Unit-4

Lecture -1

Photodiodes, Requirements, PIN photodiodes, Characteristics

Introduction

In case of any communication, there must be a device which can receive the transmitted signal.

In case of OFC system, the first element of the receive is a photodetector.

Photodetectors are semiconductor devices that can convert optical signals into electrical signals.

The function of the photodector is to:

sense the optical light

convert it into electrical variations.

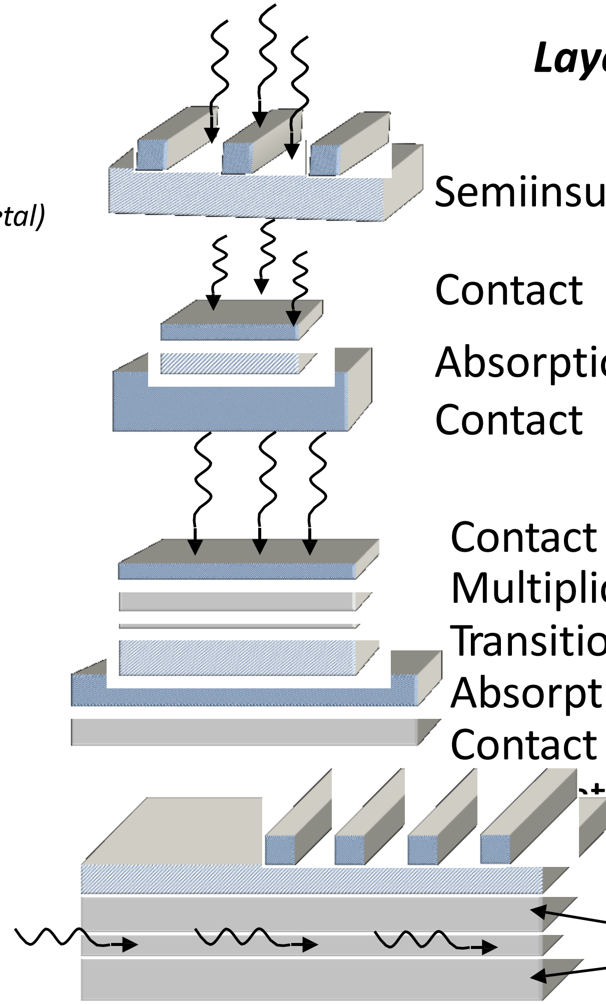
Hence referred ‘O/E Converter.

Since the optical signal is very weak and distorted signal, so the photodetector *must be able to sense the weak signals & it must be high performance device*.

Basic Requirement for the Photodetectors

1.Good Sensitivity: it must be able to produce maximum electrical signal for a given amount of optical power, i.e., the quantum efficiency should be high.
2. Fast Response Time: to obtain higher bandwidth
3. Compatible Physical Dimensions: Small Size for efficient coupling to the fiber.
4.Highly Stable: the performance characteristic of the detector must be independent of the ambient conditions.
5. High Reliability: so that it can perform its function for a long time continuously.
6. Low Biasing Voltages or Current: should not require excessive bias voltage or current.

