VIVEKANAND EDUCATION SOCIETY'S POLYTECHNIC

Study Material

Program Code: All Program

Semester: First

Course Name: Basic Science (Physics)

Course Code: 22102

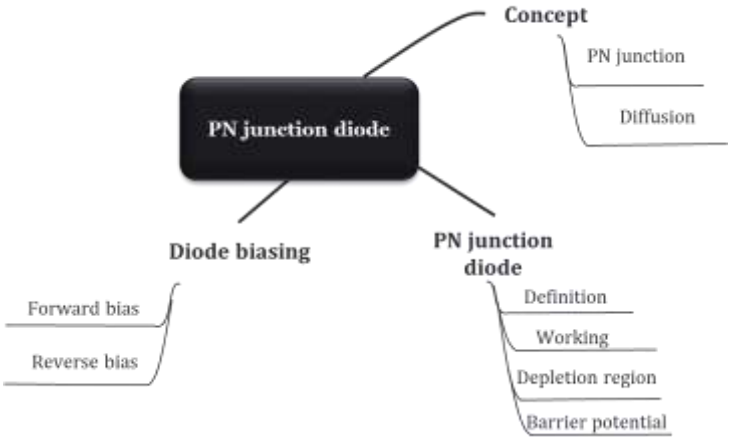
Topic Name: Electricity, Magnetism & Semiconductors

UO2f: Explain the I-V characteristics and applications of the given p-n junction diodes.

LO10: Student will be able to explain the flow of current in a p-n junction in forward and reverse bias.

Course Expert: S. K. Rawat	**Date: 02/09/2020**

Concept Map:



Key words: p-n junction, diode, depletion layer, barrier potential, forward bias, reverse bias

Key Questions:

1. What is a p-n junction diode?
2. What is depletion layer and barrier potential?
3. Working of p-n junction diode in forward bias condition.
4. Working of p-n junction diode in reverse bias condition..

Key Definition:

1. When a p-type semiconductor is joined to n-type semiconductor, the contact surface is called p-n junction.
2. A p-n junction with metallic contacts provided at the ends for the application of an external voltage is called p-n junction diode.
3. The region near the junction which is depleted of free charges is called depletion layer.
4. The potential difference developed due to increase in depletion region, which prevent continuous diffusion of charge carriers across the junction is called barrier potential.
5. When positive terminal of the external source is connected to the p-side and negative terminal of n-side of diode, the diode is said to be forward bias.
6. When positive terminal of the external source is connected to the n-side and negative terminal of p-side of diode, the diode is said to be reversed bias.

Notes

PN junction: When a p-type semiconductor is joined to n-type semiconductor, the contact surface is called pn junction.

Diffusion: The process of joining p-type and n-type material is known as diffusion.
The new formed crystal structure is called p-n junction diode or semiconductor diode or crystal diode as shown in Fig. 1 (a).

PN junction diode: A p-n junction with metallic contacts provided at the ends for the application of an external voltage is called p-n junction diode
A p-n junction diode is a two terminal device and symbolically represented as shown in Fig. 1 (b).

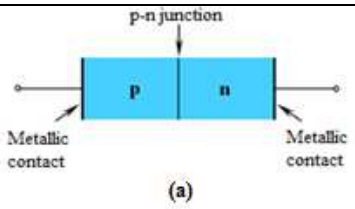


Figure 1: (a) p-n junction diode

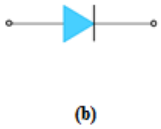


Figure 1: (b) Symbol of p-n junction diode

While junction is formed, electrons from n-side diffuse across junction and recombine with holes on p-side. When free electrons leave n-region, create positive ion and on recombining with holes create negative ion in p-region. The free charges (electrons and holes) disappear from the region near junction and thus this region is depleted from free charges as shown in Fig. 2. As the diffusion process across the junction continues the depletion regions on either side of the junction increases. The increase in depletion region builds up a difference of potential across the junction. This potential difference prevents continuous diffusion of electrons and holes across the junction.

