DETERMINATION OF THE BAND GAP OF A SEMICONDUCTOR BY FOUR PROBE METHOD

Presented by
Department of BSHU (Physics)
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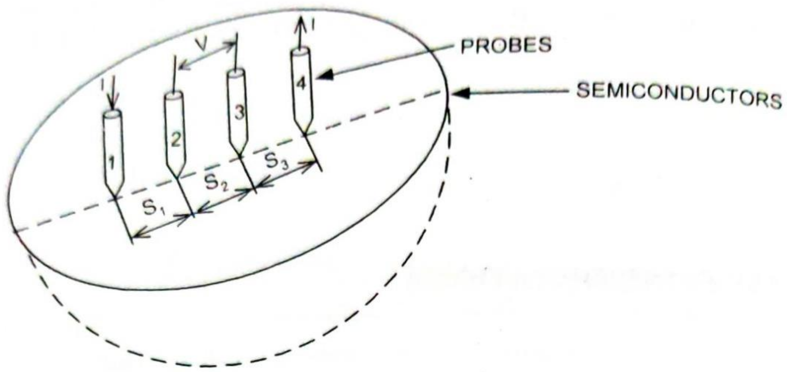
BAND GAP OF A SEMICONDUCTOR BY FOUR PROBE METHOD

APPARATUS :

Ge single crystal (n type with thickness (w) = 0.05 cm.), four probe arrangement [distance between probes (S) = 0.2 cm.], oven and thermometer.

THEORY:

In figure four probes are spaced S1, S2, S3 and S4 apart. Current I is passed through the outer probes (1 & 4) and the floating potential V is measured between the inner pairs of probes 2 & 3.



Model for the Four Probe resistivity measurement

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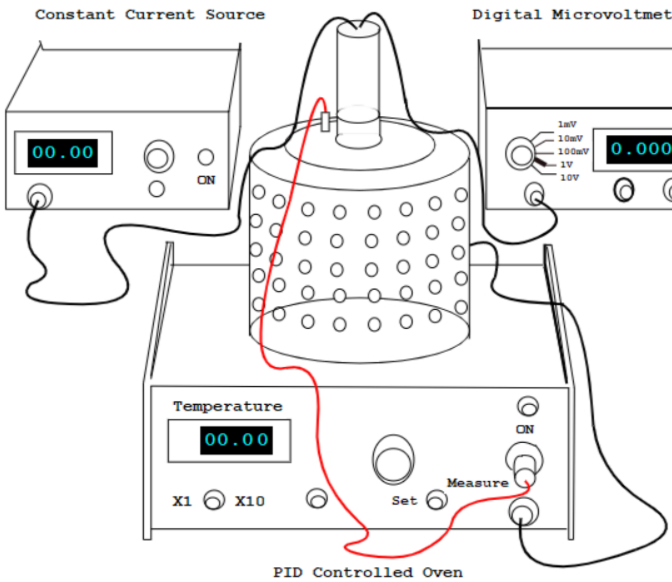

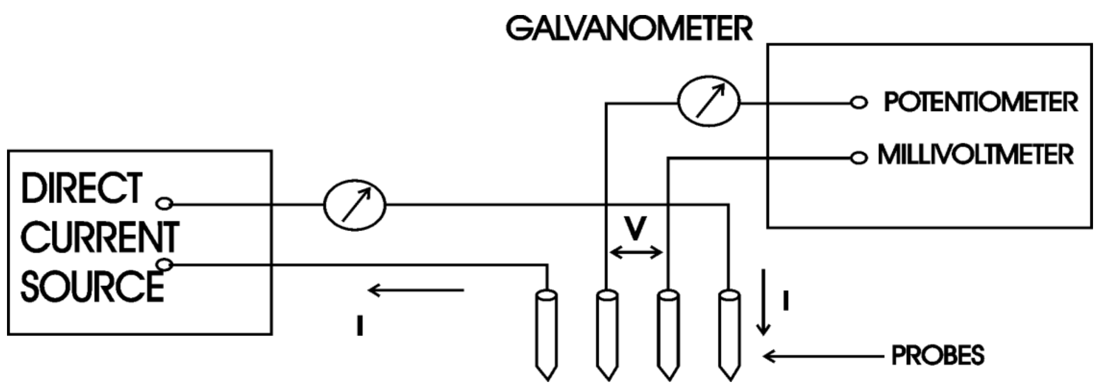

Figure : Circuit Used For Resistivity Measurements.

The potential difference *V* between probes 2 & 3 can be written as

$$V = I\rho_0 / 2\pi s \qquad (i)$$

Where ρ_0 is the resistivity of the material, *I* is the amount of current passing through the material. Therefore,

$$\rho = 2\pi s V / I \qquad (ii)$$

Since the thickness of the crystal is very small compared to the probe distance a correction factor for it has to be applied.

$$\rho = \rho_0 / G_7 = \rho_0 / f(w/s)$$

Now substituting the values,

$$\rho_0 = 2 \times 3.14 \times 0.2 \times V / I = 1.256\ V / I$$

and the correction factor G_7 i.e. $f(w/s)$ is 5.89

$$\rho = \rho_0 = 1.256\ V / 5.89\ I \Rightarrow \rho = 0.213 \times V / I \ldots(iii)$$

Thus ρ may be calculated for various temperatures.

Now, if we plot $\log \rho$ vs. $(1/T)$, we get a curve which is linear at higher temperatures.

We know resistivity, $\rho = C \exp(E_p / 2KT)$ where C is a constant. From this expression we have the following: $\ln \rho = (E_g / 2K) /T + \ln C$

Therefore, width of the energy gap may be determined from the slope of the linear portion of the experimental curve:

$\rho(\Delta \log_{10}) / \Delta(1/T)$
$= \Delta \ln \rho / 2.303 * \Delta(1/T)$
$= E_g / (2.303 \times 2K)$

Thus we have

$$\boxed{E_g = 2.303 \times 2K \times \rho(\Delta \log_{10}) / \Delta(1/T)} \quad \text{...(iv)}$$

Where K is Boltzman's Constant [$K = 8.6 \times 10^{-5}$ eV/Kelvin]

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Procedure:

1. Switch on the circuit. (Make sure that the oven is switched off.)
2. Align the voltmeter/ammeter display changer switch at ammeter position and fix the value of the probe current to any fixed value.(appx. 6-8 mA)
3. Align the display changer switch to voltmeter position and note the temperature and record the corresponding voltage value.
4. Switch on the oven at low heating mode.
5. As the temperature starts to increase, record all the corresponding values of the voltage at the **interval of 10 °C up to 60 °C** and from thereon till **140 °C at the interval of 5 °C.**
6. Switch off the oven and then switch off the circuit.
7. Calculate all the terms in the table.
8. Plot a graph between $\log_{10}\rho$ vs T^{-1}.
9. Take the slope from the linear portion of the mean graph.
10. Complete the calculation to find out the value of the Band gap for the given semiconductor.

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OBSERVATION:

Current (I) = ___________mA(constant)
Distance between probes (s) = 0.2 cm.
Thickness of the crystal (w) = 0.05 cm.

Sl no.	Temp (°C)	Voltage Readings		Temperature (T in K)	ρ (Ωcm.)	T^{-1} (K)	$\log_{10}\rho$
		Raw data	Voltage (millivolt)				

RESULT:

The band gap of the germanium sample is found out to be____________eV.

(The standard value of band gap for Ge semiconductor is 0.7 eV)