PIN DIODE

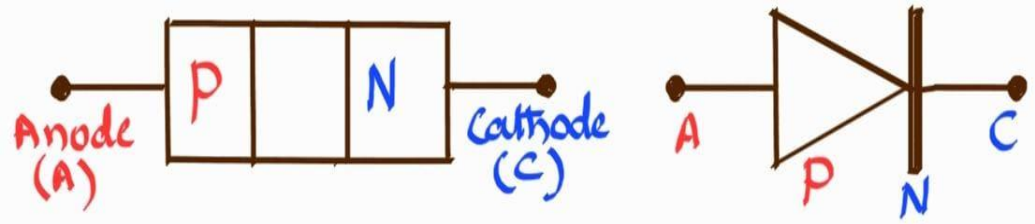
❖ Introduction:

- ❖ In 1950, Nishizawa and his colleagues invented the PIN diode.
- ❖ The PIN diode serves as an excellent absorber of light and can be utilized as a photodetector to convert optical energy into electrical energy (current).

❖ Definition:

- ❖ A PIN diode is defined as"a diode in which an intrinsic layer of high resistivity is sandwiched between P-type and N-type extrinsic layers".

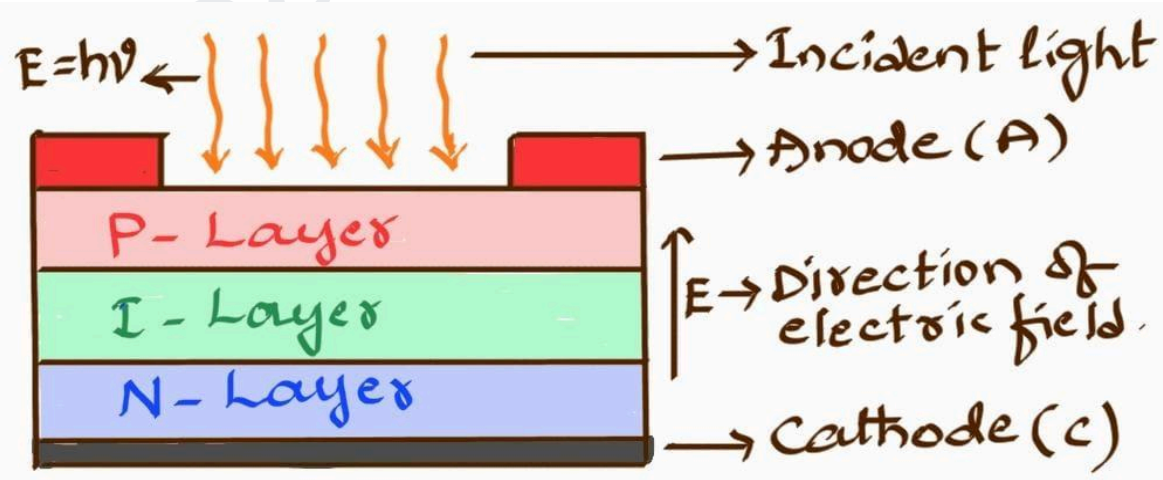
❖ Symbol of PIN diode:



- ❖ **Working principle of PIN diode:** A PIN diode operates by utilizing an intrinsic (I) region between a P-type and an N-type semiconductor, which creates a depletion region and acts as an insulator when reverse biased, while forward bias reduces the depletion region's width, allowing current flow.

❖ Construction of PIN diode:

- ❖ A PIN diode typically comprises three regions:
- ❖ i) A heavily doped P-type region.
- ❖ ii) An undoped or very lightly doped intrinsic (I)region.
- ❖ iii) A heavily doped N-type region.



