Unit 5: Solid State Microwave Device.

* Pin Diode:

Symbol:

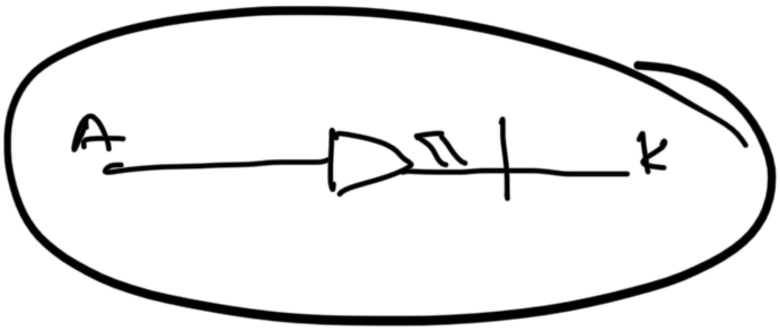
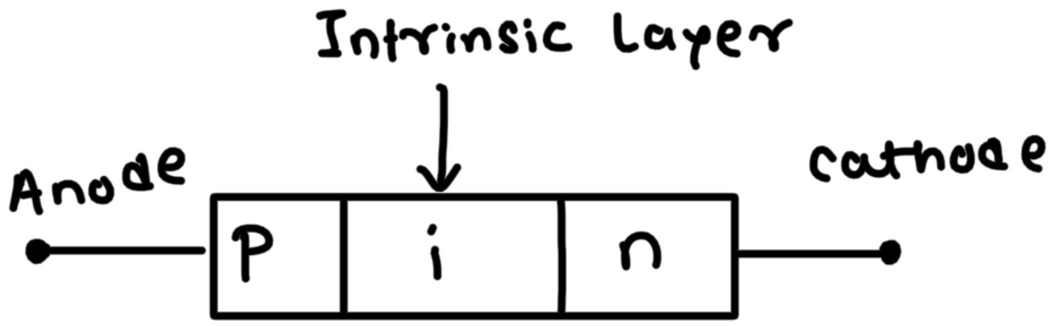


Fig. Pin Diode

Internal Structure:



- The diode consists of p-region and n-region which is separated by the intrinsic semiconductor material.
- p-region ⇒ hole majority

  n-region ⇒ electron majority.
- intrinsic ⇒ no free charge ⇒ insulator betw n and p region.
- i-region ⇒ high resistance ⇒ obstructs flow of electrons to pass through it.

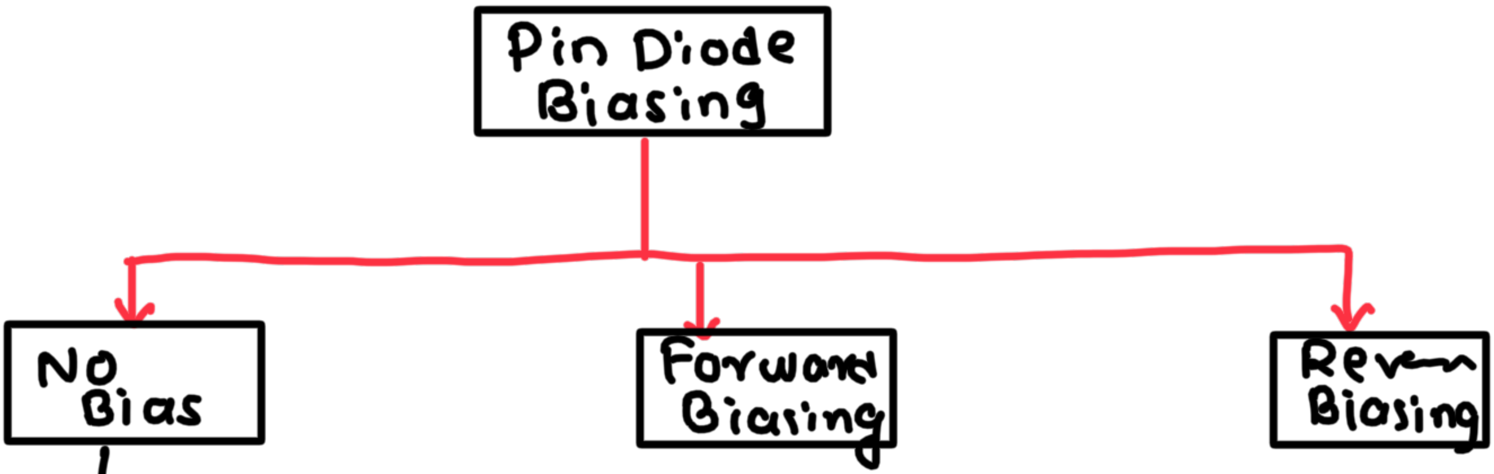
Characteristics:

