UNIT-V

MICROWAVE SOLID STATE DEVISES

The solid state microwave devices provide less noise, less switching time and more bandwidth in the performance characteristics for achieving the amplification, oscillation and frequency multiplication. The several solid state microwave devices have been developed that include two terminal devices such as varactor diodes, GUNN diode, IMPATT diode and PIN diode.

CLASSIFICATION OF MICROWAVE SOLID STATE DEVICES:

Microwave solid state devices are classified based on the following.

1) Based on their electrical behaviour
2) Based on their construction.

Based on electrical behaviour we have,

a) Non-linear resistance type
   Eg: varistors (variable resistances)
b) Non-linear reactance type
   Eg: varactors (variable reactors)
c) Negative resistance type
   Eg: Tunnel diode, Impatt diode, Gunn diode.
d) Controllable impedance type
   Eg: PIN diode

Based on construction we have,

a) Point contact diodes
b) Schottky barrier diodes
c) Metal oxide semiconductor devices (MOS)
d) Metal insulation devices.

VARACTOR DIODES

The term varactor is a shortened form of variable reactor, referring to the voltage variable capacitance of a reverse biased junction. They have non-linearity of capacitance which is fast enough to follow microwaves.

The varactor diode is a semiconductor device in which the junction capacitance can be varied as a function of the reverse voltage (bias) of the diode. Loss in this non-linear element will be almost negligible. The junction capacitance depends on the applied voltage and junction design. In some cases a junction with fixed reverse bias may be used as a capacitance of a fixed value.

The VI characteristics of a typical varactor diode and commonly used schematic symbols are shown in the figure below.

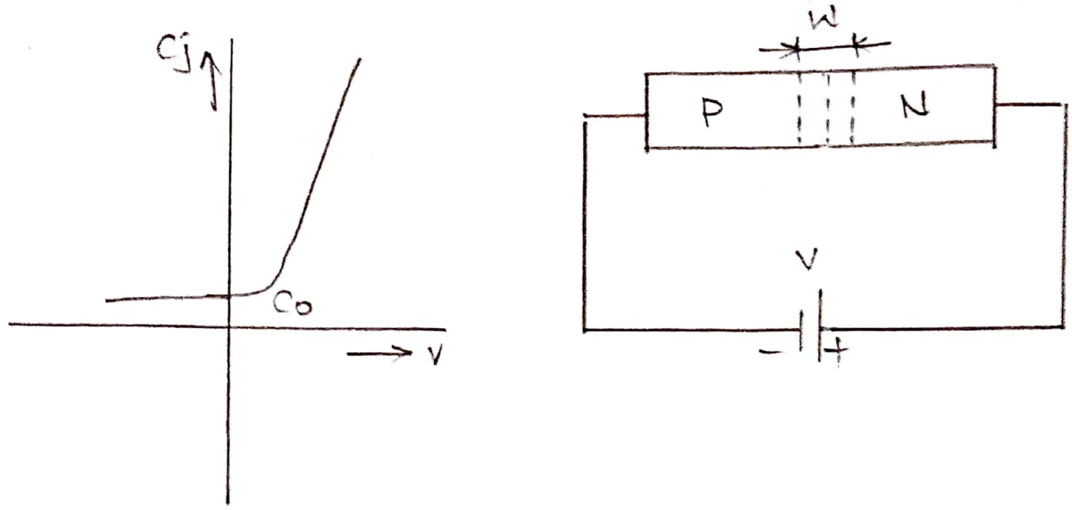


Fig: Junction capacitance vs V.

we know that,

$$C_j \propto V_r^{-n}$$

where, C_j = junction capacitance

V_r = reverse bias voltage

n = a parameter that decides the type of junction.

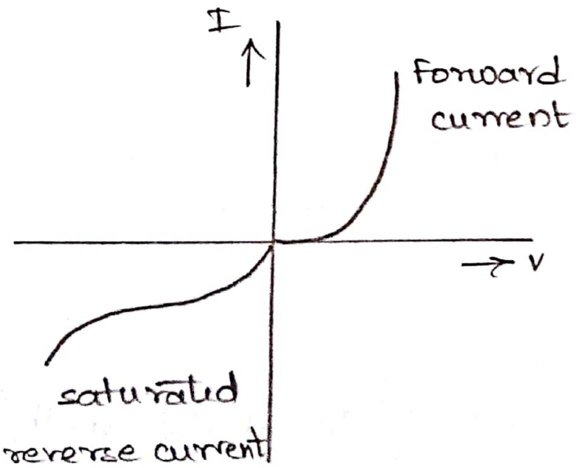


Fig: V-I characteristics

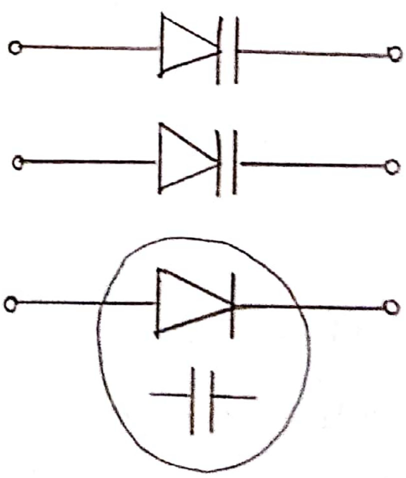


Fig: Commonly used symbols.

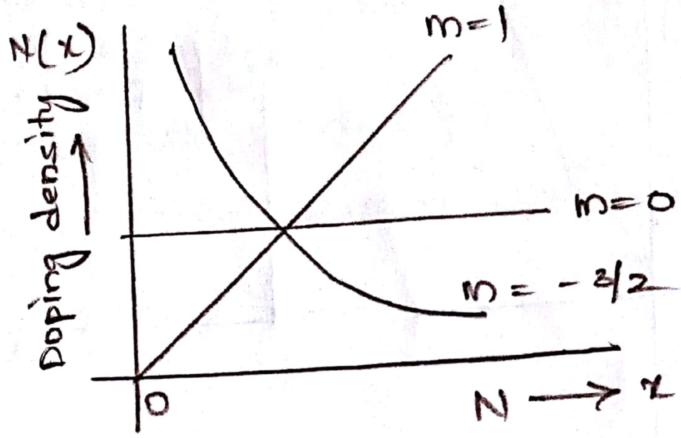


Fig: Doping profiles.

If the p-n junction is abrupt, the capacitance varies as a square root of the reverse bias 'V_r' i.e., n = 1/2. If the p-n junction is a linear graded one, n is 1/3 i.e., voltage sensitivity of C_j is greater for an abrupt junction than for a linear graded junction. For a hyper abrupt junction n > 1/2.

In general,

$$C_j \propto V_r^{-1/m+2}$$

where, m = 0 : abrupt junction.

m = 1 : Linear graded junction.

m = -3/2 : hyper abrupt junction.

When such a capacitance is used with an inductor 'L' in a resonant circuit, the resonant frequency varies linearly with the voltage applied to the varactor.

$$\omega_r = \frac{1}{\sqrt{LC}} \propto \frac{1}{\sqrt{V_r^{-n}}} \propto V_n \text{ for } n = 2$$

This clearly shows that C_j Vs V_r curve can be effectively used for choosing specific doping profiles and varactor diodes can be designed for specific applications.