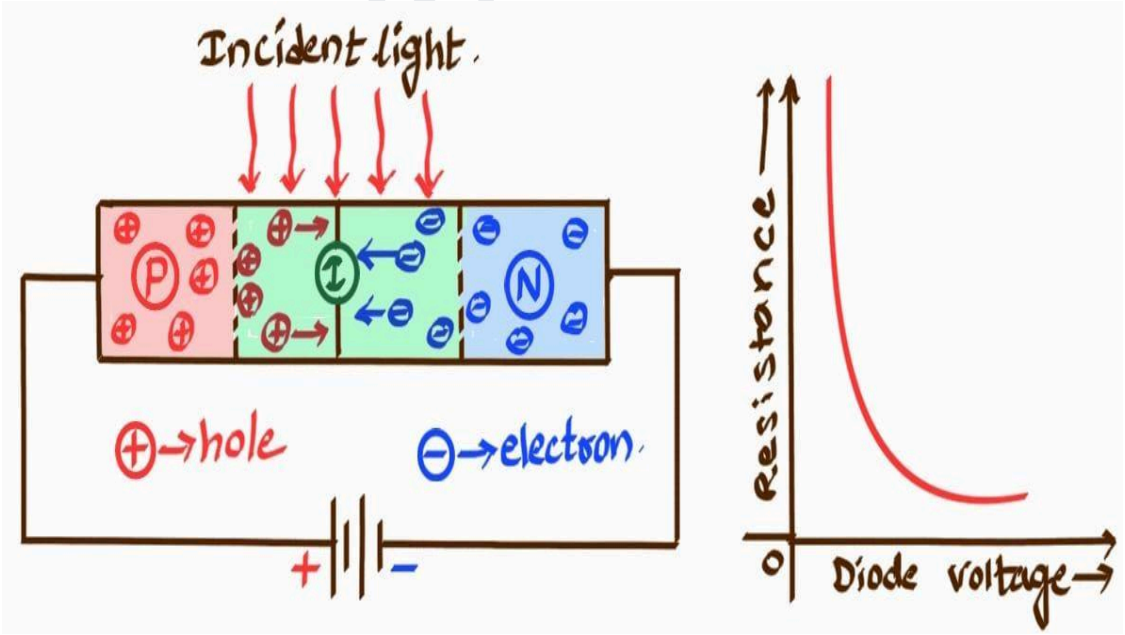
- PIN diodes can be constructed in two primary ways: 1.Mesa structure & 2.Planar structure.
- **Mesa Structure:**In this construction, the intrinsic (I) region of the PIN diode is grown or developed on the substrate, creating a mesa-like shape which provides a distinct junction between the P and N regions, facilitating efficient control of current flow.
- **Planar Structure or Epitaxial growth:** A narrow epitaxial layer is grown on the intrinsic region to form the p+ region and a similar layer on the opposite side to form the n+ region through ion implantation or diffusion.
- The high resistive intrinsic region provides a significant electric field between the P-region and N-region.
- This electric field is induced by the movement of holes and electrons, and its direction is typically from the N-region to the P-region.

Working of PIN diode:

- Due to the presence of the extra intrinsic layer, a PIN diode functions somewhat differently from a conventional photodiode, although both are comparable in overall operation.
- The PIN diode exhibits distinct behaviors under forward and reverse bias conditions:

(1) Forward Bias:

