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Investigation on the electrical behavior of $In_{1-x}Sb_x$ thin films for microelectronic application

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Abstract: Indium antimonide $In_{1-x}Sb_x$ (x = 0.8, 0.5, 0.4) thin films have been grown on glass substrates by thermal evaporation method with vacuum pressure of 10^{-4} Torr at the temperature of 343 K. The V-I characteristics of the synthesized thin films have been studied. The resistivity, ρ versus temperature graph shows that $In_{0.2}Sb_{0.8}$ and $In_{0.5}Sb_{0.5}$ show the semiconducting behavior, while $In_{0.6}Sb_{0.4}$ shows the metallic behavior. The activation energy of these films is investigated by using ln ρ vs. 1000/T graph. It is exhibited that the hoping conduction takes place in low temperature region.

Key words: Thermal evaporation, Torr, Resistivity, Activation energy, Hoping conduction etc.

1. INTRODUCTION

InSb is a prominent semiconductor for the groundwork of microelectronic devices [1]. It has become one of the most extensively examined compound because of its striking physical properties, small energy bandgap, high electron mobility, small effective mass of conduction electrons and excellent galvanometric properties [2]. It is widely used in fabricating galvanometric devices, Hall effect devices, magneto- resistance devices, optoelectronic devices and infrared detectors. Thin films of InSb have been grown by various techniques such as flash evaporation [3], molecular beam, epitaxy [4], metalorganic vapor phase epitaxy [5], liquid phase epitaxy [6] and sputtering [7, 8]. It is important to optimize the conditions for the deposition of films in order to produce high quality films. For InSb, the optical transition corresponding to the energy gap which is direct and has value 0.18 eV at 300K. The thin films were found to have crystalline structure with lattice constant 6.4794 Å [1]. The g- factor for InSb has remarkable value of – 40 which indicates that the spin splitting in a magnetic field is very large by virtue of which InSb becomes a suitable material for the application in magnetic tuned lasers [2].

In the present work, we have prepared $In_{1-x}Sb_x$ thin films by using thermal evaporation technique and investigated the electrical properties of the reported thin films. These films exhibit the properties of n-type conduction due segregation of Indium.

2. EXPERIMENTAL DETAIL

A few compositions of $In_{1-x}Sb_x$ (x = 0.8 ,0.5 ,0.4) thin films were deposited on glass substrate by coevaporation of Indium and antimony using vacuum coating unit. The ultra-pure (99.99%) indium and antimony powders were weighted separately according to their atomic percentage and the evaporated under a vacuum of the order of 10^{-4} Torr using molybdenum boat to get high. quality and uniform films. The well cleaned glass substrate was clamped on the substrate holder which was spining during the deposition process at room temperature. Finally, the prepared thin films were annealed in vacuum of 10^{-4} Torr at 343 K for 3 hours to obtain structural stability.

The thickness of the film was measured by quartz crystal thickness monitor. The thickness of $In_{0.2}Sb_{0.8}$, $In_{0.5}Sb_{0.5}$ and $In_{0.6}Sb_{0.4}$ films were 5700 Å, 4400 Å and 3800 Å respectively. The four-probe method have been applied for the measurement of electrical resistivity of $In_{1-x}Sb_x$ thin films. In V-I plot, the voltage and current were the order of millivolt and milliampere respectively.

3. RESULTS AND DISCUSSION:

Resistivity measurement: The floating potential V at a distance s from an electrode carrying a current I, in a material of resistivity ρ is given by

$$V = \frac{\rho I}{2\pi s} \qquad (1)$$

The floating potential at any point in the material (film) is the difference between the potentials induced by each electrode, since they carry current of equal magnitude but in opposite directions. The current is passed through probes 1 and 2. The potential was measured across probes 3 and 4. Therefore

$V = V_2 - V_3 = (\rho I/2\pi)\,[(1/s_1) - 1/(s_2+s_3) - (1/s_3)]$ (2)

when the point spacing is equal, $s_1 = s_2 = s_3 = s$ (set by s = 1.25 mm)

$\rho = (V/I)2\pi s$ (3)

The resistivity of prepared thin films is observed at variours temperatures from 315 K to 415 K by using V-I characteristics (as shown in Fig. 1). The resistivity of $In_{0.2}Sb_{0.8}$ and $In_{0.5}Sb_{0.5}$ films decreases linearly with temperature which exhibiting the semiconductor behavior. However, the resistivity of $In_{0.6}Sb_{0.4}$ film increases linearly with temperature exicuting the metallic behavior. It is observed that the electrical behavior of $In_{1-x}Sb_x$ thin films for $x < 0.5$ illustrate significant change. In the reported thin films, the semiconducting behavior has been observed for low atomic % of In, while the metallic behavior for higher atomic % of In [9, 10]. The resistivity and activation energy of the prepared thin films have been investigated at 315 K as shown in Table 1.

