Experiment No. - 02

Object :-

To Determine the Energy Band Gap of a semi-conductor by using P-N junction.

Apparatus required :-

Energy Band Gap kit containing a P-N junction diode placed inside the temperature controlled electric oven. microammeter, Voltmeter and connections brought out at the socket. a mercury thermometer to the front panel to measure the temperature of oven.

Formula use :-

The Reverse saturation current Is is the funcation of a temperature (T) of the juncation diode. for a small Range of Temperature the relation is expressed as,

$$\log_{10} I = \text{constant} - \frac{5.036 \times 10^3 E_g}{T}$$

where

"T" is temperature in Kelvin and "E_g" is the Band Gap in electron Volt (eV)

Graph Between $\frac{10^3}{T}$ as abscissa and $\log_{10}$ "I_s" as ordinate will be straight line having

slope = $5.036\ E_g$

BAND GAP,

$$E_g = \frac{-\text{Slope of line}}{5.036}$$

<u>Theory</u> :-

A semi-conductor always possess an energy gap between its valence and conduction bands. For the conduction of electricity a, certain amount of energy is to be given to the electron so that it can jump from the valence to the conduction band. The energy so needed is the measure of the energy gap (Eg) between the top and bottom of valance and conduction bands respectively. In case of insulator the value of Eg varies from 3 to 7 eV however for semi-conductor it is quite small for ex.