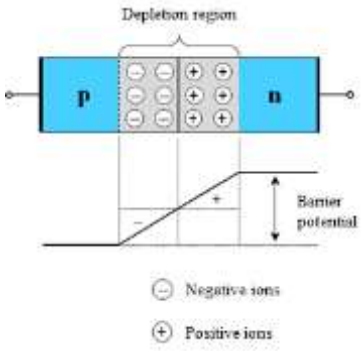


Figure 2: Depletion region & barrier potential under no bias

Depletion Layer
The region near the junction which is depleted of free charges is called depletion layer.

Barrier potential
The potential difference developed due to increase in depletion region, which prevent continuous diffusion of charge carriers across the junction is called barrier potential.

Forward bias
When positive terminal of the external source is connected to the p-side and negative terminal of n-side of diode, the diode is said to be forward bias.

Fig. 3 shows that, when p-n junction is forward biased, the holes are repelled by the positive terminal of external source and are forced to move towards the junction. Similarly, the electrons are repelled from negative terminal of the external source and move towards the junction. Due to this some of the holes and electrons enter into the depletion region and recombine. This reduces the width of depletion region as well as height of potential barrier and allows the majority carriers to diffuse through the junction and it causes a large current to flow through the p-n junction.

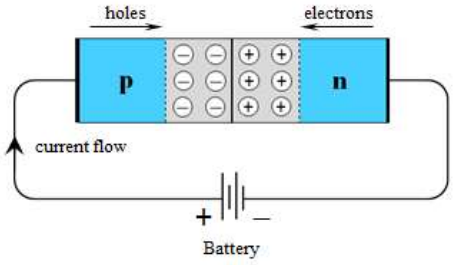


Figure 3: Forward bias of p-n junction diode

Reverse Bias

When positive terminal of the external source is connected to the n-side and negative terminal of p-side of diode, the diode is said to be reversed bias.

When p-n junction diode is reverse biased as seen in Fig. 4, the holes in the p-side are attracted towards the negative terminal of the external source and the electrons in the n-side are attracted towards the positive terminal of the external source. These majority carriers are drawn away from the junction. This widens the depletion layer and increases the barrier potential.

The increased potential barrier makes it very difficult for majority carriers to diffuse across the junction, so there is no current due to majority carriers in a reverse biased p-n junction. However in practice very small current flows through the circuit with reversed biased, which is due to flow of minority carriers which are created is crystal by taking energy from the applied reverse voltage and the reverse current flow in the junction.

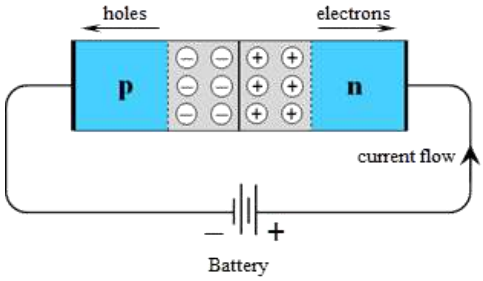
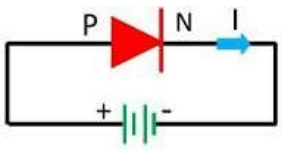
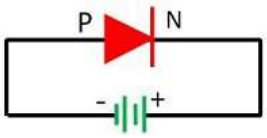


Figure 4: Reverse bias of p-n junction diode

Difference: Forward Bias and Reverse Bias

Points	Forward Biasing	Reverse Biasing
Definition	The external voltage which is applied across the PN-diode for reducing the potential barrier to constitute the easy flow of current through it is called forward bias.	The external voltage which is applied to the PN junction for strengthening the potential barrier and prevents the flow of current through it is called reverse bias.
Symbol		
Connection	The positive terminal of the battery is connected to the P-type semiconductor of the device and the negative terminal is connected to N-type semiconductor	The negative terminal of the battery is connected to the P-region and the positive terminal of the battery is connected to N-type semiconductor.
Barrier Potential	Reduces	Strengthen
Voltage	The voltage of an anode is greater than cathode.	The voltage of cathode is greater than an anode.
Forward Current	Large	Small
Depletion layer	Thin	Thick
Resistance	Low	High
Current Flow	Allows	Prevents
Current Magnitude	Depends on forward voltage.	Zero
Operate	Conductor	Insulator