- Due to intrinsic layer bet^{w} p and n region $\Rightarrow$ Acts as low capacitance

$$\because C = \varepsilon_0 \varepsilon_r \frac{A}{d}.$$

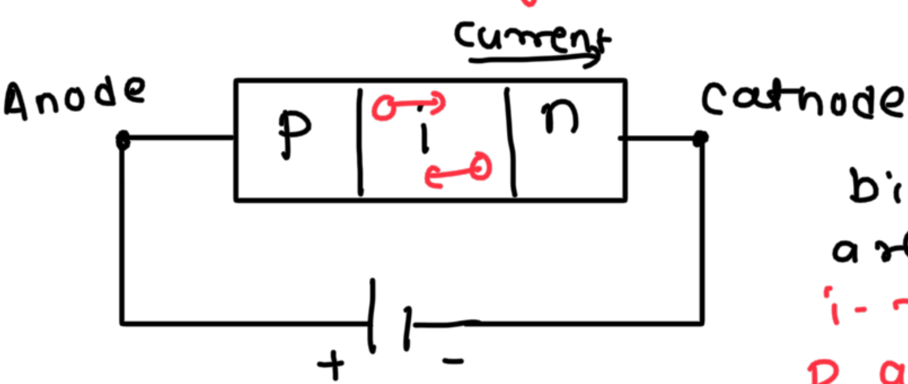
- High reverse breakdown voltage i.e. PIV is high.

* Biasing:



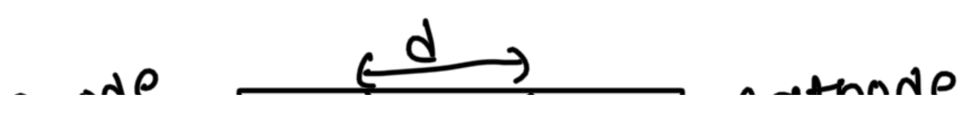
Diode is unbiased, their charge carriers will diffuse.

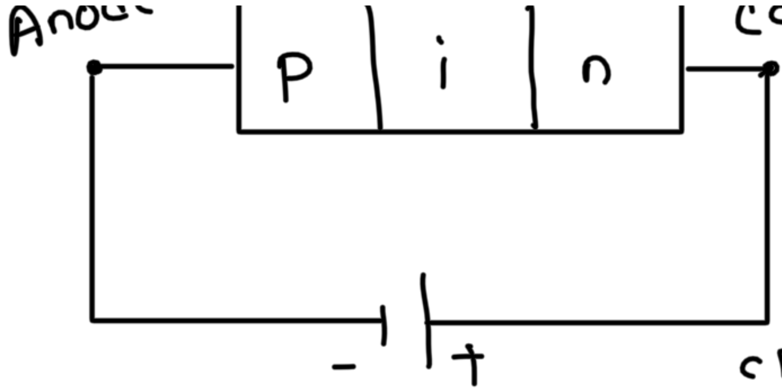
2. Forward Biasing:



- when the diode is kept forward biased, the charges are injected into i-region from the p and n-region. This reduces the resistance of the diode, and it behaves like a variable resistance.

