American International University- Bangladesh
Faculty of Engineering (FE)
Department of Electrical and Electronic Engineering (EEE)
EEE 2104: Electronic Devices Lab

Title of the Experiment: Determination of Characteristic Curve of a Diode.

Objectives:
The objectives of this experiment are to
1. Become familiar with semiconductor diodes.
2. Determine the characteristic curve of a semiconductor diode.
3. Find the different parameter values of a semiconductor diode.

Theory:
Diode Structure
The semiconductor diode is created by simply joining an n-type and a p-type material together. It is a pn junction as shown in Figure 1. As indicated, the pn junction consists of p-type semiconductor material in contact with n-type semiconductor material.

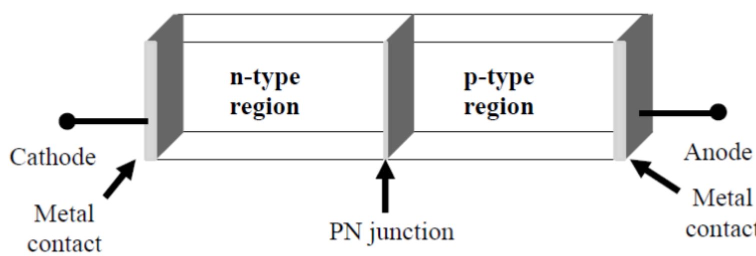


Figure 1: pn junction diode structure

A variety of semiconductor materials can be used to form pn junctions like silicon, germanium, gallium arsenide, etc. However, we will concentrate on silicon, as this is the most widely used material in microelectronics. In actual practice, both the p and n regions are part of the same silicon crystal. The pn junction is formed by creating regions of different doping (p and n regions) within a single piece of silicon. The material is doped by bringing in additional atoms (impurities). The impurities can be either donors or acceptors atoms. The words acceptor and donor can be associated with donating and accepting electrons.

PN Junction
To understand how a pn junction is formed we will start by imagining two separate pieces of semiconductor, one n-type and the other p-type as shown in Figure 2 (a). Now, we bring the two pieces together to make one piece of semiconductor. This results in the formation of a pn junction (Figure 2 (b)).

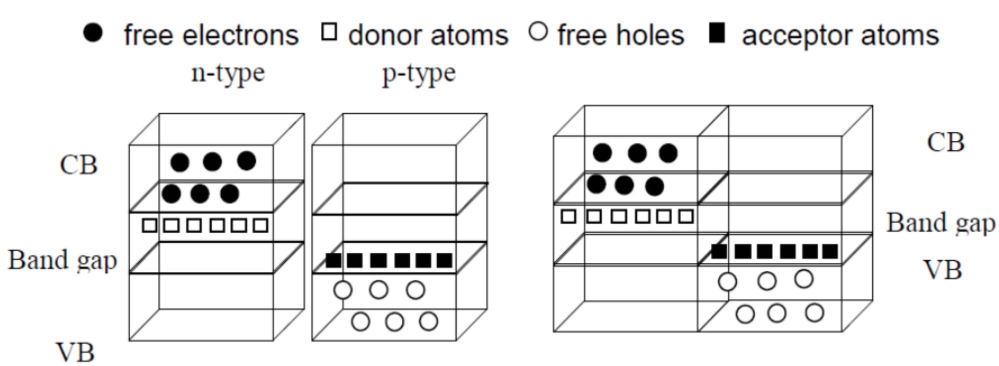


Figure 2: a) separate pieces of p and n materials, b) pn junction.

Forward/Reverse-Bias Characteristics

If a negative voltage is applied to the pn junction, the diode is reverse-biased. In response, free holes and electrons are pulled towards the end of the crystal and away from the junction. The result is that all available carriers are attracted away from the junction, and the depletion region is extended. There is no current flow through under such conditions. If the applied voltage is positive, the diode operates in forward bias. This has the effect of shrinking the depletion region. Now, electrons in the p-type end are attracted to the positive applied voltage, while holes in the n-type end are attracted to the negative applied voltage.