Construction of Varactor diode.

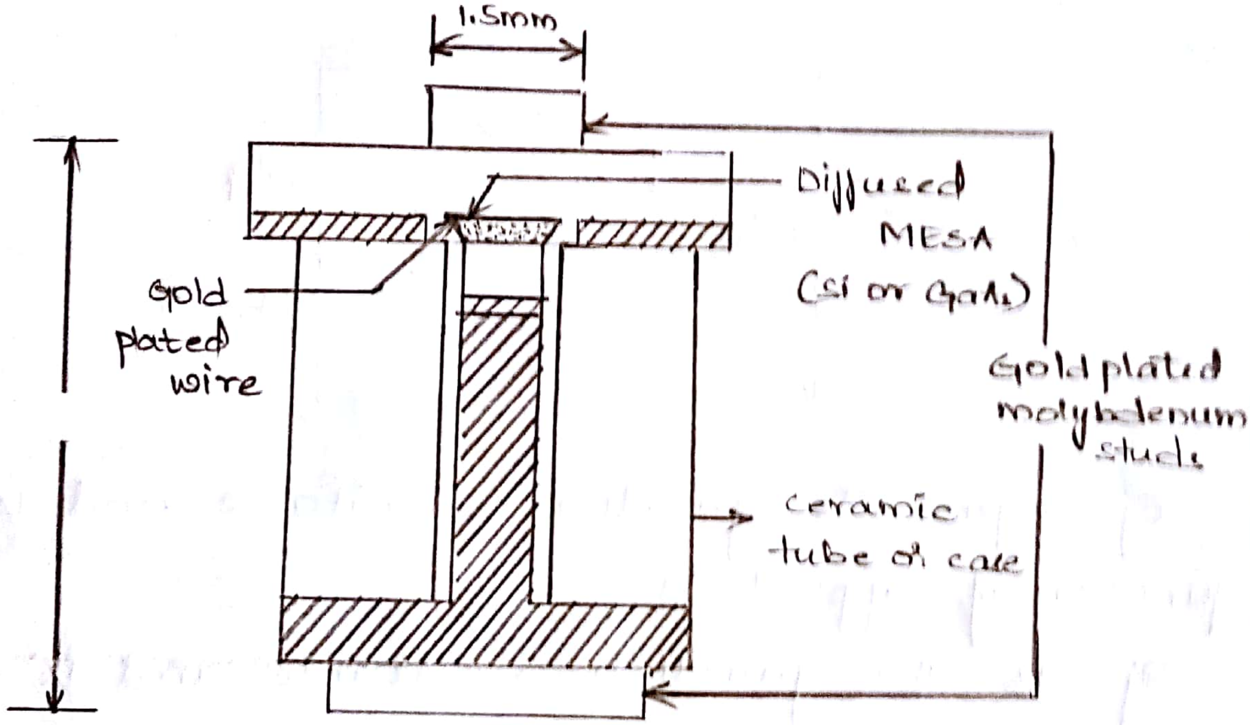
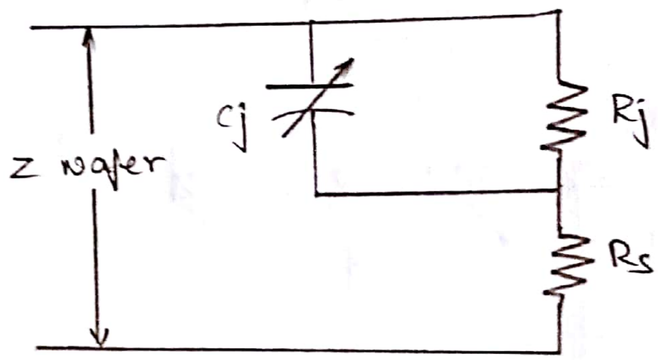


Fig: Constructional details of varactor diode

The diode encapsulation contains electrical leads attached to the semiconductor wafer and a lead to the ceramic case. Diffused junction MESA Si diodes are widely used at microwave frequencies. They are capable of handling larger powers and large reverse breakdown voltages and have low noise. Frequency limit of Si diodes is upto 25 GHz. Varactors made of GaAs have high operating frequency (over 90 GHz) and better functioning at the lowest temperatures. However the manufacturing techniques are easier for Si c

Equivalent Circuit.

The electrical equivalent circuit for a varactor diode is shown as below.



Cj represents junction capacitance and is a function of applied bias.

Rj is the junction resistance and is a function of applied bias.

Rs is the series resistance including resistance of the wafer and the resistance of the ohmic electrical leads and is a functio of applied bias.

At microwave frequencies Rj is of the order of 10 MΩ and may be neglected compared to capacitive reactance.

Although variation in junction capacitance is that most important characteristic of a varactor diode, there are parasitic resistances capacitances and conductances associated with every practical encapsulated diode. The diode encapsulation contains electrical leads attached to the wafer and low loss ceramic cases as a mechanical support to the wafer. Because of these, equivalent circuit in the above figure can be redrawn as a final equivalent circuit shown below.

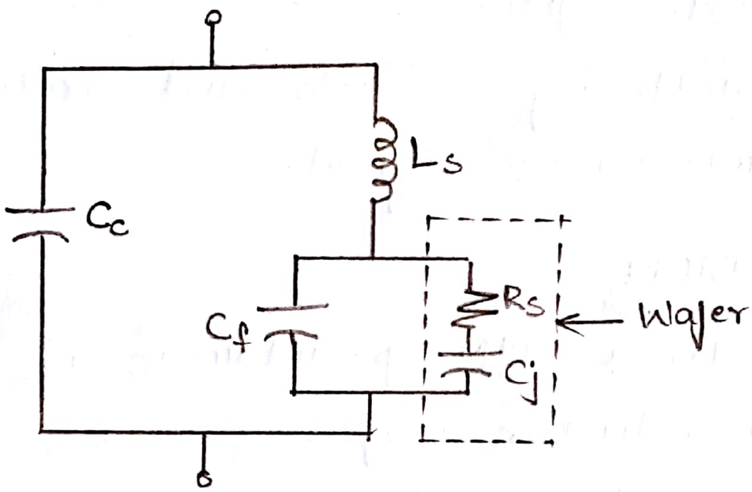


Fig: Final equivalent circuit of varactor diode

where, C_c = Capacitance of ceramic case
L_s = Lead inductance
C_f = fringe capacitance
C_j = junction capacitance
R_s = series resistance
R_j = $10 M\Omega$ (neglected)

The parasitics should be kept as low as possible. For many applications there should be a large capacitance variation and small value of minimum capacitance and series resistance.

Applications of Varactor Diodes:

They have several applications like.

1. Harmonic generation.
2. Microwave frequency multiplication (up conversion)
3. Low noise amplification (parametric amp)
4. Pulse generation and pulse shaping.
5. Tuning stage of a radio receiver (replacing the bulky variable plate capacitor)
6. Active filters.
7. Switching circuits and modulation of a microwave signal.

PIN DIODE

In a PIN (p-intrinsic-n) diode, the semiconductor wafer has a heavily doped narrow layer of p type material seperated from an equally heavily doped narrow layer of n-type material by a thicker layer of high resistivity material that is intrinsic (or very lightly doped material) as shown in fig. below.