3. Reverse Biasing:



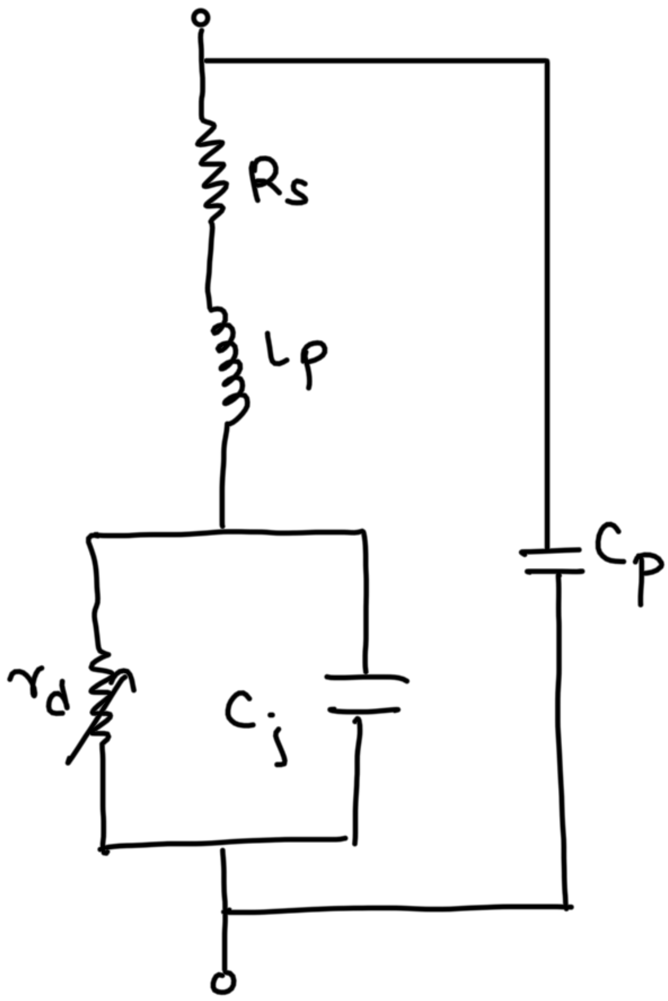


- As reverse bias condition voltage increases, depletion region start expanding, charge carriers start to move from internsic layer all charges are moved which is known as swept voltages.

- The 'd' increases so 'c' decreases, therefor Pin diode acts as variable capacitance.

Pin Diode :

At low freq model:



Forward Biased $\Rightarrow$ r_d behaves like variable resistance.

Reverse Biased $\Rightarrow$ C_j behaves like variable capacitance.

At high freq. model:

r_d and C_j behaves like RF component.

* Application :-

1. Pin diode as switch :

- forward biased $\Rightarrow$ small resistance
- reverse biased $\Rightarrow$ large resistance.

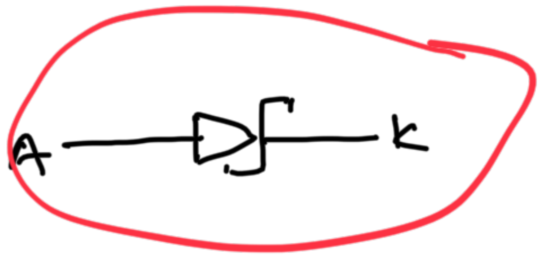
2. Pin diode as RF attenuator :

3. Pin diode as RF modulator.

4. Pin diode is used as photo detector.

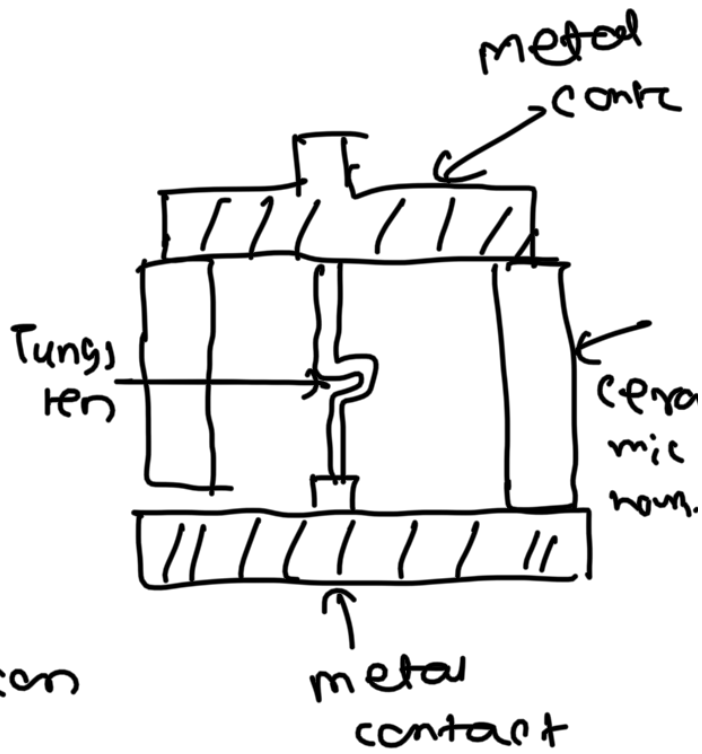
5. High voltage rectifier.

