EXPERIMENT

AIM

To draw the I − V characteristic curve of a p − n junction in forward bias and reverse bias.

MATERIAL REQUIRED

A collection of components includes a p-n junction diode rated at 30 V, a direct current (d.c.) power supply with a voltage range of 0-10V, a d.c. ammeter with a current range of 0-12 mA / 0-12 μA, a d.c. voltmeter with a voltage range of 0-1.2V, a potentiometer with a resistance of 1kΩ, a germanium diode (OA79), a silicon diode (SM 100), a one-way key, a rheostat and connecting wires.

DIAGRAM

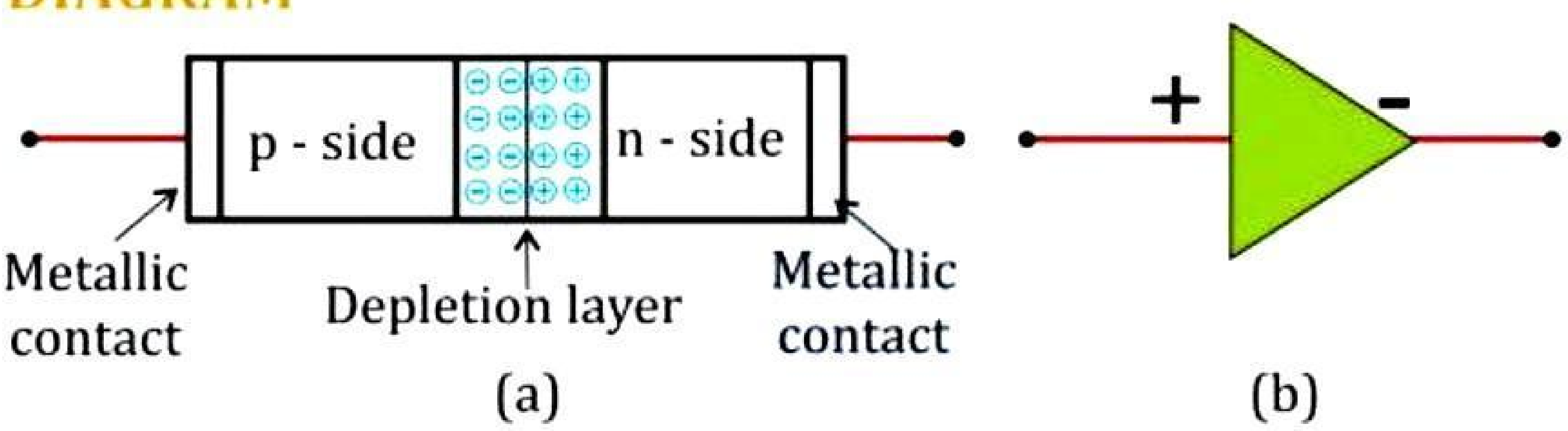


Fig. (a) SEmi conductor diode,
(b) Symbol for p-n junction diode

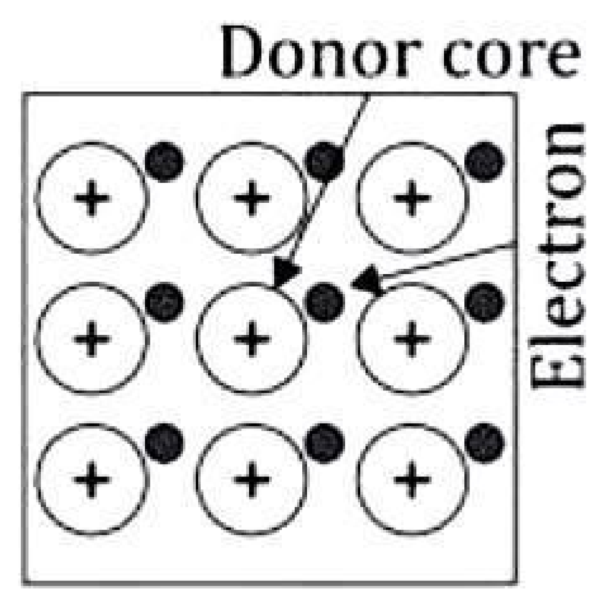


Fig. n type

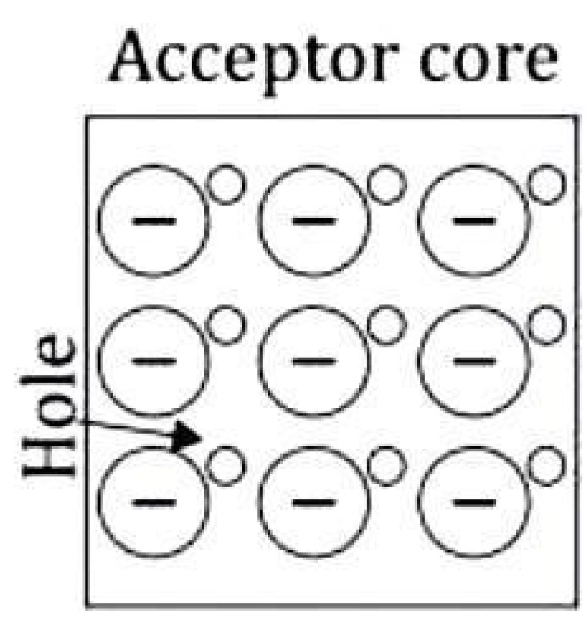


Fig. p type

THEORY

A semiconductor diode functions as a unilateral circuit element with two terminals, namely the 'anode' and 'cathode.' Referred to as a 'crystal diode,' it features a p-n junction growing out of a crystal. In the