Experiment No. 1

<u>Object:</u> To determine the band gap in a semiconductor using its p-n junction diode.

<u>Apparatus required:</u> p-n junction diode kit, electrical oven, and thermometer.

<u>Formula used:</u> The reverse biased current I_s (saturated value) is the function of temperature (T) of the junction diode. For a small range of temperature, the relation is expressed as,

$$\mathrm{Log}_{10} I_s = \text{constant} - 5.036\,\Delta E\,(10^3/T)$$

where, temperature T is in Kelvin, ΔE is the band gap in electron volts (eV).

<u>Theory:</u>

In a semiconductor, there is an energy gap between its conduction and valence band. For the conduction of electricity a certain amount of energy is to be given to the electron so that it goes from the valence band to the conduction band. The energy so needed is the measure of the energy gap (ΔE) between two bands. When PN junction is placed in reverse bias, the current flows through the junction due to minority charge carriers. The concentration of these charge carriers depends on band gap (ΔE). The saturation value of reverse current (I_s) depends on the temperature of junction diode and it is given by equation,

$$I_s = \text{Constant}\; x T^{3/2} e^{\frac{-\Delta E}{kT}}$$

where, $k = 1.38 \times 10^{-23}$ *J/K* is Boltzman's constant and T is absolute temperature of junction.

Taking log of both sides of above equation,

$$2.3026 \log_{10} I_s = 2.3026 \log_{10}\left(\text{Constant}\; x T^{3/2}\right) - \frac{\Delta E}{kT}$$

$$\log_{10} I_s = C - \frac{\Delta E}{2.3026 kT}$$

where C is a constant which is equal to the first term of RHS of above equation *(for small changes in temperature, log T can be treated as constant).* On substituting the value of *k* and converting the unit of ΔE , we get

$$\log_{10} I_s = C + (-5.036\Delta E)\frac{10^3}{T}$$

This represents a straight line ($y=mx+c$) having a negative slope (5.036 ΔE). Therefore, by knowing the slope of the line, ΔE can be determined through following formula

Slope= 5.036 ΔE

ΔE = [(slope of the line)/5.036] eV

Procedure:

1. Plug the mains lead to the nearest mains socket carrying 230V at 50 Hz A.C.
2. Fix a thermometer on p-n junction kit to measure the temperature.
3. Keep the temperature switch at OFF position.
4. Switch ON the instrument using ON/OFF toggle switch provided on front panel.
5. Adjust the voltage (e.g. 5Volt) and note down the reverse current.
6. Select the temperature control switch at ON position. Temperature starts increasing and the reading of micrometer also starts increasing.
7. As temperature reaches about 78°C, switch off the oven. The temperature will rise further, say about 80°C and will become stable for Ge diode. Note down the maximum reading shown by the micro ammeter (μA).
8. Now temperature will begin to fall. Take values of current (in μA) in the interval of 2°C.
9. Plot a graph between $\text{Log}_{10}\, I_s$ and (10^3/T) and find the slope.

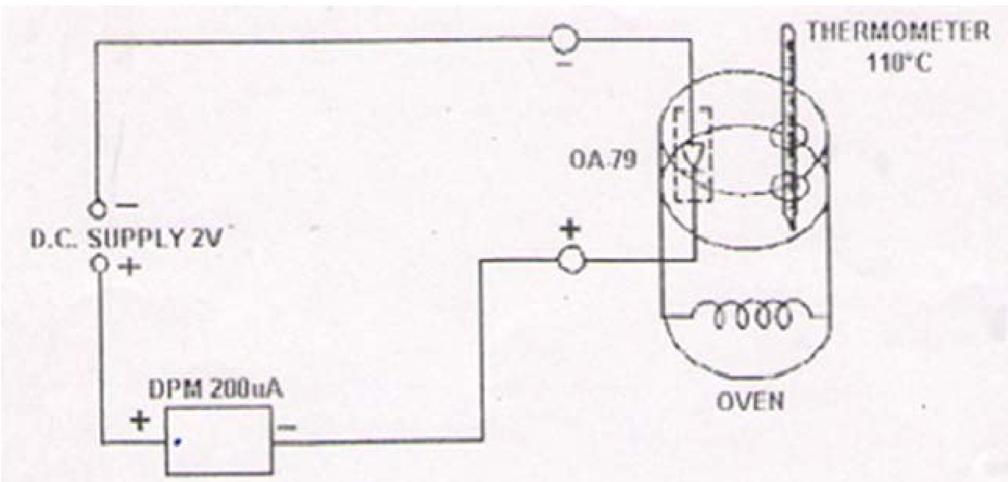

Fig.1. Schematic diagram of the set-up

Observations:

Least count of thermometer =……..

Least count of microammeter =…….

Constant voltage applied to the diode =………

(a) Table for the variation of reverse biased saturated current with temperature:

S. No.	Temperature (°C)	Current I_s (μA)	Temperature (K)	$(10^3/T)\ K^{-1}$	$Log_{10}\ I_s$

Calculations: Plot a graph between $Log_{10}\ I_s$ and $(10^3/T)$ and find the slope. Now calculate the band gap by using the relation,

$$\Delta E = [(\text{slope of the line})/5.036]\ \text{eV}$$

Result: The band gap of the given semiconductor p-n junction diode =……………….eV.

Standard results: $\Delta E = 0.7$ eV for Ge

Percentage error =……………….%

Sources of error and precautions:

1. Maximum temperature should not exceed 80°C in case of Ge diode.

Viva-Voice:

Q.1: Explain the formation of energy bands in solids.

Q.2: What is energy band gap?

Q.3: Define valence band, conduction band and Fermi level.

Q.4: Classify the solid materials on the basis of energy gap.

Q.5: Define conductors, insulators and semi conductors.

Q.6: How many types of semi conductors are there?

Q.7: Define intrinsic and extrinsic semi conductor?

Q.8: Define doping and dopant?

Q.9: Why P-type (N-type) semi conductor is called Acceptor (Donor)?

Q.10: What is P-N junction diode?

Q.11: How does depletion region form at the junction in p-n junction diode?

Q.12: What do you mean by forward biasing?

Q.13: What do you mean by reverse biasing?

Q.14: Plot the I-V characteristics of p-n junction diode?

Q.15: The p-n junction is operating under reverse bias in this experiment, why?

Q.16: What is breakdown voltage?

Q.17: Why does current increase with increase in T without changing voltage?

Q.18: How does resistance vary with temperature T in metals and semiconductors?

References:

1. Semiconductor Physics and Devices: Basic Principles (Donald A. Neamen).
2. Principle of Electronics (V. K. Mehta).
3. Introduction of Solid State Physics (C. S. Kittle).