* Schottky Barrier Diode:



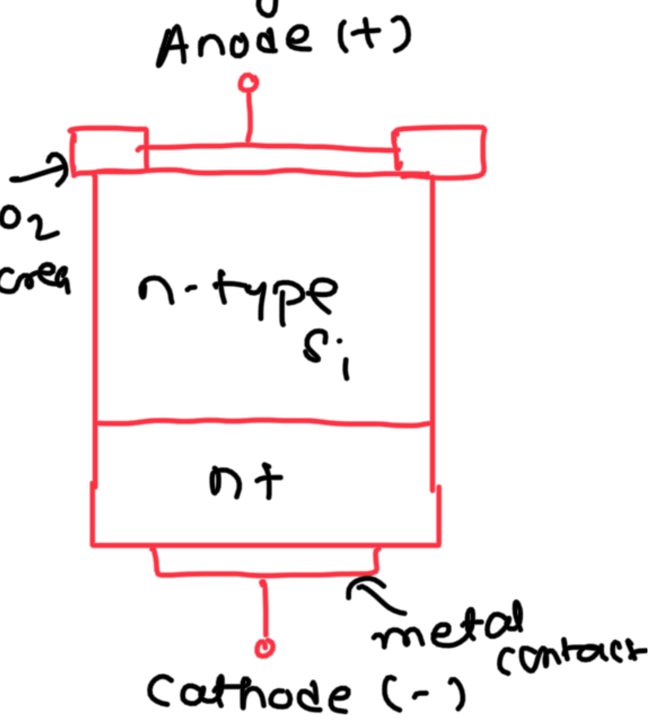
- Used for it's low turn-on voltage
- Fast recover time
- widely used for radio freq, RF application like mixer.

Construction:



- metal-semiconducter junction is formed bet^w metal and semiconducter known as schottky barrier.
- Metals : Platinum, chromium
- Semiconducter: n-type silicon
- Anode ⇒ metal, cathode ⇒ n-type semicon.
- schottky barrier ⇒ fast switching.

Operation:



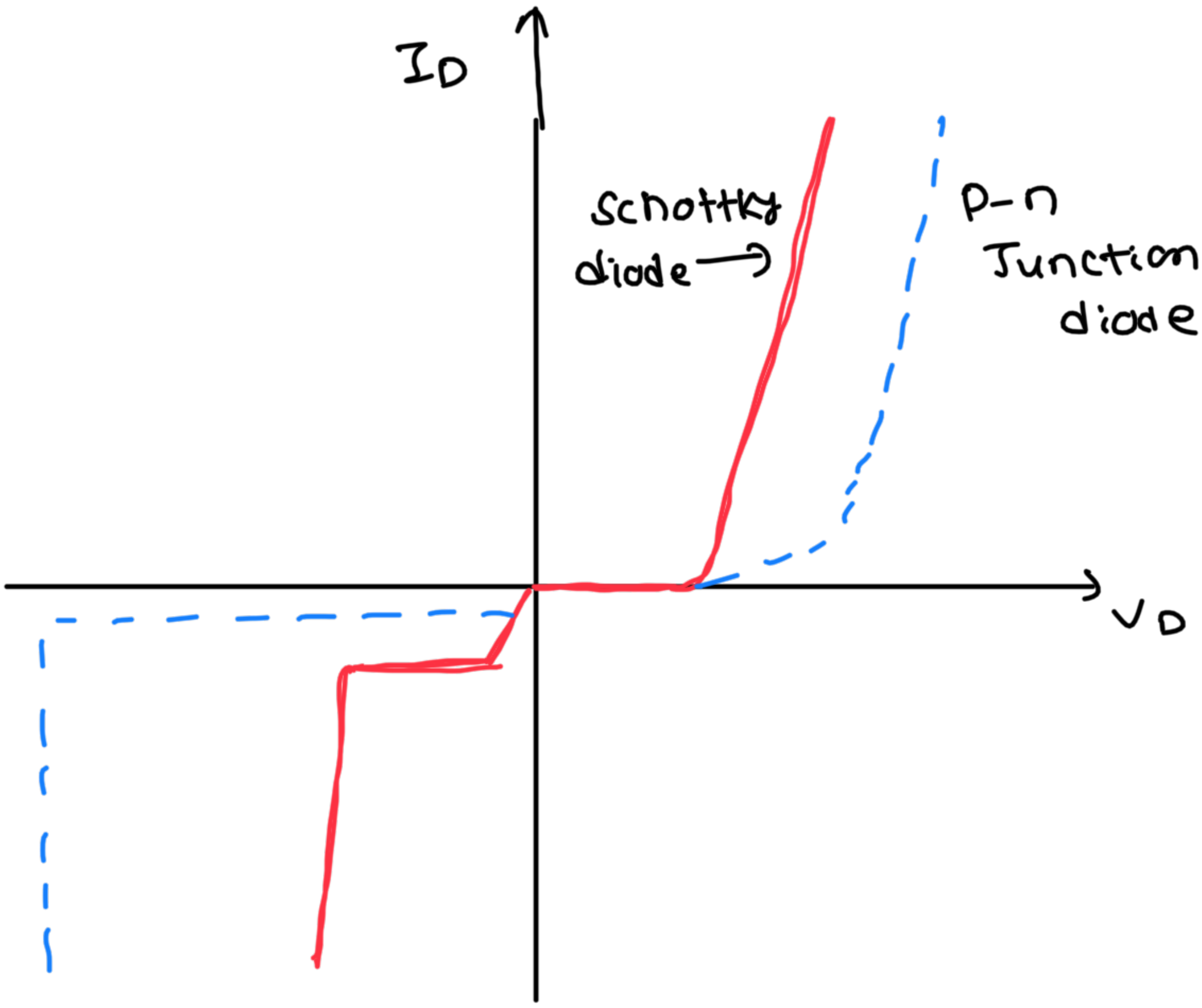
- Electrons in diff. materials have diff. potential energy
- N-type semiconducter potential energy > electrons in metals.
- When both comes in contact, flow of electrons in both