circuit symbol, the 'arrowhead' signifies the anode (+), while the 'bar' head denotes the cathode. When a p-n junction diode is forward biased, the positive polarity of a DC source connects to the p-side, and the negative polarity connects to the n-side. Conversely, reverse biasing occurs when the positive polarity is linked to the n-side, and the negative polarity is connected to the p-side. The experimental circuit displays the $I \sim V$ characteristic curve for a p-n junction diode. The ratio of forward bias voltage (V_f) to forward current (I_f) defines the static resistance (R_{sf}) of the p-n junction diode, expressed as:

$$R_{sf} = \frac{V_f}{I_f}$$

For varying bias voltage and forward current, the dynamic resistance (r_{df}) is determined by the ratio of change in forward bias voltage (ΔV_f) to the corresponding change in forward current (ΔI_f), i.e.,

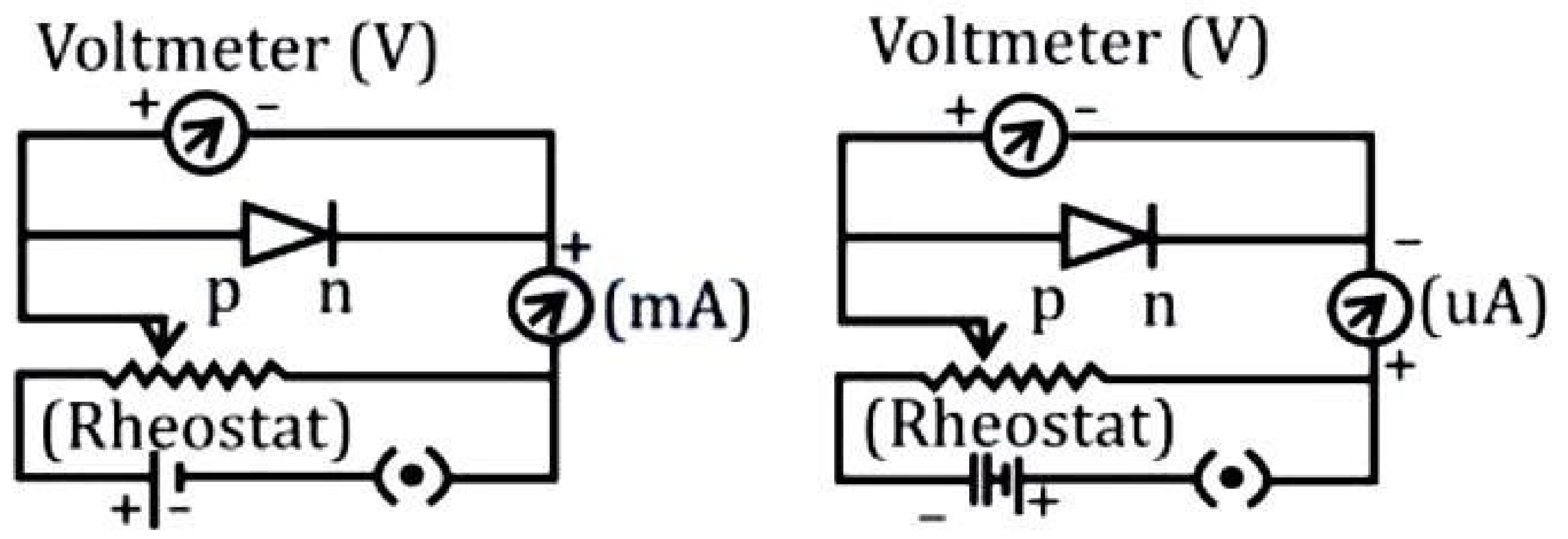
$$r_{\mathrm{df}} = \frac{\Delta V_f}{\Delta I_f}$$