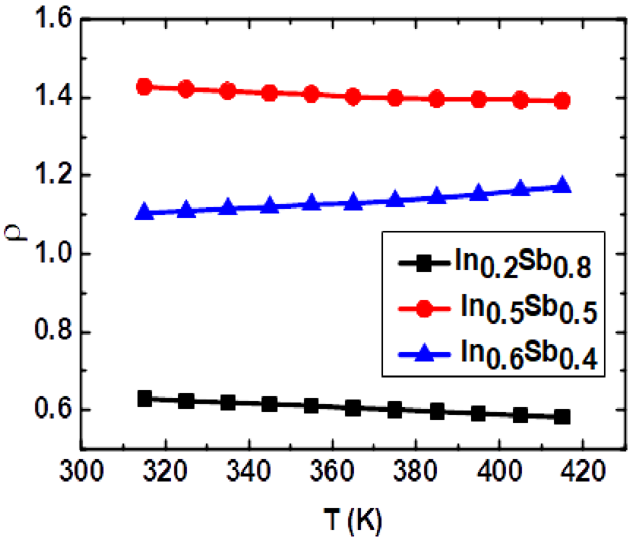


Fig:1 The plot *ρ* vs. T for the In-Sb thin films.

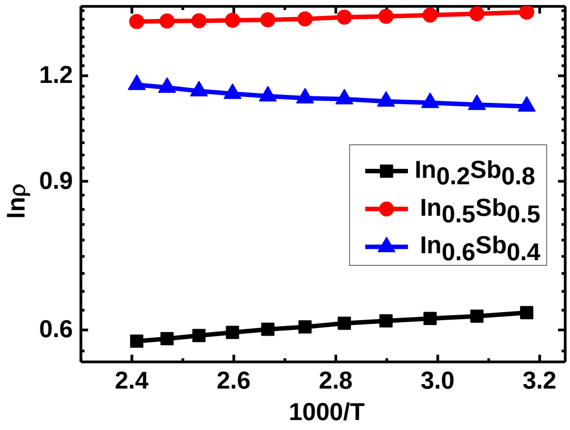


Fig. 2: The plot lnρ vs. 1000/T for the In-Sb thin films.

Activation energy measurement: The electrical resistivity of a semiconducting material depends upon the temperature T according to the relation

$\rho = \rho_o \exp(\Delta E/KT)$ (4)

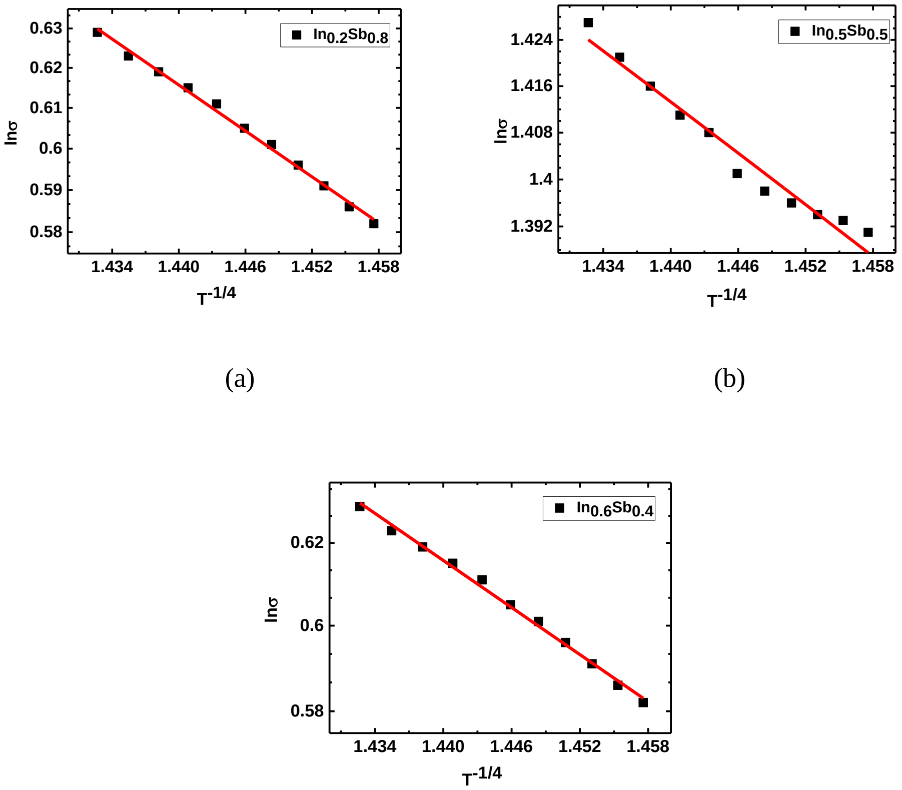
where K is the Boltzmann's constant and Δ E is an activation energy.