direction starts.

- voltage applied to schottky diode, such that metal is positive w.r.t. semiconductor

- voltage will oppose built in potential and makes easier for current flow.

* V-I characteristics:



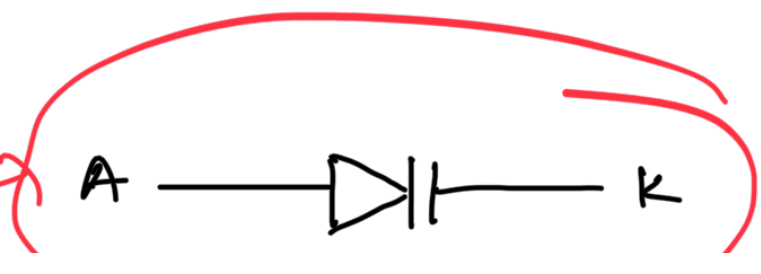
* Advantages

1. Turns on and off faster than PN Junction
2. Very high freq. range.
3. Low cost
4. Simple

* Applications

- AC - DC converters
- Microwave detectors.

* Varactor Diode:

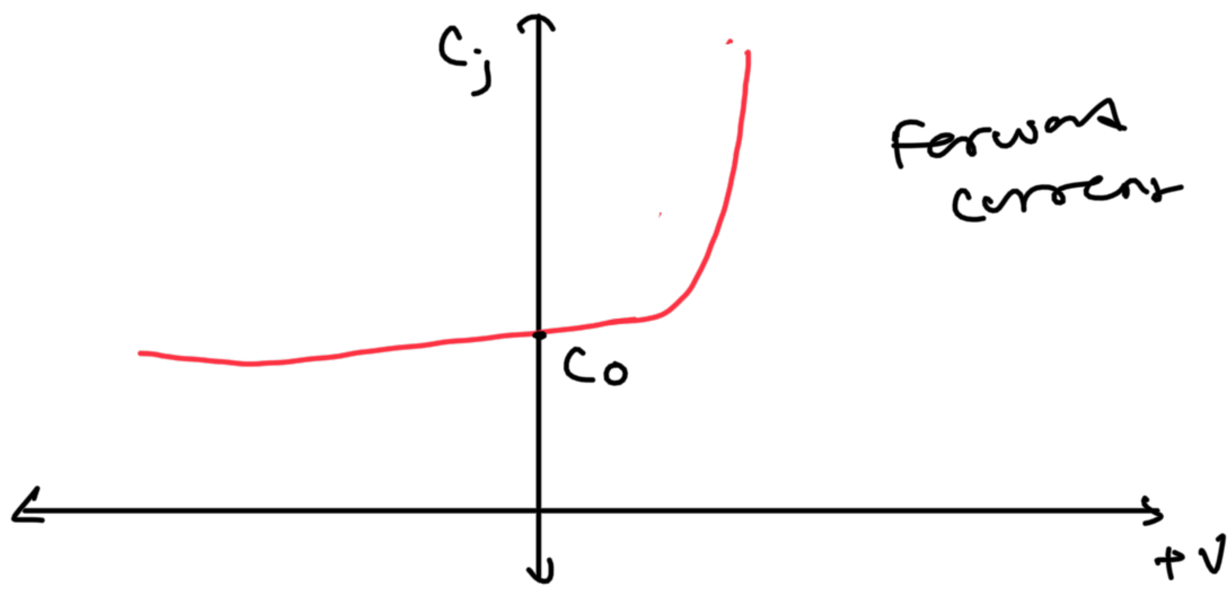


- A special diode that changes level of capacitance depending on the level of reverse bias applied to diode.

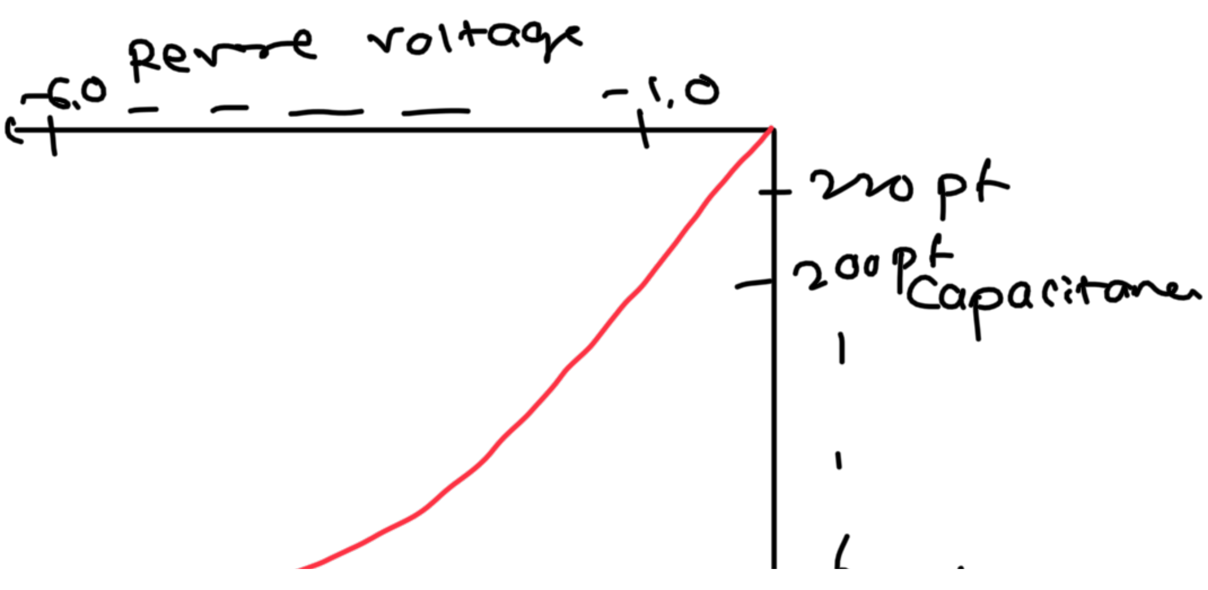
- Types:
  1. Abrupt Varacter
  2. Hyper Abrupt Varacter.

- To consruct GaAs is preferred because it has highest operating freq. Used for freq from 18GHz up to 600 GHz.

- The variation of capacitance with applied reverse bias voltage:



- The below graph represents the increase in capacitance as reverse voltage is decreased.



$\updownarrow$ 20 pf

varactor voltage - cap. curve

* Operation:

- p-n junction of semiconducting material and is always reverse-biased.

- Depletion zone depends on applied voltage and this make capacitance vary.

- width of depletion region increases with reverse bias & capacitance decreases as reverse bias increases

reverse Bias $(\uparrow)$ $\Rightarrow$ width of depletion region $(\uparrow)$ $\Rightarrow$ Capacitance $(\downarrow)$

- Avalanche region is not used as it destroys device

* Applications:

1. Freq. multiplier:

- Freq. multiplication is phenomenon which results from non-linear characteristics.

- Capacitance of varactor diode varies w.r.to. reverse bias, diode acts as non-linear characteristics

- The characteristic of diode is used for freq. multiplication.

