ECE 113- Basic Electronics

Lecture week 13: LED, Photodiodes and photovoltaic cells

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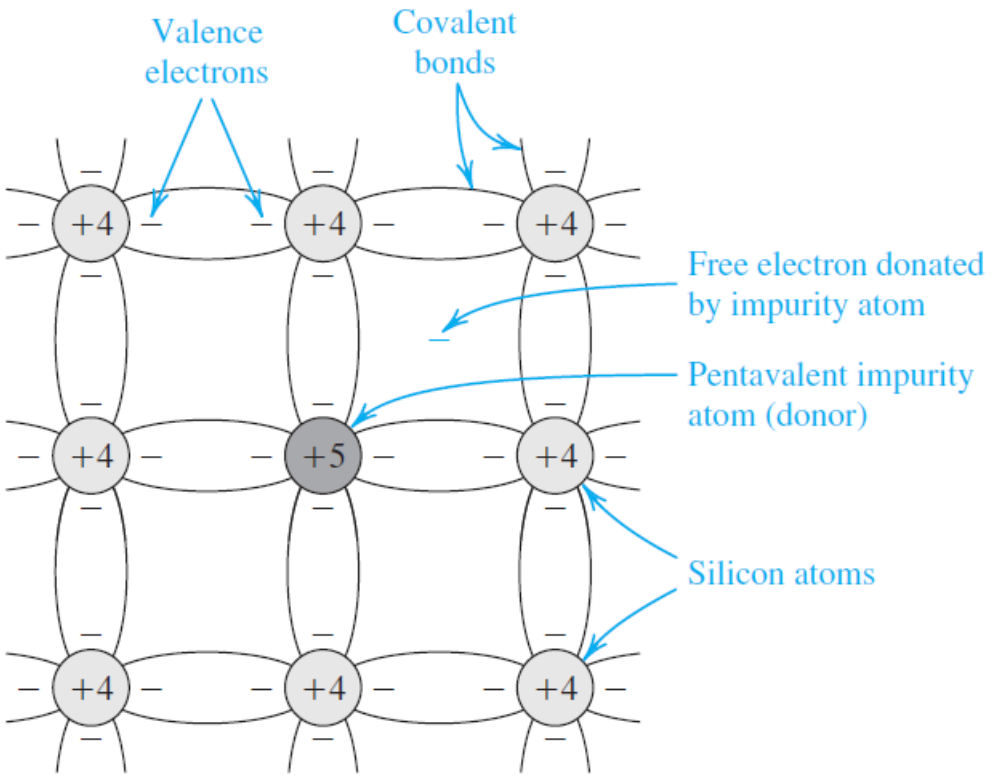
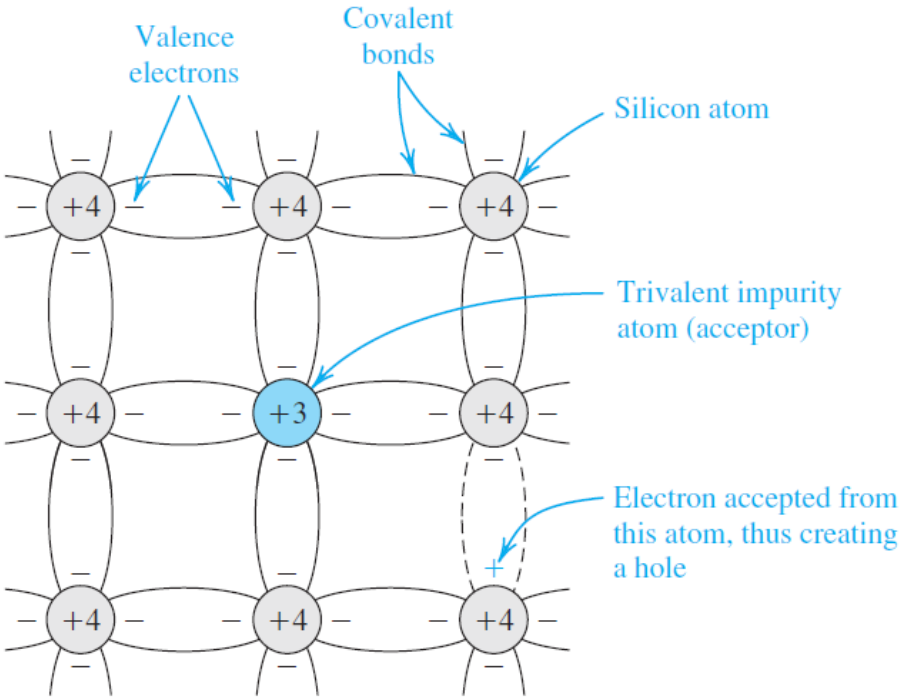
Light Emitting Diodes

