J. Pure Appl. & Ind. Phys. Vol.2 (3), 242-246 (2012)

Study of Semiconducting Behaviour of Be at Low Temperature

PURUSHOTTAM PODDAR[1] and ANIL KUMAR BARNWAL[2]

[1]Department of Physics,
Magadh University, Bodh Gaya-824234, INDIA
[2]Adarsh College Rajdhanwar, VBU Hazaribag, INDIA

(Received on : May 29, 2012)

ABSTRACT

We have analysed the variations of electrical resistance data of Be with temperature and found that it is more or less a semiconductor at very low temperature. The high value of electrical resistivity and its temperature independent of Be at low temperature suggests that the metal is virtually a semiconductor at low temperature. It also behaves as semiconductor even up to 90K.

Keywords: Electrical resistance, Semiconductor, Semimetal, Impurity Content, lattice defect, residual resistivity, Insulators, Hall Coefficient.

1. INTRODUCTION

Electrical resistivity is one of basic parameter which differentiates metals, semimetals and semiconductors. The parameter consists of so many other parameters like electron density, impurity content and lattice defect etc. At low temperature lattice defects and impurity cause in limiting the mean free path of electron in metals but the resistance caused by them is practically constant and independent of temperature. The ideal electrical resistivity caused by lattice vibrations is strongly the temperature dependent and it varies as T^5 [1] but its contribution relatively is very small in comparison to residual resistivity caused by impurities and lattice defects even in purest sample of metal. Experiments [2-5] do not find it more than 15% of the total resistivity in any case.

At low temperature, anharmonicity of lattice waves is supposed to be weak [6,7] and the Debye's model is used faithfully. There is some chance of deviation of energy spectrum of phonons from Debye's model due to presence of impurity and lattice defect which enhance the anharmonicity of lattice waves[8,9].

In a pure specimen of metal, this effect however may be reduced. On the whole the low temperature zone is suitable for the test of theory of electrical resistivity of metals. In semiconductors, the impurity plays an important role. It dominates in contributing the electrical conductivity of a semiconductor. Therefore, the theory of electrical resistivity of metals can not be applied to the electrical conductivity of a semiconductor[8,10].

Thus analysis of the electrical conductivity of solid will classify them in to metals and semiconductors at low temperatures. The electrical resistivity of metals become linear function of temperature, however, in the semiconductors it is the exponential function of temperature [8,10]. This result is helpful in distinguishing the metals from the semiconductors and insulators.

In solid both the electrons and phonons are supposed to carry thermal energy in presence of temperature gradient. In metals the electronic contribution dominates over the phonon contributions at low temperature. In semiconductors both contributions are of comparable magnitude. The magnitude and temperature variation of thermal conductivity vary in different kinds of solids viz. metals, semiconductors & insulators. Hall coefficient gives the accurate information about the different type of conductors i.e. metals and semiconductors on the basis of nature of charge carriers and density of charge carriers[10,11,8].

2. THEORETICAL DISCUSSION

At very low temperature.

$T \leq 0.077\theta$

The B.G. formula may be reduced to[12,]

$$\frac{\rho_T}{\rho_\theta} = \frac{497.6}{\theta^5} T^5 \tag{1}$$

At temperature , $t \leq 0.166\theta$, the B.G. formula is written as[13,]

$$\frac{\rho_T}{\rho_\theta} = 1.1789\,(T/\theta)-0.16636 \tag{2}$$

Here θ = Debye's temperature.

The specific heat at low temperature of metals is found to fit the equation.

$$C_v = \gamma T + BT^3 \tag{3}$$

where $\gamma = \dfrac{\pi^2 \kappa^2}{2\mu_0}$ and $\mu_0 = \dfrac{h^2}{2m}\left(\dfrac{3n}{8\pi}\right)^{2/3}$

Here γT term is interpreted as electronic contribution where BT^3 is the lattice contribution. In semiconductor and insulator at low temperature γT should be absent. In this way the presence and absence of γT term distinguishes the metals from the semiconductors and insulators.

For free electrons, the Hall Coefficient R_H is obtained as[10,8].

$$R_H - -\frac{1}{nec} \tag{4}$$

where n is the density of electrons per unit volume, e is the electronic charge and c is the velocity of light.

In metals "n" is of the order of 10^{22} and in semi-metals it ranges from 10^8 to 10^{20}. Naturally Hall Coefficient of semi-metal is much greater than that of metals. For semiconductors R_H is obtained as

$$R_H = \pm \frac{3\pi}{8}\left(\frac{1}{nec}\right) \tag{5}$$

In case of semiconductors "n" is still lower than that of semi-metals. Value of "n" in degenerate semiconductor is greater than that in non-degenerate semiconductor. In both metals and semi-metals R_H is constant and is of negative (–) sign as given by theory.

