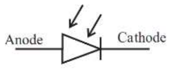
SEMICONDUCTORS PART 2

Photo Diode/ Photodetector / Photosensor

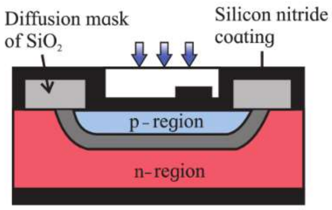
Conversion: Light energy to Electric Energy

Mode of operation: Reverse biased

Symbol:

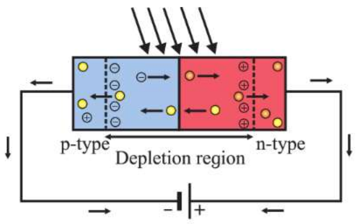


Construction:



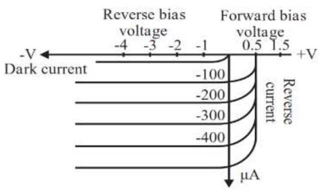
The p-n junction is enclosed inside glass in such a way that only the junction is exposed to light. Other parts are opaque.

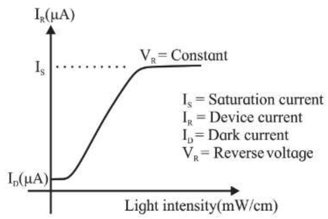
Working:



The diode is reversed bias and a reverse saturation current flows through. This current (also called dark current) depends on the concentration of the minority carriers and not on the applied voltage.

When the p-n junction is illuminated by light with sufficient energy (more than the bad gap of the semiconductor), bonds break, releasing electron hole pairs in the depletion region. Thus causing an increase in reverse current. This reverse current depends on the intensity of incident light.





The reverse current undergoes a linear increase with increase in intensity of light, till it reaches saturation current.

The sensitivity of the device can be increased by minimizing the dark current.

$$Dark\ resistance\ R_d = \frac{Maximum\ reverse\ voltage}{dark\ current}$$

Advantage of photo diode

- Quick response time to exposed light
- Linear response in reverse current vs intensity of light
- Light weight and compact
- Low cost
- wide spectral response

Disadvantage of photo diode

- Temperature dependent
- Low reverse current for low intensity of light.

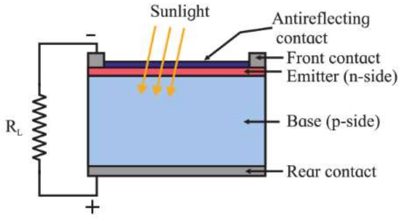
Applications

- Burglar alarm
- Counters
- Detection of radiations
- Switch
- Fiber optic communication
- Optocoupler
- To measure intensity of light
- Fire and smoke detectors

SOLAR Cell/ PHOTOVOLTAIC Cell

Conversion: Solar/Light energy to Electric Energy

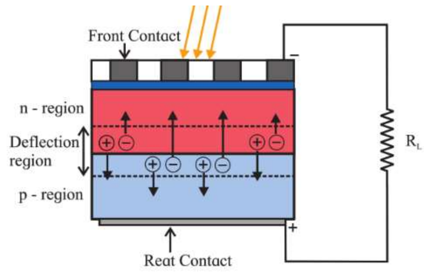
Construction

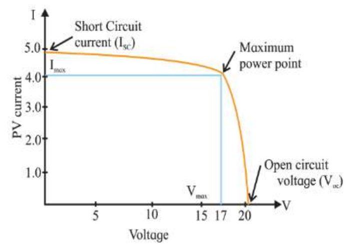


It consists of a p-n junction with n side exposed to solar radiations and a larger p-side. Both sides (n-side or front contact and p-side or back contact) have conducting contacts. The n-side is coated with anti-reflecting glass to reflect the IR (heat) radiations but allow visible light.

Working

Light of sufficient energy (more than the band gap) is incident on the p-n junction. Electron hole pairs are released. These get separated due to the intrinsic depletion voltage (-ve on the p-side and +ve on the n-side). Thus, electrons move to the positive side (n-side) and holes to the negative side (p side). These carriers generate voltage and hence power the external load.





When the load is short circuited, maximum current flows and is called I_{SC} , short circuit current.

When the load is open circuited we get the point on the x-axis of maximum voltage V_{oc}, open circuit voltage.