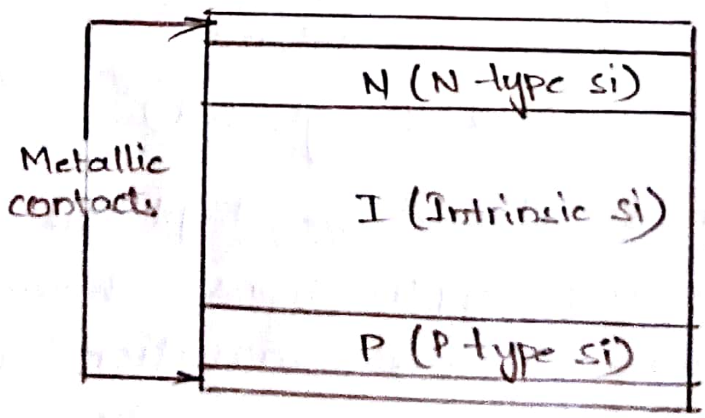


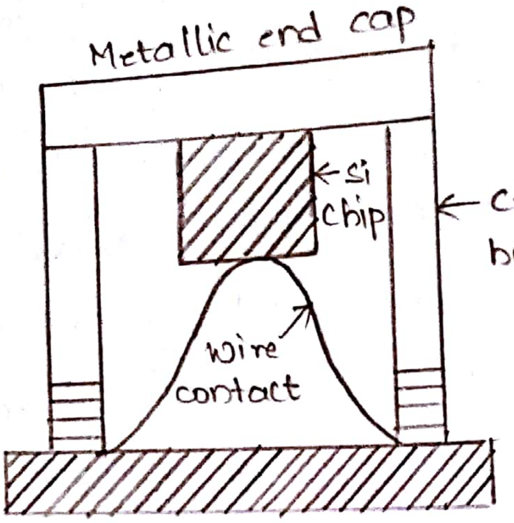
Fig: PIN Diode

Silicon is widely used because of its power handling capacity and high resistivity in the intrinsic region and easy fabrication. Electrical contacts are taken from the two heavily doped regions. PIN diodes are widely used for microwave power switching, limiting and modulation.

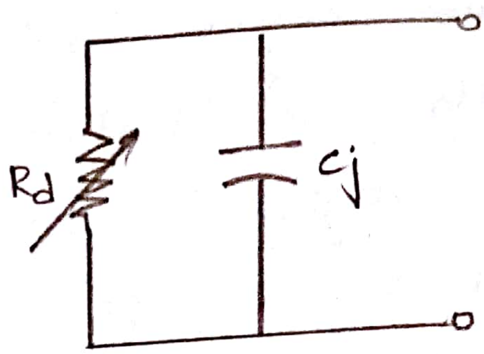
The PIN diode acts as a low frequency rectifier that could rectify more power than an ordinary p-n junction diode. Upto about 100 MHz, the operation is similar to an ordinary p-n junction diode. Rectification ceases at higher frequencies due to carrier storage junction and the transit time across the large intrinsic region.

Under zero and reverse bias, the diode has a very high impedance at microwave frequencies and a very low impedance for small forward currents. i.e., with bias variation on a PIN diode, its microwave resistance changes from nearly 5-10KΩ under negative bias to around 5Ω under positive bias. i.e., It behaves as a microwave switch.

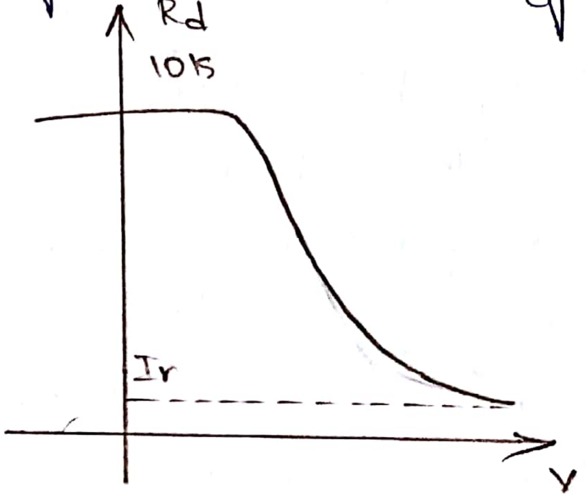
The construction, electrical equivalent circuit and the resistance variation with bias voltage are shown in fig. below.



a) Construction of PIN diode



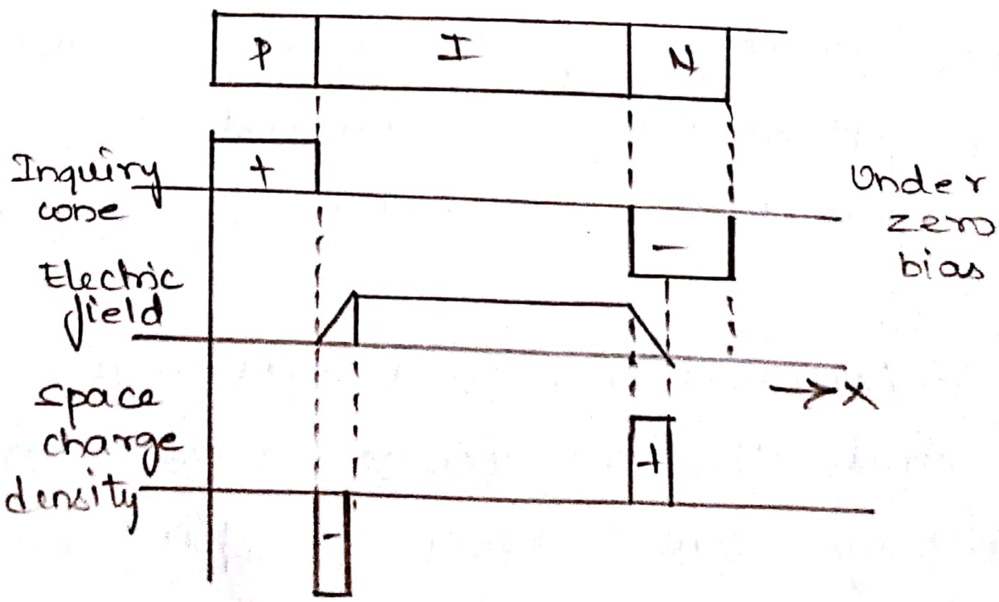
b) Equivalent circuit of a PIN diode



c) Resistance variation with bias

Operation of PIN diode.

The operation can be explained by considering zero bias, reverse and forward bias conditions.



Zero bias : At zero bias the diffusion of the holes and electrons across the junction causes space charge (density) region of thickness inversely proportional to the impurity concentration. An ideal 'i' layer has no depletion region i.e, p layer has a fixed negative charge and n layer has a fixed positive charge under zero bias.

Reverse bias : As reverse bias is applied, the space charge regions in the p and n layers will become thicker. The reverse resistance will be very high and almost constant.

Forward bias : With forward bias current carriers will be injected into the i layer and the p and n space charge regions will become thinner i.e, electrons and holes are injected into the 'i' layer from p and n layers respectively. This results in the carrier concentration in the 'i' layer becoming raised above equilibrium levels and the resistivity drops as forward bias is increased. Thus low resistance is offered in the forward direction.