In semiconductors R_H may have both positive and negative Hall Coefficient corresponding to hole and electrons as charge carriers.

3. RESULTS AND DISCUSSION

Observed value of the thermal conductivities [14] of Be with semiconducting materials are compared. We have plotted T/K against T^3 in case of a specimen Be.

The plots are straight line curve shown in Fig (1). The slope intercept and correlation factor (γ) of the curve in Fig (1) obtained by least square method is reported in Table (1). We have analyzed the observed thermal conductivity data of semiconductors viz. Ge, Sb, B in the light of electronic contribution. The plots between T/K and T^3 are straight line curve [Fig (1)]. More ever the thermal conductivity of Ge, Sb and B are linear below 10K, 12K and 14K respectively. All these results are similar to the specimen of Be. The nature of graph of these elements show the semiconducting behaviour of Be.

Table 1 : Slopes, intercepts and correlation factor of the curves between T/K~T^3.

Metals	Correlation factor	Slope × 10^{-5}	Intercept	Temperature zone in K
Be	0.9993	1.0045	-0.0797	45 $\le T \le 100$
Ge	0.9982	8.9100	0.5934	$15 \le T \le 25$
Sb	0.9924	91.7308	1.3228	$8 \le T \le 20$
B	0.9994	5.1380	6.0016	$35 \le T \le 50$

From the observation of above graph and result it is seen that in the lowest temperature zone the resistivity decreases from Be to Ba in alkaline earth metals. It suggests that the semiconducting behaviour of Be remains in the lowest temperature range and in the case of Ba it is also in the shortest temperature zone[15,16].

