SAP ID-60004200132
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**Experiment No.** 2 **Date:-** 16/03/2021

**(Module 1)** **ENERGY GAP OF SEMICONDUCTOR**

**FEC102.3:** Interpret the basic knowledge of semiconductor physics in understanding the working of semiconductor devices.

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**AIM:** - To determine the energy band gap of semiconductor.

**Apparatus:** - Semiconductor material (p-n junction diode), voltmeter, micrometer, power supply, heating source, thermometer etc.

## Theory: -

The band gap is an important physical property which specifies ease with which the covalent bonds can be broken and electrons are set free in semiconductor. Thus band gap determines electrical behaviour of device made with this material. Electrons and holes are the majority charge carriers in n and p region respectively. Majority charge carriers arise due to doping while minority carriers are generated due to temperature effect. Minority charge carriers are generated due to breaking of covalent bonds which require a supply of energy equal to $E_g$. So by studying the effect of temperature variation on the conduction of minority charge carriers, it is possible to evaluate $E_g$.

The semiconductor diode characteristics may be represented closely by the following equation:

$$I = I_s \left[exp^{\frac{eV}{kT}} - 1\right]$$

Where, I=Forward current
e= charge on electron
T= temperature in °K
$I_s$=reverse saturation current
V=applied voltage
K = Boltzmann's constant

The saturation current ($I_s$) is sensitive to temperature and may be given by,

$$I_s = AT^2 e^{\left[\frac{-E_g}{kT}\right]} \quad \text{.......... (1)}$$

Where A= area of junction

$$\text{i.e. } \log_e \frac{I_s}{T^2} = -\frac{E_g}{kT} + \log_e A \quad \text{.......... (2)}$$

$$\text{i.e. } \log_{10} \frac{I_s}{T^2} = -\frac{E_g}{2.303k}\left[\frac{1}{T}\right] + \text{Constant} \quad \text{.......... (3)}$$

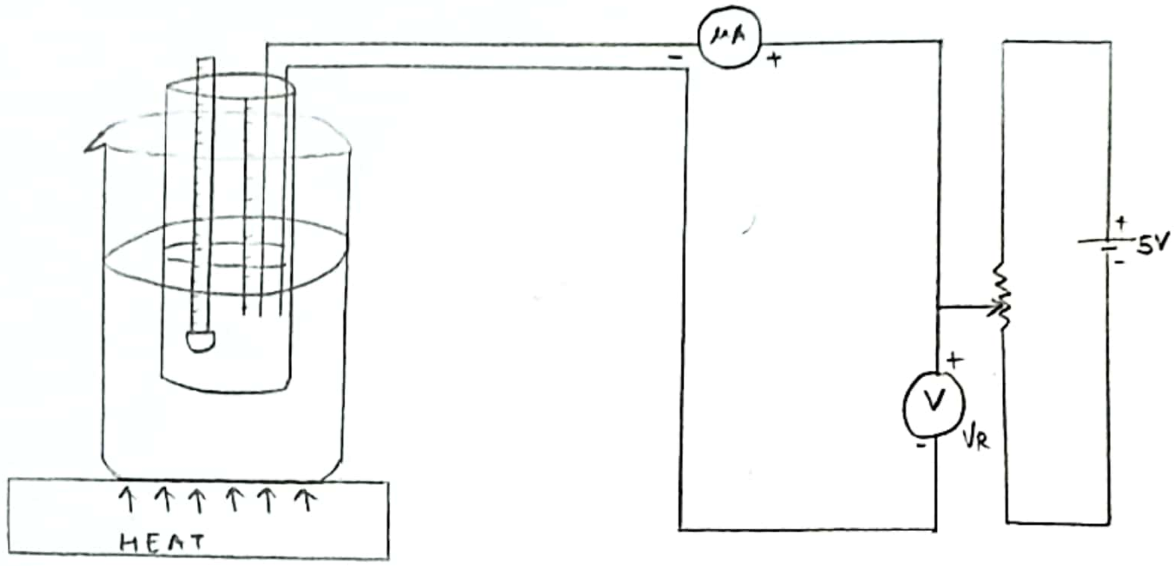
So, the slope of the graph of $\log_{10}\frac{I_s}{T^2}$ vs $\frac{1}{T}$ is given by following relation

$$\text{Slope} = -\frac{E_g}{2.303k} \quad \text{.......... (4)}$$

$$\text{i.e. } E_g = -2.303 \times k \times slope \quad \text{.......... (5)}$$

$$\text{i.e. } E_g = -\frac{2.303 \times 1.38 \times 10^{-23} \times slope}{1.6 \times 10^{-19}} \text{ eV} \quad \text{.......... (6)}$$

