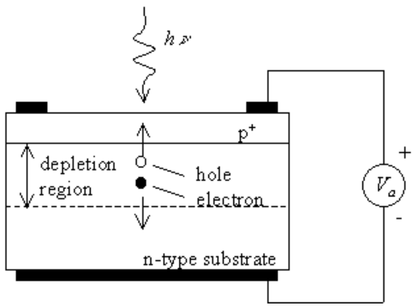
13. Opto Electronic Devices

Source: Principles of Semiconductor Diodes, B. Van Zeghbroeck

P-n junctions are an integral part of several optoelectronic devices. These include photodiodes, solar cells light emitting diodes (LEDs) and semiconductor lasers. In this section, we discuss the principle of operation of these devices. A large number of optoelectronic devices consist of a p-type and n-type region, just like a regular p-n diode. The key difference is that there is an additional interaction between the electrons and holes in the semiconductor and light. This interaction is not restricted to optoelectronic devices. Regular diodes are also known to be light sensitive and in some cases also emit light. The key difference is that optoelectronic devices such as photodiodes, solar cells, LEDs and laser diodes are specifically designed to optimize the light absorption and emission, resulting in a high conversion efficiency.

13.1. Photodiodes

Photodiodes and crystalline solar cells are essentially the same as the p-n diodes. However, the diode is exposed to light, which yields a photocurrent (Iph) in addition to the diode current. The additional photocurrent is due to photo generation of electrons and holes as shown in Figure below.

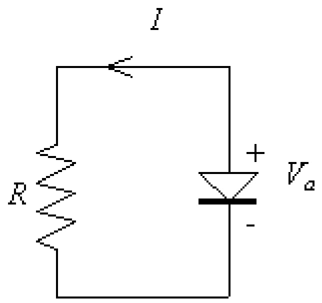


The photo-generated carriers cause a photocurrent, which opposes the diode current under forward bias. Therefore, the diode can be used as a photo detector - using a reverse or even zero bias voltage - as the measured photocurrent is proportional to the incident light intensity. The diode can also be used as a solar cell - using a forward bias – to generate electrical power.

13.2. Solar Cell

Solar cells are typically illuminated with sun light and are intended to convert the solar energy into electrical energy. A significant part of the solar spectrum is in the visible range of the spectrum (400 - 700 nm). The power density is approximately 100mW/ cm^2.Only part of solar spectrum actually reaches the earth's surface. Scattering and absorption in the earth's atmosphere and the incident angle affects the incident power density. Thus available power density depends on the time of the day, the season and the latitude of a specific location.

Of the solar light which reaches a solar cell, only photon with energy larger than the energy band gap of the semi-conductor generate electron hole pairs. The overall power conversion efficiency of a single crystalline solar cell ranges from 10 to 30% yielding 10-30 mW/cm^2. The circuit diagram and sign convention of a p-n diode solar cell connected to a resistive load is as shown in figure below.



13.3. LED

Light emitting diodes are p-n diodes in which the recombination of electrons and holes yields a photon.

Electroluminescence

As shown in Fig 13.1.1, the conducting surface connected to the *p*-material is much smaller, to permit the emergence of the maximum number of photons of light energy. Note in the figure that the recombination of the injected carriers due to the forward-biased junction results in emitted light at the site of recombination. There may, of course, be some absorption of the packages of photon energy in the structure itself, but a very large percentage are able to leave, as shown in the figure.

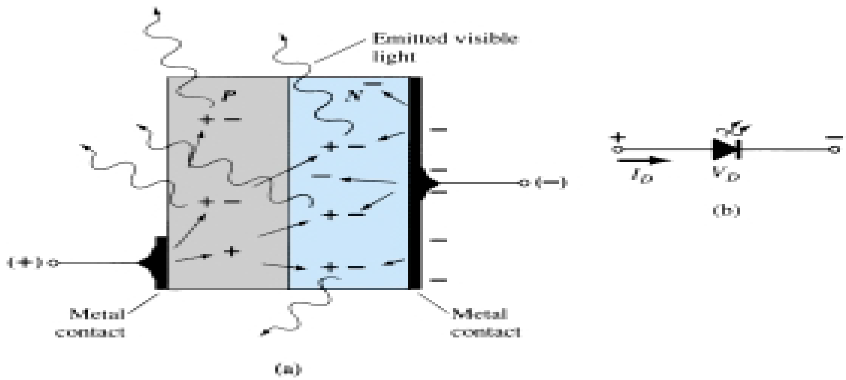


Fig 13.1.1(a) Process of electroluminescence in the LED; (b) graphic symbol.

Working Principle

The light-emitting diode (LED) is a diode that will give off visible light when it is energized. In any forward-biased p-n junction there is, within the structure and primarily close to the junction, a recombination of holes and electrons. In all semiconductor p-n junctions some of this energy will be given off as heat and some in the form of photons. In silicon and germanium the greater percentage is given up in the form of heat and the emitted light is insignificant. In other materials, such as gallium arsenide phosphide (GaAsP) or gallium phosphide (GaP), the number of photons of light energy emitted is sufficient to create a very visible light source. The process of giving off light by applying an electrical source of energy is called electroluminescence.

Types of LED

The light emitting region is available in lengths from 0.1 to 1 in. Numbers can be created by segments such as shown in Fig 13.1.3. By applying a forward bias to the proper *p*-type material segment, any number from 0 to 9 can be displayed.

There are also two-lead LED lamps that contain two LEDs, so that a reversal in biasing will change the color from green to red, or vice versa. LEDs are presently available in red, green, yellow, orange, and white, and white with blue soon to be commercially available. In general, LEDs operate at voltage levels from 1.7 to 3.3 V, which makes them completely compatible with solid-state circuits. The power requirement is typically from 10 to 150 mW with a lifetime of 100,000_ hours. Their semiconductor construction adds a significant ruggedness factor.

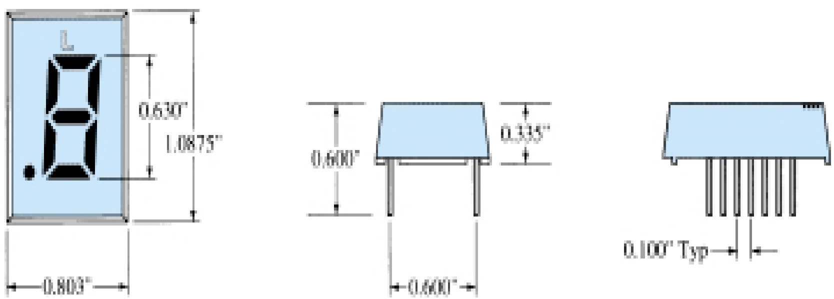


Fig 13.1.2