EXPERIMENT NO.5

OBJECT:

To determine the energy band gap of Ge (Germanium) crystal by four probe method.

APPARATUS:

1. Probe arrangement: It has four individually loaded probes, coated with Zn at the tips. The probes are collinear and equally spaced. The Zn coated and individual spring ensures good electrical contacts with the sample. The probes are mounted in a Teflon bush, which ensure a good electrical insulation between the probes, a Teflon spacer near the tips is also provided to keep the probes at equal distance. The whole arrangement is mounted on a suitable stand and leads are provided for current and voltage measurements.
2. Sample: Ge (Germanium) crystal in the form of a chip slice.
3. Oven: It is a small oven for the variation of temperature of the crystal from room temperature to about 200°C.
4. Four probe set up(Measuring Unit): It has three subunits all enclosed in one cabinet

   (a) Multi-range Digital Voltmeter

   (b) Constant Current Power supply

   (c) Oven Power Supply

THEORY:

The four points probe, as depicted schematically in fig.1, contains four thin collinear probes are made to contact the sample under test. Current I am made to flow between to outer probes, and voltage Vis measured between the outer probes and voltage V is measured between the two inner probes, ideally without drawing any current. If the sample is of semi-infinite volume and if inter probe spacing are

$s_1=s_2=s_3=s$, then it can be shown that the resistivity of the semi –infinite volume is given by

$$\rho_O = \frac{2\pi s V}{I}$$

The subscript 0 in the preceding equation indicates the measured value of the resistivity and in extent, a combination of correction factors must be multiplied by the right hand side of this equation. By following the procedure below, the need for many of these factors is eliminated. The correction factors still needed, and the final forms of the formulas for resistivity is given below

$$\rho = \frac{\rho}{5.89}$$

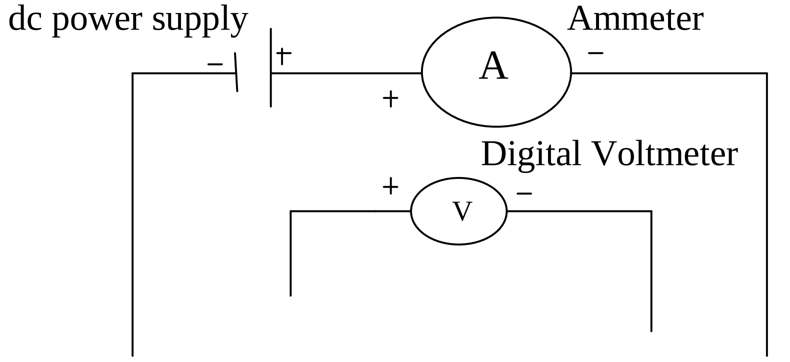
Where correction factor=5.89

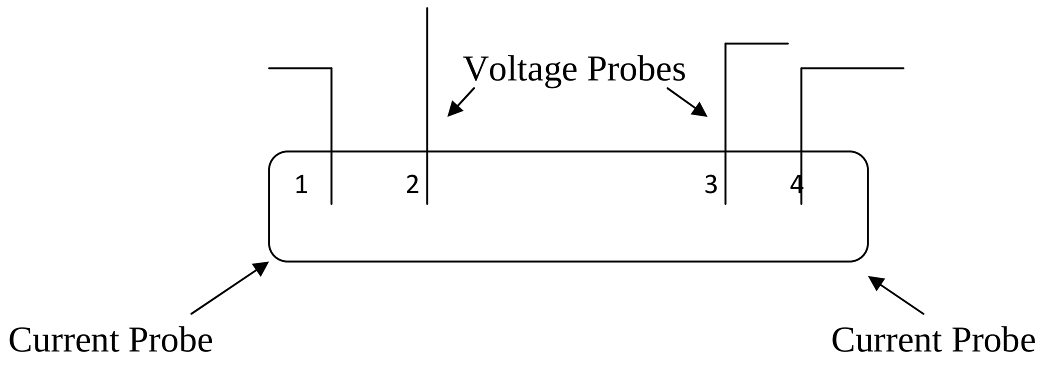
$$\rho = \frac{2\pi s V}{5.89 I}$$

Determination of energy band gap

$$\rho=\rho_a \exp (E_g / 2kT)$$

$$\text{and } E_g=\text{In}(\rho)\{2kT\}$$





Four Probe Method:

Many conventional methods for measuring resistivity are unsatisfactory for semiconductors because metal-semiconductor contacts are unusually rectifying in nature. Also there is generally minority carrier injection by one the current carrying contacts. An excess concentration of minority carriers will affect the potential of other contacts and modulate the resistance of the material.