## Circuit Diagram:-




CIRCUIT DIAGRAM FOR THE MEASUREMENT OF ENERGY BAND GAP

## Procedure:-

1. Place the diode in a thin –walled test tube together with a thermometer and put the whole arrangements in the water bath.
2. Connect the circuit.
3. At room temperature, increase the reverse bias in suitable steps and note down the reverse current. Take sufficiently more readings beyond saturation point.
4. Plot the graph of $I_R$ vs. $V_R$ and determine the saturation current $I_s$ at room temperature. Also determine the minimum reverse voltage $V_R$ at which the saturation is obtained.
5. Now adjust the reverse voltage to a value much greater than $V_R$. Keep this reverse voltage constant. Increase the temperature of the water bath with the help of heating system above 80°C.
6. Switch off the heater and let the water bath cool down. Note the saturation reverse current $I_S$ at various temperatures starting from 75°C up to 35°C by a step of 5°C.
7. Plot the graph of $\log_{10}\frac{I_s}{T^2}$ vs. $\frac{1}{T}$ and find the slope. Hence determine the value of energy band gap by, using the formula given in equation (6).

## Observations:-

### Table 1: Determination of $V_R$

Room Temperature= 24 °C

| Obs. No. | $V_R$ (Volts) | $I_R$ (μA) |
|---|---|---|
| 1 | 0 | 0 |
| 2 | 0.1 | 2 |
| 3 | 0.2 | 2 |
| 4 | 0.3 | 2 |
| 5 | 0.4 | 2 |
| 6 | 0.5 | 2 |
| 7 | 1.0 | 2 |
| 8 | 1.5 | 2 |

### Table 2: Measurement of $I_S$ at various temperatures

$I_S$ at room temperature = 2 μA

Reverse bias voltage= 1 Volt

| Obs. No. | t°C | T°k | $\frac{1}{T^o} k^{-1}$ | $I_S$ (μA) | $T^2$ | $\log_{10} \frac{I_s}{T^2}$ |
|---|---|---|---|---|---|---|
| 1 | 75 | 348 | 0.002874 | 96 | 121104 | -3.100887 |
| 2 | 70 | 343 | 0.002915 | 68 | 117649 | -3.238079 |
| 3 | 65 | 338 | 0.002959 | 48 | 114244 | -3.376592 |
| 4 | 60 | 333 | 0.003003 | 34 | 110889 | -3.513410 |
| 5 | 55 | 328 | 0.003049 | 22 | 107584 | -3.689325 |
| 6 | 50 | 323 | 0.003096 | 16 | 104329 | -3.814285 |
| 7 | 45 | 318 | 0.003145 | 11 | 101124 | -3.963462 |
| 8 | 40 | 313 | 0.003195 | 08 | 97969 | -4.087999 |
| 9 | 35 | 308 | 0.003247 | 04 | 94864 | -4.375041 |
| 10 | 30 | 303 | 0.003300 | 02 | 91809 | -4.661855 |

## Calculations:-

Slope = $-3.66 \times 10^{3}$

$$E_g = -\frac{2.303 \times 1.38 \times 10^{-23} \times slope}{1.6 \times 10^{-19}} =$$

$E_g$ = 0.71 eV

Slope Calculation

Pts: $2.8 \times 10^{-3}, -3.1$

$3.2 \times 10^{-3}, -4.4$

$$\text{slope} = \frac{-4.4 + 3.1}{(3.2 - 2.8) \times 10^{-3}}$$

$$= -3.66 \times 10^{3}$$

**Result:** - Energy band gap of semiconductor = $E_g$ = 0.71 eV

**Comments: -**

1. Material of given semiconductor diode is Germonium
2. What happens to energy band gap of semiconductor if temperature increases?