* TED:

- TED are devices with no junctions as compared to microwave transistors which operate with junctions/gates

- Fabricated from compound semiconductors such as GaAs, InP, CdTe

- operate with hot electrons (energy > thermal energy)

1. Gun Diode:

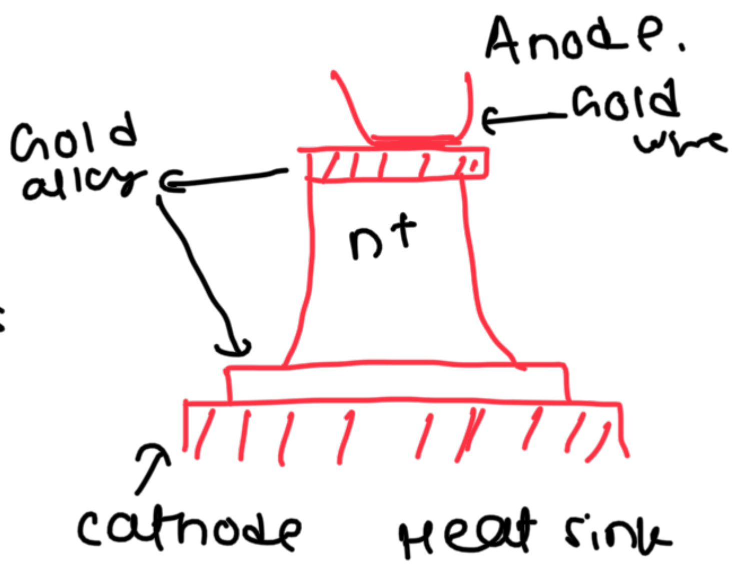
- bulk semiconductor device.

- Based on TED.

• Construction:

- Heavily doped slice of N-doped sample of GaAs is taken.

- Two ends are soldered with gold alloy.