Link to YouTube/ OER/ video/e-book:

1. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
2. https://www.electronics-tutorials.ws/diode/diode_1.html
3. https://www.electronics-notes.com/articles/basic_concepts/conductors-semiconductors-insulators/what-is-a-semiconductor.php
4. https://circuitglobe.com/difference-between-forward-and-reverse-biasing.html#:~:text=The%20Forward%20bias%20decreases%20the,current%20to%20flow%20through%20it.

Key Take away:

1. P-N junction diode in forward bias.
2. P-N junction diode in reverse bias.

Formative Assessments

<22102> : <All Program> : < All Program >: <Electricity, Magnetism & Semiconductors>: <UO2f> : <LO10> : <Assessments> : <Formative>

<S. K. Rawat>

Assessment Type: Formative Assessments: Embedded questions in video/ PPT

Set 1		
Question No 1	Question No 2	Question No 3
The process of joining p-type and n-type material is known as _____	The immobile charges left behind on N-side and P-side of PN junction diode are called _____ charges	When p-n junction diode is in forward bias, the width of depletion region and height of barrier potential _____.
Remembering	Remembering	Understanding
a) doping	a) bound	a) decreases
b) diffusion	b) free	b) increases
c) fusion	c) mobile	c) remain same
d) ageing	d) None of the above	d) is zero
Ans: <diffusion>	Ans: < bound >	Ans: < decreases >

Set 2		
Question No 1	Question No 2	Question No 3
In P-N Junction Diode, the P-side consists high concentration of _____	A region which is depleted of free charge carriers (i.e., electrons and holes) and has only immobile charges is called _____ region	When p-n junction diode is in reverse bias, the width of depletion region and height of barrier potential _____.
Remembering	Understanding	Understanding
a) electrons	a) conduction	a) decreases
b) holes	b) valence	b) increases
c) ions	c) depletion	c) remain same
d) charges	d) filled	d) is zero
Ans: < holes >	Ans: < depletion >	Ans: < increases >

Practice Worksheets

<22102> : <All Program> : < All Program >: <Electricity, Magnetism & Semiconductors>: <UO2f> : <LO10> : <Assessments> : <Summative>:<S. K. Rawat>

A. In P-N Junction Diode, the N-side consists of high concentration of _____ a) electrons b) holes c) ions d) charges	B. The process of combining of holes with electrons across the junction is known as _____ a) doping b) diffusion c) fusion d) ageing
Ans A:	Ans B:
C. What factor(s) do(es) the barrier potential of a pn junction depend on? a) Type of semi-conductive material b) The amount of doping c) The temperature d) All of the above	D. A forward biased pn junction diode conducts, if the applied voltage is _____ potential barrier. a) smaller than b) equal to c) greater than d) independent of
Ans C:	Ans D:
E. As the forward current through a silicon diode increases, the internal resistance _____ a) increases b) decreases c) remains the same d) none of the above	F. In pn junction diode, the conductivity is due to a) electrons only b) holes only c) electron-hole pair d) None of the above
Ans E:	Ans F:
G. For a forward-biased diode, the barrier potential _____ as temperature increases. a) decreases b) remains constant c) increases d) none of the above	H. When positive terminal of the external source is connected to the p-side and negative terminal of n-side of diode, the diode is said to be - a) No-bias b) Forward bias c) Reverse bias d) None of the above
Ans G:	Ans H:
I. When positive terminal of the external source is connected to the n-side and negative terminal of p-side of diode, the diode is said to be a) No-bias b) Forward bias c) Reverse bias d) None of the above	J. The region near the junction which is depleted of free charges is called _____. a) Barrier potential b) Barrier junction c) Depletion region d) None of the above
Ans I:	Ans J: