FOUR- PROBE METHOD

Aim:- To Determine the energy band gap of a semiconductor by Four- Probe Method.

Apparatus required:-Sample (Ge crystal), Thermometer, four– Probe set up, oven.

Formula used:-

$$\log_e \rho = \frac{E_g}{2K_B T} - \log_e Q \quad (1)$$

where, ρ = Resistivity
E_g = Band gap
K_B = Boltzmann Constant =8.6 x10^{-5} eV/K
T = Temperature in Kelvin
Q = Constant

Resistivity can be calculated using

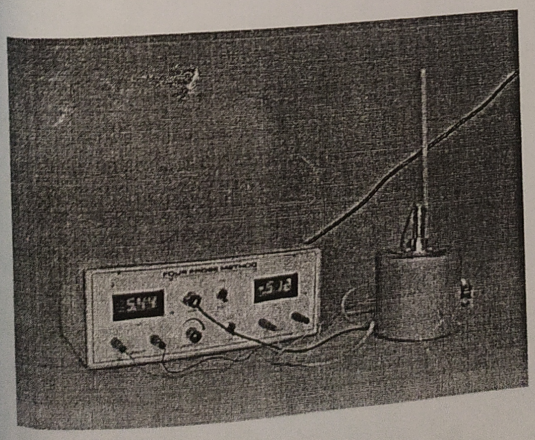
$$\rho = \frac{\rho_0}{G_7(\frac{W}{S})} = \frac{V}{I} \times 0.227$$

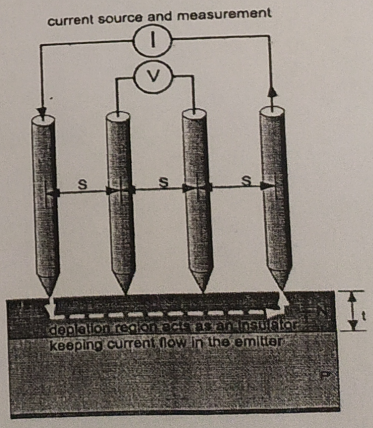
Where $\rho_0 = \frac{V}{I} \times 2\pi s$,

W= thickness of crystal = 0.5mm
S= Distance between probes = 2mm

$$G_7\left(\frac{W}{S}\right) = \frac{2s}{w}\log_e 2$$

(For smaller of $\left(\frac{w}{s}\right)$ approaches the case for an infinitely thin slice)





Procedure :-

1. Put the Sample on the base plate of the four probe arrangement. Unscrew the pipe holding the four probes and let the four probes res in the middle the sample. Apply a very gentle pressure the probes and tighten the pipe the in this position. Check the continuity between the probes for proper electrical contacts.

   CAUTION: The Ge crystal is very brittle. Therefore use only the minimum pressure required for proper electrical contacts.

2. Connect the outer pair of probes (black leads to the constant current power supply) and the inner pair (red leads) to the probe voltage terminals.
3. Place the four probe arrangement in the oven and fix the thermometer in the over though the hole provided.
4. Switch on the ac mains of four probe set –up and 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 desired value (Say 5 mA).
5. Now put the digital on panel meter in voltage measuring mode. In this position LED facing mV or V would grow Depending on position of switch and the meter would read the voltage between the probes.
6. Connect the over 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 Over. The glowing LED indicates the power to the over is 'ON'.

OBSERVATIONS:-

Current (I) = 5 mA (Constant)

S.No.	Temperature (^{0}C)	Voltage (volts)	Temperature T in (^{0}K)	ρ (Ohm.cm)	T^{-1}	$\log_{10}\rho$

Calculation:

Distance between probes (S) = 2 mm

Thickness of the crystal = 0.5 mm

Plot a graph for $\log_{10}\rho$ vs T^{-1}.

Using Eq. (1) $$log_e \rho = \frac{E_g}{2K_BT} - \log_e Q$$

The slope of the curve is given by

$$\frac{\log_e \rho}{\frac{1}{T}} = \frac{E_g}{2K_B}$$

Thus E_g may be obtained from the slop of the graph. Note that $\log_e = 2.3026 \log_{10}$ and the Eq. (1) is applicable only in the intrinsic region of the semiconductor ..