Detector Technologies



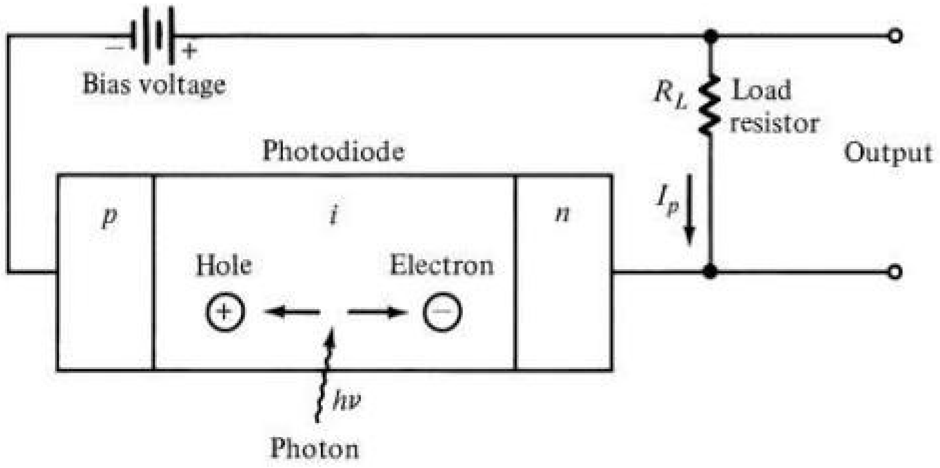
	Layer Structure			**Features**
MSM *(Metal Semiconductor Metal)*	Semiinsulating GaAs			*Simple, Planar, Low Capacitance Low Quantum Efficiency*
PIN	Contact	InGaAsP	p $5x10^{18}$	*Trade-off Between*
	Absorption	InGaAs	n- $5x10^{14}$	*Quantum efficiency*
	Contact	InP	n $1x10^{19}$	*and Speed*
APD	Contact	InP	p $1x10^{18}$	*Gain-Bandwidth:*
	Multiplication	InP	n $5x10^{16}$	*120GHz*
	Transition	InGaAsP	n $1x10^{16}$	*Low Noise*
	Absorption	InGaAs	n $5x10^{14}$	*Difficult to make*
	Contact	InP	n $1x10^{18}$	*Complex*
	[illegible]te	InP	Semi insulating	
Waveguide	Absorption Layer			*High efficiency*
	Guide Layers			*High speed*
				Difficult to couple into

Key: Absorption Layer

Contact layers

PIN Photodetector

- The pin refers to positive intrinsic negative.



- So, the device consists of 3 layers.
- P and N regions are separated by very lightly n-doped intrinsic (i) region.
- The reverse bias voltage is applied across the device, so that the i region is fully depleted of carriers.

Now, the photon can give its energy and excite an electron from the valance band to the conduction band, *only when the incident photon has an energy greater than or equal to the band gap energy of this semiconductor material*.

- This process will generates mobile electron-hole pairs as shown on next slide.

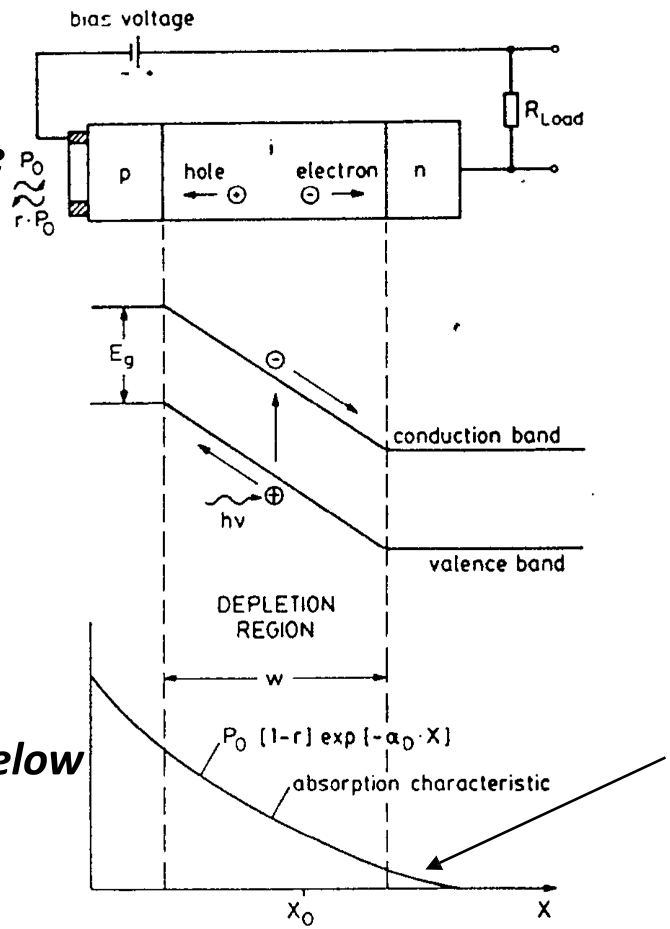
- These electrons and holes are known *photocarriers*, since they are photogenerated charge carriers.

