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Effect of the annealing temperature on the current-voltage and Hall effect studies of Bi_2S_3 thin films grown on glass substrates by using chemical bath deposition

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ABSTRACT

Bi_2S_3 thin films have been prepared and annealed at different temperatures (150^0C, 200^0C and 250^0C) by chemical bath deposition method. The effect of annealing temperature of Bi_2S_3 films on I-V characteristics and Hall Effect studies were investigated. The current-voltage (I-V) studies show that current is directly proportional to the applied voltage. The increase in conductivity is due to the improvement in the crystallinity of films, which decreases the resistivity. Hall Effect results show that the Hall coefficient increases with hall mobility and annealed temperature. Bi_2S_3 films are found to be n-type semiconductor.

Key words: Bi_2S_3, Thin films, Chemical bath deposition, I-V characteristics, Hall Effect studies

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INTRODUCTION

Thin solid films of metal 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 etc. [1]. There have been several techniques of thin-film growth including sputtering, sol-gel, chemical vapour deposition and chemical bath deposition. Among them, chemical bath deposition of semiconducting materials offers the possibility of depositing high quality thin films at low temperature under atoms at low fabrication cost. Binary semiconductors are interesting to study in detail the various properties of some of the members of this family. Bismuth sulphide, which has a large band gap appears to be a suitable materials for solar applications and has been used in liquid junction solar cells [2]. In order to develop films that are suitable for solar applications, in terms of sensitivity, reproducibility and stability, it is important to identify and understand how the film properties are influenced by thermal annealing [3].

In the present investigation, Bi_2S_3 films have been prepared chemically by using thiosulphate as a sulphide ion source. The thickness of the films was varied by changing the annealing temperature and its effect on the electrical conductivity and Hall parameters was studied and results are reported.

MATERIALS AND MEHODS

Bi_2S_3 thin films were prepared by chemical bath deposition technique and annealing of the film was done at various temperatures (150^0C, 200^0C and 250^0C). Preparation and characterisation of Bi_2S_3 films was explained and reported

in our previous paper [4]. Current-Voltage (I-V) characteristics of Bi_2S_3 films were done by using Electrometer (Keithley) with two point probe system. Hall effect studies were carried out using Hall measurement system [5].

RESULTS AND DISCUSSION

I-V characteristics of Bi_2S_3 films annealed at different temperatures. The as grown films were annealed at different temperatures (150^0C, 200^0C and 250^0C). Current-Voltage (I-V) characteristics were carried out and electrical parameters can be determined by using the relation:

$$\rho = 2\pi s\,(V/I) \quad (1)$$

$$\sigma = 1/\rho \quad (2)$$

Where ρ is the surface resistivity of a material, I is the current in the probe, V is the applied voltage and s is the distance between the voltage measurement and the current probe. σ is the conductivity of material. Table 1 depicts effect of annealed temperature on current-voltage (I-V) characteristics of Bi_2S_3 thin films. The thickness of films was changed by annealing at different temperatures. Electrical conductivity is found to increase from $7.71X10^{-9}$ to $2.5X10^{-8}$ (S/m) with decrease in film thickness. Such behaviour of Bi_2S_3 thin films is attributed to the improved grain size and/ or reduction of defect levels [6]. The dependence of voltage on current, conductivity and resistivity are shown in Figures (1-3). It shows that current is directly proportional to applied voltage. It indicates that films are exhibiting semiconducting nature.

Table 1: Electrical parameters of Bi_2S_3 thin films annealed at different temperatures