- Unlike the light bulb in which electrical energy first converts into heat energy, the electrical energy can also be directly converted into light energy.
- In Light Emitting Diodes (LEDs), electrical energy flowing through it is directly converted into light energy.
- Light Emitting Diodes (LEDs) are the most widely used semiconductor diodes today. Light emitting diodes emit either visible light or invisible infrared light when forward biased. The LEDs which emit invisible infrared light are used for remote controls.

Discussion on p-n junction

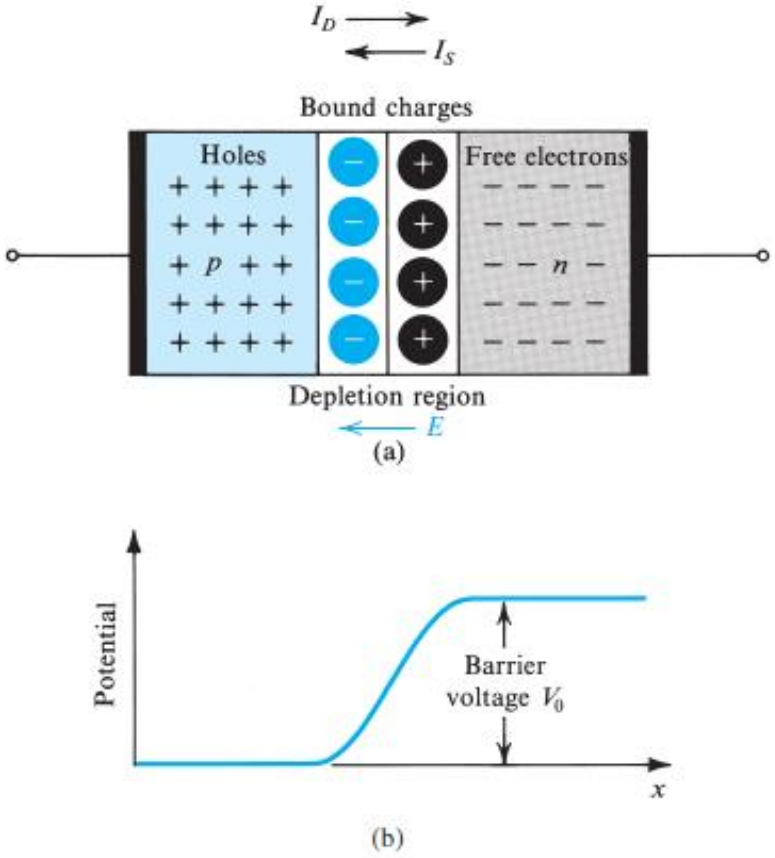


n- type



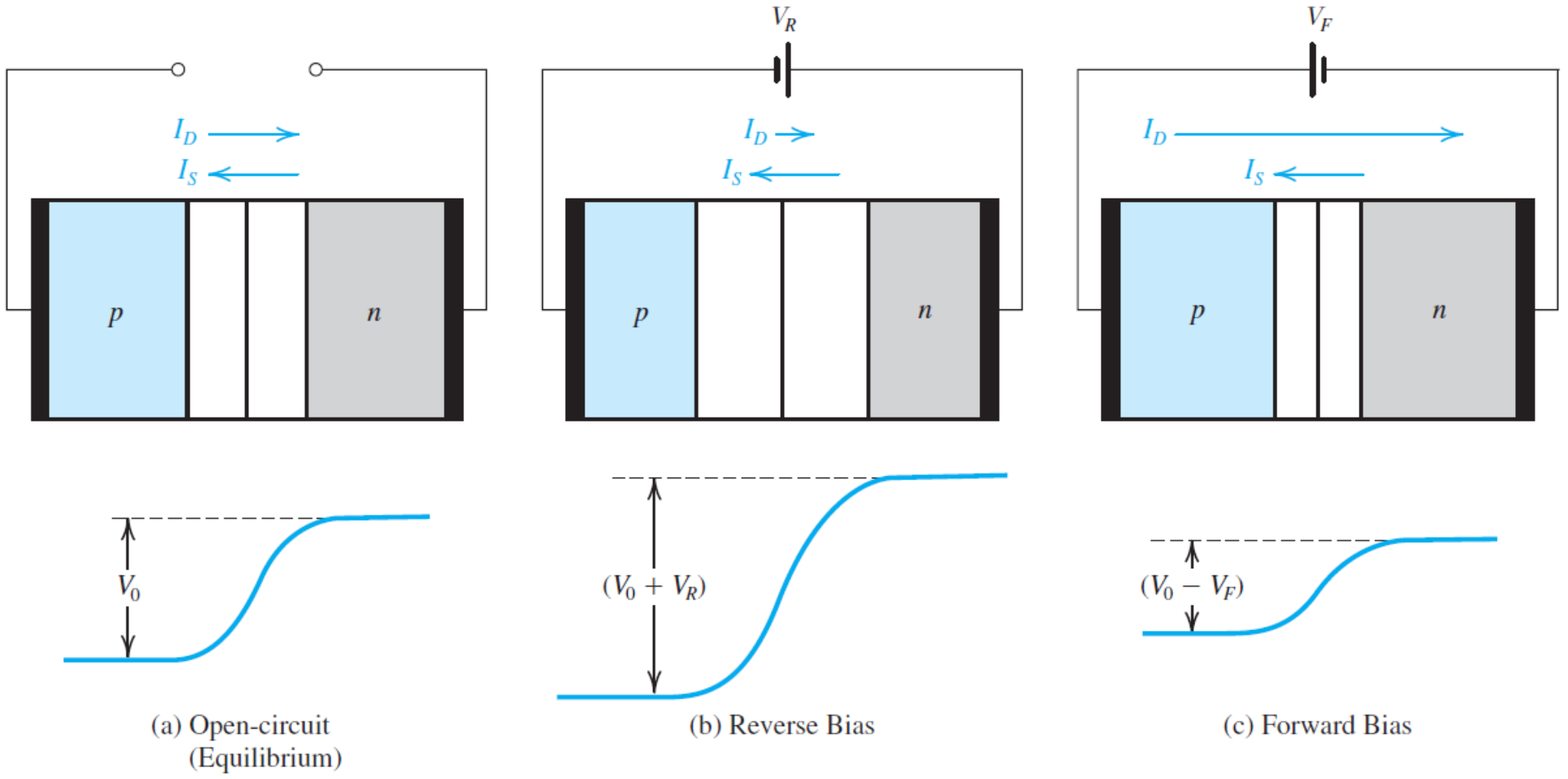
p- type

p-n junction



- Due to doping free electrons are available in n-type and holes are available in p-type
- When a p-n junction is created through fabrication, some free electrons diffused to the p-side, and some holes diffused to the n-side, resulting in charge imbalance.
- Net charge remains 0

Various bias conditions

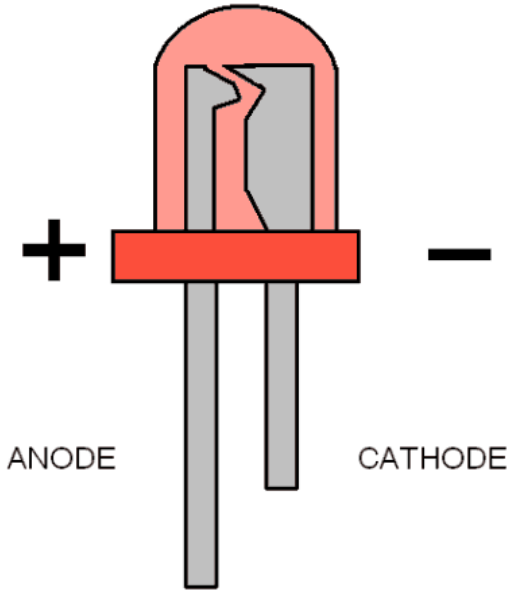


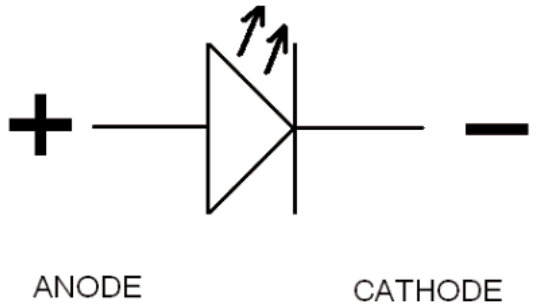
(a) Open-circuit (Equilibrium)

