LECTURE 19/10/20

SPECIAL DIODES

(2) VARACTOR DIODE

The depletion region in a PN junction forms a barrier which separates the positive and negative charges on each side of the junction. The charges can be compared to the charges on opposite plates of capacitor and the depletion region acting like a dielectric. Thus a P-N junction posses junction capacitance.

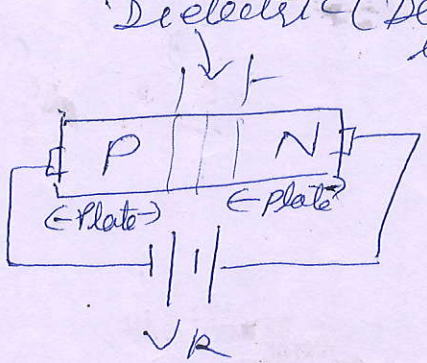
When a reverse bias is applied the junction capacitance decreases because the depletion width increases.

A varactor diode is specially manufactured P-N junction with suitable impurity concentration profile and operated under reverse biased condition so as to yield a variable junction capacitance

Symbol

Equivalent circuit

Working:



When the reverse bias voltage is increased, the depletion layer widens which increases the dielectric thickness. As a result the capacitance is reduced.

When the reverse bias voltage is decreased, the depletion layer becomes narrower. This decreases the dielectric thickness and the capacitance increases.

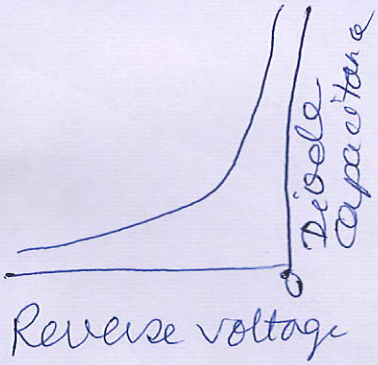


Fig: Variation of diode capacitance with applied reverse voltage.

$$C_T = \frac{\varepsilon A}{d}$$

ε = permittivity of semiconductor material

A = Area of the P-N junction

d = width of the space charge region

In terms of applied reverse bias V

$$C_T = \frac{K}{(V_T + V)^n}$$

where K is a constant determined by the semiconductor material and fabrication technique,

V_T = volt equivalent of temperature

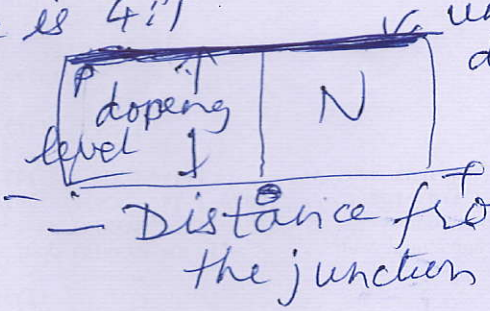
V = reverse bias applied in volts

$n = \frac{1}{2}$ for alloyed junction & $n = \frac{1}{3}$ for diffused junctions

Types of varactor diode

(i) Abrupt doping profile: In this the doping is uniform on both sides of junction

Tuning range is 4:1



(ii) Hyper abrupt profile:- Doping level increases towards the junction. Due to narrower depletion layer, a larger capacitance occurs at the junction. A small change in reverse bias voltage makes a larger variation in capacitance. The tuning range for this profile is 10:1. It can tune broad cast receiver over the waveband of 550KHz to 1650 KHz.

Applications:
1. Used in automatic frequency control
2. Used in tuning circuits
3. Used in adjustable band pass filter

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(3) PIN DIODE:

Construction

A PIN diode is made up of three semiconductor materials; two heavily doped P and one N type material separated by an intrinsic (i.e. undoped) semiconductor (I)

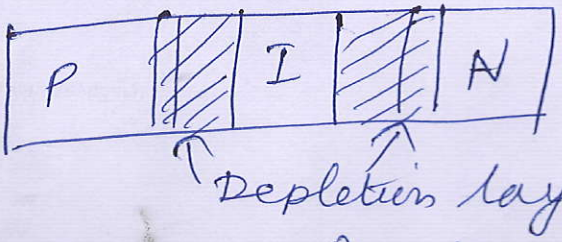
The intrinsic region offers high resistance to the current flowing through it