Energy bond gap decreases as temperature increases. As the temperature increases, the atomic vibrations increase leading to greater outeratomic spining.

| D.J.S.C.E. (Physics) | | |
|---|---|---|
| Journal | | |
| Knowledge | 3 | |
| Documentation | 3 | |
| Punctuality | 3 | |
| Virtual Lab (Performance & Documentation) | 6 | |
| Total | 15 | |

| | |
|---|---|
| | |
| Date | Signature of the faculty |

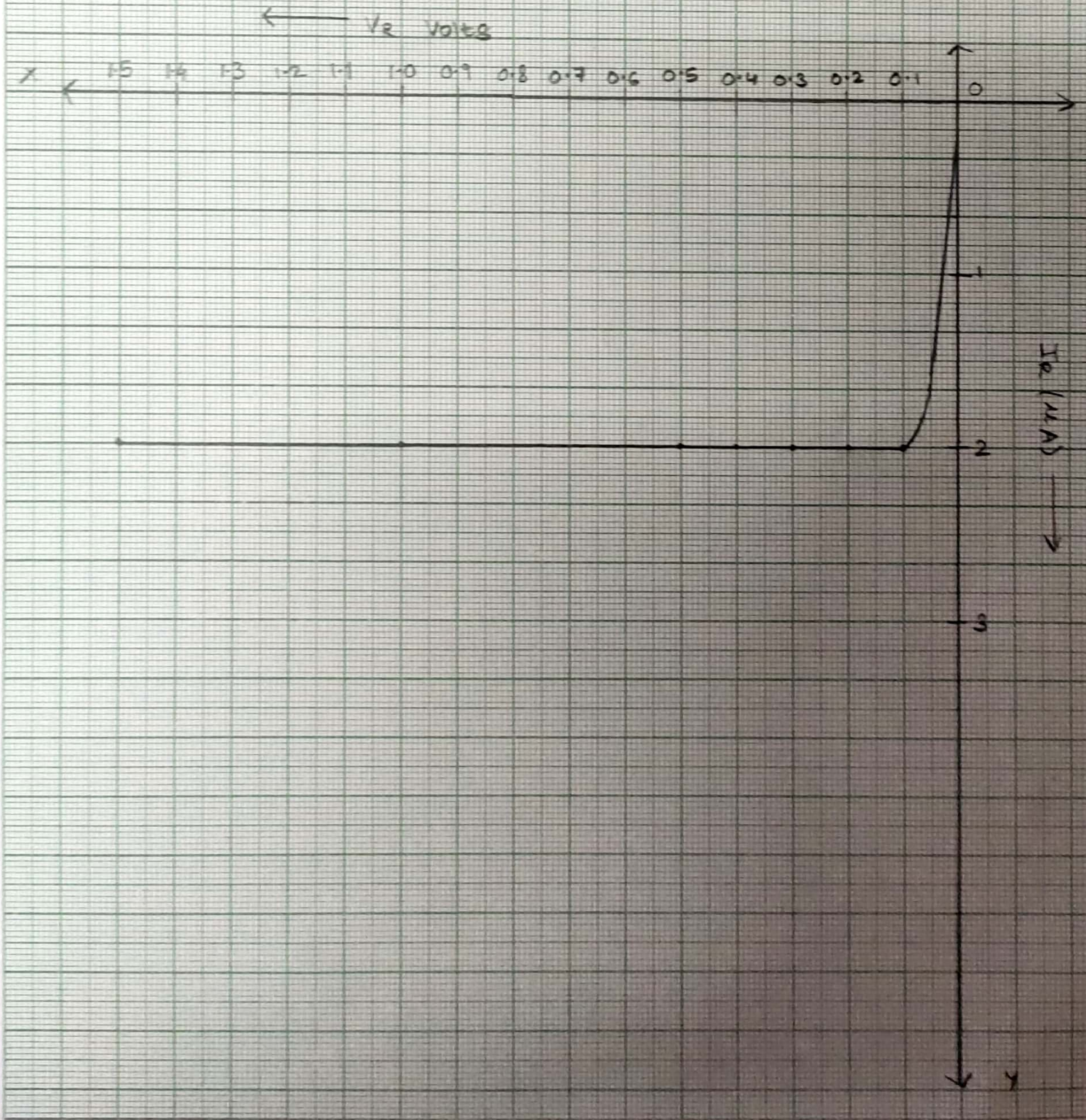
1) Ie v/s VR at room temperature



Scale:

On x axis : 1cm = 0.1 Volts

On Y axis : 3cm = 1 μA



2) $\log_{10}\left[\frac{I_S}{T^2}\right]$ v/s $\left[\frac{1}{T}\right]$

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