [11]. Chaudhary et-al.,[12-13] have extensively studied the electro deposition of PbS thin films. The important parameters in the understanding of fundamental properties of Lead chalcogenides included carrier density, mobility and band gap energy. Hall constant and electron and Hall mobility were determined by Allgair [14].
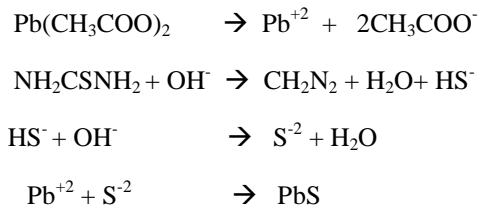
EXPERIMENT:

Lead sulphide thin film grown on glass substrate using the Chemical Bath Deposition method [15-17]. First of all the glass slides washed with liquid detergent and then boiled in concentrated chromic acid for 90 minute, after which the slides were kept in this for further 50 hours. The glass slides were then washed with distilled water. Finally glass slides were dried using AR grade acetone before use. The cleaned micro slides of glass are immersed horizontally wet in the mixture of 80 c.c distilled water and 20 c.c thiourea, (0.5 M concentration). 20 c.c lead acetate (0.5M concentration) solutions is then added and the slides are left for five minutes in the bath which is stirred by an electric stirrer with constant speed gear motor and were rotated at a speed of 72 ± 2 rpm. This provides a uniform and constant automatic mechanical churning of the bulk of the reaction mixture. 4 c.c of NaOH solutions,(5.0 M concentration) is added. When the solution becomes brown, we add the rest 6 c.c NaOH solution in the reaction bath. After completion of reaction the slides are removed from solution and washed with cotton wool, socked in 1% solution of ammonia. It is the case of PbS. The impurity added to the solution was taken of 0.001 M concentration 0.0225 gm. $SnCl_2$, was dissolved in 100 c.c of demonized water to get solution of these impurities.
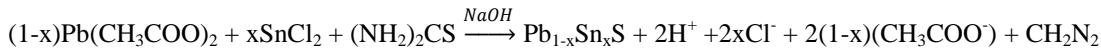
Table 1- Detailed summary of chemicals used in deposition of Thin film

S.No.	Distilled water (c.c)	Lead Accetate (c.c)	Thiourea (c.c)	NaOH (c.c)	Impurity $SnCl_2$(c.c)	Sample number
1	80	20	20	10	0	PR0
2	80	19	20	10	1	PR1
3	80	18	20	10	2	PR2
4	80	17	20	10	3	PR3
5	80	16	20	10	4	PR4
6	80	15	20	10	5	PR5
7	80	14	20	10	6	PR6
8	80	13	20	10	7	PR7
9	80	12	20	10	8	PR8
10	80	11	20	10	9	PR9
11	80	10	20	10	10	PR10

The stepwise reaction involved in the complex ion formation and film deposition process leading to PbS thin film are as follows.

$$Pb(CH_3COO)_2 \rightarrow Pb^{+2} + 2CH_3COO^-$$

$$NH_2CSNH_2 + OH^- \rightarrow CH_2N_2 + H_2O + HS^-$$

$$HS^- + OH^- \rightarrow S^{-2} + H_2O$$

$$Pb^{+2} + S^{-2} \rightarrow PbS$$

It is the case of pure lead sulphide, for impurity case the following reaction takes place

$$(1-x)Pb(CH_3COO)_2 + xSnCl_2 + (NH_2)_2CS \xrightarrow{NaOH} Pb_{1-x}Sn_xS + 2H^+ + 2xCl^- + 2(1-x)(CH_3COO^-) + CH_2N_2$$

After thin film deposition, they were characterized to determine their electrical properties [18-20].