(b) Reverse Bias

(c) Forward Bias

Light Emitting Diode (LED)





LED

- In forward bias condition, defused minority carrier recombines with the majority carrier.
- Through the recombination process, the electron releases energy governed by the Planck-Einstein equation:

$$\Delta E = h\nu$$

- Semiconductors can be designed in such a way the energy release happens in the visible region of the electromagnetic radiation

Various LED types

There are different types of light emitting diodes present and some of them are mentioned below

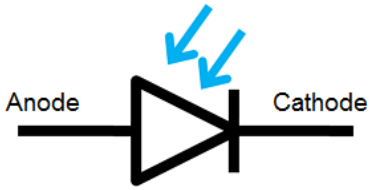
- Gallium Arsenide (GaAs) – infra-red
- Gallium Arsenide Phosphide (GaAsP) – red to infra-red, orange
- Aluminium Gallium Arsenide Phosphide (AlGaAsP) – high-brightness red, orange-red, orange, and yellow
- Gallium Phosphide (GaP) – red, yellow and green
- Aluminium Gallium Phosphide (AlGaP) – green
- Gallium Nitride (GaN) – green, emerald green
- Gallium Indium Nitride (GaInN) – near ultraviolet, bluish-green and blue
- Silicon Carbide (SiC) – blue as a substrate
- Zinc Selenide (ZnSe) – blue
- Aluminium Gallium Nitride (AlGaN) – ultraviolet

Applications of LED

- LED is used as a bulb in the homes and industries
- The light emitting diodes are used in the motorcycles and cars
- These are used in the mobile phones
- At the traffic light signals LED’s are used
- TV screens, display monitors etc
- LEDs are also used for Visible light communication

Photodiodes

- A photodiode is one type of light detector, which allows current flow in presence of light. Can be used to convert light signals into electrical signals.
- The photodiode is an important component of a growing family of circuits known as optoelectronics or photonics.
- Combining an LED with a photodiode in the same package results in a device known as an opto-isolator.
- Operates in reverse-bias



Photodiode symbol

Photodiode applications

- Smoke detectors
- Space applications – Inter-satellite optical link, laser ranging, LIDAR
- Photodiodes are used in medical applications such as computed tomography, instruments to analyze samples, and pulse oximeters
- Photodiodes are used for optical communications
- Photodiodes are frequently used for exact measurement of the intensity of light in science & industry

Solar cell/ Photovoltaic cells

- Works in unbiased mode
- The covalent bond in the depletion region of a p-n junction can break when energy is absorbed
- For Gallium arsenide based semiconductor, this bond can break in the visible spectrum and electron-hole pairs are created.
- These pairs creates reverse current flow, i.e. optical energy is converted into electrical energy

Solar cell/ Photovoltaic cells

There are three qualitative differences between a solar cell and photodetector

1. A photodiode works on a narrow range of wavelength while solar cells need to work over a broad spectral range (solar spectrum).
2. Solar cells are typically wide area devices to maximize exposure.
3. In photodiodes the metric is quantum efficiency, which defines the signal to noise ratio, while for solar cells, it is the power conversion efficiency

https://nptel.ac.in/courses/113106062/Lec19.pdf

Example

Cadmium sulfide (CdS) is commonly used to fabricate resistors whose value depends on the intensity of light shining on the surface. In Fig. 6.61 a CdS "photocell" is used as the feedback resistor R_f. In total darkness, it has a resistance of 100 kΩ, and a resistance of 10 kΩ under a light intensity of 6 candela. R_L represents a circuit that is activated when a voltage of 1.5 V or less is applied to its terminals. Choose R_1 and V_s so that the circuit represented by R_L is activated by a light of 2 candela or brighter.