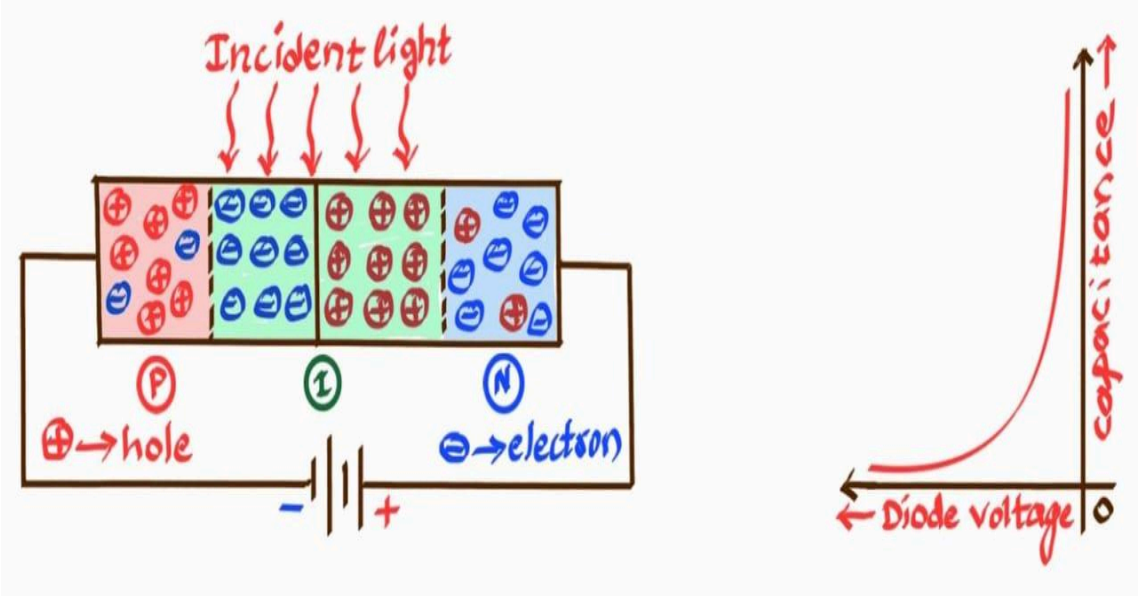
- When a positive voltage is applied to the P-region and a negative voltage to the N-region, the diode is forward biased.



- When the PIN diode is operated under forward bias, the width of the depletion region at the P-N junction significantly reduces which causes holes (positive charge carriers) to be injected from the P-region and electrons (negative charge carriers) to be injected from the N-region into the intrinsic region
- These charge carriers are then swept across the intrinsic region by the high electric field created by the forward bias, enabling current flow.
- As the forward voltage increases, the width of the depletion layer further decreases, allowing more charge carriers to enter the intrinsic region.
- This increased carrier concentration in the intrinsic region leads to a lower resistance, making the PIN diode act as a variable resistor.

(2) Reverse Bias:

- When a positive voltage is applied to the N-region and a negative voltage to the P-region, the diode is reverse biased.



- When the PIN diode is operated under reverse bias, the width of the intrinsic(depletion) region increases.
- At a certain reverse bias voltage, the entire intrinsic region becomes depleted of charge carriers, effectively acting as an extended depletion region. This is referred to as the "swept-free" I-region.
- Because of the lack of charge carriers within the I-region, the diode acts like an insulator which prevents current flow, and the diode acts as a capacitor with the P and N regions forming plates and the depletion region acting as a dielectric.

❖ Applications of PIN diode:

❖ **The PIN diode has diverse applications, including:**

❖ **RF switches:** It is widely used as an ideal Radio Frequency (RF) switch.

❖ **Photodetector:** It functions as a photodetector, converting incident light into electrical current.

❖ **High voltage rectifier (HVR):** It is employed as an HVR due to its ability to tolerate higher voltages across its junctions.

❖ **Electronic pre-amplifiers:** It can be used to boost sensitivity in certain electronic circuits.

❖ **Phase shifter:** Commonly found in microwave circuits for phase shifting.

❖ **Other applications:** These include voltage-controlled oscillators, amplitude modulators, and various other electronic circuit designs.

❖ Characteristics of PIN diode:

❖ Structure:

- **P-type – Intrinsic – N-type** layers

❖ Electrical Behavior

- **Forward Bias**: Acts like a resistor with low impedance.
- **Reverse Bias**: Acts like a capacitor or insulator with high impedance.

❖ Frequency Response

- **High-frequency performance** is excellent.
- Fast switching times due to thin intrinsic region.
- Used in RF and microwave applications.

❖ Capacitance

- Has **low junction capacitance** compared to a regular diode, especially in reverse bias. Capacitance remains relatively constant with changes in reverse voltage.

❖ Power Handling

- Can handle **high RF power** and large voltage swings without breakdown.
- Suitable for **attenuators, RF switches, and limiters**.