The static (R_s) and dynamic resistance (r_d) of the p-n junction diode are derived from the $I \sim V$ characteristic curve. Under reverse bias conditions, the static reverse resistance (R_{sr}) and dynamic reverse resistance (r_{dr}) are obtained from the I ~ characteristic curve, expressed as:

$$R_{sr} = \frac{V_r}{I_r}$$

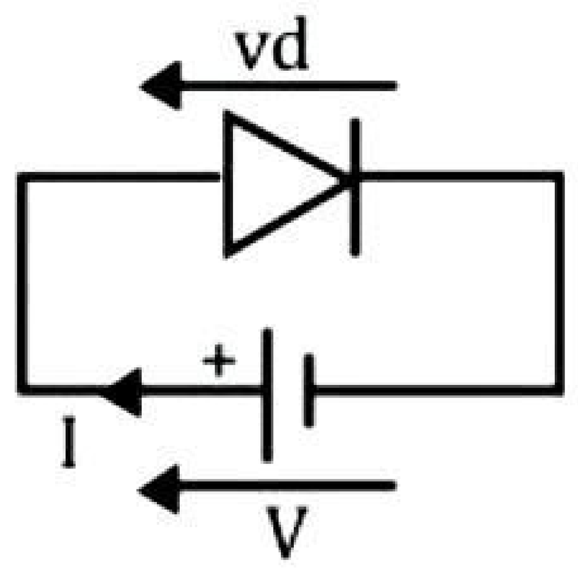
$$r_{dr} = \frac{\Delta V_r}{\Delta I_r}$$

Here, V_r represents reverse voltage, I_r is reverse current, ΔV_r is incremental reverse voltage, and ΔI_r is the corresponding increment in reverse current.

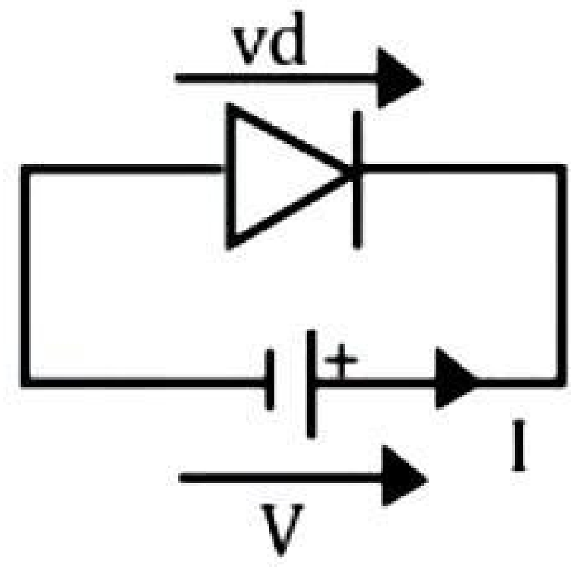


(a) Foeward bias (b) Reverse bias

Exerimental circuit arranaement for studvina I-v



Forward and bias condition for a p-n junction diode



Reverse and bias condition for a p-n junction diode

PROCEDURE

1. Set up the circuit to examine the forward and reverse bias configurations of the p-n junction diode. Ensure proper connections, with the milliammeter/microoammeter in series and the voltmeter in parallel to the p-n junction diode.
2. Record the least count (LC) of the provided voltmeter and milliammeter/microoammeter. Ensure both instruments read zero on their marked scales when the applied voltage is present. Correct the initial reading (zero) if necessary. Connect the positive-marked terminals of the milliammeter/microoammeter and voltmeter to the higher potential, i.e., the +ve side of the dc power supply.
3. Adjust the potential divider arrangement's rheostat to its minimum value.
4. Turn on the circuit key (K) for the forward bias configuration of the p-n junction.
5. Gradually move the rheostat's contact point to apply a small forward bias voltage. For very low forward bias voltage, the milliammeter should display a zero reading.
6. Increase the forward bias voltage across the p-n junction diode in increments of 0.1 V. Record the values of forward bias voltage (V_f) and the corresponding forward current (I_f) from the milliammeter reading.
7. Repeat steps 3 to 6 for the reverse bias configuration of the p-n junction. Measure the reverse current (I_r) and the corresponding voltage (V_r) using the microammeter, ensuring accuracy.

OBSERVATION

1. Voltmeter range= V
2. Voltmeter least count = ... V
3. Milliammeter/microammeter range = $\cdots$ mA/μA
4. Milliammeter/microammeter least count (LC) = $\cdots$ mA/μA
5. Diodes utilized: Ge (OA79), Si (SM100).
6. Manufacturer-specified maximum permissible power (power rating) for the diode, $P = 0.5$ W (indcated).
7. Manufacturer-specified maximum permissible voltage (voltage rating) for the diode, $V = 30$ V (indcated).

8. Document the voltmeter and milliammeter/microammeter readings systematically in tabular form for- both forward and reverse bias configurations of the $p-n$ junction diode, ensuring accuracy in significant figures.

TABLE FOR VARIATION OF VOLTAGE AND CURRENT IN FORWARD BIASING AND REVERE BIASING

S. No.	Forward bias configuration		Reverse bias configuration	
	Voltmeter reading, V_f (V)	**Milliammeter reading, I_f (μA)**	**Voltmeter reading, V_r (V)**	**Microammeter reading, I_r (μA)**
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

GRAPH

1. Generate a plot illustrating the relationship between forward voltage (V_f) and forward current (I_f), with V_f on the X-axis and I_f on the Y-axis. Utilize the voltmeter readings in conjunction with the milliammeter readings from Table. This process will yield the diode's forward characteristic, depicted in Figure. Analyze the nature of the $I \sim V$ graph and provide an interpretation.
2. Identify the point T on the graph where the current initiates an increase. This specific point corresponds to a voltage referred to as the knee voltage (V_k).
3. Select any point P beyond the knee voltage and construct perpendiculars PA and PB on the X-axis and Y axis, respectively. Subsequently, determine the static resistance at point P using the formula $R_{sf} = \frac{OA}{OB}$. Draw a tangent to the $I - V$ characteristics curve at point P, intersecting the X-axis at C. The dynamic resistance of the diode at point P is $r_{df} = \frac{CA}{PB} = \frac{OA-OC}{OA}$.
4. Repeat the procedure for two additional points, Q and R, on the $I \sim V$ plot beyond the knee voltage regions and determine R_{sf} and r_{df} as per steps (3) and (4).
5. Create a graph illustrating the relationship between reverse voltage (V_r) and reverse current (I_r), positioning V_r on the X-axis (negative side) and I_r on the Y-axis (negative side). Utilize the voltmeter readings and corresponding microammeter readings from Table. This will yield the reverse bias characteristic of the diode in the third quadrant of the graph, as depicted in Figure. Analyze the nature of the $I \sim V$ graph and provide an interpretation.
6. Determine the static reverse resistance (R_{sr}) of the diode by applying a procedure analogous to step (3).
7. Calculate the dynamic reverse resistance (r_{dr}) of the diode from the $I \sim V$ graph by estimating the incremental voltage (ΔV_r) and the corresponding incremental current (ΔI_r).