Diode Characteristics

In the forward bias condition, a cut-in voltage must be overcome for the diode to start conduction. In silicon, this voltage is about 0.6-0.7 V. In reverse-bias conditions, the current is limited to I_S (reverse saturation current). For higher values of reverse voltages, the junction breaks down. Figure 3 shows the diode *I-V* characteristics.

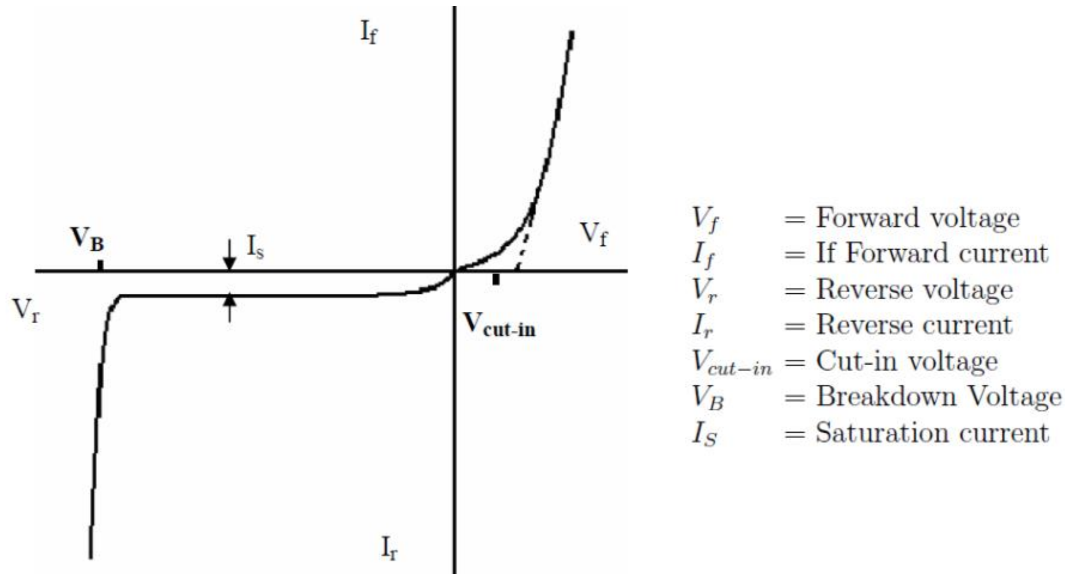


Figure 3: Diode IV Characteristics.

Methodology:

The diode will be forward biased from a DC voltage source, starting from 0 V to 1 V in a step of 0.1 V and then 1 V to 10 V in a step of 1 V. The diode voltage and resistor voltage drops will be measured using a multimeter. If the resistor voltage drop is divided by the resistance of that resistor, then we will get the diode current. Then, a forward-biased diode curve will be plotted. From this curve, the dynamic resistance of the diode can be obtained.

Equations Required:

Thediode forward current, $I_d = I_s\left(1 - e^{-\frac{qV_d}{kT}}\right)$

The slope of the forward curve gives the diode conductance, $g_d = \frac{1}{r_d} = tan\theta = \frac{dI_d}{dV_d} = \frac{\Delta I_d}{\Delta V_d}$

The diode's dynamic resistance, $r_d = \frac{dV_d}{dI_d} = \frac{\Delta V_d}{\Delta I_d}$

The diode's static resistance, $r_s = \frac{V_d}{I_d}$ (for any given point)

Pre-Lab Homework:

Students will be provided with the upcoming lab manuals, and they will be asked to prepare the theoretical (operations/working principle) information on the topic from the textbook.

Besides, they must implement the circuit (as given in Figure 4) using a MultiSIM simulator. Some other diodes can also be used, such as IN914, IN4001, or IN4007. Measure the values of different parameters and fill up the table (Table 1) using the simulation tool.