$$E_g = 0.72 \text{ (Germanium)}$$

$$E_g = 1.1 \text{ eV (sillicon)}$$

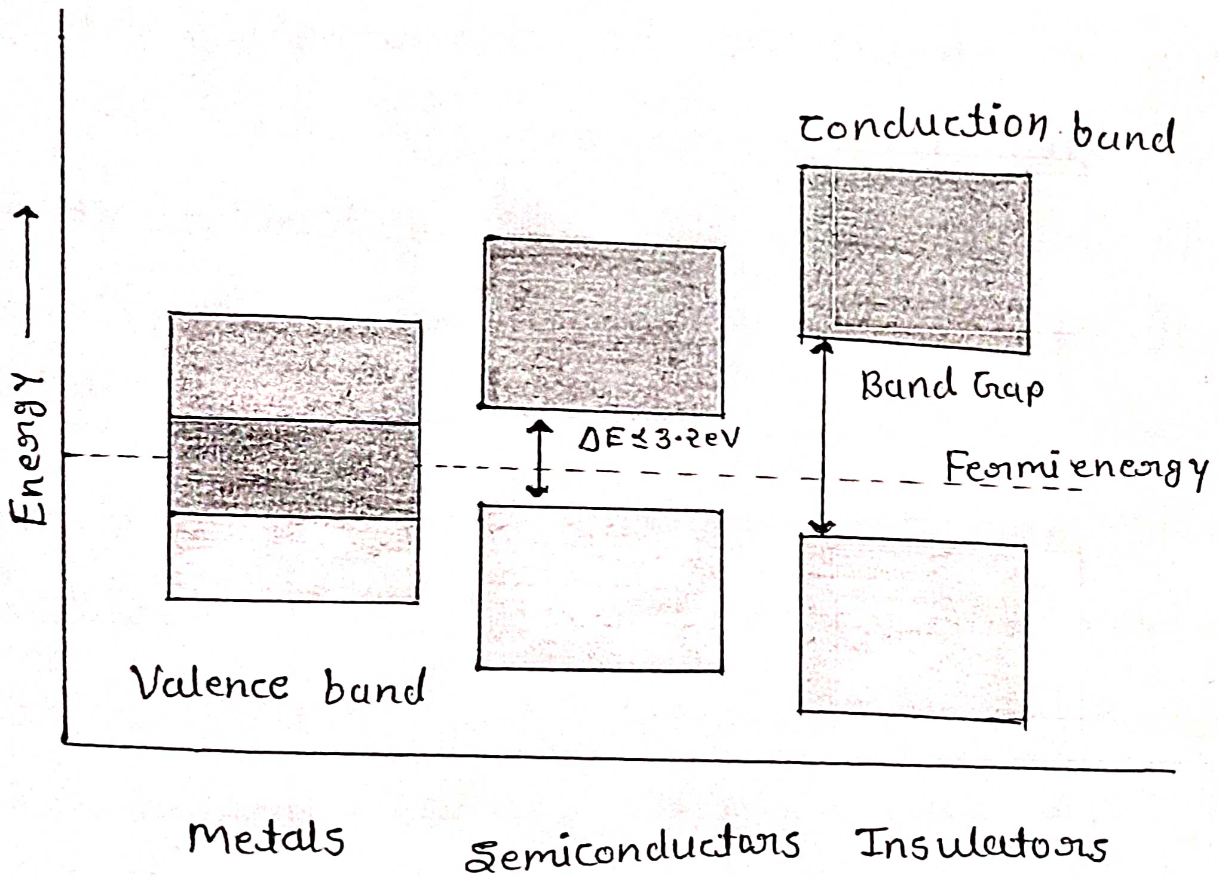


fig. :- Energy Gap in Metals, Semi-conductors and Insulators

In semi-conductor at low temperatures there are few charge carriers to move, so conductivity is quite low. However with increase in temperatures more number of charge carries get sufficent energy to be excited to the conduction band. This lead to increase in the number of free charge carries and hence increase in conductivity. In addition to the dependence of electrical conductivity on the no. of free charge, it also depends on their mobability. The mobility of the charge carries however decreases with increasing Temperature

to determine the energy band gap of a semi-conductor material, we study the veriation of Its conductor with temperature in reverse bias. the current flowing through the P-N junction is quite small and internal heating of the junction does not take place. when P-N junction is placed in reverse bias as shown in figure the current must flows through the junction due to miniority charge carries only the concentration of these charge carries depends on band gap "Eg" the saturation value Is reverse current depends on the temprature of junction diode and it is given by the following eqn

$$I_s = A(N_n e V_n + N_p e V_p)\, e^{-Eg/KT}$$

$N_n \rightarrow$ Concentration of electrons

$V_n . V_p \rightarrow$ Drift Velocities of electron and holes

$A \rightarrow$ Area of junction

$K \rightarrow$ Boltzman constant 1.38×10^{-23} J/K

Taking log of both sides of above equation, we have

$$\log_e I_s = \log_e A(N_n e V_n + N_p e V_p) - \frac{E_g}{KT}$$

or

$$2.303 \log_{10} I_s = 2.303 \log_{10} A(N_n e V_n + N_p e V_p) - \frac{E_g}{KT}$$

or

$$\log_{10} I_S = C - \frac{E_g}{2.303kT}$$

where C is a constant, which is equal to the first term of RHS of above equation. On substituting the value of k and converting the units of Eg from eV to joule, we get

$$\log_{10} I_S = C - \frac{1.6 \times 10^{-19} E_g}{2.303 \times 1.38 \times 10^{-23} T}$$

or

$$\log_{10} I_S = C - \frac{5.036 \times 10^{3} E_g}{T}$$

which can be expressed as,

$$\log_{10} I_S = C + (-5.036 E_g) \frac{10^3}{T}$$

This represents the equation of straight line having negative slope of the (5.036 Eg) for graph drawn between $\log_{10} I_S$ and $10^3/T$. Therefore, by knowing the slope of the line. E_g can be determined through following formula,

$$Slope = 5.036\,E_g$$

$$E_g = -\frac{\text{Slope of graph drawn between } \log_{10} I_s \text{ and } \frac{10^3}{T}}{5.036}$$

Procedure :-

1) Insert the thermometer in the hole of the oven.

2) Switch on the instrument using on/off toggle switch provide on the front pannel keep the temperature control switch to the high side.

3) Adjust the voltage at 1V DC.

4) Switch on and using on/off toggle temperature starts increasing and the reading of

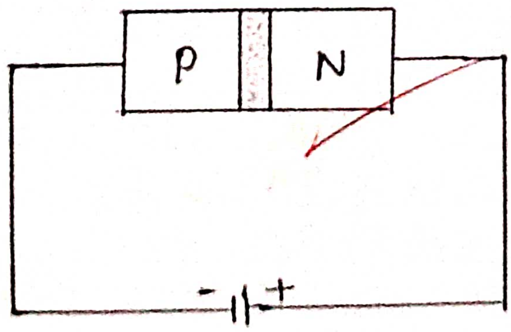
microammeter also starts increasing.

5) when temperature reaches to 90°C or 100°C, switch off the oven and note down the reading of microammeter (μA).

6) As the temperature starts falling, note down the reading of microammeter after every 5°C or 10°C drop in temperature.