Annealed temperature (degree)	Thickness (nm)	Applied Voltage (V)	Current (A)	Resistance (Ohms)	Resistivity (ρ)	Conductivity σ(S/m)
150	100	0.457913	3.99E-10	1.15E+09	1.30E+08	7.71E-09
		1.173589	5.98E-10	1.96E+09	2.22E+08	4.51E-09
		1.944172	8.64E-10	2.25E+09	2.54E+08	3.93E-09
		2.808341	9.71E-10	2.89E+09	3.27E+08	3.06E-09
		3.72147	1.50E-09	2.48E+09	2.80E+08	3.57E-09
		4.665654	1.89E-09	2.46E+09	2.78E+08	3.59E-09
		5.641633	1.91E-09	2.95E+09	3.33E+08	3.00E-09
		6.672209	1.84E-09	3.62E+09	4.09E+08	2.45E-09
		7.61845	2.43E-09	3.14E+09	3.55E+08	2.82E-09
		8.578468	2.61E-09	3.29E+09	3.72E+08	2.69E-09
200	78	1.021177	3.06E-09	3.34E+08	3.77E+07	2.65E-08
		2.007394	5.80E-09	3.46E+08	3.91E+07	2.56E-08
		3.002534	8.62E-09	3.48E+08	3.94E+07	2.54E-08
		3.99747	1.42E-08	2.81E+08	3.17E+07	3.15E-08
		4.990102	1.71E-08	2.91E+08	3.29E+07	3.04E-08
		5.988822	2.03E-08	2.95E+08	3.34E+07	3.00E-08
		6.984071	2.32E-08	3.01E+08	3.40E+07	2.94E-08
		7.98065	2.66E-08	3.00E+08	3.39E+07	2.95E-08
		8.977178	2.95E-08	3.04E+08	3.44E+07	2.91E-08
		9.977457	2.30E-08	4.33E+08	4.90E+07	2.04E-08
250	62	1.113993	2.65E-09	4.20E+08	4.75E+07	2.11E-08
		2.100959	5.38E-09	3.90E+08	4.41E+07	2.27E-08
		3.092709	8.75E-09	3.54E+08	4.00E+07	2.50E-08
		4.079901	1.53E-08	2.67E+08	3.01E+07	3.32E-08
		5.066788	1.87E-08	2.72E+08	3.07E+07	3.26E-08
		6.056662	2.12E-08	2.86E+08	3.23E+07	3.10E-08
		7.045559	2.60E-08	2.71E+08	3.07E+07	3.26E-08
		8.032639	2.99E-08	2.68E+08	3.03E+07	3.30E-08
		9.0168	3.37E-08	2.68E+08	3.02E+07	3.31E-08
		10.00635	3.70E-08	2.70E+08	3.06E+07	3.27E-08

Table 2: Annealed temperature dependence of Hall coefficient, Hall mobility and Carrier concentration for Bi_2S_3 thin films

Annealed Temperature (^{0}C)	Hall coefficient R_H (cm^3C^{-1}) X10^3	Hall mobility μ ($cm^2V^{-1}S^{-1}$) X10^1	Carrier concentration n(cm^3) X10^{15}
150	-1.750	6.235	3.567
200	-4.725	16.834	1.322
250	-12.757	45.441	0.4899

Figure 1: Current-Voltage plot of Bi_2S_3 films annealed at different temperatures