Apparatus:

SL#	Apparatus	Quantity
1	Diode	1
2	Resistance (1 kΩ)	1
3	Project Board	1
4	DC Power Supply	1
5	Multimeter	1

Precaution!
The following is a list of some of the special safety precautions that should be taken into consideration when working with diodes:

1. **Never remove or insert a diode into a circuit with voltage applied.**
2. **When testing a diode, ensure that the test voltage does not exceed the diode's-**
   a. **Maximum allowable voltage.**
   b. **Ensure a replacement diode into a circuit is in the correct direction.**

Experimental Procedures:

1. Measure the actual value of the 1 kΩ resistor.
2. Connect the circuit as shown in Figure 4.

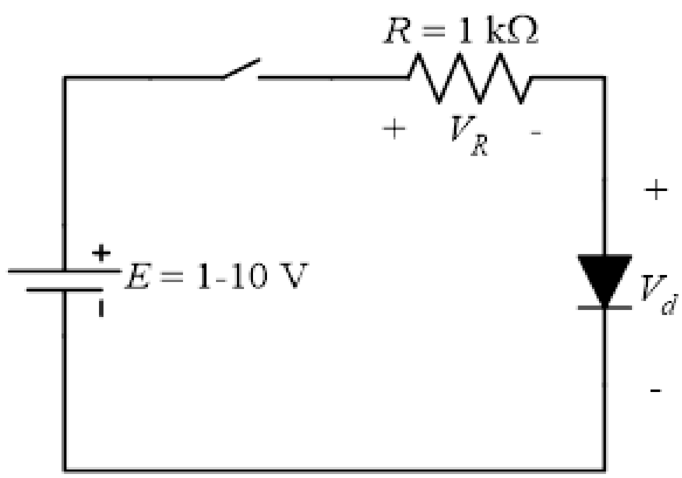


Figure 4: Circuit diagram for determining diode characteristics.

3. Turn on the DC power supply with the voltage control nob at 0 V.
4. Rotate the voltage control nob from 0 V to 10 V gradually with a step of 0.1 V and 1 V as shown in Table 1.
5. Measure the voltage across the two terminals of the supply voltage, diode, and resistor for all cases.
6. Record the measured data in Table 1.
7. Turn off the Power Supply.
8. Calculate the drain current (I_d) and fill up Table 1.
9. Plot the V_D - I_d characteristic curve for the diode.
10. Determine the knee voltage and static and dynamic resistance of the diode.

Table 1 Data for the V_D - I_d Curve

Source Voltage, E_s (V)	Diode Voltage, V_D (V)	Resistor Voltage, V_R (V)	Diode Current, I_d (mA)
0			
0.1			
0.2			
0.3			
0.4			
0.5			
0.6			
0.7			
0.8			
0.9			
1.0			
2.0			
3.0			
4.0			
5.0			
6.0			
7.0			
8.0			
9.0			
10.0			
12.0			

Questions:

1. Show the difference between your simulated and measured values. Comment on the results.
2. Plot the V_D - I_d characteristic curve for the diode and comment on the graph.
3. Compute the knee voltage and dynamic and static resistances of the diode from the plotted graph.
4. What will happen if the polarity of the supply voltage is reversed in the case of using a diode with a PIV of 4.8 V?
5. Discuss the overall aspects of the experiment. Did your results match the expected ones? If not, explain.

References:

[1] Robert L. Boylestad, Louis Nashelsky, Electronic Devices and Circuit Theory, 9th Edition, 2007-2008

[2] Adel S. Sedra, Kenneth C. Smith, Microelectronic Circuits, Saunders College Publishing, 3rd ed., ISBN: 0-03-051648-X, 1991.

[3] American International University–Bangladesh (AIUB) Electronic Devices Lab Manual.

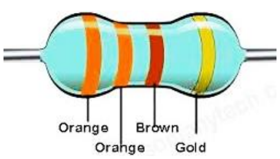
[4] David J. Comer, Donald T. Comer, Fundamentals of Electronic Circuit Design, John Wiley & Sons Canada, Ltd., ISBN: 0471410160, 2002.