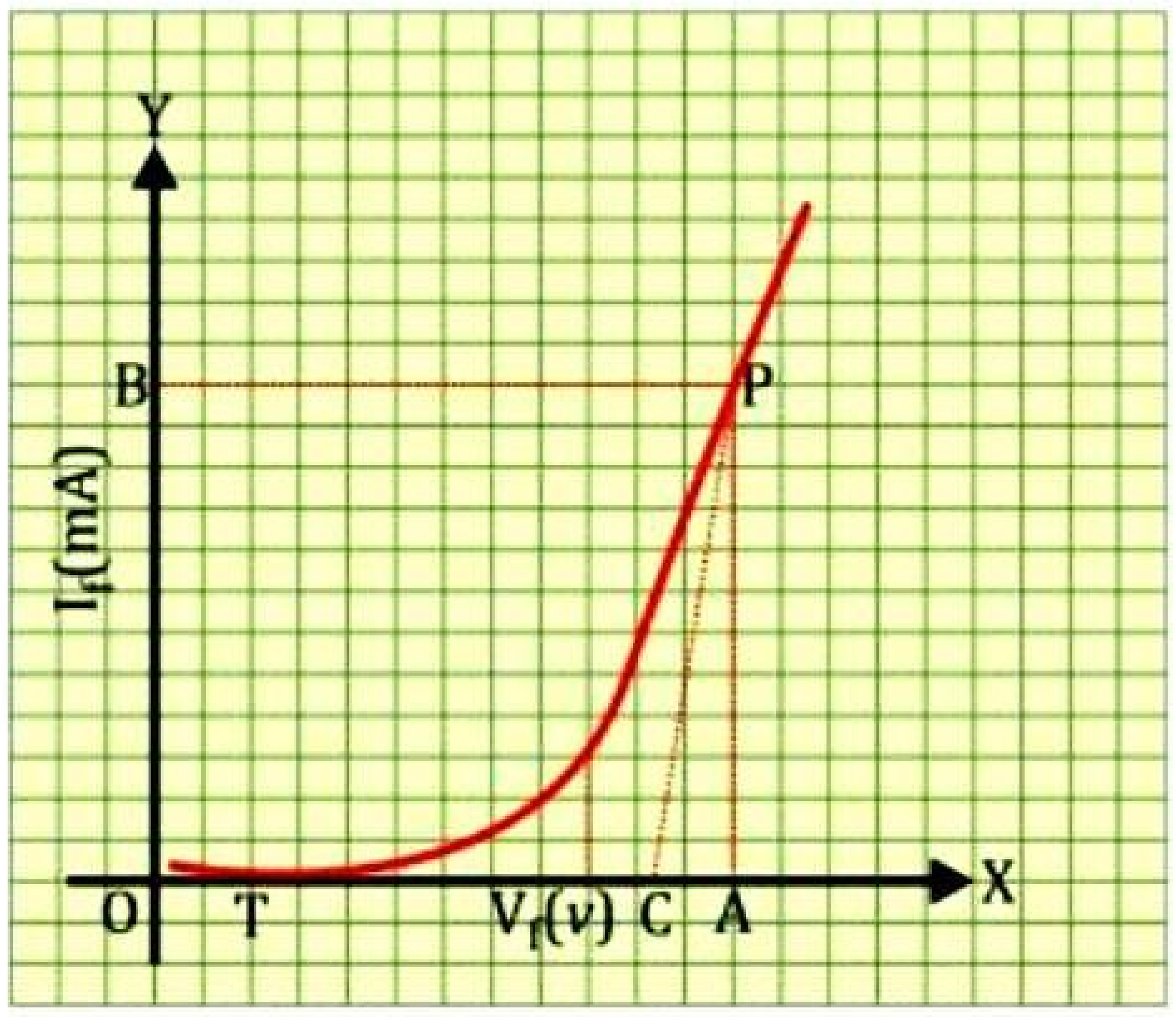
