
EXPERIMENT

Semiconductor diode characteristics

1 Objectives

1. To study and plot the forward and reverse bias characteristics of a normal diode and to determine the threshold voltage, static and dynamic resistance.

2 Circuit components/equipment

1. Junction diodes
2. A current limiting Resistor (1 k Ω)
3. D.C. Power supply
4. 2 multimeters
5. Breadboard
6. Connecting wires

3 Theory

A diode is a nonlinear circuit element. The symbol of a diode and a real commercial diode is shown in figure 2. Generally, there is a band marked at its cathode for its identification. There exists another type of diode known as zener diode, which has a heavily doped PN junction.

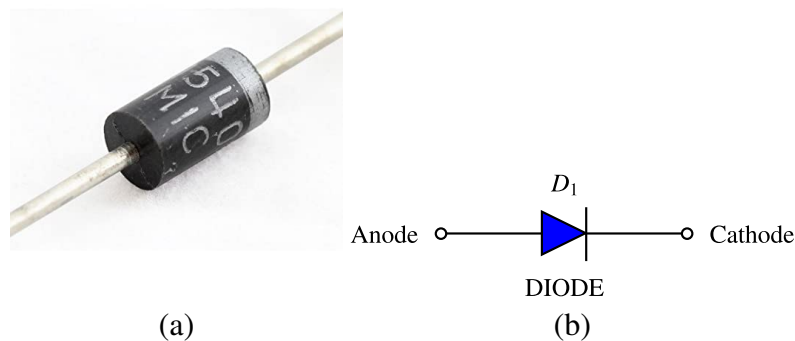


Figure 1: (a) Picture of a diode. (b) Symbol of a diode.

The theoretical equation for the diode current I_D is

$$I_D = I_S \left[\exp \left(\frac{V_D}{\eta V_T} \right) - 1 \right],$$

where V_D is the diode voltage drop, I_S is the saturation current, η is the emission coefficient, and $V_T = kT/q (\approx 0.026 \text{ V at } T = 300 \text{ K})$ is the thermal voltage.

The emission coefficient accounts for recombinations of electrons and holes in the depletion region, which tend to decrease the current. For discrete diodes, it has the value η is 2.

The IV characteristic of an ideal diode is shown in figure 2(a). Under forward biased condition of a real PN junction diode, the P-side is connected to the positive and N-side is connected to the negative terminal of the power supply. This reduces the potential barrier. As a result current flows from P to N-type in forward direction. When the applied voltage is more than the barrier potential, the resistance is small (ideally 0) and the current increases rapidly. This point is called the Knee-point or turn-on voltage or threshold voltage (Figure 2(b)). This voltage is about 0.3 volts for Ge diodes and 0.7 volts for Si diodes.

Under reverse biased condition, the P-side of the junction diode is connected to the negative and the N-side is connected to the positive terminal of the power supply. This increases the potential barrier due to which no current should flow ideally. But in practice, the minority carriers can travel down the potential barrier to give very small current. This is called the reverse saturation current. This current is about 2-20 μA for Ge diodes and 2-20 nA for Si diodes (the values might differ for diodes of different makes).

However, if the reverse bias is made too high, the current through the PN junction increases abruptly. The voltage at which this phenomenon occurs is known as the *break-down or reverse voltage* and the mechanism involved depends on the construction of the diode. In conventional diodes with a lightly doped junction, application of higher reverse voltage leads to a large number of carriers produced by collision of thermally generated electrons and the phenomenon is called avalanche breakdown. When the reverse bias exceeds this breakdown voltage, a conventional diode is subject to high current. Unless this current is limited by external circuitry, the diode will be permanently damaged. If the junction is heavily doped with narrow depletion layers, break-down occurs when the reverse voltage is strong enough to rupture the covalent bonds generating a large number of electron-hole pairs. This phenomenon is called zener breakdown.

3.1 Static and dynamic resistance

At a given operating point, the static and dynamic resistance of a diode can be determined from its characteristics as shown in figure 3. The static or DC resistance, R_D , of the diode at the operating point (the point where the load line intersects the diode characteristics), Q , is simply the quotient of the corresponding levels of V_D and I_D . The DC resistance

