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Lecture 11 : PIN photodiodes

(Positive-Intrinsic-Negative) photodiode

1. A **PIN Photodiode** is a kind of photodetector, **it can convert optical signals into electrical signals**. It can be defined as:

   A diode with a wide and undoped intrinsic semiconductor region between a P-type and an N-type semiconductor region.

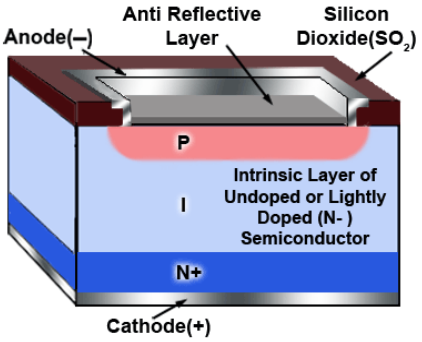
   Thus, PIN photodiode consists of three layers naming :

   a. P-type layer,

   b. Intrinsic layer and

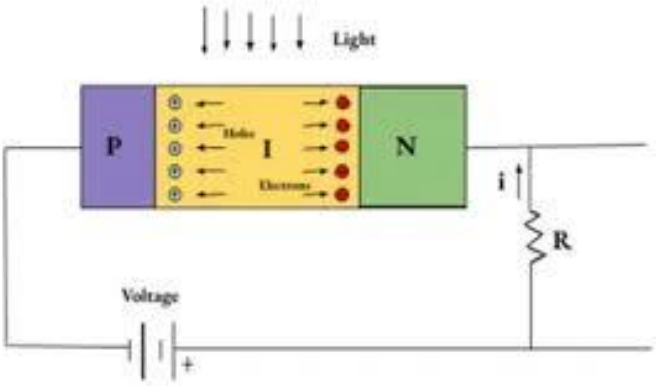
   c. N-type layer as shown in the figure below:

2. The region between them consists of the intrinsic material and the doping level is said to be very low in this region.
3. The thickness of the intrinsic layer is very narrow relatively, which ranges from 10 – 200 microns.
4. The P region and the N-type regions are known to be heavily doped.



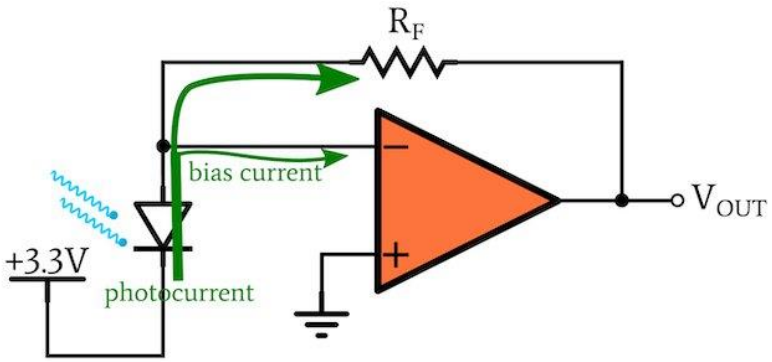
5. **P** terminal acts as anode , and **N** terminal acts as cathode. Notice that unlike the general PN junction diode, the width of the intrinsic layer (I) in the PIN-Photodiode is larger than that in the PN junction diode.
6. The resistivity decreases with an increase in impurity and vice-versa. **P** and **N** layers have very low resistivity , while resistivity in the I layer is very high. PIN-photodiode has a large depletion region which is used in the reception of light.
7. PIN-photodiodes are used in Photodetectors and photovoltaic cell and the PIN photodiodes are also used for **fiber optic network cards as well as switches**.

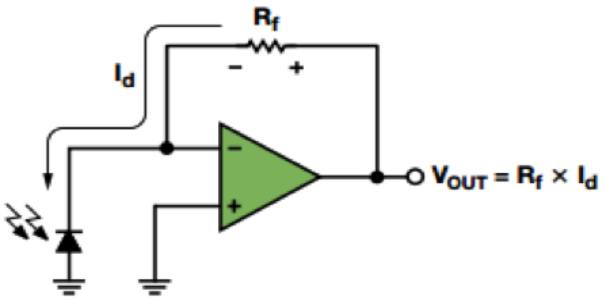
8. The **PIN**-photodiode works as a **photodetector only when it is functioning in reverse bias.** The Anode is connected with the negative terminal of the battery. The positive side of the battery is connected to the cathode through a resistor.

