

# Photodiode

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**Abstract:-** Light detection is important for many types of electronic instruments. One of the most important of these light detecting tools is the photodiode. These tools are present in dozens of electronic devices. Photodiodes are semi-conductors that convert light into electrical voltage. This turns light signals into electrical input instructions that the machine can understand. In fact photodiodes are optoelectronic devices, meaning that they create electricity when light shines on them, similar to photovoltaic cells. In this article a brief about photodiodes are discussed.

**Keywords:-** photodiode, semiconductor, valence band, depletion region, p-n photodiode, p-i-n photodiode, quantum efficiency, dark current, photovoltaic mode, photoconductive mode.

## 1. INTRODUCTION

In semiconductors, electrons are released from the valence band, when energy is supplied to such electrons. This energy can be supplied in the form of heat or through an accelerating voltage. Light energy can also be used to produce the current in semiconductors. A junction diode made from light (or photo) sensitive semiconductor is called a photodiode.

Photodiode technology developments came out of the basic developments of the PN junction diode that started in the 1940s in earnest. Applications for the use of the PN junction diode were found outside the basic use of rectifying signals. It was found that they could be used for many photonic applications - photodiodes, solar cells and light emission. There are many types of photodiodes. The Photodiode has a p-n junction or PIN structure. The P-N junction is made up of a light sensitive semi conductor. Silicon (190-1100 nm), Germanium (400-1700 nm), Indium Gallium Arsenide (800-2600 nm), Lead Sulphide (1000-3500 nm) etc are the semiconductors used for making different types of photodiodes. The photodiode is similar to an LED in construction but its p-n junction is highly sensitive to light. The p-n junction may be exposed or packaged with a window to enter light into the P-N junction. Under the forward biased state, current passes from the anode to cathode, while in the reverse biased state, photo current flows in the reverse direction. In most cases, the packaging of Photodiode is similar to

LED with anode and cathode leads projecting out from the case. But a photodiode is the exact opposite of an LED in function. Instead of emitting light, the photodiode absorbs light and produces current. A photodiode and its symbol are shown in fig-1(a) and fig-1(b) respectively.



Fig-1(a): photodiode



Fig-1(b): Symbol for photodiode

## 2. TYPES OF PHOTODIODE

Although the term photodiode is widely used, there are actually a number of different types of photodiode technology that can be used. As they offer different properties, the different photodiode technologies are used in different areas.

### 2.1 PN photodiode:

The PN photodiode was the first form of photodiode to be developed and used. Nowadays, it is not as widely used as other types which are able to offer better performance parameters. Nevertheless it is still used in some instances.

### 2.2 PIN photodiode

This type of photodiode is one of the most widely used forms of photodiode today. Although the PIN or p-i-n photodiode was not the first type of photodiode to be used, it collects the light photons more efficiently than the more standard PN photodiode, and also offers a lower capacitance. A p-i-n or **PIN photodiode** is a photodiode with an intrinsic (i) (i.e., undoped) region in between the n- and p-doped regions. Most of the photons are absorbed in the intrinsic region, and carriers generated therein can efficiently contribute to the photocurrent.

### 2.3 Avalanche photodiode

Avalanche photodiode technology is used in areas of low light. The avalanche photodiode offers very high levels of gain, but against this it has high levels of noise. Accordingly this photodiode technology is not suitable for all applications and it tends to be used .

### 2.4 Schottky photodiode

As the name indicates, Schottky photodiode technology is based upon the Schottky diode. In view of the small diode capacitance it offers a very high speed capability and is used in high bandwidth communication systems.

## 3. WORKING AND CHARACTERISTICS OF PHOTODIODE

Although there are several different types of photodiode, they all utilize the same basic principles, although some are enhanced by other effects. Different types of photodiode work in slightly different ways; the basis of operation of all photodiodes remains the same.

Light energy can be considered in terms of photons or packets of light. When a photon of sufficient energy enters the depletion region of a semiconductor diode, it may strike an atom with sufficient energy to release the electron from the atomic structure. This creates a free electron and a hole (i.e. an atom with a space for an electron). The electron is negatively charged, while the hole is positively charged. This mechanism is also known as inner photoelectric effect. If the absorption occurs in the junction's depletion region, or one diffusion length away from it, these carriers are swept from the junction by the built-in electric field of the depletion region. Thus holes move toward the anode, and electrons toward the cathode, and a photocurrent is produced. The total current through the photodiode is the sum of the dark current (current that flows with or without light) and the photocurrent, so the dark current must be minimized to maximize the sensitivity of the device.

PN and PIN photodiodes are different in their performance. The PIN photodiode has an intrinsic layer, so they must be reverse biased. As a result of reverse biasing, the width of the depletion region increases and the capacitance of the p-n junction decreases. This allows the generation of more electrons and holes in the depletion region. But one disadvantage of the reverse biasing is that, it generates noise current that may reduce the S/N (signal/noise) ratio. So reverse biasing is suitable only in applications that require higher band width. The PN photodiode is ideal for lower light applications because the operation is unbiased.