Due to increased separation between P and N region, the capacitance decreases so PIN diode has fast response time Hence useful at very high frequencies above 300 MHz

PIN : Positive - Intrinsic - Negative

Working:

(i) No bias: There will be diffusion of carriers because there is concentration gradient across the junction. The diffusion electrons and holes produce a depletion layer across PI and IN junctions. The depletion layers penetrate to a little distance in P and N regions while longer distance in I region. ∴ the device has high value of resistance



(ii) Reverse bias: As the reverse bias is gradually increased, the depletion layer becomes more and more until the entire I region is swept free of mobile carriers The applied bias necessary for this to happen is termed as the swept out voltage

(iii) Forward bias: At zero bias most of the I layer has mobile carriers

and diode has high resistance. As the forward bias is increased carrier injection into I layer from P and N regions increases and forward resistance is reduced. ∴ PIN diode in forward bias acts as a variable resistance

APPLICATIONS:

(1) Used as ~~attenuator~~ attenuator.
(2) constant impedance device
(3) construction of phase modulator and amplitude modulator.
(4) As a microwave switch.
(5) Used in radar applications

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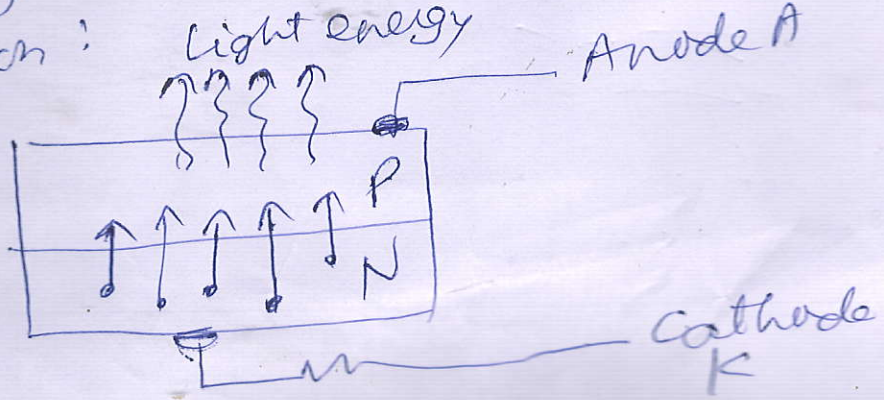
(4) LIGHT EMITTING DIODE (LED).

A P-N junction diode which emits light when forward biased is known as light emitting diode. The emitted light may be visible or invisible

Symbol.

Construction:



Here an N type layer is grown on a P type substrate (not shown in figure) by a diffusion process. Then a thin P type layer is grown on N type layer. Metal connections are made in both the layers to make anode and cathode terminals. The light energy is released at the junction when the recombination of electrons with holes take place. After passing through p region the light is emitted through the window provided at the top of the surface

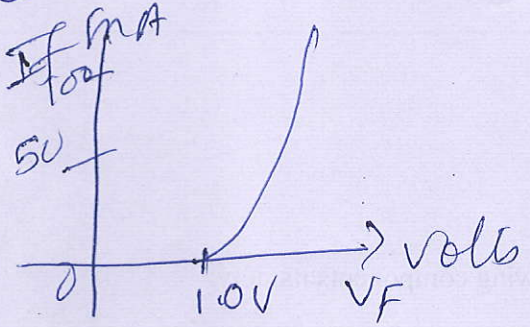
Working:

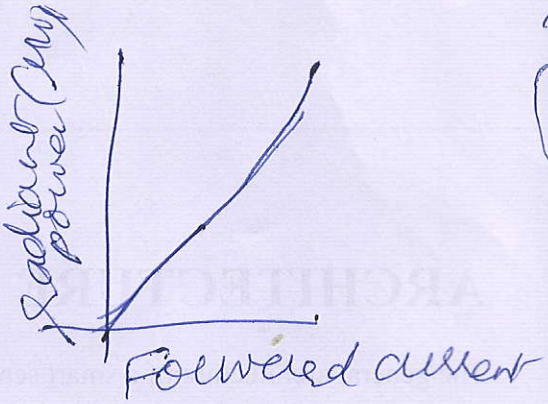
When the LED is fowward biased the electrons and holes move towards the junction and recombination takes place. After recombination, the electrons lying in the conduction band of N region fall into the holes lying in the valence band of a P region. The difference of energy between the conduction band and valance band is radiated in the form of light energy.