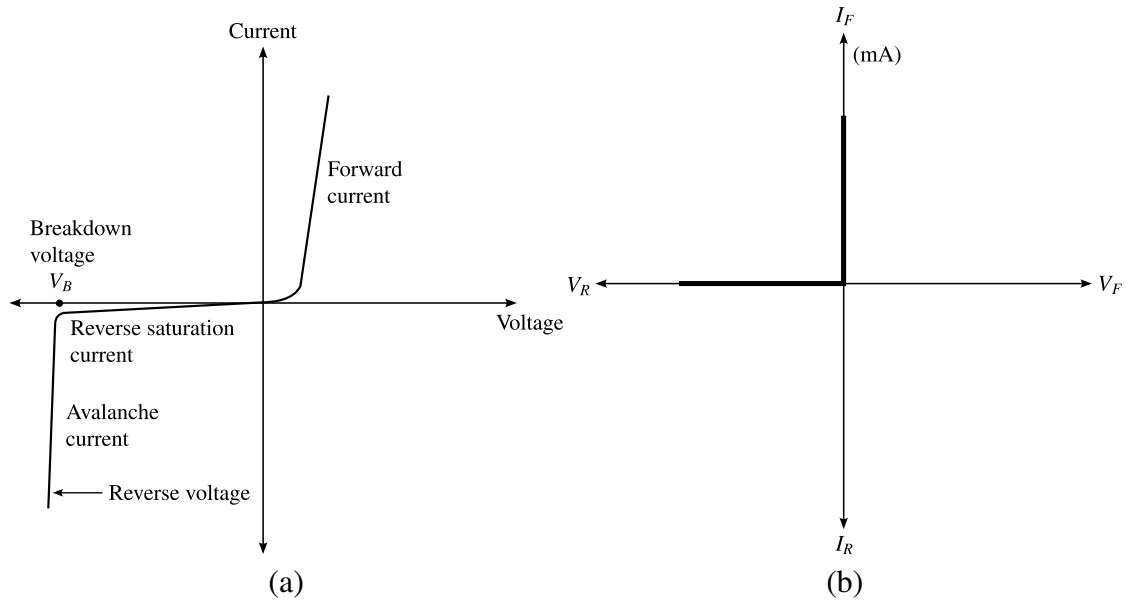


Figure 2: (a) IV characteristics of a practical diode. (b) IV characteristics of an ideal diode.

levels at the knee and below will be greater than the resistance levels obtained for the vertical rise section of the characteristics.

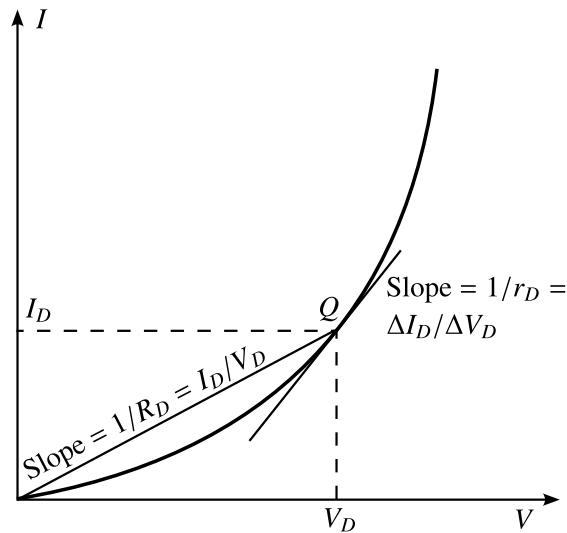


Figure 3: IV characteristics of a diode.

The diode circuits generally operate with varying inputs, which will move the instantaneous operating point up and down a region of the characteristics and defines a specific change in current and voltage. Dynamic or AC Resistance, r_d , is defined as the quotient of this change in voltage and change in current around the DC operating point.