Applications of PIN Diode.

1) PIN diode act as a switch

2) PIN diode can be used as a Amplitude Modulator

3) PIN diode as a phase shifter

4) PIN diode as a limiter.

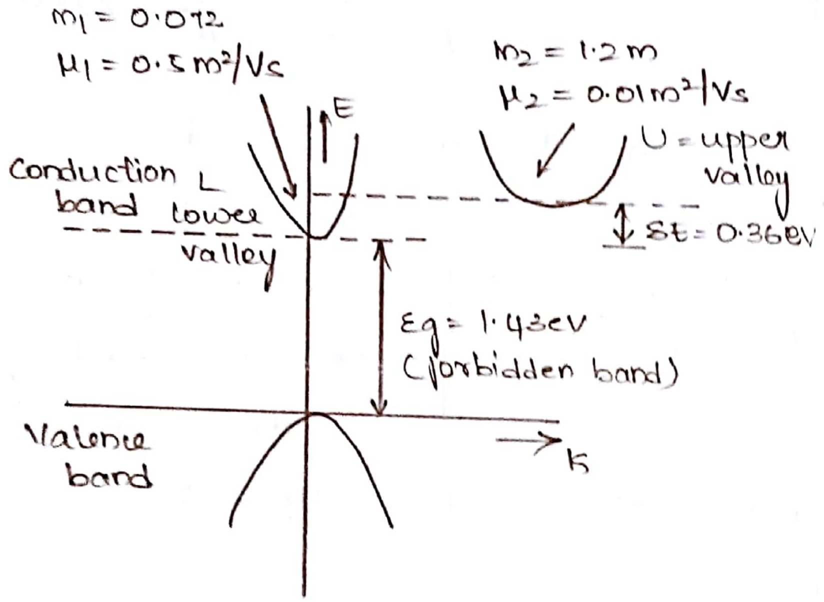
GUNN DIODE :

Gunn effect diodes are named after J. B. Gunn (1963), who discovered periodic fluctuation of current passing through the n-type GaAs specimen when the applied voltage exceeded a certain critical value.

Gunn effect can be explained on the basis of two valley theory of Ridely Watkins -Hilsum (RWH) theory or the transferred electron mechanism.

Basic mechanism involved in the operation of bulk n-type GaAs devices is the transfer of electrons from lower conduction valley the L-valley, to upper subsidiary valley the U-valley.

As show in the fig. below, the curvature of the two valleys in the conduction band also called the sub bands are different so that an electron in L-valley has a smaller effective mass ($m_1 = 0.072\,m_0$) than one in the U-Valley ($m_2 = 1.2\,m_0$). The different effective masses mean different mobilities for the L-valley ($\mu_1 = 0.5\ m^2/volt\ sec$) and the U-valley ($\mu_2 = 0.01\ m^2/volt\ sec$) respectively. The ratio of density of states in the U-valley to that in the L-valley is about 60. Thus the upper valley has a very high density of states compared with the k=0 location.



At low electric fields, conduction electrons are distributed in a manner determined by energy separation ∂E, the lattice temeperature T_0 and the density of states.

With the typical values stated in the figure, most of the electrons at low electric fields and at low lattice temperatures will occupy states in the L-valley and carry ohmic current $J = \sigma E$.

As the applied field is increased, the electrons gain energy from it and move upward in the U-valley. Actually the probability of this inter valley transfer of electrons is good as there are many available states in the U-valley. As the electrons transfer to this U-valley, their effective mass is increased thus decreasing the mobility decreases and the current density J and hence the negative differential conductivity.

There is a certain threshold field, approximately 3.3KV/cm hence above which this inter valley transfer of charges from lower L-valley to U-valley or the Transfer Electron effect takes places. As the transfer of electron is taking place, the current density should be given as

$$J = \sigma E = e(n_1+n_2)\bar{\mu}E = en_0\bar{\mu}E$$

where,

$$\bar{\mu} = \frac{n_1\mu_1 + n_2\mu_2}{n_0}$$ = the average mobility of electrons.

As the applied field is raised even higher almost all the electrons in the L-valley are transferred to U-valley and the current density will be given as

$$J = \sigma E = en_2\mu_2 E$$

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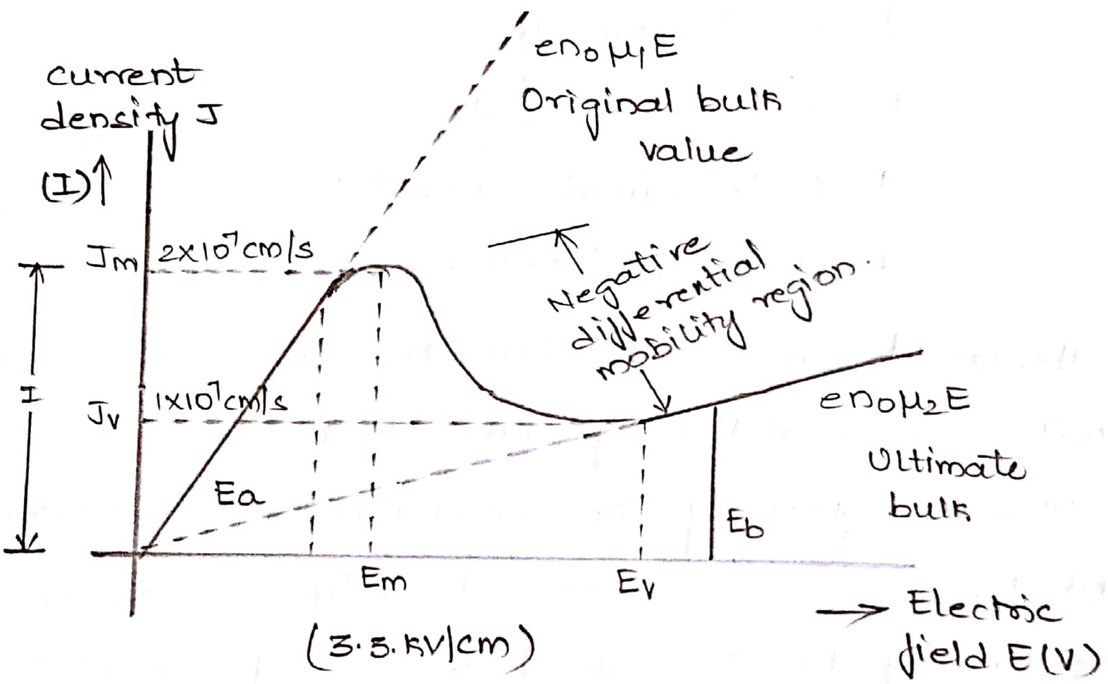
where,

n_2 = carrier concentration.

μ_2 = mobility in U-valley.

Thus a J vs. E curve is obtained similar to V-I characteristics of pn junction diodes for the voltage controlled bulk negative conductance GaAs sample as in figure below.



JE characteristic of a Gunn diode.

where, J_m = Maximum current density

J_v = Valley current density

E_m = Maximum electric field required before the onset of negative conductance region.

E_a = Maximum electric field for which $J = \sigma E$ is valid.