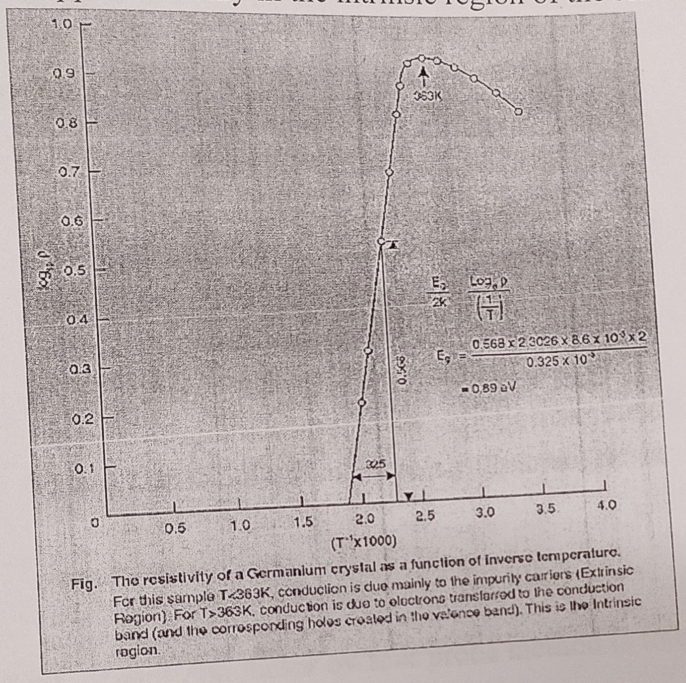


Fig. The resistivity of a Germanium crystal as a function of inverse temperature. For this sample T<363K, conduction is due mainly to the impurity carriers (Extrinsic Region). For T>363K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the Intrinsic region.

Result :

The energy band gap of the given semiconductor (Ge) crystal is found to be _____ eV.

% error :

Sources of error :

1. The resistivity of the material should be uniform in the area of measurement.
2. The surface on which the probes rest should be flat with no surface leakage.
3. The diameter of the contact between the metallic probes and the semiconductor crystal chip should be small compared to the distance between the probes.

Calculation :-

Distance between probes (S) = 2 mm

Thickness of the crystal = 0.5 mm

The slope of the curve is given by

$$\text{Slope} = \frac{\log_e \rho}{\frac{1}{T}} = \frac{E_g}{2KB}$$

$$E_g = 2.303 \times K_B \times 2 \times \text{slope}$$

We know, Boltzmann constant $K_B = 8.6 \times 10^{-5}$ eV/K

$$E_g = 2.303 \times 8.6 \times 10^{-5} \times 2 \times \text{slope}$$

$$E_g = 3.96 \times 10^{-4} \times \text{slope}$$

esult:-

he energy band gap of semiconductor by four probe method is found to _____eV.

recautions :-

1. Current through the sample should be kept constant.
2. Temperatre should be taken carefully.
3. Exert minimum pressure to get electrical contact of probe with the wafer.

FOUR PROBE

1. What are the types o f Semiconductor?

   Intrinsic semiconductor, Extrinsic semiconductor.

2. What is Intrinsic Semiconductor?

   Pure form of semiconductors are said to be intrinsic semiconductor. Ex: germanium, silicon.

3. What is Extrinsic semiconductor?

   If certain amount of impurity atom is added to intrinsic semiconductor the resulting semiconductor is Extrinsic or impure Semiconductor.

4. Define Mass – action law.

   Under thermal equilibrium the product of free electron concentration (n) and hole concentration (p) is constant regardless of the individual magnitude. $n.p = ni^2$

5. What are the types of Extrinsic Semiconductor?

   P-type Semiconductor , N- Type Semiconductor.

6. What is N-type Semiconductor?

   The Semiconductor which are obtained by introducing pentavalent impurity atom (phosphorous, antimony) are known as N-type Semiconductor.

7. What is P-type Semiconductor?

   The Semiconductor which is obtained by introducing trivalent impurity atom (gallium, indium) are known as P-type Semiconductor.

8. What is doping?

   Process of adding impurity to a intrinsic semiconductor atom is doping. The impurity is called dopant.

9. Which charge carriers is majority and minority carrier in N-type Semiconductor?

   Majority carrier: electron and minority carrier: holes.