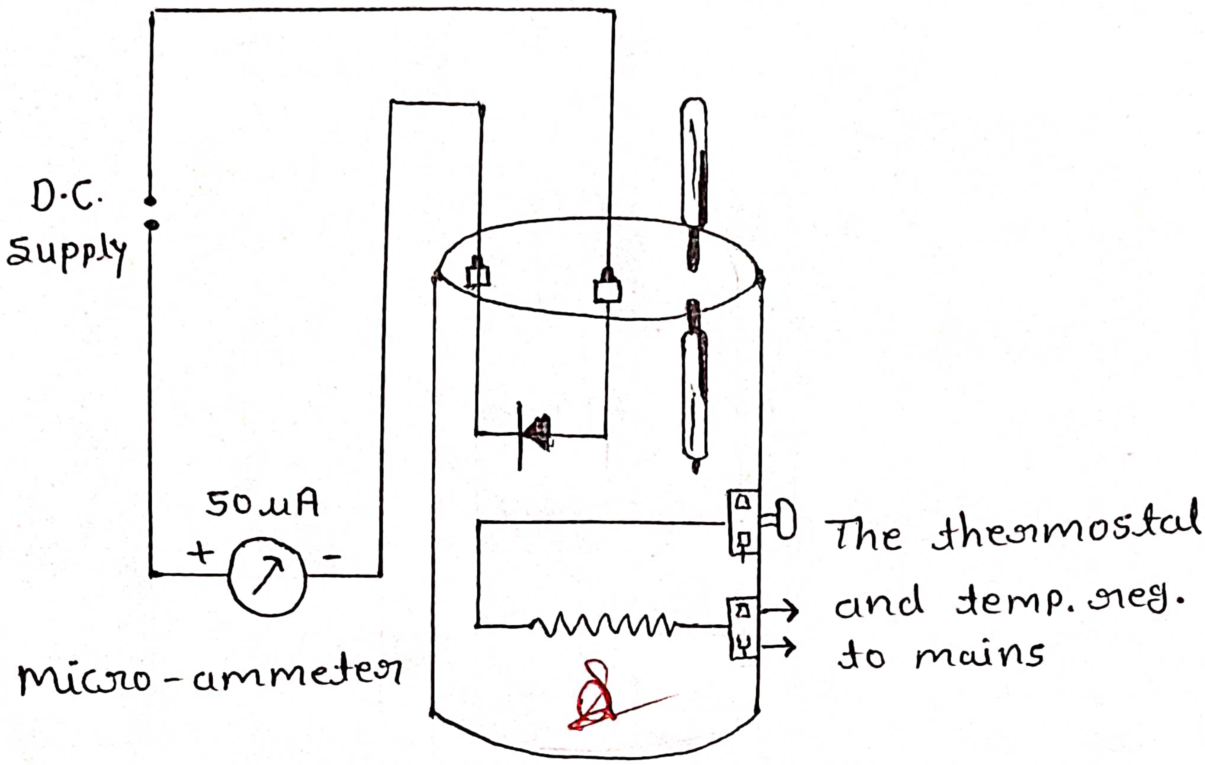
7) Repeat the whole procedure for 2V and 3V DC.

8) Plot graph between $\log_{10} I_s$ and $\frac{10^3}{T}$ for different Voltages.



(a)