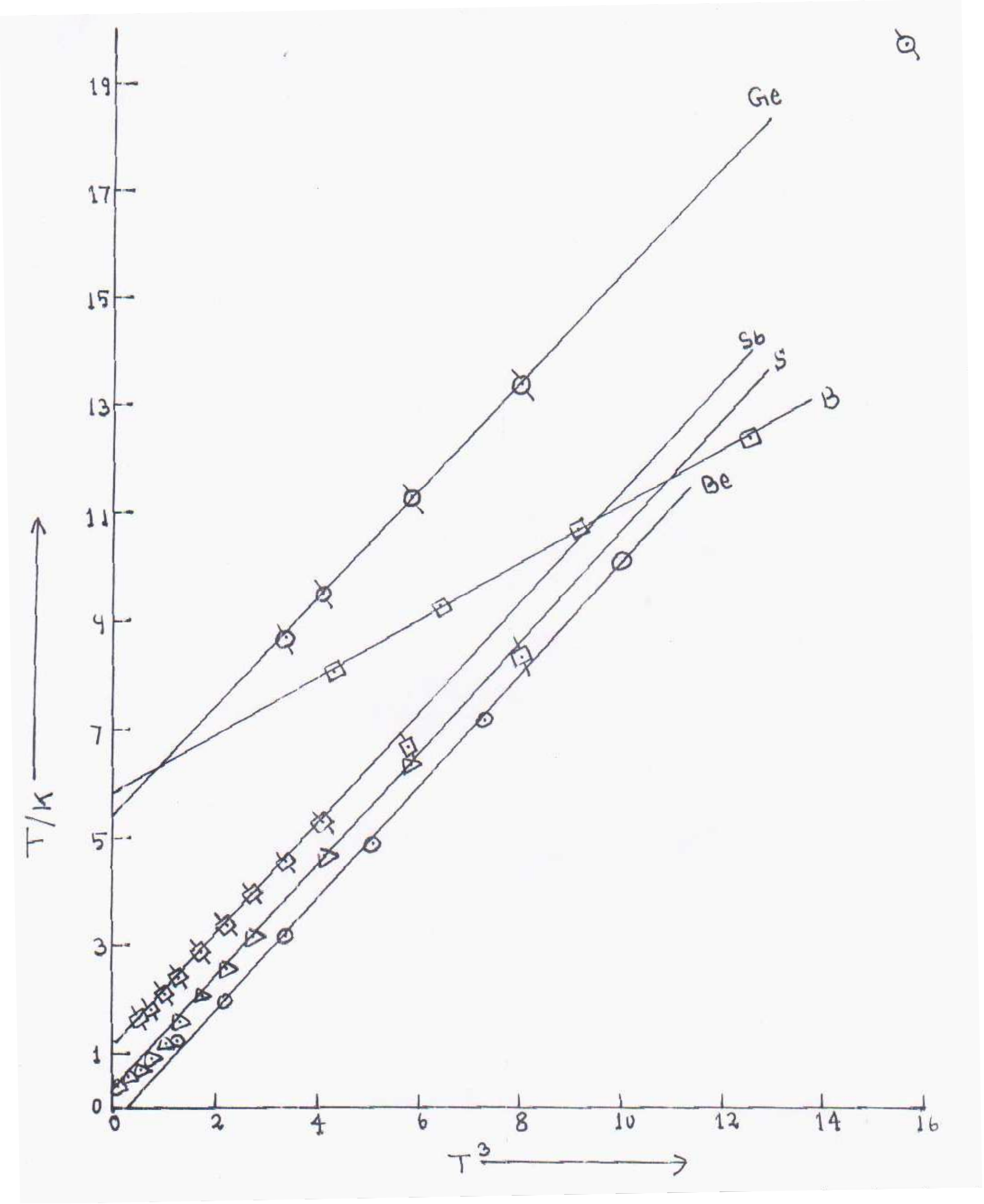

Fig.1 Plots between T/K and T³ of insulators (Se, Ge, S. B and Sb)
[The scales and origin have been suitably altered to portray the desired shapes of the curves].

4. CONCLUSION

The high value and nearly temperature dependence of electrical and thermal conductivity of Be at low temperature suggests that the alkaline earth-metal is similar as semiconductors. It also behaves as semiconductor even upto 90K.

REFERENCES

1. Bloch F.Z. *Phys* 59, 208 (1930).
2. Wood S.B. *Can. J. Phys.* 34, 233 (1956).
3. Kos J.F. *Physica State Solidi* 52, 389 (1972).
4. Rumbo E.R. *J. Phys.* F,6 85 (1976).
5. Lawrence W.E. *Phys Rev* 13, 12,5316 (1976).
6. Martin D.L. *Phys Rev* 138A, 434 (1965).
7. Tolpadi S. *I.J.P.* AP 13 503 (1975).
8. Kittel C. *Introduction to solid state phys, Wiley East Pvt. Ltd. Ed* (1977).
9. Poddar P. *Acta Ciencia Indica XVIII P.No.* 4 257 (1992).
10. Seitz F. *The modern theory of solid Mc Graw Hill Book Comp. Inc. New York & London* (1940).
11. Wilson A.H. *The theory of metals. Second Edn. Camb Uni. Press P 279* (1965).
12. Thakur and Poddar I., *J.P.A.P.* 14, 988 (1976).
13. *Thermo physical properties of Matter, Vol. 4.* (1972).
14. Poddar Ph.D. Thesis Bhagalpur Univ., Bhagalpur (1991).
15. Poddar and Choudhary, *Acta Ciencia Indica*, XXIVP, No. 4, 121 (1998).
16. International Critical Table of Numerical Date. Phys. Chem and Technology. Vol. VI, 1st Ed. Mc Graw Hill Book Co., Inc. New York (1929).

@inproceedings{Pinarbai2007ANES, title={AN EXPERIMENTAL STUDY ON LOW TEMPERATURE BEHAVIOR OF ELASTOMERIC BRIDGE BEARINGS}, author={Seval PinarbaÅŸi and U. Akyuz and G. Ozdemir}, year={2007} }. Seval PinarbaÅŸi, U. Akyuz, G. Ozdemir. Published 2007. Materials Science. Elastomeric bearings have widely been used in bridges to accommodate movements caused by creep and shrinkage of concrete, by traffic-induced forces and recently by seismic excitations.Â However, stiffness of rubber can increase considerably at low temperatures. This is an undesirable property for isolation bearings since as the stiffness of the bearings increases, their efficiency decreases. The experimentalâ€¦ CONTINUE READING. This low-temperature response-mechanism is mediated by a thin layer of adsorbed water with the semiconductor materials themselves acting as pH sensors. In this adsorbate-limited state the gas sensitivity is limited to molecular species that can easily dissolve in H 2 O and subsequently undergo electrolytic dissociation.Â Low-temperature gas response of an SnO2:Au sensor to a number of reducing analyte gases: (a) as measured at room temperature, (b) as measured at the normally employed high sensor operation temperatures.Â (a) Boiling points of the main air constituents and of a number of often studied analyte gas molecules; (b) heat of vaporisation of the main air constituents. We discuss in section 2 the HEMT static, dynamic and HF noise properties at low temperature with the main emphasis on the InP HEMT. In section 3 we investigate in a similar way the low temperature behaviour of the InP HBT. As often as possible, the data are compared with corresponding performances of cooled GaAs devices and of state of the art transistors at 300K. Basic aspects about HEMTâ€™s and HBTâ€™s can be found in [2] and [5]. Keywords. Impact Ionization Cryogenic Temperature Noise Performance High Electron Mobility Transistor Heterojunction Bipolar Transistor. These keywords were added by m As temperature increases, thermal vibrations (phonons) within a semiconductor increase and cause increased scattering. This results in a decrease in the carrier mobility.Â In general, ionized impurity scattering dominates at low temperatures, whilst at higher temperatures, phonon scattering dominates. Experimental values of the temperature dependence of the mobility in Si, Ge and GaAs are listed in table below [1]. Si. Ge.