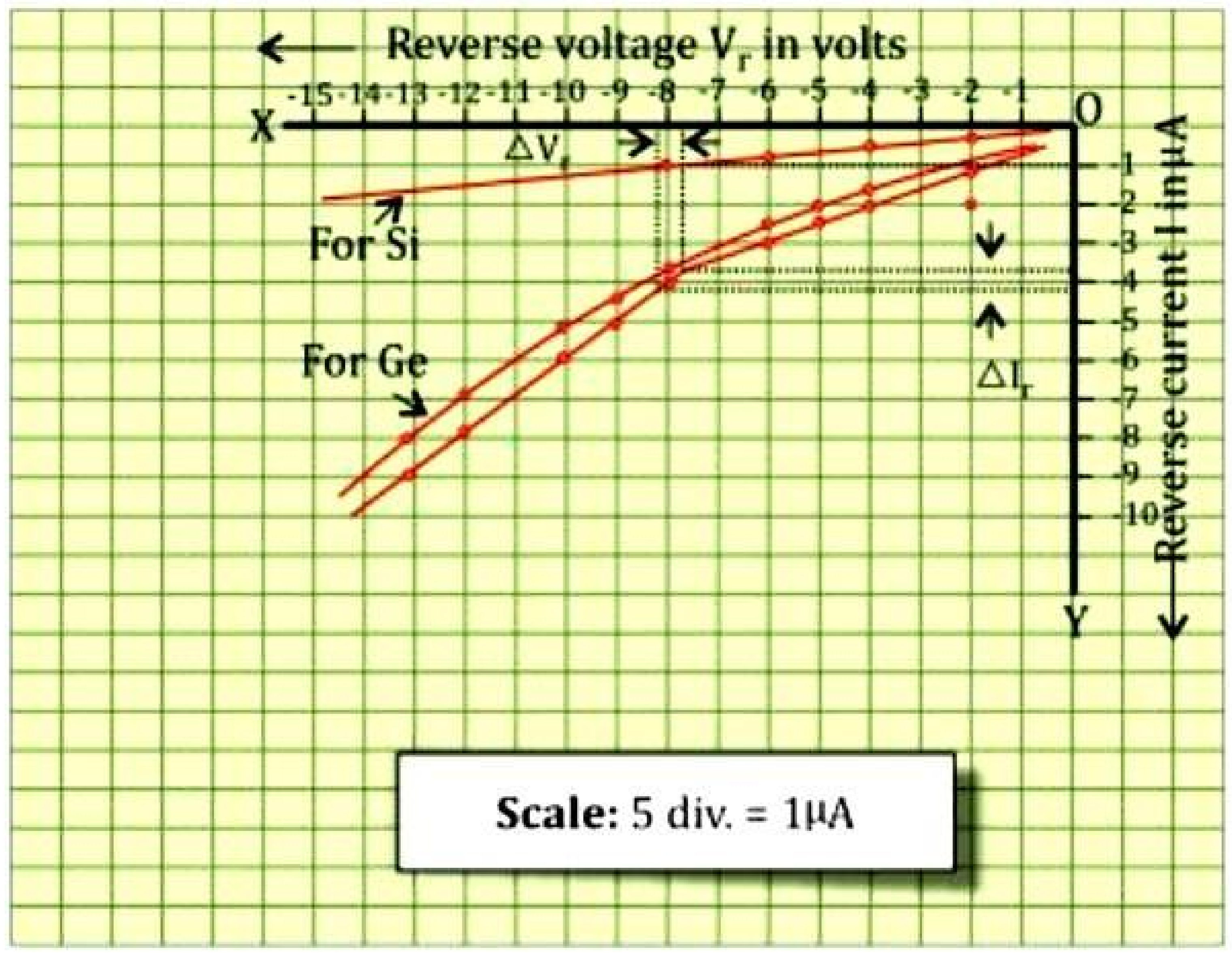