Since, $\ln\rho = \Delta E/KT + \ln\rho_0$ which means that the graph between lnρ and 1000/T will be a straight line as shown in Fig. 2. The activation energy of the films depends on the atomic % of Indium and is measured by the slope of straight line. The activation energy of the prepared films in the temperature range of 315 K – 415 K are given in Table1.

Hoping conduction: At low temperatures, the conduction process involves localized states near the Fermi level and the conduction is due to variable range of hoping in accordance with Mott's relation [11]

$$\sigma = \sigma_0 \exp[-(T_o/T)^{1/4}] \qquad (5)$$

A graph between lnσ and $T^{-1/4}$ for $In_{0.5}Sb_{0.5}$ and get a straight line as shown in Fig. 3, which exhibits that the conduction in low temperature region is due to hoping via states near the fermi level [12,13].



(a) (b)

(c)

Fig. 2: The Fitted plot between lnσ and $T^{-1/4}$ for **(a)** $In_{0.2}Sb_{0.8}$, **(b)** $In_{0.5}Sb_{0.5}$ and **(c)** $In_{0.6}Sb_{0.4}$

Table 1: Resistivity and activation energy of $In_{1-x}Sb_x$ thin films

Compositions of thin film	Resistivity, ρ (ohm-cm) at 315 K	Activation energy, ΔE (eV)
$In_{0.2}Sb_{0.8}$	0.628	0.019
$In_{0.5}Sb_{0.5}$	1.430	0.008
$In_{0.6}Sb_{0.4}$	1.107	---

4. CONCLUSION

$In_{1-x}Sb_x$ thin films have been grown on glass substrates by thermal evaporation technique [14]. The variation of resistivity with temperature suggests that the electrical behavior (semiconducting or metallic) of the reported films which depends on the atomic % of indium [15]. The activation energy of the films also changes accordingly. In low temperature region, the $T^{-1/4}$ law is satisfied which exhibit the hoping conduction. As a result, the $In_{0.2}Sb_{0.8}$ is a promising thin film for the application in microelectronic devices.

REFERENCES

1. S. M. Size. Physics of semiconductor Devices, Wiley, New York, 1979.
2. R. A. Smith, F. E. Jones and R. P. Chasmar, Detection and measurement of Infrared Radiation, (Clarendon, Press, 1968).
3. L. H. Chou, Thin Solid films. 215 (1992) 188.
4. J. L. Davis and P. E. Thompson, Appl. Phys. Lett. 54 (1989) 223.
5. P. K. Chiang and S. M. Bedair, Appl. Phys. Lett. 46 (1995) 38.
6. D. E. Holmes. and G. S. Kamath, J. Electron materials 9 (1980) 95.
7. T. Miyazaki and S.Adachi, Appl. Phys. 70 (1991) 1672.
8. T. Miyazaki, M. Kunugi,Y. Kitamura, S. Adachi, Thin Solid Films, 287 (1996) 51.
9. P. S. Nikam and R. R. Pawar, Indian J. Pure and Appl. Phys., 29 (1991) 263.
10. G. Bate and K. N. R. Tayler, J. Appl. Phys., 31 (1960) 991.
11. N. F. Mott, Phil.Mag.,19 (1969) 833.
12. Sharma S K, Tomokiyo Y, Singh Sukhvir, Annual Report HVEM Lab, Kyushu University Japan, 25 (2001) 3.
13. Chou L H, Thin Solid Films, 215 (1992) 188.
14. J. I. Chyi, S. Kalem, N. S. Kumar, C. W. Litton and H. Morkoc, Appl. Phys. Lett., 53 (1988) 1092.
15. J. Shigeta, N. Kotera and T. Oi, J. Appl. Phys., 47 (1976) 621.