Photo Detection Principles

Device Layer Structure

Band Diagram showing carrier movement in E-field

Light intensity as a function of distance below the surface

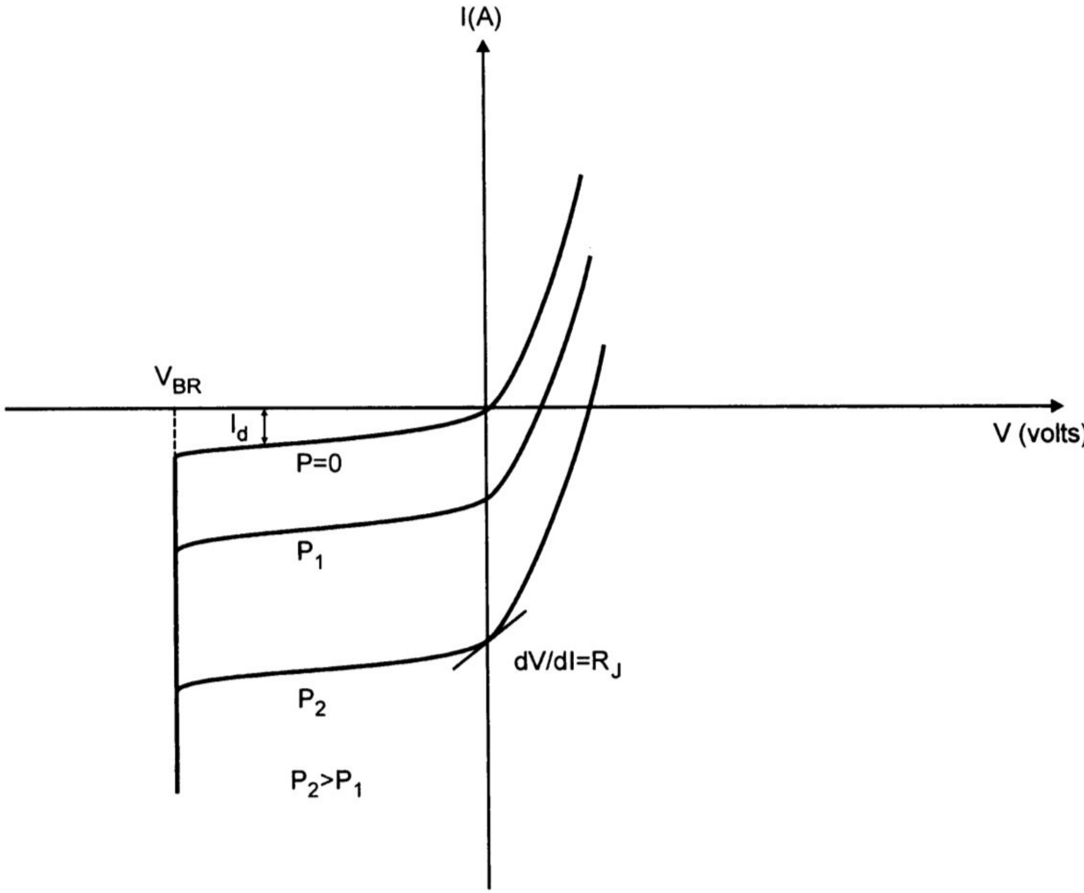


Bias voltage usually needed to fully deplete the intrinsic "I" region for high speed operation

Carriers absorbed here must diffuse to the intrinsic layer before they recombine if they are to contribute to the photocurrent. Slow diffusion can lead to slow "tails" in the temporal response.

(Hitachi Opto Data Book)

Current-Voltage Characteristic for a Photodiode



These charge carriers are available to produce a current flow, when a bias voltage is applied across the device.

The most of the incident light is absorbed in the depletion region, so the photo carriers are generated in this depletion region.

A high electric field is available in the depletion region, so it will cause the carriers to separate.

These carriers are collected across the reverse bias junction.

The current will flow because of these carriers.

The one electron will flow for every carrier pair generated.

This current is known as *photocurrent.*

Since the charge carriers flow through the material, the electron-hole pair will recombine and hence disappear.

On average, the charge carriers move a distance Ln or Lp for electrons and holes respectively.

This distance is known as the *diffusion length*.

The time for recombination or electron or hole is known as *carrier lifetime*.