

Electrical conduction in solid bodies

Objectives:

- 1-to study and measure the resistance of a noble metal and a semiconductor as a function of temperature.
- 2-to find α (the temperature coefficient of the resistor).
- 3-determining the band gap of the semiconductor resistor.

Theory:

The electrical resistance of an electrical conductor is the opposition to the passage of an electric current through that conductor; the inverse quantity is electrical conductance, the ease at which an electric current passes. The resistance (R) of an object is defined as the ratio of voltage across it (V) to current through it. The electrical resistivity of

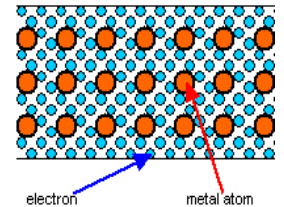


fig.1 electronic structure in metals

A)In metals:

In metals the free electrons are in constant random motion. As they move about they collide with each other and with the atoms of the metal. If a potential difference is now applied across the metal the electrons tend to move towards the positive connection. As they do so their progress is interrupted by collisions. These collisions impede their movement and this property of the material is called its resistance. If the temperature of the metal is raised the atoms vibrate more strongly and the electrons make more violent collisions with them and so the resistance of the metal increase.

Over a wide range of temperatures (far from absolute zero and far from the melting point) we find empirically that the resistance of a metal varies linearly with temperature. The functional form of the resistance R at a temperature T in Celsius is

$$R_T = R_{ref} [1 + \alpha(T - T_{ref})] \quad (1)$$

where R_{ref} is the resistance of the sample at the reference temperature T_{ref} and α is the temperature coefficient of resistance (or resistance change per degree). Note that α is constant and positive for a given reference temperature. It is also the fractional change in resistance with temperature.

In this experiment the reference point is chosen to be zero Celsius therefore eq 33 becomes:

$$R_T = R_0(1 + \alpha T) \quad (2)$$

when a noble metal resistor is used a linear relation is obtained as the temperature rises. the temperature coefficient α is determined from the slope of the line:

$$\alpha = \frac{\text{slope}}{R_0} \quad (3)$$

B:In semiconductors:

In general, resistivity of intrinsic semiconductors decreases with increasing temperature. The electrons are bumped to the conduction energy band by thermal energy, where they flow freely and in doing so leave behind holes in the valence

band which also flow freely. The electric resistance of a typical intrinsic (non doped) semiconductor decreases exponentially with the temperature:

$$R_T \sim e^{\frac{E_g}{2kT}} \quad (4)$$

where:

ΔE : energy gap

R_T : electric resistance at temperature T

k : $1.38 \times 10^{-23} \text{ J.K}^{-1}$ (Boltzmann constant)

T : Absolute temperature in Kelvin.

or

$$R_T = R_0 e^{\frac{E_g}{2kT}} \quad (5)$$

$$\ln R_T = \ln R_0 + \frac{E_g}{2kT} \quad (6)$$

If $\ln R_T$ is plotted against $1/T$ on a coordinate system, we obtain a straight line with the gradient

$$\text{slope} = E_g / 2k \quad (7)$$

It is thus possible to determine the band space ΔE from the temperature dependence of the semiconductor resistor:

$$E_g = \text{slope} * 2k \quad (8)$$

Extrinsic (doped) semiconductors have a far more complicated temperature profile. As temperature increases starting from absolute zero they first decrease steeply in resistance as the carriers leave the donors or acceptors. After most of the donors or acceptors have lost their carriers the resistance starts to increase again slightly due to the reducing mobility of carriers (much as in a metal). At higher temperatures it will behave like intrinsic semiconductors as the carriers from the donors/acceptors become insignificant compared to the thermally generated carriers.

Equipments:

sensor-cassy

Cassy Lab 2

current source box

NiCr-Ni adaptor S

Temperature sensor NiCr-Ni type K

Noble metal resistor

semiconductor resistor

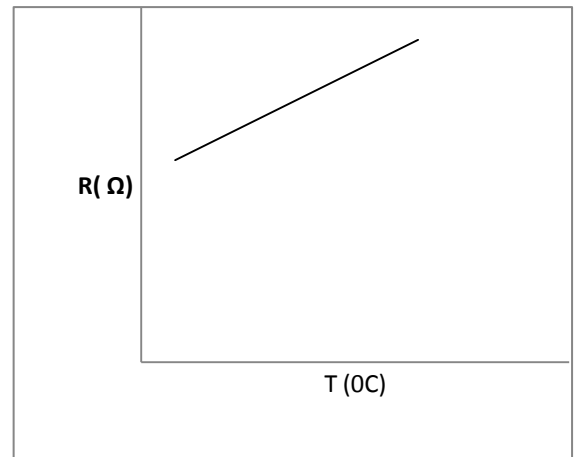
Electric oven

safety connecting box

Connecting leads

PC with Windows XP/Vista/7/8

- find the slope
- find R_0
- find $\alpha = \frac{\text{slope}}{R_0}$
- find the error where the literature value of $\alpha=0.000392 \text{ K}^{-1}$



B:Semiconductor resistor:

T (K)	R(Ω)	lnR	1/T(K ⁻¹)

- find the slope
- find $\Delta E = \text{slope} * (2k)$ in eV
 where k is Boltzmann constant= $1.38 \times 10^{-23} \text{ J K}^{-1}$ or $8.617 \times 10^{-5} \text{ eV K}^{-1}$ and $1\text{eV}=1.602 \times 10^{-19} \text{ J}$

- find the error
 where the energy gap $\Delta E = 0.49 \text{ eV}$ for resistors with serial number 586821 and $\Delta E = 0.69 \text{ eV}$ for the ones with serial number 586821