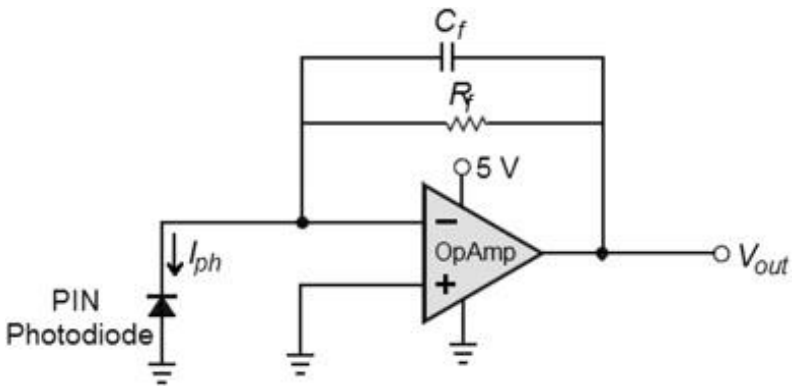


9. PIN Photodiode Circuit Diagram

In the circuit diagram of the PIN photodiode, a high value resistance must be connected. **The reason** is that the photodiodes are low current sourcing devices (several microamperes). A big resistor (for silicon photodiodes, R is tens, hundreds, or even thousands of mega ohms MΩ) is needed to convert that into an easily-readable voltage (V= IR)..(for example, a common logic-level high is **3.3 V**). The larger the photodiode, the higher current that will be developed. A 1mm square diode is a fairly large one by today's standards and the current at ambient room light levels can be several microamperes.







10. Junction capacitance is an important parameter sometimes added because it strongly influences the photodiode's frequency response. Lower junction capacitance allows for high-frequency operation.

11. PIN Photodiode Characteristics

a. **Resistivity:** It offers low resistivity in **P** , and **N** layers (less than **1kΩ/cm**) and high resistivity in **I** layer (up to 100 **kΩ/cm**).

b. **Capacitance:** As capacitance is inversely proportional with the gap between P and N layers, capacitance in this photodiode is lower than the standard diode.

$$C = \varepsilon_0 \varepsilon_r \frac{A}{d}$$

Where ε_0 = dielectric value of free space

ε_r= dielectric constant of the semiconductor

A= area of the intrinsic layer

d= width of depletion region

c. **The flow of current:** The current flow is directly proportional to the amount of light incident on the detector.

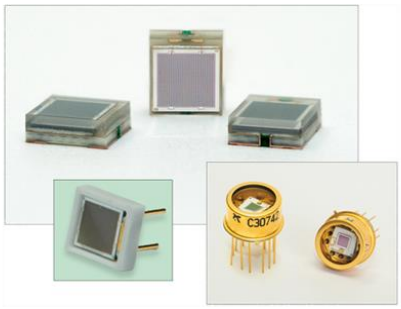
Photomultiplier

1. A **photomultiplier** is a device that converts incident photons into an electrical signal. **They are useful for light detection of very weak signals**, Thus, they are used in research laboratories to measure the intensity and spectrum of light-emitting materials .

2. Types of photomultiplier :

i. Photomultiplier tube, is a vacuum tube converting incident photons into an electric signal. Photomultiplier tubes (PMTs) are members of the class of vacuum phototubes, which are **very sensitive detectors of light** in the ultraviolet, visible, and near-infrared ranges of the electromagnetic spectrum.

ii. Silicon photomultiplier (SiPM), a solid-state sensitive devices converting incident photons into an electric signal. based on Single-photon avalanche diode (SPAD) based on a silicon substrate.



3. Why is the photomultiplier very sensitive to light ?

Because they exhibit a high detection bandwidth owing to their avalanche multiplication process .

4. Photomultiplier Applications

Photomultipliers are extensively used in medical equipments like

i. **PETs (Positron Emission Tomography) : التصوير المقطعي**

ii. Gamma Cameras :

iii. Planar imaging devices اجهزة التصوير المستوي

iv. X-Ray diagnostic equipment معدات التشخيص بالاشعة السينية