ROHINI
COLLEGE OF ENGINEERING AND TECHNOLOGY
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DEPARTMENT OF BIOMEDICAL ENGINEERING

III Semester- BM3301 SENSORS AND MEASUREMENTS

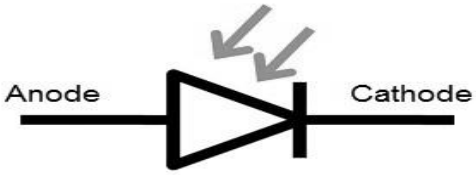
UNIT - 3

3.6 Photo Diodes

- A photodiode is a p-n junction or pin semiconductor device that consumes light energy to generate electric current.
- It is also sometimes referred as photo-detector, photo-sensor, or light detector.
- Photodiodes are specially designed to operate in reverse bias condition.
- Reverse bias means that the p-side of the photodiode is connected to the negative terminal of the battery and n-side is connected to the positive terminal of the battery.
- Photodiode is very sensitive to light so when light or photons falls on the photodiode it easily converts light into electric current.
- Solar cell is also known as large area photodiode because it converts solar energy or light energy into electric energy. However, solar cell works only at bright light.

The construction and working of photodiode:

- The construction and working of photodiode is almost similar to the normal p-n junction diode. PIN (p-type, intrinsic and n-type) structure is mostly used for constructing the photodiode instead of p-n (p-type and n-type) junction structure because PIN structure provide fast response time. PIN photodiodes are mostly used in high-speed applications.
- In a normal p-n junction diode, voltage is used as the energy source to generate electric current whereas in photodiodes, both voltage and light are used as energy source to generate electric current.
- The symbol of photodiode is similar to the normal p-n junction diode except that it contains arrows striking the diode. The arrows striking the diode represent light or photons. A photodiode has two terminals: a cathode and an anode.



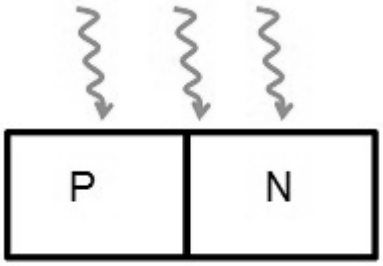
Photodiode symbol

Working:

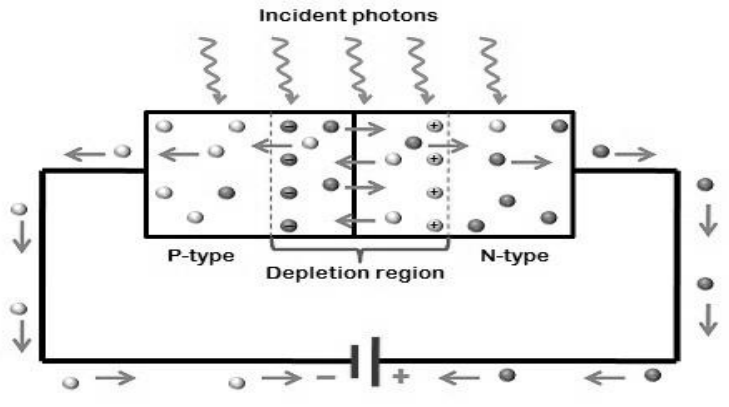
- A normal p-n junction diode allows a small amount of electric current under reverse bias condition.
- To increase the electric current under reverse bias condition, we need to generate more minority carriers.
- The external reverse voltage applied to the p-n junction diode will supply energy to the minority carriers but not increase the population of minority carriers.
- However, a small number of minority carriers are generated due to external reverse bias voltage.
- The minority carriers generated at n-side or p-side will recombine in the same material before they cross the junction. As a result, no electric current flows due to these charge carriers. For example, the minority carriers generated in the p-type material experience a repulsive force from the external voltage and try to move towards n-side.
- However, before crossing the junction, the free electrons recombine with the holes within the same material. As a result, no electric current flows.
- To overcome this problem, we need to apply external energy directly to the depletion region to generate more charge carriers.
- A special type of diode called photodiode is designed to generate more number of charge carriers in depletion region.
- In photodiodes, we use light or photons as the external energy to generate charge carriers in depletion region.
- The different types of photodiodes are

  PN junction photodiode
  PIN photodiode
  Avalanche photodiode

Among all the three photodiodes, PN junction and PIN photodiodes are most widely used.



- When external light energy is supplied to the p-n junction photodiode, the valence electrons in the depletion region gains energy.
- If the light energy applied to the photodiode is greater the band-gap of semiconductor material, the valence electrons gain enough energy and break bonding with the parent atom. The valence electron which breaks bonding with the parent atom will become free electron. Free electrons moves freely from one place to another place by carrying the electric current.
- When the valence electron leave the valence shell an empty space is created in the valence shell at which valence electron left. This empty space in the valence shell is called a hole. Thus, both free electrons and holes are generated as pairs. The mechanism of generating electron-hole pair by using light energy is known as the inner photoelectric effect.
- When no light is applied to the reverse bias photodiode, it carries a small reverse current due to external voltage. This small electric current under the absence of light is called dark current.



PN Junction photodiode

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- When the valence electron leave the valence shell an empty space is created in the valence shell at which valence electron left. This empty space in the valence shell is called a hole. Thus, both free electrons and holes are generated as pairs. The mechanism of generating electron-hole pair by using light energy is known as the inner photoelectric effect.
- The total current through the photodiode is the sum of the dark current and the photocurrent. The dark current must be reduced to increase the sensitivity of the device.

Advantages of Photodiode:

1. Fast Response Time:
2. High Sensitivity
3. Low Noise
4. Compact Size
5. Low Power Consumption

Disadvantages of Photodiode:

1. Changes in ***temperature can affect*** the dark current, response time, and overall sensitivity of the photodiode.
2. Noise at Low Light Levels
3. Limited Dynamic Range
4. While photodiodes are generally cost-effective, certain types, such as high-performance or specialized photodiodes, can be ***relatively expensive***.

Applications of Photodiode:

<u>Medical Applications</u>:

1. Photodiodes are widely used in ***pulse oximeters***, devices that measure oxygen saturation levels in blood.
2. In ***glucose monitoring*** devices, photodiodes can be employed to measure the intensity of light passing through a blood sample.
3. Photodiodes are used in ***fluorescence spectroscopy*** to detect emitted light from fluorophores.
4. ***Photoplethysmography*** (PPG): PPG is a technique that uses photodiodes to measure changes in blood volume in peripheral tissues.

5. ***Optical Coherence Tomography*** (OCT): Photodiodes play a role in OCT, a high-resolution imaging technique used in ophthalmology and other medical fields.

Other Applications:

1. Compact disc players
2. Smoke detectors
3. Space applications
4. Photodiodes are used for optical communications.
5. Photodiodes are used to measure extremely low light intensities.

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