$$r_d = \Delta V_D / \Delta I_D$$

4 Circuit diagram

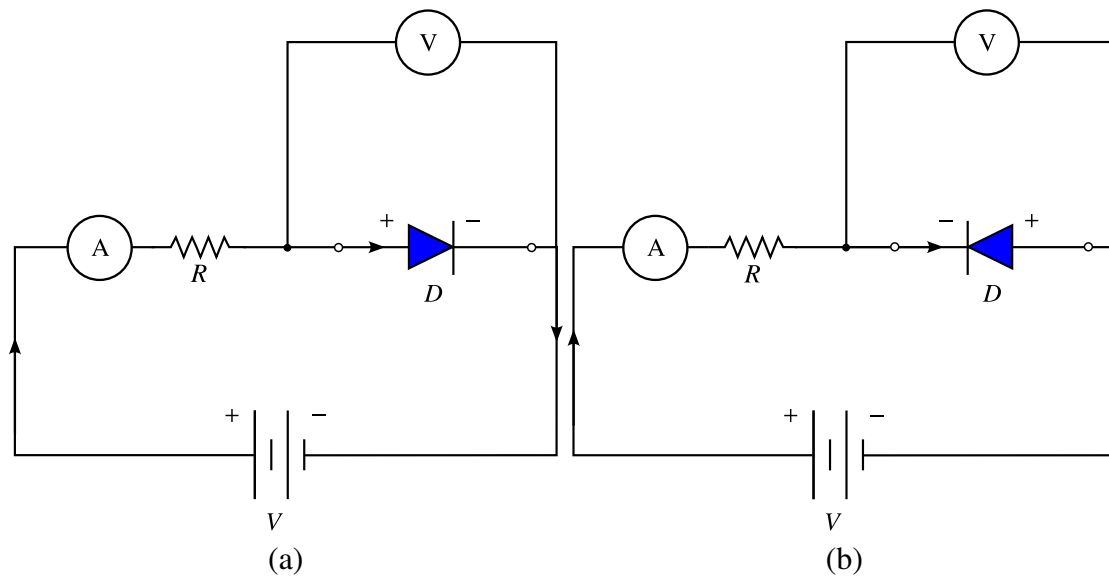


Figure 4: (a) Forward bias circuit. (b) Reverse bias circuit.

5 Procedure

Before you proceed, identify the p and n-side of the diode in order to connect properly in forward and reverse bias mode.

5.1 Forward and reverse bias characteristics of a normal diode

5.1.1 Forward bias characteristics

1. Assemble the circuit on your breadboard as shown in figure 4(a). Connect to the 0 – 30 V DC power supply.
2. Switch on the power supply. Slowly increase the supply voltage in steps of 0.1 Volt using the fine adjustment knob and note down the corresponding readings of diode current. When you find the change in current is larger (which means you have already crossed the threshold point), increase the supply voltage in steps of 0.5 to note down current.
3. Using multimeter in appropriate modes, measure voltage drop across the diode and the current in the circuit. Switch off the supply after taking sufficient readings.
4. Plot the I-V characteristics and estimate the threshold voltage.
5. Choose two operating points below and above the threshold point and determine the static and dynamic resistance at each of the points.

5.1.2 Reverse bias characteristics

1. Assemble the circuit on your breadboard as shown in figure 4(b). Connect to the 0-30 V DC power supply.
2. Switch on the supply. Increase the supply voltage in steps of 0.5 Volt to note down the diode current.
3. Use multimeters for voltage and current measurements. Keep in mind that the magnitude of current flowing in the circuit will be very small, so choose current range properly. Switch off the supply after taking sufficient readings.
4. Plot the I-V characteristics on the same graph sheet and estimate the reverse saturation current.

6 Observations

Code Number of diode:

Obs. No.	Forward biasing			Reverse biasing		
	Voltage applied (V)	Voltage V_D (V)	Current I_D (mA)	Voltage applied (V)	Voltage V_D (V)	Current I_D (μ A)
1						
...						
...						

Table 1: Diode characteristics.

7 Graphs

Plot IV characteristics for the diode and estimate the required parameters.

8 Results

1. Describe the behaviour of the IV curve for each diode.
2. Threshold voltage for the diode is _____ V (What type of diode is it. Si/Ge?)
Static resistance = _____, Dynamic resistance = _____ at operating point Q .

9 Precautions

1. Check circuit connections carefully
 - Verify all connections before switching on the power supply.
 - Ensure the diode polarity is correct for forward-bias and reverse-bias circuits.
2. Keep the power supply OFF while making connections
 - Never alter the circuit when the supply is ON.
3. Use proper meter ranges
 - Select suitable ranges for voltmeters and ammeters to avoid overloading them.
 - Start with the highest range and then adjust if necessary.
4. Do not exceed the diode's rated current
 - Excessive forward current may overheat and permanently damage the diode.
5. Increase voltage gradually
 - Vary the supply voltage slowly while taking readings to avoid sudden current surges.
6. Observe correct polarity of measuring instruments
 - Connect the positive and negative terminals of ammeters and voltmeters correctly.
7. Avoid excessive reverse voltage
 - Do not exceed the diode's Peak Inverse Voltage (PIV) rating, as breakdown may occur.
8. Take readings carefully
 - Read meters at eye level to avoid parallax error.
 - Record readings accurately and systematically.
9. Maintain stable temperature
 - Diode characteristics are temperature-dependent.
 - Avoid touching the diode unnecessarily during measurements, as heating can affect results.
10. Ensure tight and clean connections
 - Loose connections can cause fluctuating readings and inaccurate observations.