The emitted light depends upon the type of material used.

(i) GaAs – infrared radiation (invisible)
(ii) GaP – red or green light
(iii) GaAsP → red or yellow light

Characteristics





LED applications:

1: In 7 segment, 16 segment and dot-matrix displays. Such displays are used to indicate alphanumeric characters and symbols in various systems such as digital clocks, microwave ovens, calculators etc.

(2) Indicating power ON/OFF conditions, power level indicators.

(3) Optical switching applications

(4) Burglar alarm uses LED radiating infrared light.

(5) Used for backlighting of automobile dashboards.

(6) Traffic signal management.

(7) For image sensing circuits in picture phone.

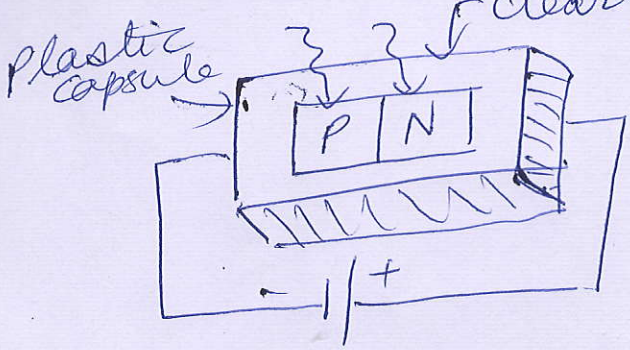
(8) Video displays (TV)

(5) PHOTODIODES

A P-N photodiode is essentially a reverse biased junction diode with light permitted to fall on one surface of the device across the junction keeping the remaining sides unilluminated.

Construction:

Here P-N junction is embedded in a clear plastic capsule. All the sides of the plastic capsule except the illuminated one are painted black or enclosed in metallic case.



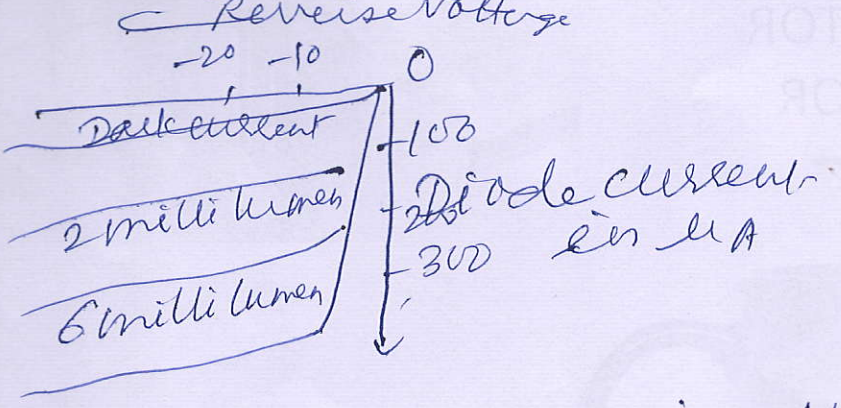
Working:

A reverse biased P-N junction has a small amount of reverse saturation current due to thermally generated electron hole pairs i.e. minority carriers, holes in N type and electrons in P type.

When the radiation is incident, electron hole pairs are created on both sides of junction. The photoinduced electrons in the conduction band of P type will move across the junction

down the potential hill with thermally generated minority carriers. Similarly holes produced in the valence band of N type will flow across the junction to P side. The process of diffusion and rapid crossing of depletion region due to strong electric field in the depletion region takes place so rapidly that there is little possibility of recombination.

Characteristics



With zero illumination the current equals the reverse saturation current is shown as dark current.

Symbol

(6) Character recognition
(7) Encoders

Applications:

(1) Photo detection
(2) Demodulation
(3) Logic circuits
(4) Switching
(5) optical communication system