E_b = Electric field for which $J = en_2\mu_2 E$ holds.

E_V = Electric field corresponding to J_V.

$$\mu_l = \frac{V_d}{E}$$

$$\mu_n = \frac{dV_d}{dE}$$

$$\mu_a = \frac{V_d}{E}$$

$$V_d = fL$$

where, V_d = electron drift velocity.

f = frequency.

L = device length

$J \propto$ terminal current I

$E \propto$ applied voltage V.

Hence these J-E characteristics represent the V-I characteristics of Gunn diode.

The region of the characteristic between E_m and E_V where current density decreases with increasing electric field is one of negative differential resistivity (NDR).

Differentiating $J = \sigma E = en_0 \bar{\mu} E$ w.r.t to E, we get,

$$\frac{dJ}{dE} = \sigma \left[1 + \frac{E}{\sigma}\frac{d\sigma}{dE}\right]$$

The condition for negative conductance (or resistance) is

$$\frac{dJ}{dE} < 0 \text{ or } 1 + \frac{E}{\sigma}\frac{d\sigma}{dE} < 0.$$

Hence if $\frac{\partial E}{\partial \sigma}$ satisfies the above condition, i.e., if differential conductivity is negative, then slope of V-I characteristics will be negative and the device will present a net negative conductance to the external circuit. It is to be noted that this inter valley transfer must take place at realistic field levels. The threshold field Em should not raise the temperature so high as to cause significant generation of electrons from valance band by impact ionization. Thus δE should be less than E_G as in the case of n-type GaAs ($\delta = 0.36$ eV, $E_G = 1.43$ eV).

Construction of Gunn diode:

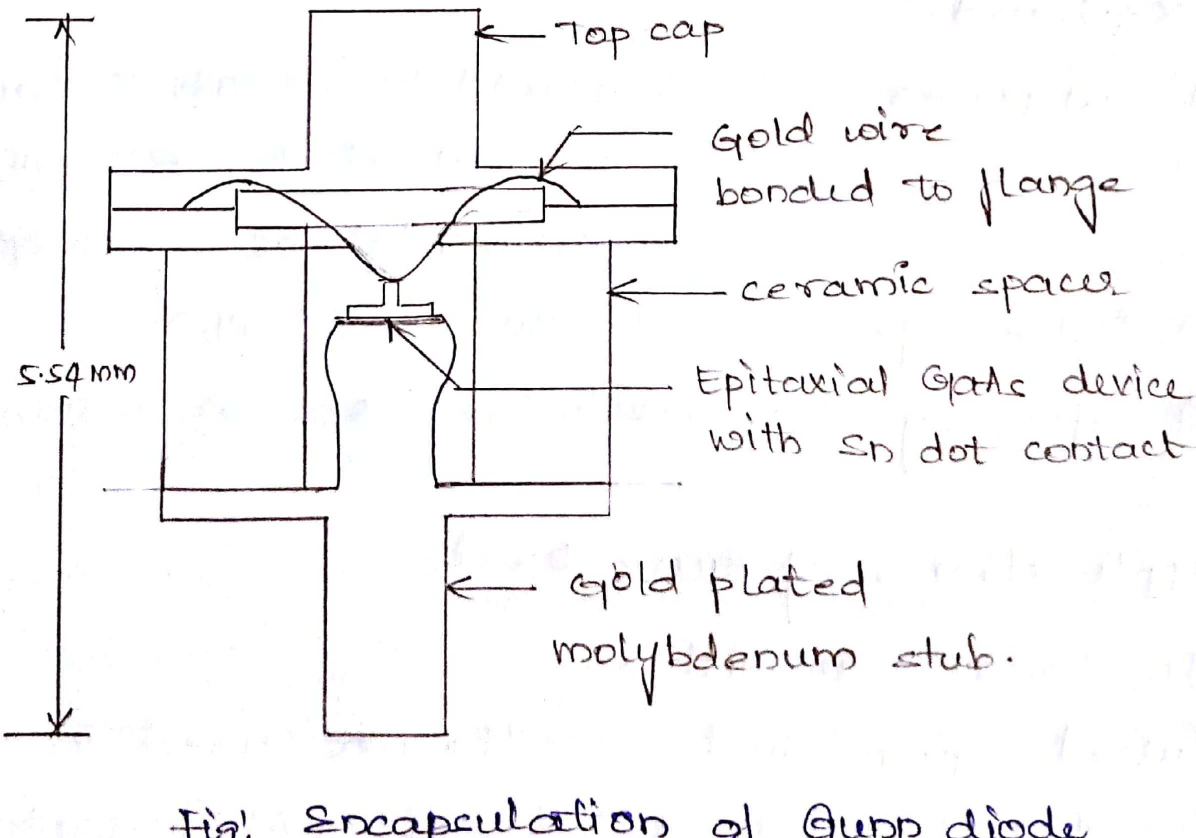


Fig: Encapsulation of Gunn diode

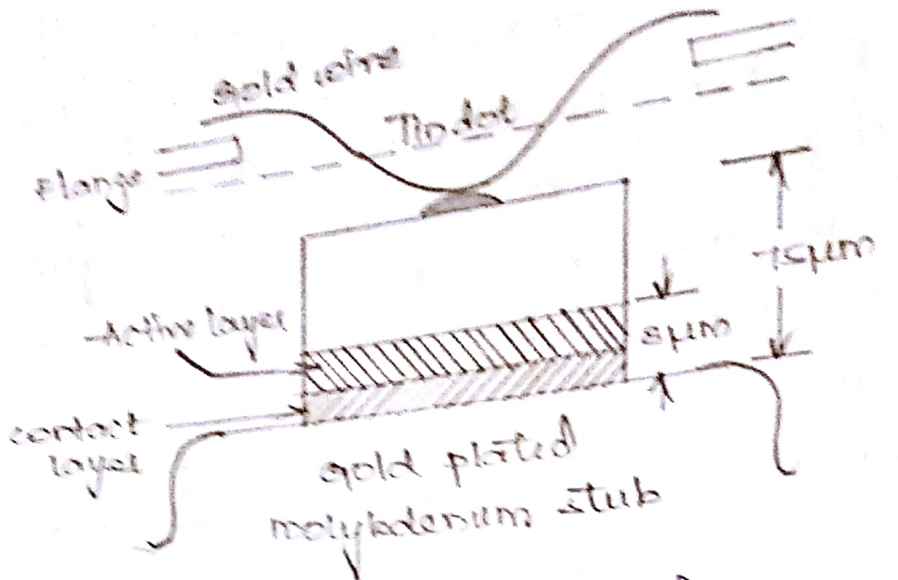


Fig: construction details.

Typical Characteristics:

It typically uses a 10-12V supply with a typical bias current of 250mA giving a continuous wave power of 25mW in the x-band.

1) CW power : 25mW to 250mW x-band
   100mW at 18-26.5 GHz
   40mW at 26.5-40 GHz
2) Pulsed power : 5W (5-12 GHz)
3) Efficiency 2% to 12% (at 1.5W CW to 50mW CW)

Applications of Gunn Diode:

1) In Radar transmitter.
2) Pulsed Gunn diode oscillators used in transponders for air traffic (ATC) control and in industry telementry systems.

