ENERGY BAND GAP EXPERIMENT

Aim/Objective

To determine the Energy Band Gap of a Semiconductor by using PN Junction Diode.

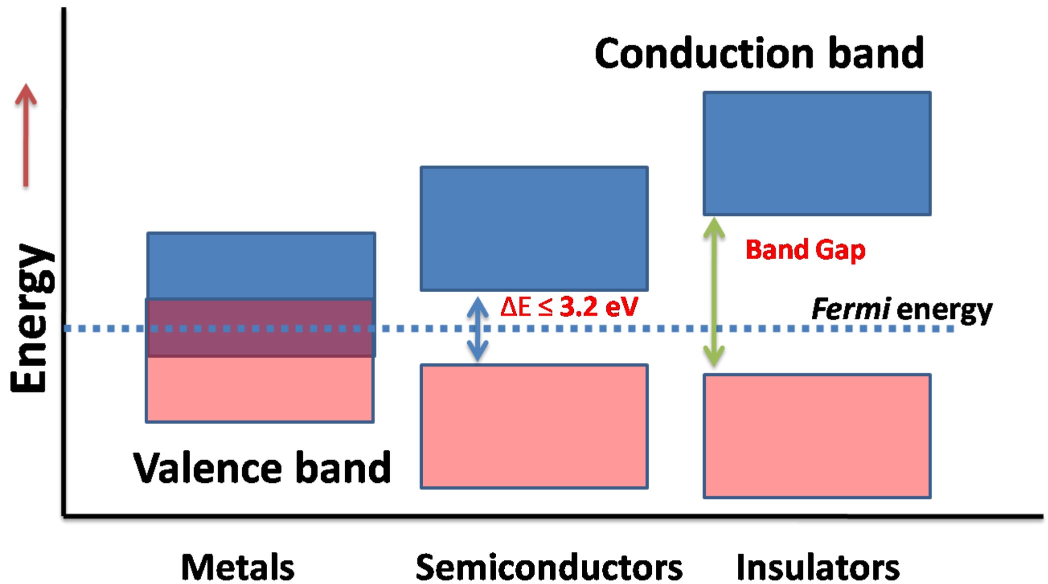
Apparatus Required

- **Energy band gap kit containing a PN junction diode placed inside the temperature controlled electric oven.**
- **A mercury thermometer to mount on the front panel to measure the temperature of oven.**

Theory

A semi-conductor (either doped or intrinsic) always possesses an energy gap between its valence and conduction bands. For the conduction of electricity in semiconductors, a certain amount of energy is to be given to the electron so that it can jump from the valence band to the conduction band. The energy so needed is the measure of the energy gap (Eg) between the top and bottom of valence and conduction bands respectively.

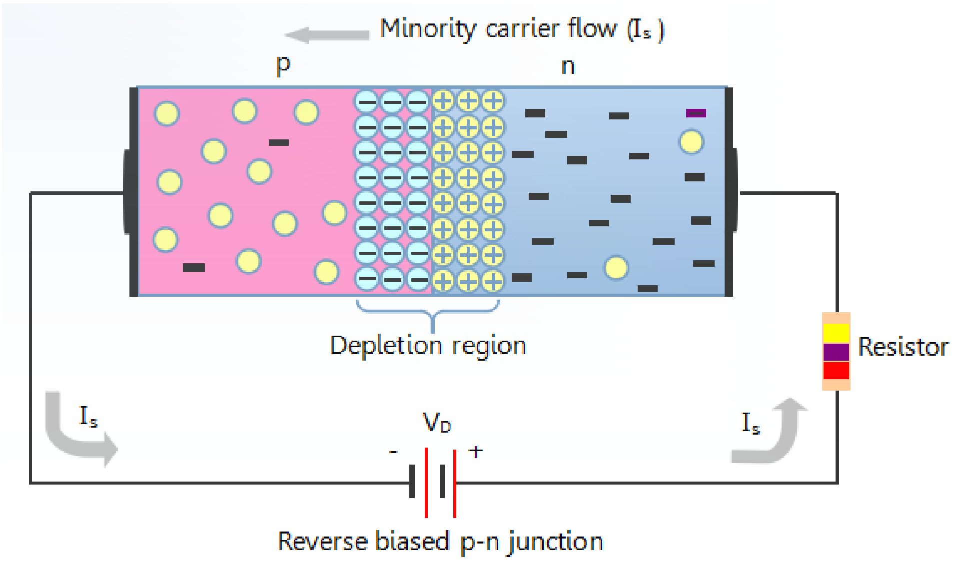
In case of insulators, the value of Eg varies from 3 to 7 eV. However, for semiconductors, it is quite small. For example, in case of germanium, Eg = 0.72 eV and in case of silicon, Eg = 1.1 eV.



In semi-conductors at low temperatures, there are few charge carriers to move, so conductivity is quite low. However, with increase in temperature, more number of charge carriers get sufficient energy to be excited to the conduction band. This lead to increase in the number of free charge carriers and hence increase in conductivity.

To determine the energy band gap of a semi-conducting material, we study the variation of its conductance with temperature. In reverse bias, the current flowing through the PN junction is quite small and internal heating of the junction does not take place.

When PN junction is placed in reverse bias as shown in figure, the current flows through the junction due to minority charge carriers only. The concentration of these charge carriers depend on band gap Eg. I_s is the saturation reverse current.