A photodiode has a depleted region with a high electric field that serves to separate photo generated electron-hole pairs. For high speed operation, the depletion region must be kept thin to reduce the quantum efficiency the depletion layer must be sufficiently thick to allow a large fraction of the incident light to be absorbed. Thus there is a trade-off between the speed of response and quantum efficiency.

When photodiode is kept under dark condition and a sufficient reverse voltage is applied, then an almost constant current, independent of magnitude of reverse bias is obtained. This current corresponds to the reverse saturation current due to thermally generated minority carriers. It is called dark current. It is proportional to the concentrations of minority carriers and is denoted by  $I_d$ . Majority charge carriers are not allowed to cross the junction by the potential hill under this reverse bias condition.

When light falls on the diode surface additional electron- hole pairs are formed. But since the concentration of majority carriers is much greater as compared to that of minority carriers, the percentage increase of majority carriers is much smaller than the percentage increase of minority carriers. Hence we can neglect the increase in majority carrier density and can consider the radiation entirely as a minority carriers diffuse to the junction, cross it and contribute to the additional current.

Thus under large reverse bias conditions the total reverse current is given by

$$I = I_d + I_s$$

Where  $I_s$  is the short circuit current and is proportional to light intensity. With any bias  $V$ , the reverse current due to thermal electron- hole pairs i.e., dark current is given by,

$$I_d = I_0 ( 1 - e^{Vq / (\square kT)} )$$

Where  $I_0$  = reverse bias saturation current,

$V$  = voltage across the photodiode,

$q$  = magnitude of charge on an electron,

$\square$  = quality factor = 1 for Ge and 2 for Si.

$k$  = Boltzmann constant,

$T$  = absolute temperature of the photodiode.

Hence the total reverse current of photodiode in reverse bias is given by

$$I = I_s + I_0 ( 1 - e^{Vq / (\square kT)} )$$

I – V characteristics of a photodiode is shown in fig-2.

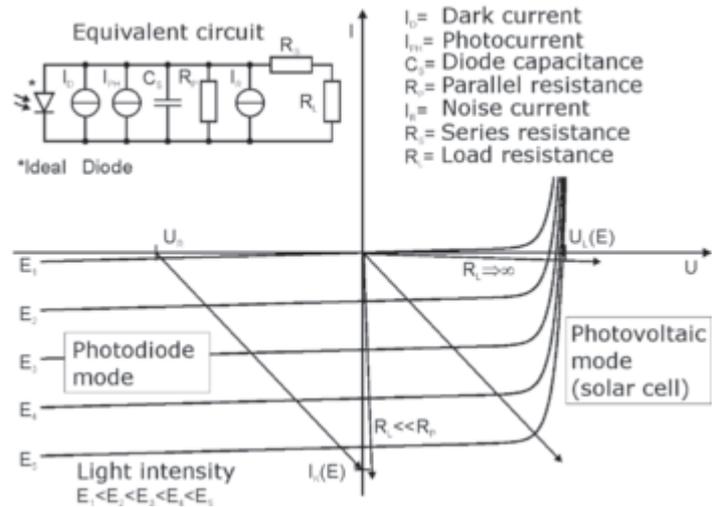


Fig-2. I-V characteristic of a photodiode.

The photodiode works in two modes namely Photovoltaic mode and Photoconductive mode. In the photovoltaic mode (also called Zero bias mode), the photocurrent from the device is restricted and a voltage build up. The Photoconductive mode occurs when the photodiode is reverse biased.. The photocurrent remains same in this condition. The photocurrent is always proportional to the luminescence. Even though the Photoconductive mode is faster than the Photovoltaic mode, the electronic noise is higher in photoconductive mode. Silicon based photodiodes generate less noise than germanium based photodiodes since the silicon photodiodes have greater band gap.

#### 4. APPLICATION OF PHOTODIODE:

- i) P-N photodiodes are used in photoconductors, charge-coupled devices, and photomultiplier tubes. They may be used to generate an output which is dependent upon the illumination (analog; for measurement and the like), or to change the state of circuitry (digital; either for control and switching, or digital signal processing).
- ii) Photodiodes are used in consumer electronic devices such as compact disc players, smoke detectors, and the receivers for infrared remote

control devices used to control equipment from televisions to air conditioners. For many applications either photodiodes or photoconductors may be used. Either type of photosensor may be used for light measurement, as in camera light meters, or to respond to light levels, as in switching on street lighting after dark.

- iii) Photodiodes are often used for accurate measurement of light intensity in science and industry. They generally have a more linear response than photoconductors.
- iv) They are also widely used in various medical applications, such as detectors for computed tomography (coupled with scintillators), instruments to analyze samples (immunoassay), and pulse oximeters.
- v) PIN diodes are much faster and more sensitive than p-n junction diodes, and hence are often used for optical communications and in lighting regulation.
- vi) Avalanche photodiode, photomultiplier tubes are used for applications such as astronomy, spectroscopy, night vision equipment and laser range finding etc.

### 5. CONCLUSIONS:

Photodiodes are optoelectronic devices which are diverse in type and use and can be adapted for use in almost any electronic device. They can be used with

infrared light sources like LED, neon, fluorescent and laser light. They are also cheaper than many light detection diodes.

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