3) Broadband linear amplifier.

4) Fast combinational and sequential logic circuits.

5) Low and medium power oscillators in microwave receivers.

6) As pump sources in par amp.

Gunn diodes have an <u>advantage</u> over IMPATT diodes in that they have lesser noise.

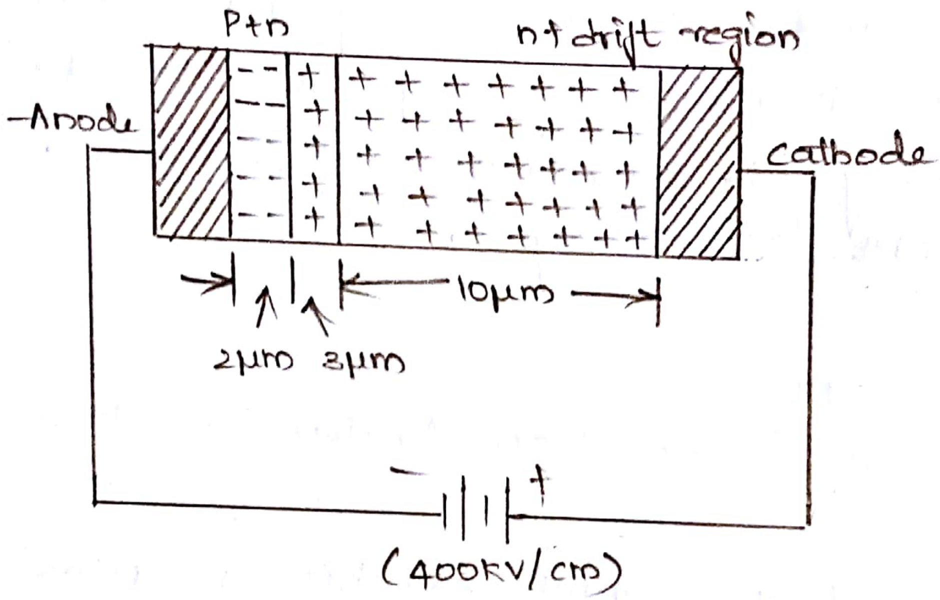
The <u>disadvantage</u> of Gunn diode is that it is very temperature dependent. It has 0.5 - 3MHz /°C change.

<u>IMPATT DIODE</u> :

Impact Ionization Avalanche Transit Time device.

Any device which exhibits negative resistance for dc will also exhibit it for ac, i.e; If an ac voltage is applied, current will rise when voltage falls at an ac rate. Hence negative resistance can also be defined as that property of a device which causes the current through it to be 180° out of phase with the voltage across it. This is the kind of negative resistance exhibited by IMPATT diode; i.e; If we show voltage and current have a 180° phase difference, then negative resistance in IMPATT diode is prooved.

- A combination of delay involved in generating avalanche current multiplication together with delay due to transit time through a different space provides the necessary 180° phase difference between applied voltage and the resulting current in an IMPATT diode.



- An extremely high voltage gradient (400KV/cm) is applied to the IMPATT diode eventually resulting in a very high current. A normal diode would very quickly breakdown under these conditions but IMPATT is constructed such that it will withstand these conditions repeatedly. Such a high potential gradient back biasing the diode causes a flow of minority carriers across the junction.

Let us consider application of a RF ac voltage superimposed on top of the high dc voltage. Increased velocity of electrons and holes result in additional electrons and holes by knocking them out of the crystal structure by so called Impact Ionization.

These additional carriers continue the process at the junction and it now snowballs into an avalanche. If the original dc field was just at the threshold of allowing this situation to develop, this voltage will be exceeded during the whole of the RF positive cycle and the avalanche current multiplication will be taking place during this entire time.

Since it is a multiplication process avalanche is not instantaneous. This process in fact takes a time such that the current pulse maximum at the junction occurs at the instant when RF voltage across the diode is zero and going negative. A 90° phase shift or phase difference between voltage and current has then been achieved.

The current pulse as shown in fig. below is situated at the junction.

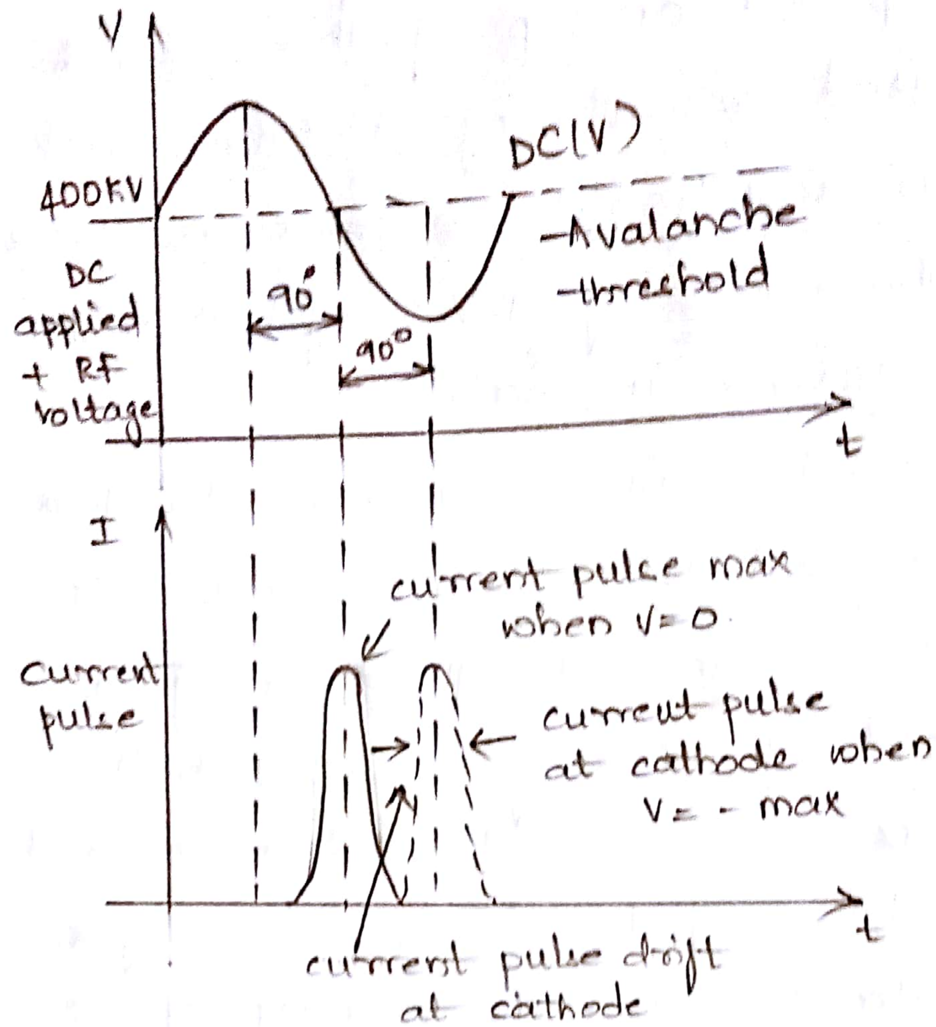


Fig: V and I vs t characteristics

It does not stay there but moves towards the cathod due to applied reverse bias at a drift velocity dependent on the presence of high dc field. The time taken by the pulse to reach the cathode depends on this velocity and on the thickness of the highly doped n^+ layer. The thickness is adjusted such that time taken for current pulse to move from V=0 position to V= negative maximum of RF cycle is exactly 90°.

