EXPERIMENT NO. 9

OBJECT:

To plot characteristics between reverse saturation current and $10^{3}/T$ and find out the approximate value of Energy Band Gap in PN junction diode

APPARATUS:

1. Energy Band Gap Apparatus containing Micrometer, Voltmeter, temperature controlled electric oven to heat up the diode, PN junction diode placed inside the oven and connection brought out at the socket
2. Mercury thermometer to mount on front panel to measure the temperature of oven.
3. Patch cords for interconnections.

THEORY:

We know in the case of insulators, the region between highest level of completely filled band (called valence band) and the lowest level of allowed empty band (called conduction band) is very wide. This is called energy gap, denoted by $E_g$ and is about 3 to 7 eV (electron volt) in case of insulators. In case of semiconductors, this energy gap is quite small. For example, in case of germanium, $E_g=0.7$ eV and in case of silicon $E_g=1.1$ eV.

In semiconductors at low temperatures, there are few charges to move so conductivity is quite low. At higher temperatures, the donor or acceptor levels come into action and provide carriers and hence the conduction rises. In addition to the dependence of the electrical conductivity on the number of free charges, it also depends on their mobility. However, mobility of the charge carriers somewhat decrease with increasing temperature but on the average the conductivity of the semiconductors rises with increasing temperature.

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

In the reverse bias, the saturated value of the reverse current for a pn-junction diode is given by,

$$I_s = \text{constant}. \ T^{3/2}. \ e^{-\frac{E_g}{KT}} \ _{(1)}$$

Where,

$I_s$ = saturation current in micro ampere
$T$ = temperature of junction diode in Kelvin
$E_g$ = band gap in eV
$K$ = Boltzman constant in eV per Kelvin

For small changes in temperature where log $T$ can be treated as constant relation (1) can be written as

$$\log_{10}I_s = \text{constant} - 5.04 \ E_g. \ 10^{3/T} \ _{(2)}$$

Graph between $10^{3/T}$ as abscissa and $\log_{10}I_s$ as ordinate will be a straight line having a slope = $5.04E_g$
Hence band gap $E_g$ = slope of the line / 5.04

![Fig. 1](image-url)
PROCEDURE:

1. Connect the circuit as shown in fig.1 i.e. positive of 0-20 V power supply to N-side of diode and to positive of voltmeter. Connect negative of power supply to negative of voltmeter and negative of microammeter (µA) and positive of microammeter to P-side of diode.
2. Keep the temperature control knob fully anti-clockwise.
3. Switch on the instrument using on/off toggle switch provided on front panel keeping temperature control knob fully anticlockwise.
4. Adjust the voltage at 2.5V DC and note down the reverse current.
5. Adjust the temperature control knob at maximum position. Temperature starts increasing and the reading of the microammeter starts increasing.
6. When temperature reaches to 80°C or 100°C, switch off the oven by rotating the pot anticlockwise down to minimum side. Note down the maximum reading shown by micro ammeter.
7. As the temperature starts falling, record the values of microammeter reading in observation table after every 5°C drop in temperature.
8. Repeat the whole procedure for 5VDC and 7.5V DC.
9. Plot a graph between $10^3/T$ along x axis and $\log_{10}I_s$ along y axis, and the slope of the line is determined from the graph.

OBSERVATION TABLE:

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Current $I_s$ in microampere</th>
<th>Temperature of the junction diode</th>
<th>$\log_{10}I_s$</th>
<th>$10^3/T$</th>
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<tbody>
<tr>
<td></td>
<td>V = 2.5V</td>
<td>V = 5V</td>
<td>V= 7.5 V</td>
<td>In K</td>
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GRAPH:

From graph slope of the line $dy/dx = $ 
$E_g = \text{slope} / 5.04$ 
$= \text{----------- eV}$

RESULT:

The band gap $E_g$ for the given semiconductor = -------------- eV.

Standard value for Ge = 0.72 eV
Standard value for Si = 1.1 eV

$\text{standard value – experimental value}$ 
$\text{Percentage error} = \frac{\text{---------}}{\text{Standard value}} \times 100 = \text{---------%}$

PRECAUTIONS:

1. The diode should be reversed biased.
2. Do not exceed the temperature of the oven above $100^0\text{C}$ to avoid overheating of diode.
3. The voltmeter and ammeter reading should initially be at zero mark.
4. Voltmeter and ammeter reading should be varied in small steps.
5. After doing the experiment switch off the circuit.