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Electrical Resistivity, Hall Coefficient and Electronic Mobility in Indium Antimonide at Different Magnetic Fields and Temperatures

MADAN JEE*, VEENA KUMARI†, RAM NATH SINGH‡,
VIJAY PRASAD and AMITA SINGH
Department of Physics
J.L. College, Hajipur (Vaishali), Bihar University, India

The electrical resistivity, Hall coefficient and electronic mobility of n-type and p-type crystals of indium antimonide have been measured from 25°–100°C temperature range. It has been found by this measurement that indium antimonide is a compound semiconductor with a high mobility $\approx 10^6 \text{cm}^2/\text{V.S}$. The Hall coefficient R_H was measured as a function of magnetic field strength H for a number of samples of both p and n-type using fields up to 12 kilogauss. The Hall coefficient R_H decreases with increasing magnetic fields as well as with increase in temperature of the sample. The electric field is more effective on samples with high mobilities and consequently the deviations from linearitly are manifested at comparatively low values of the electric field. The measurement of R_H in weak and strong magnetic fields makes it possible to determine the separate concentration of heavy and light holes. Measured values of Hall coefficient and electrical resistivity show that there is a little variation of ρ and R_H with temperatures as well as with magnetic fields.

INTRODUCTION

Indium antimonide is a semiconducting compound of III–V group of the Periodic Table. At temperature above 78 K it behaves like a conventional semiconductor according to previously measured values[1, 2] of Hall coefficient and resistivity.

Investigations of the electrical properties of high resistivity p-type InSb crystals have established the presence of deep acceptor levels with an activation energy $\Delta t = 0.08–0.12$ eV[3].

Howarth[4] and others studied the dependence of Hall coefficient of InSb in the temperature range 14 K–290 K upon magnetic induction up to 10,000 gauss. The

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†Department of Chemistry, Samta College, Jandaha, Bihar University.

‡P.R. College, Sonepur.

variation of R_H with B at 77 K for one specimen was of the order predicted by Wilson theory, although the behaviour goes over to high field case at lower induction than the theory predicts. The variation of hole mobility with temperature shows that above 40 K it falls as the temperature rises, but as lower temperatures it increases with temperature.

Baev[5] studied the dependence of Hall effect in high resistance p-type InSb crystals. A change in the sign of R_H was observed in weak magnetic fields and E ~ 10 V/cm and the conductivity becomes electronic.

This paper reports the measurement of electric resistivity, Hall coefficient and electronic mobility at magnetic fields from 1–12 kilogauss and temperature range 25–100°C.

EXPERIMENTAL

Preparation of the samples

Indium antimonide compound is prepared by melting the components together in stoichiometric proportions. The melting process was done in an induction furnace with helium or argon as a protecting atmosphere. The melt is contained in a grade A carbon crucible. Further, purification of the compound was done by repeated zone melting. Ingots were drawn from the melt by the Kyropoulos technique starting with a small seed. In some cases the compound was prepared by melting together atimony and indium in an evacuated Vycor tube. The atimony used was chemically purified, following the method of Groschuff[6]. All ingots showed p-type semiconductor and were slightly polycrystalline. The n-type crystals were prepared by adding tellurium to the melt.

Procedure

Standard D.C. method as well as van der Power technique have been utilized for the determination of electrical resistivity, Hall coefficient and electronic mobility of indium antimonide of both p-type and n-type semiconductor crystals.

In this experiment a potentiometer is used with the detecting galvanometer. When the potentiometer is correctly adjusted it indicates the Hall voltage and the current flowing round the measuring circuit is zero. Errors due to the sample or due to contact resistance will be eliminated. The sample holder was mounted in a brass envelope, which was filled with nitrogen gas to establish heat contact with the heating coil. The magnetic field strength was varied up to 12,000 gauss, with the help of electromagnet. The electromagnet produced a homogeneous field over a volume much larger than the volume of the sample. The field strength was measured with Haritron gaussmeter type of GM-25. A sensitive thermometer was used for the measurement of temperature of the envelope in which the sample was placed.

TABLE-1
n-TYPE InSb AT 25°C

H in kg	ρ in ohm-cm	R_H in cm^3/ coulomb	μ in cm^2 (volt sec)	n per cc extrinsic carrier density
1	6.50×10^{-3}	311.25	40645.72	2.3775×10^{16}
2	7.08×10^{-3}	275.62	29317.48	2.6848×10^{16}
3	9.05×10^{-3}	245.62	28037.43	3.0127×10^{16}
4	10.07×10^{-3}	228.75	19281.93	3.2349×10^{16}
5	11.05×10^{-3}	215.62	16563.25	3.4319×10^{16}
6	12.00×10^{-3}	208.12	14721.48	3.5556×10^{16}
7	12.90×10^{-3}	204.37	13447.64	3.6208×10^{16}
8	13.80×10^{-3}	200.62	13339.96	3.6885×10^{16}
9	14.67×10^{-3}	200.62	11608.00	3.6885×10^{16}