Fig. Variation of I_f with V_f



RESULT

1. Static forward resistance values for the provided $p-n$ junction diode:
   (i) At point $P, R_{sf1} = \cdots \Omega$
   (ii) At point $Q, R_{sf2} = \cdots \Omega$
   (iii) At point $S, R_{sf3} = \cdots \Omega$
   Mean static forward resistance, $R_{sf} = \frac{R_{sf1}+R_{sf2}+R_{sf3}}{3} = \cdots \Omega$
2. Dynamic forward resistance of the provided $p-n$ junction diode: $r_{df} = \cdots \Omega$
3. Static reverse resistance values for the provided p − n junction diode:
   (i) At point $A, R_{sr1} = \ldots \Omega$
   (ii) At point $B, R_{sr2} = \ldots \Omega$
   (iii) At point $C, R_{sr3} = \ldots \Omega$
   Mean static reverse resistance, $R_{sr} = \frac{R_{sr1}+R_{sr2}+R_{sr3}}{3} = \cdots \ldots \Omega$
4. Dynamic reverse resistance of the provided $p-n$ junction diode: $r_{dr} = \ldots \Omega$
5. The static forward resistance, R_{sf}, exceeds the dynamic forward resistance, R_{df}, i.e., $R_{sf} > r_{df}$.
6. The static reverse resistance, R_{sr}, is equal to the dynamic reverse resistance, r_{dr}, i.e., $R_{sr} = r_{dr}$.

PRECAUTIONS

1. Connecting wires and terminals must be cleaned properly.
2. All connections should be tight.
3. Zero error must be noted properly if any, and necessary zero correction should be applied.

SOURCES OF ERROR

1. There may be contact resistance particularly if any connection remains loose.
2. Each time the pointer of ammeter (milli or micro) may not be on a scale mark.
3. Zero error of the meters may not be accurately eliminated.
4. Personal errors.

VIVA- VOCE

Q 1. Define an intrinsic semiconductor.

Ans. A pure semiconductor material is called an intrinsic semiconductor.

Q 2. Define the extrinsic semiconductor.

Ans. A semiconductor material doped with a suitable impurity is called an extrinsic semiconductor.

Q 3. What do you mean by n-type semiconductor?

Ans. In n-type semiconductors, electrons are the majority of charge carriers. A pentavalent impurity doped in a tetravalent host lattice produces n-type semiconductor.

Q 4. What do you mean by p-type semiconductor?

Ans. In p-type semiconductors, holes are the majority of charge carriers. A trivalent impurity doped in a tetravalent host lattice produces p-type of semiconductor.

Q 5. Define a hole.

Ans. A hole is a name given to a vacancy created due to the release of an electron. It acts as a positive charge carrier.

Q 6. What do you mean by $p-n$ junction?

Ans. $p-n$ junction is a surface common to p-type and n-type semiconductors.

Q 7. Define the depletion layer.

Ans. A depletion layer is a thin region around the $p-n$ junction which has no free charge carriers, i.e., electrons or holes but has immobile ions.

Q 8. Define the potential barrier.

Ans. It is the potential difference that develops across the $p-n$ junction on account of the diffusion of electrons from n-type semiconductor to p-type semiconductor and holes from n-region to p-region.

Q 9. Define biasing.

Ans. Biasing is the phenomenon of applying an external potential difference across a $p-n$ junction.

Q 10. How many types of biasing you have read?

Ans. I have read about two types of biasing: (i) Forward biasing and (ii) Reverse biasing.

Q 11. When is a $p-n$ junction forward biased?

Ans. A $p-n$ junction is said to be forward biased when p-type semiconductor is connected to the positive terminal of the battery and n-type semiconductor is connected to the negative terminal of the battery. Hence, external potential difference forces the majority of charge carriers to cross the junction.

Q 12. When is a $p-n$ junction said to be reverse biased?

Ans. A $p-n$ junction is said to be reverse biased when p-type semiconductor is connected to the negative terminal of the battery and n-type semiconductor is connected to the positive terminal of the battery It opposes the tendency of majority charge carriers to cross the junction.

Q 13. What is the effect of biasing on the thickness of the depletion layer?

Ans. The forward bias reduces the junction resistance and the reverse bias increases the junction resistance.

Q 14. A $p-n$ junction conducts only when forward biased. Where is this property used?

Ans. This property of $p-n$ junction is used in rectification, i.e., conversion of ac into dc.