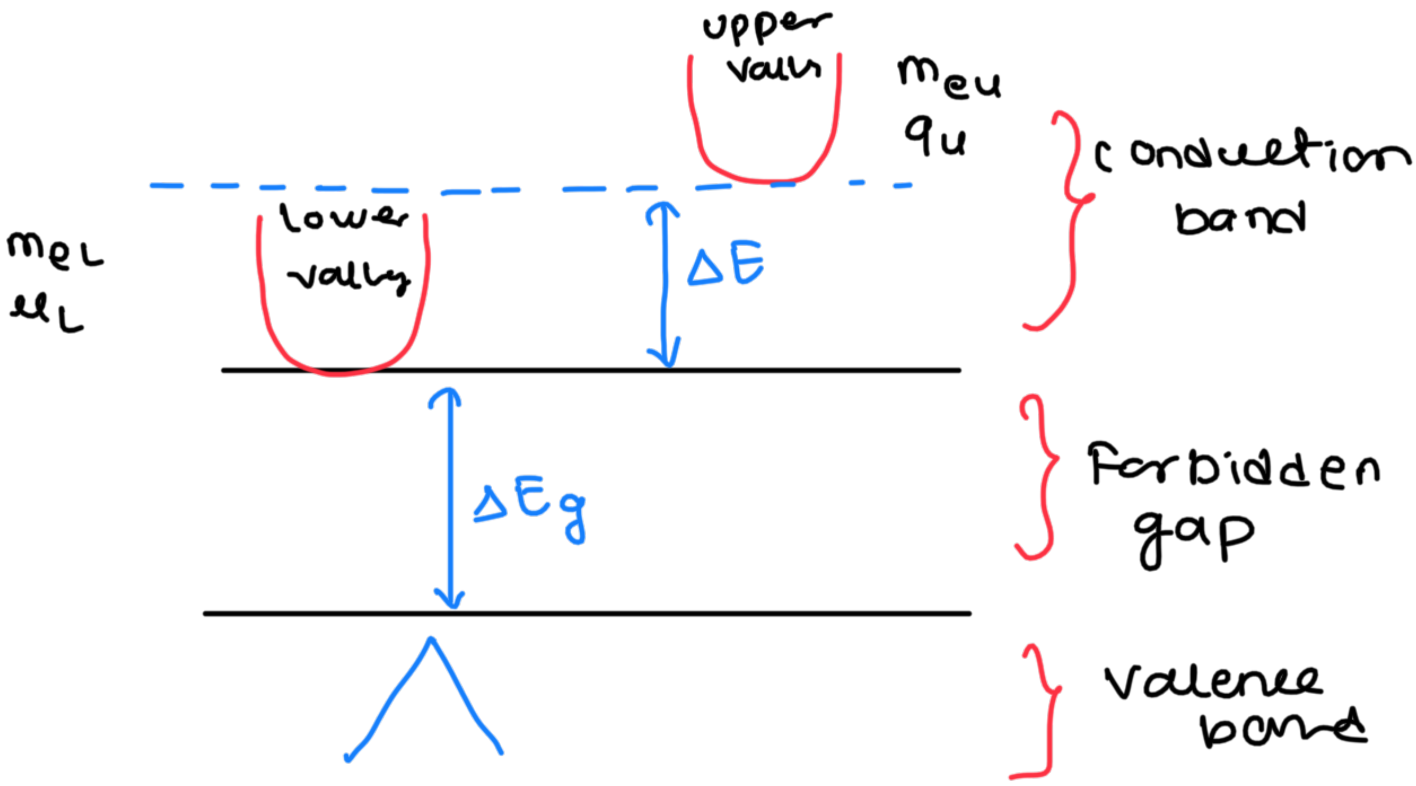


• Two Valley Model Theory:

- TEE = material which supports two valley model.

- From this model, negative resistance of gunn diode can be explained.

- Energy bands for material which exhibits this model :-



low mobility
High effective mass $\Rightarrow$ Upper valley

High mobility
Less effective mass $\Rightarrow$ Lower valley.

- Two valley model describes:

1. The separation energy between lower and upper valley must be larger than thermal energy of room temp.
2. The separation energy betw lower and upper valley must be less than forbidden gap energy.
3. Electrons in:

Upper valley $\Rightarrow$ low mobility, High effective mass $\Rightarrow$ Higher density

Lower valley $\Rightarrow$ high mobility, low effective mass $\Rightarrow$ Lower density

- **Operation:**

- when very high electric field is applied across the slice of N-type heavily doped GaAs, electron flow towards the positive end of slice.

- With Increase in electric field across normal diode, velocity of electron increases which in turn increases no. of. electrons flowing in turn current flow increases.

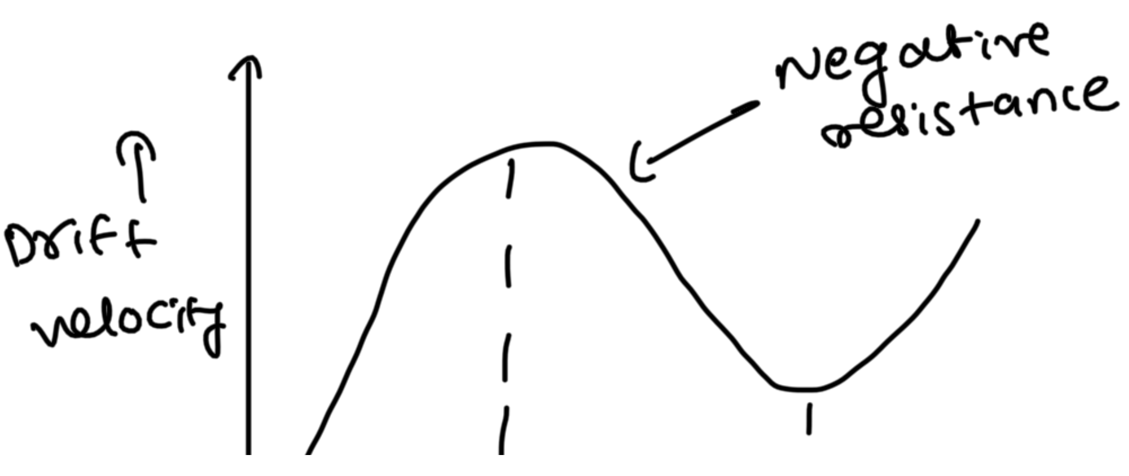
- GaAs having multiple energy level in it's energy.

- With increase in applied electric field, current reduces, which can be explained with the help of following steps:

1. When very high electric field applied across gunn diode, valence electrons observed high energy and enter into conduction band. But energy of electrons is very high. They get transferred from conduction band to higher energy level.

2. When electron from conduction band enters into higher energy level, its mobility decreases.

3. Increase in electric field $\Rightarrow$ velocity of electron decrese $\Rightarrow$ decreases the current.



- Eventually voltage across slice becomes sufficient to remove electrons from higher energy, so again current increase.