TABLE-2
n-TYPE InSb AT 40°C

H in kg	ρ in ohm-cm	R_H in cm^3/ coulomb	$\mu = 8/3\pi \cdot \frac{R_H}{\rho}$ in cm^2 (volt sec)	$n = 7.4 \times 10^{18}/R_H$ per cc extrinsic carrier density
1	2.8444×10^{-3}	246	73411.36	3.01×10^{16}
2	3.2888×10^{-3}	225	58071.62	3.29×10^{16}
3	3.5555×10^{-3}	204	48702.17	3.63×10^{16}
4	3.8222×10^{-3}	188	41750.65	3.94×10^{16}
5	4.2666×10^{-3}	182	36208.32	4.06×10^{16}
6	4.4444×10^{-3}	180	34377.81	4.11×10^{16}
7	4.9777×10^{-3}	180	33694.65	4.11×10^{16}
8	5.3330×10^{-3}	183	29125.54	4.04×10^{16}
9	5.5999×10^{-3}	194	29406.29	3.81×10^{16}

TABLE-3
n-TYPE InSb AT 48°C

H in kg	ρ in Ohm-cm	R_H in cm^3/ coulomb	$\mu = 8/3\pi \cdot \frac{R_H}{\rho}$ in cm^2 (volt sec)	$n = 7.4 \times 10^{18}/R_H$ per cc extrinsic carrier density
1	2.325×10^{-3}	165.625	60467.47	4.46×10^{16}
2	2.525×10^{-3}	150.000	50425.33	4.93×10^{16}
3	2.750×10^{-3}	136.250	42055.48	5.43×10^{16}
4	3.000×10^{-3}	125.620	35543.19	5.89×10^{16}
5	3.300×10^{-3}	115.620	29739.79	6.40×10^{16}
6	3.665×10^{-3}	101.870	23593.44	7.26×10^{16}
7	4.125×10^{-3}	98.750	20320.39	7.49×10^{16}
8	4.650×10^{-3}	91.500	16702.71	8.08×10^{16}
9	5.350×10^{-3}	81.125	12871.22	9.12×10^{16}

TABLE-4
p-TYPE-InSb AT 25°C

H in kg	ρ in Ohm-cm	R_H in cm^3/ coulomb	$\mu = 8/3\pi \cdot \frac{R_H}{\rho}$ in cm^2 (volt sec)	$n = 7.4 \times 10^{18}/R_H$ per cc extrinsic carrier density
1	5.215×10^{-3}	349.50	56886.824	2.1173×10^{16}
2	5.35×10^{-3}	347.25	55094.375	2.1310×10^{16}
3	5.51×10^{-3}	334.95	51599.703	2.2092×10^{16}
4	5.8×10^{-3}	317.85	46517.144	2.3281×10^{16}
5	6.11×10^{-3}	305.85	42489.938	2.4194×10^{16}
6	6.46×10^{-3}	298.50	39222.082	4.4790×10^{16}
7	6.85×10^{-3}	292.50	36245.502	2.5299×10^{16}
8	7.8×10^{-3}	286.50	33313.525	2.5828×10^{16}
9	7.76×10^{-3}	282.00	30846.522	2.6241×10^{16}

TABLE-5
p-TYPE-InSb AT 40°C

H in kg	ρ in ohm-cm	R_H in cm^3/ coulomb	$\mu = 8/3\pi \cdot \frac{R_H}{\rho}$ in cm^2 (volt sec)	$n = 7.4 \times 10^{18}/R_H$ per cc extrinsic carrier density
1	2.90×10^{-3}	218.70	64013.210	3.3836×10^{16}
2	2.94×10^{-3}	209.50	60500.527	3.5313×10^{16}
3	2.99×10^{-3}	201.45	57189.317	3.6733×10^{16}
4	3.03×10^{-3}	197.40	55299.772	3.7487×10^{16}
5	3.03×10^{-3}	194.25	54372.467	3.8095×10^{16}
6	3.11×10^{-3}	190.20	51912.142	3.8906×10^{16}
7	3.16×10^{-3}	187.20	50284.899	3.9529×10^{16}
8	3.20×10^{-3}	184.50	48940.141	4.0108×10^{16}
9	3.24×10^{-3}	182.85	47829.857	4.0470×10^{16}

RESULTS AND DISCUSSION

Graphs drawn from experimental results show the general feature of the variation of Hall coefficient and resistivity. During analysis, and interpretation of the experimental results microscopic inhomogeneities, for example impurity gradients across the specimen need to be given a special consideration in the case of InSb as impurities, these can segregate anisotropically. During combined measurements of resistivity and of the Hall coefficient, voltages resulting from inhomogeneities may predominate over those due to effects which are characteristic of the material. In our case, however, repeated measurements of the different coefficients yield fairly identical results within the experimental errors. The errors originate from uncertainties of the signals measured at the voltage probes and in the determination of sample geometry.

The experimental results have been analysed in terms of the two conductors three-band model which has been used successfully in the interpretation of the dependence of R_H and ρ on magnetic fields and temperature of the specimen.

The measurement of R_H in weak and strong magnetic fields makes it possible to determine the separate concentrations of heavy and light holes.

It is evident from $R_{H—H}$ curves that R_H decreases approximately two times in the region of the fields being studied and this shows a second mechanism of the current carrier scattering in the p-type InSb samples. Hence we come to the conclusion that low frequency scattering mechanism predominates for heavy holes and impurity ion scattering for light holes during the determinatin of the given values. The Hall coefficient R_H decreases with increasing magnetic field as well as increase in temperature of the sample. The magnetic field has the maximum influence on mobility; the mobility decreases with increase in magnetic field.

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