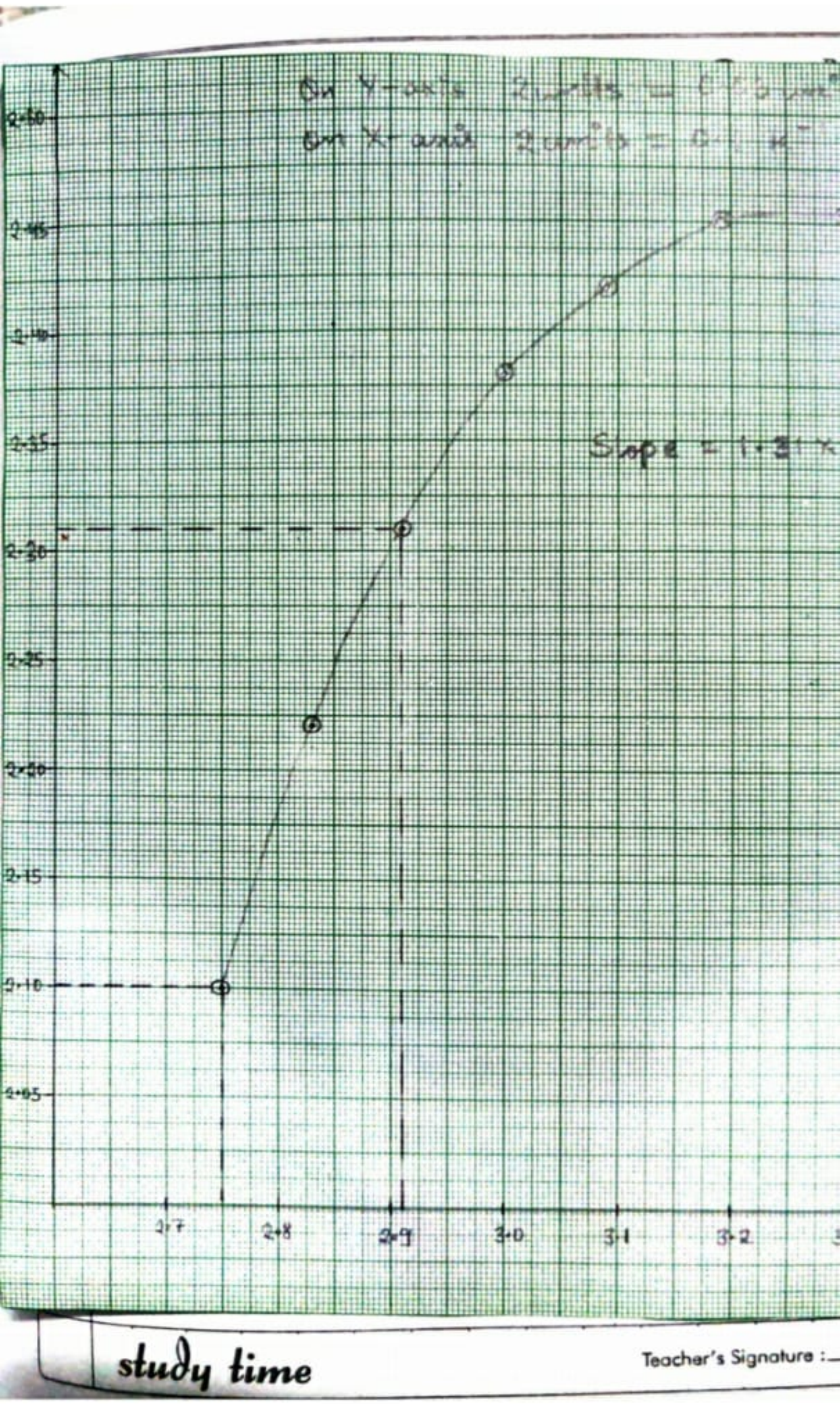
10. Which charge carriers is majority and minority carrier in P-type Semiconductor?

    Majority carrier: holes and minority carrier: electron

11. Why N - type or penta valent impurities are called as Donor impurities?

    N- type impurities will donate the excess negative charge carriers (Electrons) and therefore they are referred to as donor impurities.

12. Why P – type or trivalent impurities are called as acceptor impurity?



Teacher's Signature :

urrent (I) = 5mA (constant)

	Temperature		Voltage
	(°C)	(°K)	(Volts)
	20	293	0.582
	30	303	0.598
	40	313	0.593
	50	323	0.561
	60	333	0.504
	70	343	0.435
	80	353	0.351
	90	363	0.268

$$\text{slope} = \frac{y_2 - y}{x_2 - x}$$

$$\text{slope} = \frac{2.31}{(2.91 - 2.75)}$$