[5] Resistor values: *https://www.eleccircuit.com/how-to-basic-use-resistor/*, accessed on 20 September 2023.

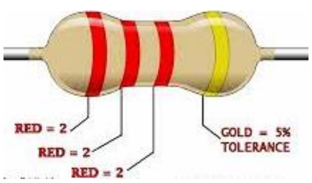
List the references that you have used to answer the "Discussion" section.

Appendix A:
Resistance Color Code:

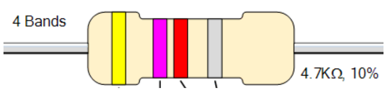
Color	Numeric Value	Multiplier	Tolerance	Temperature coefficient
BLACK	0	1Ω		250
BROWN	1	10 Ω	±1%	100
RED	2	100 Ω	±2%	50
ORANGE	3	1K Ω		15
YELLOW	4	10 Ω		25
GREEN	5	100 Ω	±0.5%	20
BLUE	6	1M Ω	±0.25%	10
VIOLET	7		±0.1%	5
GREY	8			1
WHITE	9			
GOLD			±5%	
SILVER			±10%	



$XY\times10^Z \pm$ E of $XY\times10^Z$
$= 33\times10^1 \pm 5\%$ of 330
$= 330 \pm 16.5$
= 346.5 or 313.5 Ω



$XY\times10^Z \pm$ E of $XY\times10^Z$
$= 22\times10^2 \pm 5\%$ of 2200
$= 2200 \pm 110$
= 2310 or 2090 Ω



$XY\times10^Z \pm$ E of $XY\times10^Z$
$= 47\times10^2 \pm 10\%$ of 4700
$= 4700 \pm 470$
= 5170 or 4230 Ω
= 5.17 or 4.23 kΩ

Standard Resistor Values Table (Commercially Available):

The following are the standard resistor values table available in carbon film with 5% tolerance:

Resistances in Ohm range:

1Ω	10Ω	100Ω
1.1Ω	11Ω	110Ω

1.2Ω	12Ω	120Ω
1.5Ω	15Ω	150Ω
1.8Ω	18Ω	180Ω
2Ω	20Ω	200Ω
2.2Ω	22Ω	220Ω
2.7Ω	27Ω	270Ω
3.3Ω	33Ω	330Ω
4.7Ω	47Ω	470Ω
5.6Ω	56Ω	560Ω
6.8Ω	68Ω	680Ω
7.5Ω	75Ω	750Ω
8.2Ω	82Ω	820Ω
9.1Ω	91Ω	910Ω

Resistances in kilo Ohm range:

1kΩ	10kΩ	100kΩ
1.1kΩ	11kΩ	110kΩ
1.2kΩ	12kΩ	120kΩ
1.5kΩ	15kΩ	150kΩ
1.8kΩ	18kΩ	180kΩ
2kΩ	20kΩ	200kΩ
2.2kΩ	22kΩ	220kΩ
2.7kΩ	27kΩ	270kΩ
3.3kΩ	33kΩ	330kΩ
3.6kΩ	36kΩ	360kΩ
3.9kΩ	39kΩ	390kΩ
4.7kΩ	47kΩ	470kΩ
5.6kΩ	56kΩ	560kΩ
6.8kΩ	68kΩ	680kΩ
7.5kΩ	75kΩ	750kΩ
8.2kΩ	82kΩ	820kΩ
9.1kΩ	91kΩ	910kΩ

Resistances in Mega Ohm range:

1MΩ	3MΩ	9.1MΩ
1.1MΩ	3.3MΩ	10MΩ
1.2MΩ	3.6MΩ	12MΩ
1.5MΩ	4.3MΩ	15MΩ
1.8MΩ	5.6MΩ	18MΩ
2MΩ	6.2MΩ	20MΩ
2.2MΩ	6.8MΩ	22MΩ
2.4MΩ	7.5MΩ	
2.7MΩ	8.2MΩ	