EXPERIMENT NO.5

ENERGY BAND GAP OF A SEMICONDUCTOR

OBJECTIVE :

To determine the energy band gap of a given semiconductor material using a reverse biased p-n junction diode.

APPARATUS REQUIRED:

D.C power supply, electrically heated oven, Voltmeter, Micro-ammeter, Thermometer and Semiconductor diode.

FORMULA USED :

Energy band gap of a semiconductor material is given by

$$= 2.303 \times 10^{3} \times \quad \times \text{ slope of line (In } eV\text{)}$$

THEORY:

Semiconductors are the class of materials having conductivity between conductors and insulators. The characteristic feature of semiconductors is their energy band gap that ranges from 0.3 *eV* to 3 *eV*. Semiconductors are only materials which conduct *via* electrons and holes. Semiconductors are broadly classified as intrinsic and extrinsic semiconductors. Intrinsic semiconductors are pure semiconductors, when intrinsic semiconductors are added with suitable impurity it is referred as extrinsic semiconductor. Silicon (Si) and Germanium (Ge) are the intrinsic semiconductors with band gaps 1.12 *eV* and 0.67 *eV* at room temperature respectively.

Band theory explains the electronic behaviour of solids. According to this theory - a solid contains an enormous numbers of atoms packed closely together. Each atom in isolated form has discrete set of electron energy levels.When two atoms come closer then the outermost electron in either atom can be influenced on each other. The wave functions of those electrons begin to overlap. The two overlapping wave functions combine describing two electronic states having slightly different energies. In this way, if N atoms are broght to form a solid, each level of the isolated atom becomes N levels of solid. A continuous band having all the valence band is called conduction band (C. B.). These allowed states are now grouped into bands with energy gaps between them in which no electronic state exist.

An intrinsic semiconductor doped with trivalent atoms leave unpaired electrons of the lattice. This result to vacant electron sites or holes in excess. This is called a p- type semiconductor. If the doping is done by pentavalent atoms, then electrons become available in excess and the semicondurtor is n–type . When a junction is formed between n–type and p– type semiconductor the junction behaves as a semiconductor diode.

When the semiconductor is available in the form of devices, then this method is used for determining the band gap of semiconductor. The relevant circuit diagram is shown below.

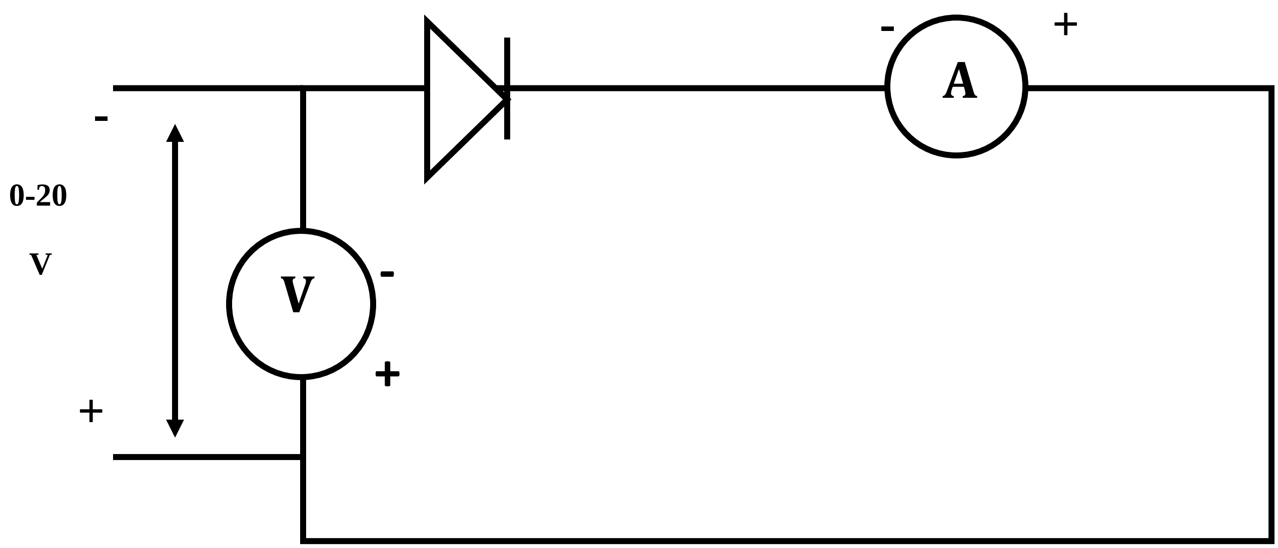

Figure.1 Circuit digram for determining energy band gap of a semiconductor

In a reverse biased p –n junction diode the current is given as

$$I = C \exp\left(-\frac{E_g}{2\pi n}\right) \qquad (1)$$

Where C = Constant

k_B = Boltzmann’s constant = 8.6×10^{-5} *eV*/ degree

T = Temperature (K)

E_g = Energy band gap of semiconductor

Taking natural logarithm of equation (1) from both sides, we get

$$\ln I = \ln C - \frac{E_g}{k_B T} \qquad (2)$$

$$2.303 \log I = 2.303 \log C - \frac{E_g}{k_B T}$$

$$\log I = \log C - \frac{E_g}{2.303 \times k_B T}$$

$$\log I = \log C - \frac{E_g}{2.303 \times k_B \times 10^3} \left[\frac{10^3}{T}\right] \qquad (3)$$

Equation (3) shows that the reverse saturation current *I* in a given semiconductor diode is dependent only on the temperature and varies inversely with temperature. A plot between log *I* and *T* gives a straight line with a negative slope $\frac{10^3}{T}$.