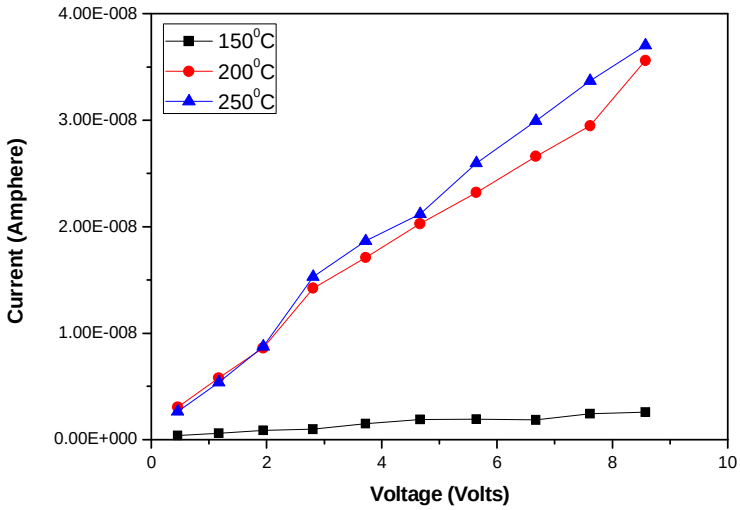
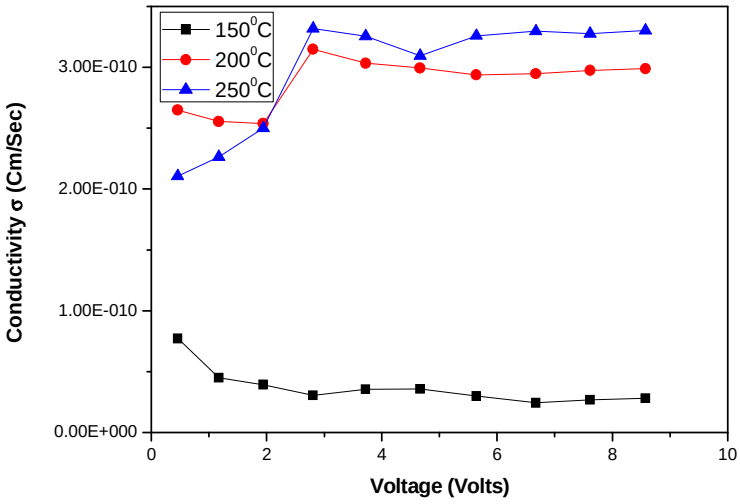


Figure 2: Voltage-Conductivity plot of Bi_2S_3 films annealed at different temperatures



Hall Effect studies of Bi_2S_3 films annealed at different temperatures. Figures (4-6) shows the dependence of Hall coefficient, Hall mobility and carrier concentrations of Bi_2S_3 thin films annealed at different temperatures (150^{0}C, 200^{0}C, and 250^{0}C). The various electrical parameters of the Bi_2S_3 thin films determined from the Hall Studies are given in Table.2. Hall Effect measurements show that the films exhibit n-type conductivity because of R_H values (negative sign). It was strongly suggested that carrier electrons are generated by the formations of sulphur vacancies [5, 7-9]. It may be noted that the mobility increases with an decrease of the film thickness which may be due to the decrease in carrier concentration film. The above fact can be attributed to the improvement in the crystallinity of the films. This is associated with a decreased number of structural defects and increased crystal grain volume. It is

observed that the value of Hall coefficient increases, while the carrier concentration decreases with increasing annealed temperature [5].

Figure 3: Voltage-Resistivity plot of Bi_2S_3 films annealed at different temperatures

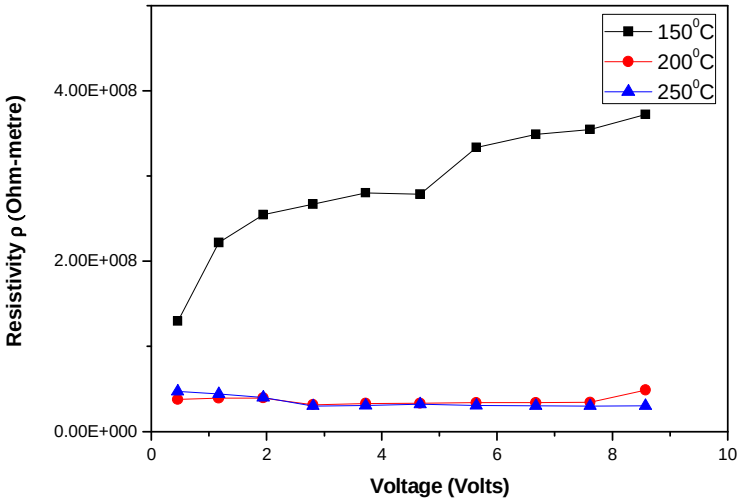


Figure 4: Annealed temperature dependence of Hall coefficient for Bi_2S_3 thin films