Result:
Fig 1, Fig 2, Fig 3 and Fig 4 show the Hall coefficient, mobility and carrier concentration with respect to the temperature of Pb1-xSnxS samples. In fig 1 shows a relation between Hall Coefficient and temperature. This indicates that if we increase the temperature, the Hall coefficient decrease, and if we increase the amount of Tin impurity the Hall Coefficient increase. Fig 2 shows a relation between Hall mobility and temperature. It is inversely proportional to the temperature i.e. if we increase the temperature Hall mobility decrease. And if Tin impurity increase the Hall mobility increase as shown in fig2. Fig 3 shows a relation between carrier concentrations as a function of temperatures, if we increase the temperature carrier concentration is increase as shown in fig 3. Fig 4 shows the variation in the band gap energy with the increase of Tin concentration. If doping of Tin impurity increase the energy band gap increases.   Tin ions diffuse from the bulk to the layer surface. Probably the strong affinity of oxygen for Tin ions facilities the diffusion process. In the adsorption process electron are transferred from the impurity levels or from the top of energy bands to the adsorbed oxygen. The variation of band gap as function of tin concentration shows that band gap increases due to formation of solid solution and lies in the range 0.4eV to 1.3 eV.
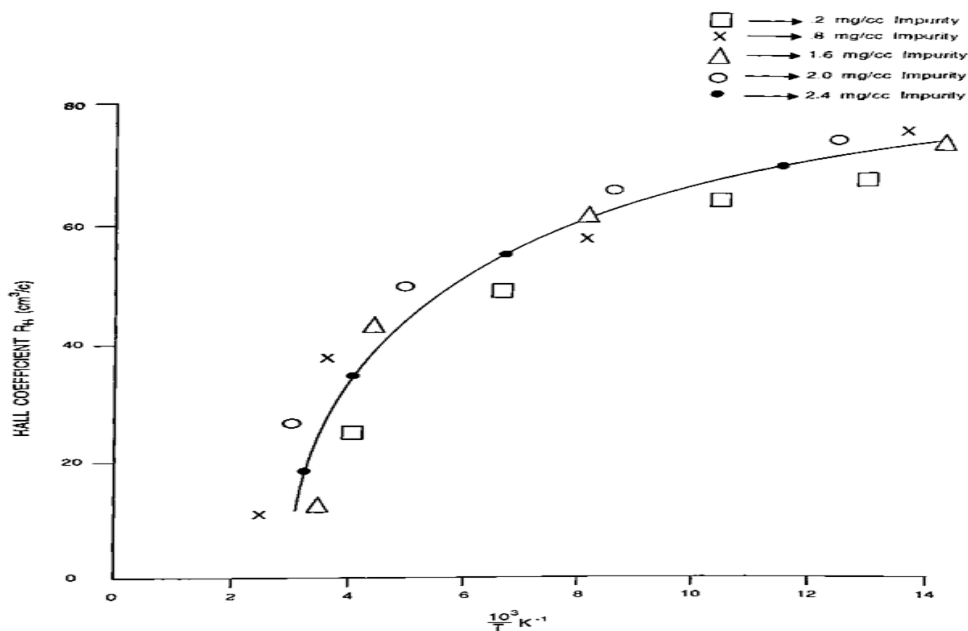

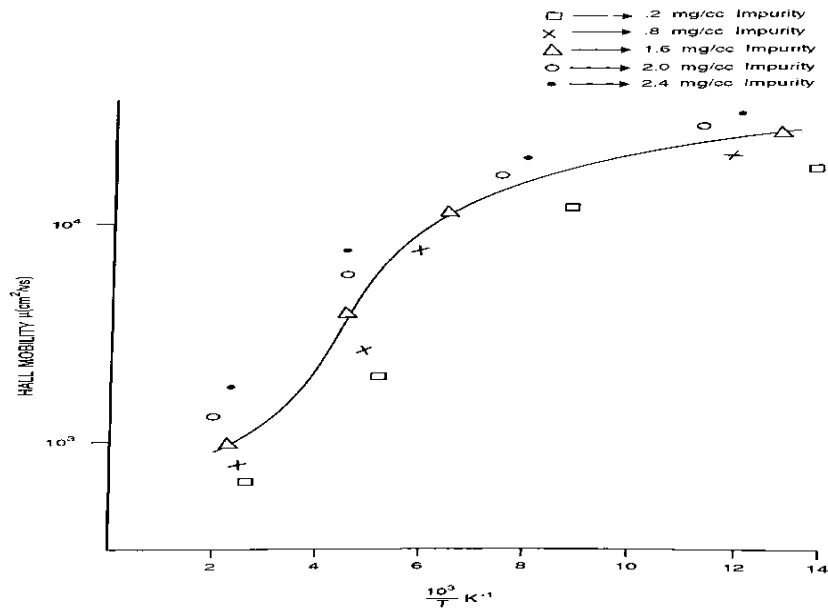**Fig 1. Hall Coefficient as a function of Temperature of Pb$_{1-x}$Sn$_x$S Thin film**