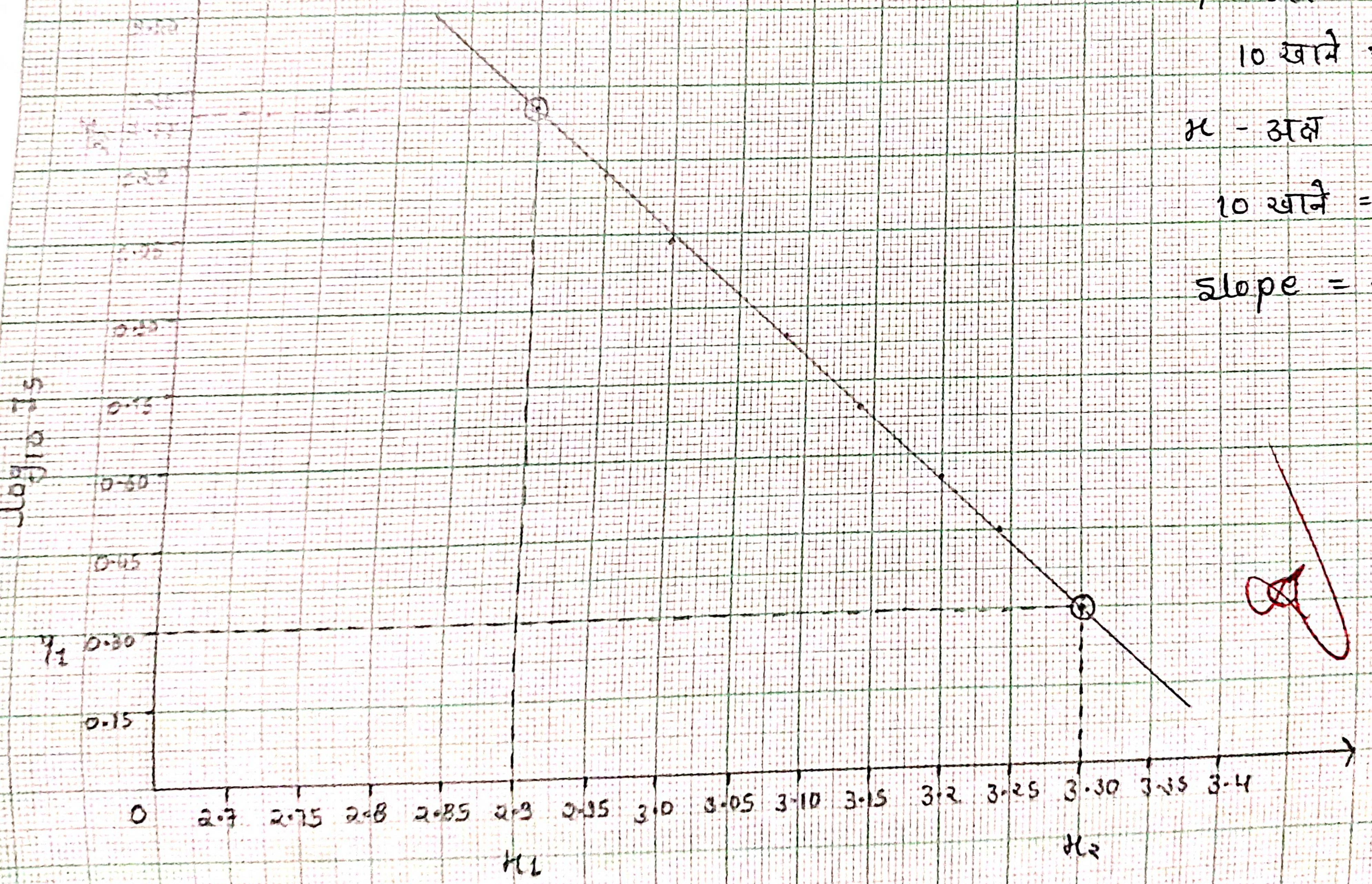
fig. (a) = Reverse biased PN junction Diode



(b)

fig :- Experimental setup

(INCREASE)



Y - अक्ष

10 खाने = 0.15

x - अक्ष

10 खाने = 0.5

slope = -3.43

Observation Table :-

S.No.	Tem °C	Current Is (μA)		T = t+273K	$\frac{10^3}{T}$	$\log_{10} I_c$	
		Increasing	Decreasing			Increasing	Decreasing
1.	24°C	1.5	1.5	297K	3.36	0.17	0.17
2.	30°C	2.0	2.0	303K	3.30	0.30	0.30
3.	35°C	2.7	2.6	308K	3.24	0.431	0.41
4.	40°C	3.7	3.3	313K	3.19	0.568	0.51
5.	45°C	5.2	4.7	318K	3.14	0.71	0.67
6.	50°C	6.4	5.8	323K	3.098	0.80	0.76
7.	55°C	8.5	7.7	328K	3.04	0.92	0.886
8	60°C	10.8	10.5	333K	3.00	1.033	1.021
9.	65°C	14.1	15.2	338K	2.95	1.149	1.681
10.	70°C	20.6	20.6	343K	2.91	1.313	1.313

Calculations :-

Taking $10^3/T$ along X-axis and $\log_{10} I_s$ Y-axis plot a graph between $\log_{10} I_s$ and $10^3/T$ for three diff. voltage. The graph will be "straight line" determine the slope of straight line from this graph and then calculate band gap using formula.

$$E_g = \frac{-\text{slope}}{5.036} = 0.68\ eV \qquad (\text{slope } -3.43)$$

Result :-

The Band gap (E_g) of the given semi-conductor is found to be 0.68 eV.

Precaution :-

1) The diode must be reverse biase

2) Do not exceed the temperature of the oven above 100°C to avoid over heating of diode.

3) Bulb of the thermometer should be inserted well in the oven.

4) Reading of micrommeter should be taken when the temperature is decreasing..

Seen & checked
23/12/2022