PROCEDURE:

1. Connect p and n sides of junction diode to micro-ammeter and battery in reverse bias configuration , as shown in figure 1.
2. Set a fix voltage at any value (preferably less than 10 V)
3. Vary the heater current so that the temperature of the oven vary slowly. For convenience fast hating may be done up to 60^0 C and then slowly heat up to 90^0 C.
4. Switch off the heater and note the current with decreasing temperature starting from 80^0 C to 45^0 C with a step of 5^0 C.

OBSERVATION:

S. No.	Temperature		Voltage V = ………. Volts		
	T (^{0}C)	T (K)	Current I (amp)	log I	$\frac{10^3}{T(K)}$
1.	80				
2.	75				
3.	70				
4.	65				
5.	60				
6.	55				
7.	50				
8.	45				

CALCULATION:

Plot a curve between log I and $\frac{10^3}{T}$ gives a straight line with a negative slope having a value $\frac{E_g}{2.303 \times k_B \times 10^3}$

Slope of line = $\frac{AB}{BC}$

Thus $E_g = 2.303 \times 10^3 \times k_B \times$ slope of line (In eV)

Similarly find the energy band gap on finding the slope of line taken from the set of voltage. Finally determine the mean value of them.

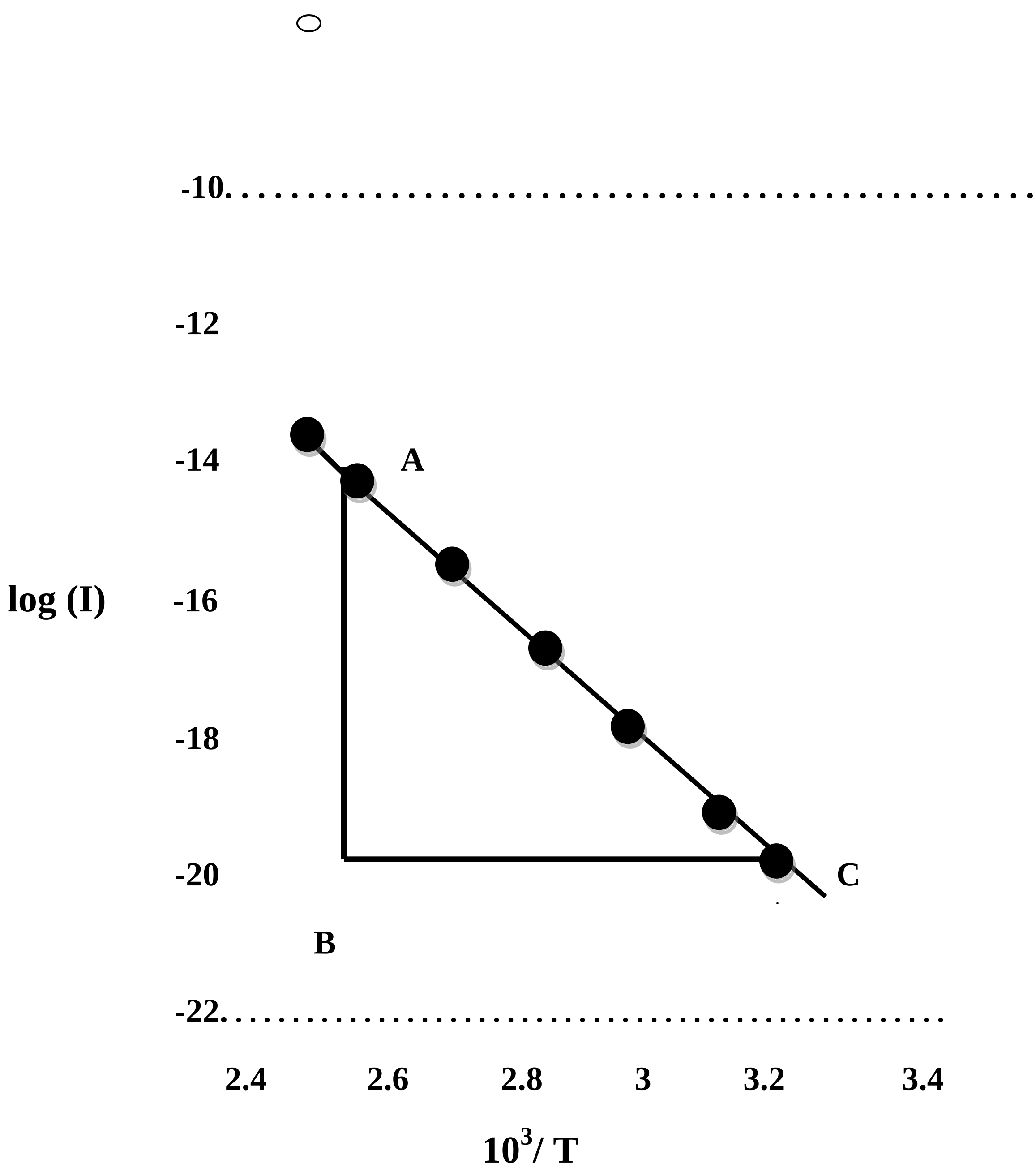

Figure.1 Plot a curve between log *I* and $\frac{10^3}{T}$

RESULT:

(a) Energy band gap of given semiconductor material = --------------- *eV*

(b) Given semiconductor is ---------------------------------- (Ge or Si)

STANDARD RESULT: Band gap of Ge and Si are as

= 0.67 eV (for Ge)

= 1.12 eV (for Si)

ERROR:

% Error = ----------------- %

PRECAUTIONS:

(1) Diode should be in reverse biased.

(2) Do not heat more than 100^0 C .

(3) Reading must be taken during cooling.