Fig 2. Hall Mobility as a function of Temperature of $Pb_{1-x}Sn_xS$ Thin film

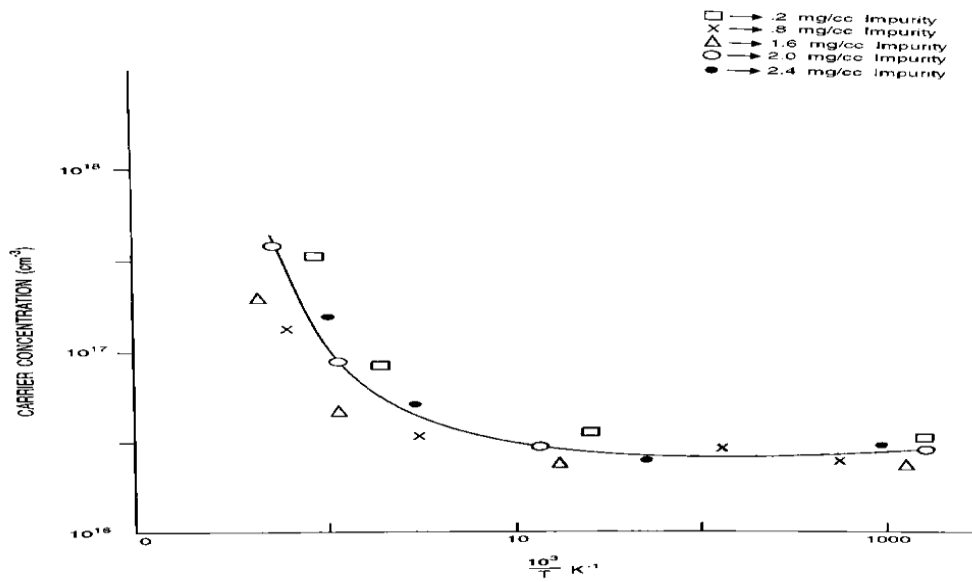**Fig 3. Carrier concentration as a function of Temperature of $Pb_{1-x}Sn_xS$ Thin film**
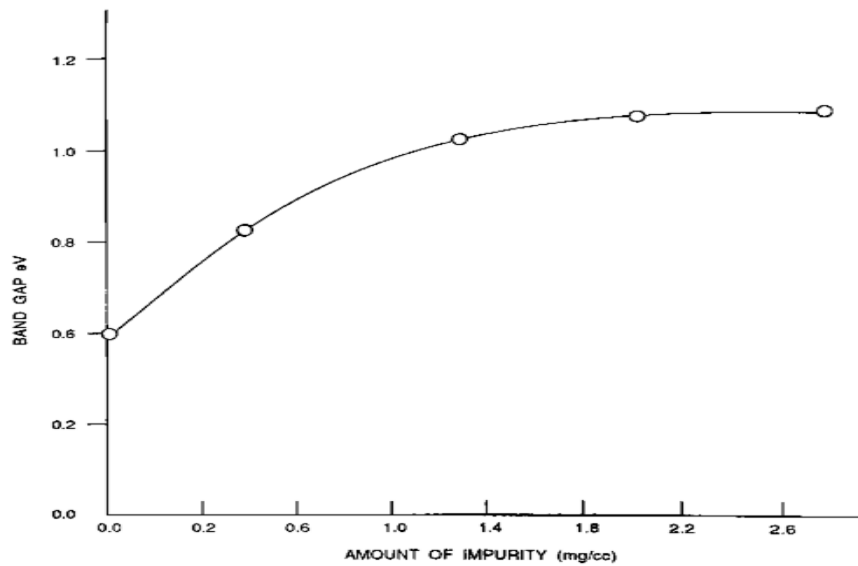
Fig 4. Variation of Band Gap of $Pb_{1-x}Sn_xS$ with Different impurity concentration

Conclusion:

Crystalline $Pb_{1-x}Sn_xS$ thin film with different concentration have been prepared and characterized.   The Hall coefficient, Mobility and carrier concentration is effected by the temperature. The variation of energy band gap as function of tin concentration shows that band gap increases due to formation of solid solution and lies in the range 0.4eV to 1.3 eV.

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