The method described here overcomes the difficulties mentioned above and also offers several other advantages. It permits measurement of resistivity in samples having a wide variety of shapes, including the resistivity of small volumes within bigger pieces of semiconductor. In this manner the resistivity of both sides of p-n junction can be determined with good accuracy before the materials is cut into bars for making devices. This method of measurement is also applicable to silicon and other semiconductor materials.

In order to use this four probe method in semiconductor crystals or slides it is necessary to assume that:

- The resistivity of the materials is uniform in the area of measurement.
- If there is minority carrier injection into the semiconductor by the current – carrying electrodes most of the carriers recombine near the electrodes so that their effect on the conductivity in negligible.(this means that the measurement should be made on the surface which have a high recombination rate, such as mechanical lapped surfaces)
- The surface on which the probes test is that no surface leakage
- The four probes used for resistivity measurement contact the surface at points that lie on a straight line

- The diameter of the contact between the metallic probes and the semiconductor should be small compared to the distances between probes
- The boundary between the current-carrying electrodes and the bulk materials is hemispherical and small in diameter.

PROCEDURE:

1. Put the sample on the base plate of the four probe arrangement. Unscrew the pipe holding the four probes and the middle of the sample. Apply a very gentle pressure on the probes and tighten the pipe in this position. Check the continuity between the probes for proper electrical contacts.
2. Connect the outer pair of probes (yellow/green leads) leads to the constant current power supply and the inner pair to the probe (red/ black) voltage terminals.
3. Place the four probe arrangement in the oven and fix the thermometer in the oven though the hole provided.
4. Switch ON the AC mains of four probes set up ant put the digital panel meter in the current measuring mode through the selector switch. In this position LED facing mA would glow. Adjust the current to a desire value (say 5Ma.)
5. Now put the digital panel meter in voltage measuring mode. In this position LED facing mV would glow and the meter would read the voltage between the probes.
6. Connect the oven power supply. Rate of heating may be selected with the help of a switch Low or High as desired. Switch on the power to the oven. The glowing LED indicates the power to the oven id 'ON'.
7. Now note down the reading of mili-voltmeter at every increase in the temperature. Not down reading in the table No.(1) plot a graph between $T \times 10^3$ & $\log_{10}\rho$ by taking $T \times 10^3$ along X-axis & along $\log_{10}\rho$ Y-axis

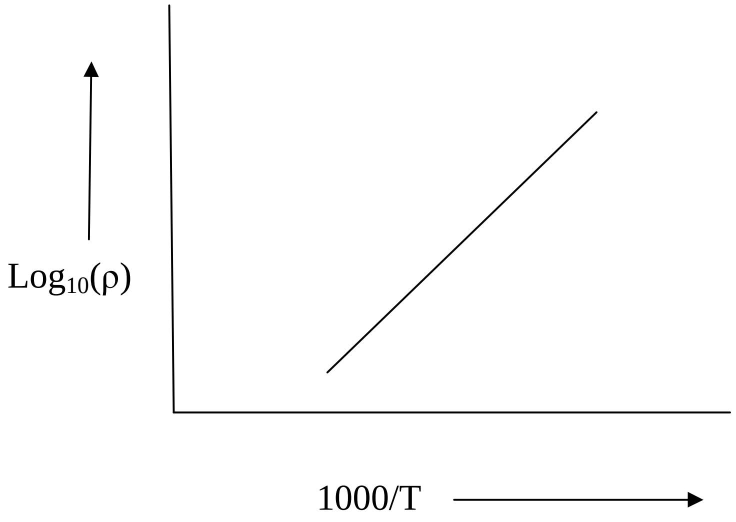
OBSERVATIONS:

Current (I) = ………mA (Constant)

Distance between probes(S) =.2 cm

Thickness of the crystal (W) = .05 cm

S. No.	Temp(ºC)	Temp(K)	Voltage (V)	Resistivity (ρ)	1000/T(K)	Log(ρ)
1.						
2.						
3.						
4.						
5.						



RESULT:

The energy band gap of given sample is E_g =………eV.

PRECAUTIONS:

1. Temperature should not be increased beyond 120^{o}C.
2. Observations should be noted while the temperature is falling.
3. Current should be kept constant throughout the experiment.

4. The Ge crystal is very brittle. Therefore, only the minimum pressure is required for proper electrical contacts.