In both the above cases power delivered to load is zero. There will be a point where the power delivered is maximum

Requirements for material selection

- band gap 1eV to 1.8 eV
- high optical absorption
- good electrical conductivity
- Easily available

Example: GaAs, CdTe, CuInSe

Advantages

- Non-polluting
- less maintenance
- long lasting

Disadvantage

- high cost of installation
- low efficiency

Application

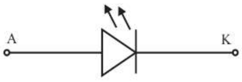
- Provide power to remote places
- Calculators
- Operation of Satellites and space station
- Power traffic signals
- Lux meter to measure intensity of light

Light Emitting Diode (LED)

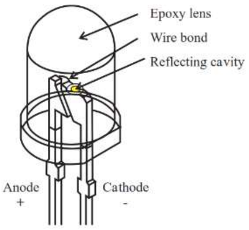
Conversion: Electric Energy to Light

Mode of operation: Forward biased

Symbol:

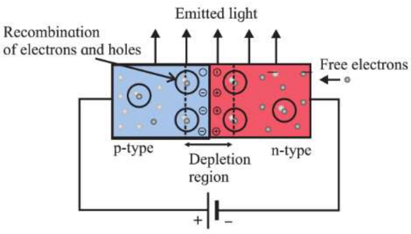


Construction:

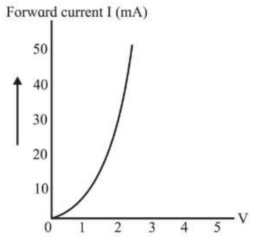


n region is heavily doped compared to p region. The p-n junction is encased in a dome shaped transparent casing so that light is uniformly emitted and internal reflections are minimized. Metal electrodes are attached. The longer lead is the anode.

Working:



The diode being forward biased, the electrons in the conduction band recombine with the hole in the valance band and the energy released in the form of light. It is made in such a way that the recombination takes place at the surface for maximum light output. The amount of light is directly proportional to the forward current. By varying the proportion of doping, different wavelength can be emitted. E.g. AlGaAs emits infrared, GaAsP emits red or yellow, AlGaP emits red or green, ZnSe emits blue light.



The I-V characteristics is very similar to a forward biased p-n junction diode.

Advantage

- Efficient, Lesser power consumption
- Long life (approximately 50000 hours)
- Rugged and durable
- Quick turn-on time. No warmup time
- Excellent colour rendering.
- Environment friendly (Mercury free)
- Brightness and colour controllable

Disadvantage

- Temperature dependent
- High initial cost
- Hazardous blue light quality

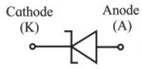
Applications

- Burglar alarm
- Counters
- indicator lights
- display screens of mobiles.
- LED TV
- Vehicle head lamps
- domestic and decorative lighting
- Street lighting
- Optical communication

Zener Diode

Mode of operation: Reverse biased for use as a voltage regulator

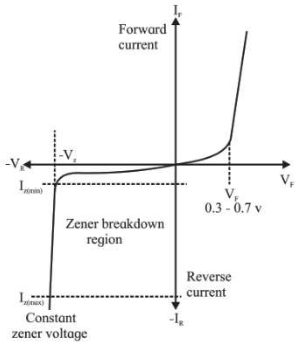
Symbol:



Zener Breakdown:

When a reverse voltage across a p-n junction, the electric field increases causing the electrons to be torn out of the covalent bonds, near the junction, resulting in a large current. This is called Zener breakdown voltage. More the applied reverse voltage, more the current. Zener diodes are heavily doped for a lower reverse breakdown voltage.

Working/VI characteristics of Zener Diode:

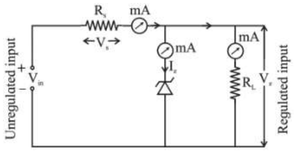


A Zener diode works like a normal diode in forward bias mode. When reverse biased, it shows breakdown effect at a voltage V_Z , which is dependent on the doping level. At breakdown the voltage is almost constant (V_Z) even in the current changes from I_{Zmin} to I_{Zmax} . This property is used in voltage regulator.

Application:

- Voltage regulator
- Peak clipper

Zener Diode as a Voltage regulator



Construction:

Working:

Line regulation: When the input voltage increases, the current of R_s and Zener increases. But since the Zener voltage (V_Z) does not change, the entire change in voltage is taken up by Rs. Since R_L (load resistance) is in parallel to the Zener diode, hence the output voltage stays V_Z. Hence increase in input voltage causes increase in voltage across R_s, increases current in R_s and Zener, but keeps voltage and hence current in R_L constant. Similarly, voltage regulation is achieved for decrease in input voltage.

Let, V_S = voltage across R_S

When current is minimum, $V_S = I_{Zmin}. R_s$

When current is maximum, $V_S = I_{Zmax} . R_s$

By KVL, $V_{in} = V_S + V_Z$

thus, $V_{in(low)} = I_{Zmin}. R_s + V_Z$

and $V_{in(high)} = I_{Zmax}. R_s + V_Z$

Load Regulation: If input voltage is kept constant and the load resistance R_L is decreased, the load current will increase. This increase is possible if Zener current decreases. But since Zener voltage V_Z does not change even if its current changes, hence voltage across RL will also stay V_Z.

With R_L as infinite (no load condition), hence I_L =0, we get maximum I_z and hence maximum power dissipation in Zener diode ($P_z = I_{Zmax} . V_Z$).

R_s has to be selected in such a way that the max power of Zener does not cross the specified limits.

Limitation: The Zener current should be in the range I_{Zmin} to I_{Zmax} in order to provide regulation. Above I_{Zmax} will damage the diode and below I_{Zmin} it wont act as a voltage regulator.

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