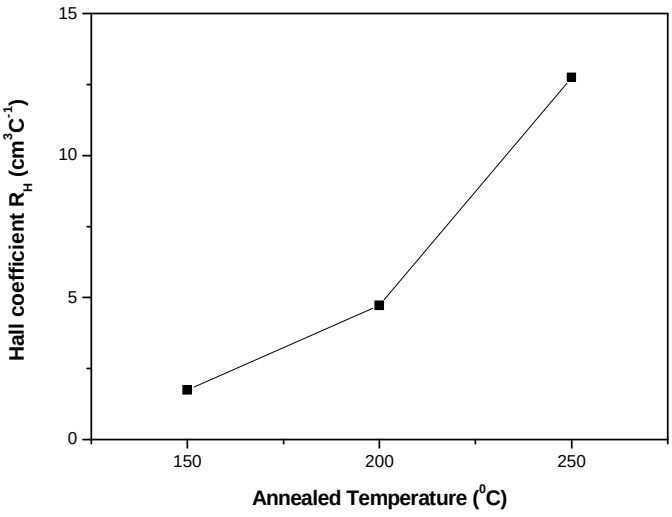


Figure 5: Annealed temperature dependence of Hall mobility for Bi_2S_3 thin films

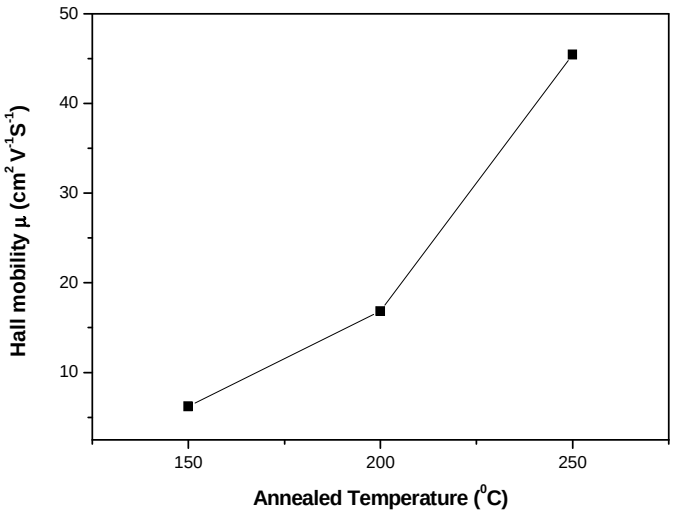
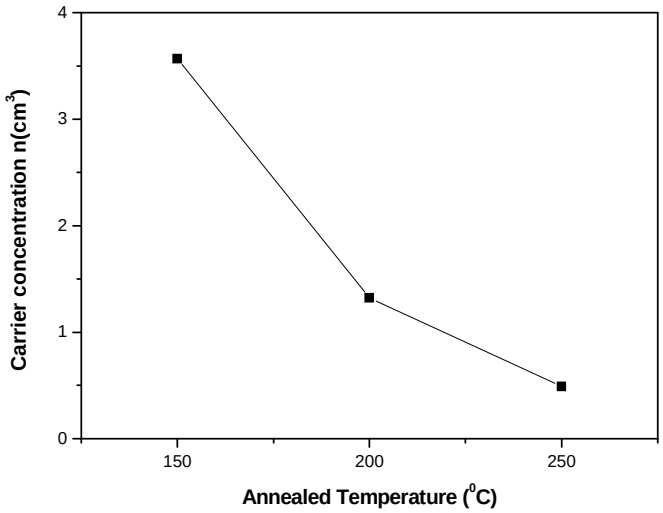


Figure 6: Annealed temperature dependence of Carrier concentration for Bi_2S_3 thin films



CONCLUSION

Bi_2S_3 thin films prepared and annealed at different temperatures by chemical bath deposition technique. From I-V characteristics, it is concluded that the current is directly proportional to the applied voltage. The increase in conductivity is due to the improvement in the crystallinity of films, which decreases the resistivity. This behaviour indicates that the semiconducting nature of films. Hall Effect studies revealed that Bi_2S_3 films are found to be n-type semiconductor. It is also observed that the Hall coefficient (R_H), Hall mobility (μ) increases and carrier concentration decreases with the increase of annealed temperature.

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