Hence voltage and current are 180° out of phase and a dynamic RF negative resistance has been proved to exist.

Hence IMPATT diode is useful both as an oscillator and as an amplifier.

The Resonant frequency of IMPATT diode is given by

$$f = \frac{V_d}{2L}$$

where, V_d = carrier drift velocity.

L = Length of the drift space charge region.

The effiency η of IMPATT diode is given by

$$\eta = \left(\frac{P_{ac}}{P_{dc}}\right) = \frac{V_a}{V_d}\left(\frac{I_a}{I_d}\right)$$

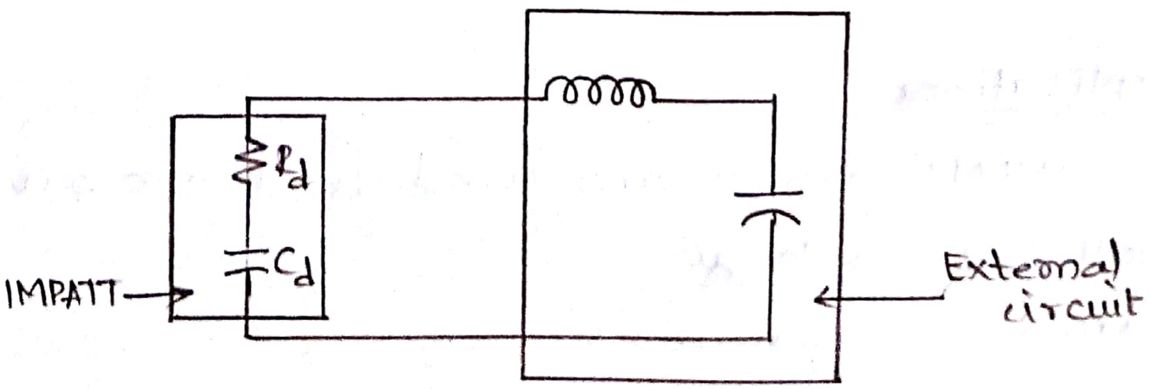
where, P_{ac} = ac power

P_{dc} = dc power

V_a and I_a = ac voltage and current

V_d and I_d = dc voltage and current.

Equivalent circuit :



Construction :

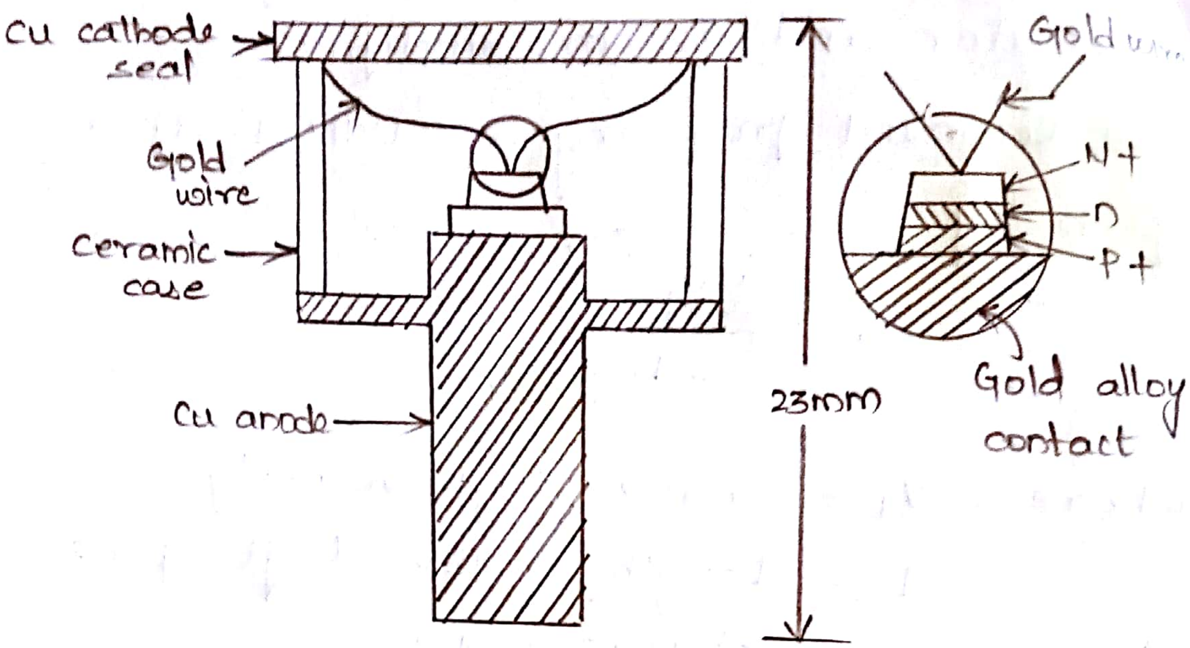


Fig 1: Constructional details of IMPATT

Performance characteristics :

Theoritical η = 30% (< 30% in practice)

= 15% for Si,

= 23% for GaAs

Frequency : 1 to 300 GHz

Maximum output power for single diode :

5W in X-band to 0.5W at 30 GHz.

several diodes combined : 40W at X band

Pulsed powers : 4KW.

Applications :

IMPATT diodes are used as microwave oscillators such as

1) Microwave generators

2) Modulated output oscillators

3) Receiver local oscillators and
4) Par. amp. pumps.
5) IMAPTT diodes are also suitable for negative resistance amplification.
6) HIGH Q IMPATTS are used in Intrusion alarm network, police radar.
7) Low Q IMPATTS are useful in FM telecommunica-tion transmitters and CW doppler radar transmitter.

Advantages :

The following are the advantages of IMPATT diode,

1) The main advantage of IMPATT diode is their high power capability.
2) IMPATT diode based on silicon are most suitable for mm wave power. A millimeter wave covers the wavelength range from 10mm to 1mm corresponding to 30 - 300 GHz.
3) IMPATT diode provides potentially reliable, compact, inexpensive and moderate efficient microwave power sources.

Disadvantages :-

1) The main disadvantage of IMPATT diode is that it is very noisy because avalanche is a noisy process.

2) The tuning range of IMPATT diode is not as good as Gunn diodes.

3) Noise figures for IMPATT being 30dB are not as good as klystron | Gunn diode | TWT amplifier.

MICROWAVE TRANSMISSION LINES :

At microwave frequencies, the following transmission lines will be employed.

i) Multiconductor lines
- co-axial lines
- Microstrip lines
- Coplanar lines etc.
- strip lines
- slot lines

ii) single - conductor lines (waveguides)
- Rectangular waveguides
- Circular waveguides
- Ridge waveguides etc.

iii) Open - boundary structures
- Dielectric rods
- Open waveguides etc.