The saturation value, Is of reverse current depends on the temperature of junction diode and it is given by the following equation,

$$I_s = A\,(N_n\, e\, v_n + N_p\, e\, v_p)\ \exp\,(-\,Eg/kT)$$

Where, N_n (N_p) is the concentration of electrons (holes) in N(P)-type region, v_n and v_p are the drift velocities of electrons and holes respectively, A is the area of junction, k = 1.38 x 10-23 J/K, is Boltzman's constant and T is absolute temperature of junction.

Taking log of both sides of above equation, we have

$$log_e I_s = log_e A\,(N_n\, e\, v_n + N_p\, e\, v_p) - Eg/kT$$

Or

$$2.303\ log_{10} I_s = 2.303\ log_{10} A\,(N_n\, e\, v_n + N_p\, e\, v_p) - Eg/kT$$

Or

$$log_{10} I_s = C - Eg/2.303\ kT$$

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

$$log_{10} I_s = C - Eg/2.303\ kT \quad \text{or} \quad log_{10} I_s = C - (1.6 \times 10^{-19}\, Eg)/[2.303 \times 1.38 \times 10^{-23}\, T]$$

Or

$$log_{10} I_s = C - 5.036 \times 10^3 Eg/\mathrm{T}$$

This equation $log_{10} I_s = C - 5.036 \times 10^3 Eg / \mathrm{T}$ can be expressed as

$$log_{10} I_s = C + (-5.036\ Eg) 10^3 / \mathrm{T}$$

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

Slope = 5.036 Eg

Or

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

Procedure

1. Insert the thermometer in the hole of the oven.
2. Switch ON the instrument using ON/OFF toggle switch provided on the front panel.
3. Keep the temperature control switch to the high side. Adjust the voltage at 1V DC.
4. Switch ON the oven using ON/OFF toggle switch provided on the front panel.
5. Temperature starts increasing and the reading of micro-ammeter (μA). also starts increasing.
6. When temperature reaches to 90°C or 100°C, switch OFF the oven and note down the reading of micro-ammeter
7. As the temperature starts falling, note down the readings of micro-ammeter after every 5°C or 10°C drop in temperature.
8. Repeat the whole procedure for 2V and 3V DC.
9. Plot graph between $log_{10}I_s$ and $10^3/T$. for different voltages.

Observations

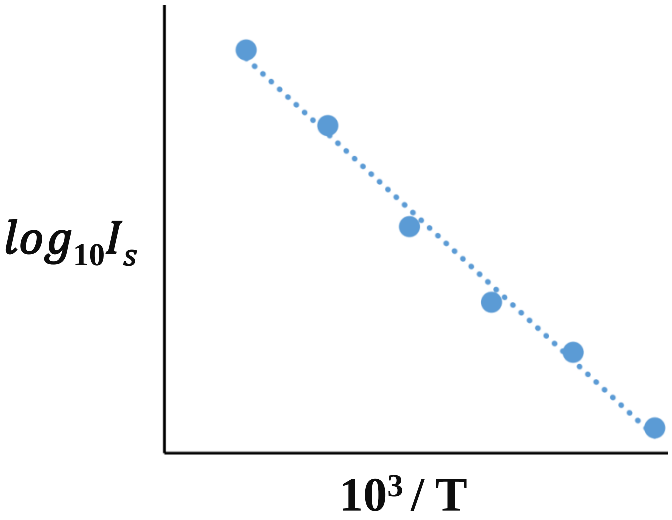
S.No.	Temp. (°C)	Current I_s (μA)			Temp. (K)	10^3/ T	$\log_{10} I_s$
		V = 1V	V = 2V	V = 3V			
1.	30						
2.	40						
3.	50						
4.	60						
5.	70						
6.	80						
7.	90						
8.	100						

Calculations

- Taking $\mathbf{10^3 / T}$ along X-axis and $log_{10}I_s$ along Y-axis, plot a graph between $log_{10}I_s$ and $\mathbf{10^3 / T}$ for three different voltages.

- The graph will be a straight line as shown in figure.

- Determine the slope of straight line from this graph and then calculate band gap using formula,



$$\text{Band gap } (E_g) = \frac{Slope}{5.036} = \_\_\_\_\_\_\_\_ \text{ eV.}$$

Result:

The band gap (Eg) of the given semiconductor is found to be ______ eV.

Sample Viva Voce Questions

1.What is PN junction diode ?
2. What do you understand by band gap of a semi-conductor ?
3. What do you mean by valence band, conduction band and forbidden band ?
4. How many types of semi-conductors are there ?
5. What are P-type and N-type semi-conductors ?
6. Define doping and dopant.
7. Why P-type (N-type) semi-conductor is called Acceptor (Donor) ?
8. What do you mean by Fermi energy level ?
9. What is the position of Fermi level in an intrinsic semi-conductor and in a p-type or n- type semi-conductor with respect to the positions of valence and conduction bands ?
10. What do you mean by forward biasing and reverse biasing ?
11. Why diode is reverse biased in determining the band gap of semi-conductor ?
12. What is the shape of graph between $log_{10} I_s$ and $10^3 / \mathrm{T}$? How do you find band gap energy from this graph ?
13. Why conductivity of metals decreases with increase in temperature ?
14. Why conductivity of a semi-conductor increases with increase in temperature ?

Thank You