STRIP LINES :

Strip lines are essentially modifications of the two wire lines and coaxial lines. These are basically planar transmission lines that are widely used at frequency from 100MHz to

100 GHz.

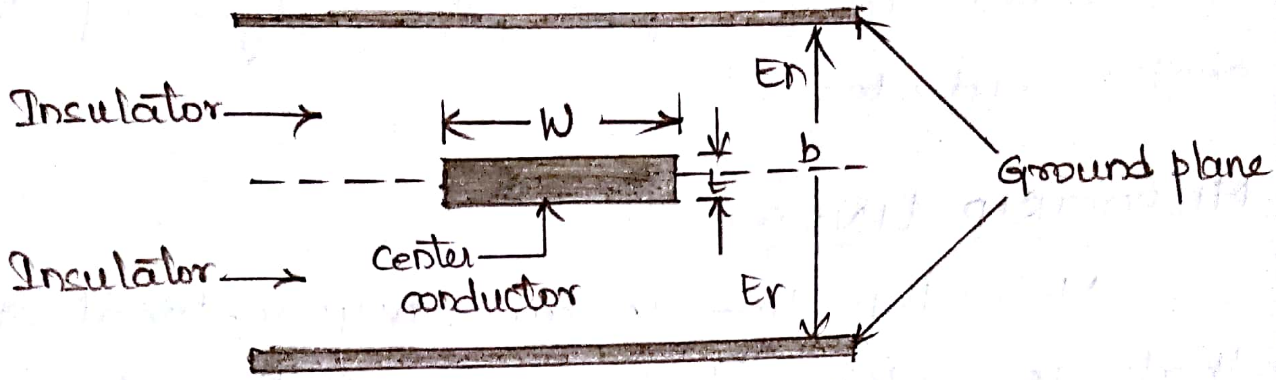


Fig: strip line.

As seen in fig., a strip line consists of a central thin conducting strip of width 'w' which is greater than its thickness 't', placed inside the low loss dielectric (ε_r) substrate of thickness $\frac{b}{2}$ between two wide ground plates. Usually the thicknesses of the metallic central conductor and the metallic ground planes are the same. The dominat mode for the strip line is a TEM mode and the fields are confined within the transmission line with no radiation losses. The width of the ground planes is atleast five times greater than the spacing between the plates there by avoiding any vertical side walls at the two transverse ends.

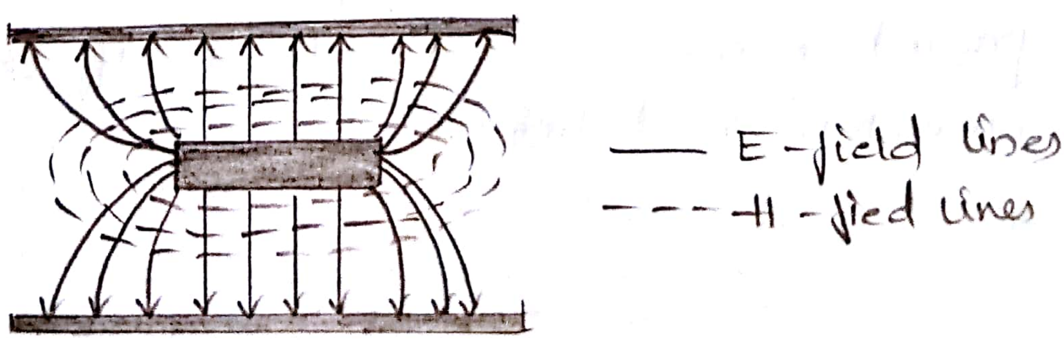
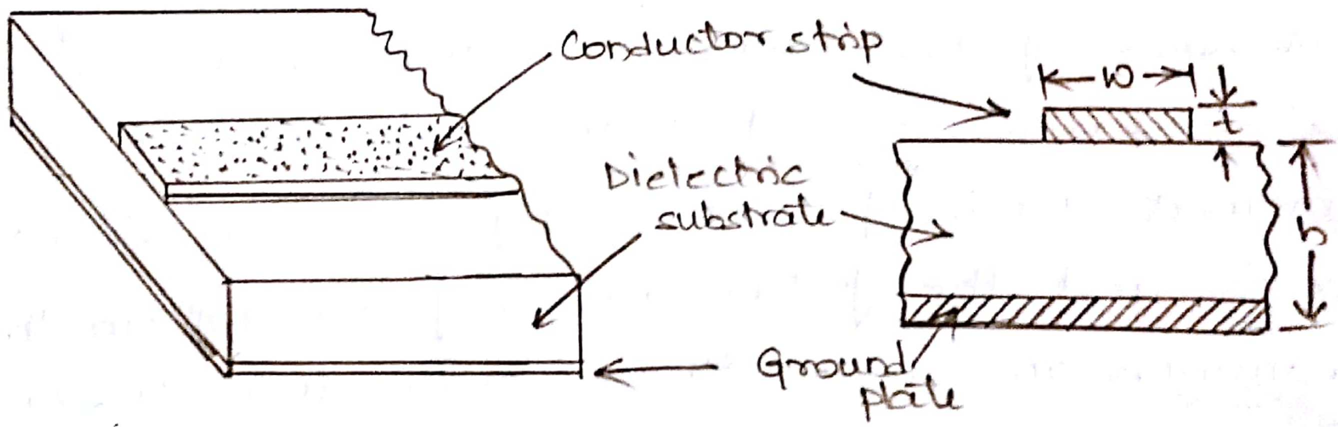


Fig: TEM mode of strip line

There are practically no fringing fields after a certain distance from the edges of the center conductor.

MICROSTRIP LINES :

Microstrip line is an unsymmetrical stripline that is nothing but a parallel plate transmission line having dielectric substrate, the one face of which is metallised ground and the other face has a thin conducting strip of certain width 'w' and thickness 't'.



The top ground plane is not present in a microstrip as compared to a stripline. Sometimes a coverplate is used for shielding purposes but it is kept much farther away than the ground plane so as not to affect the microstrip field lines.

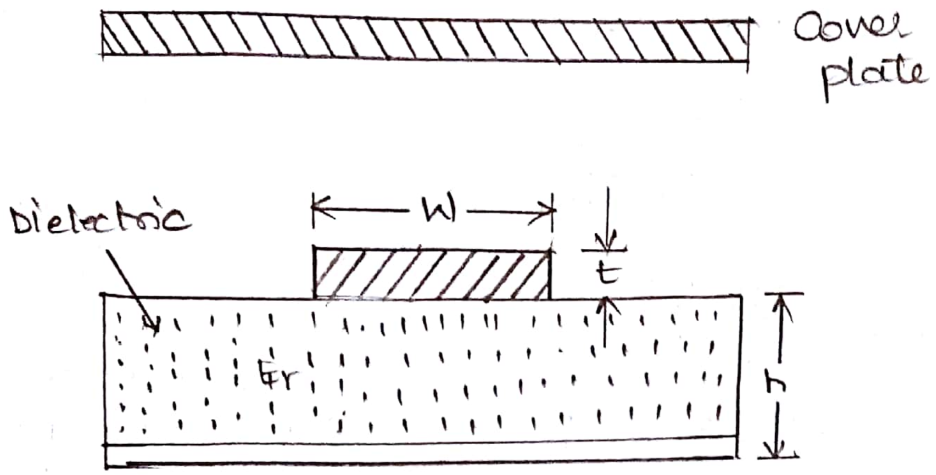
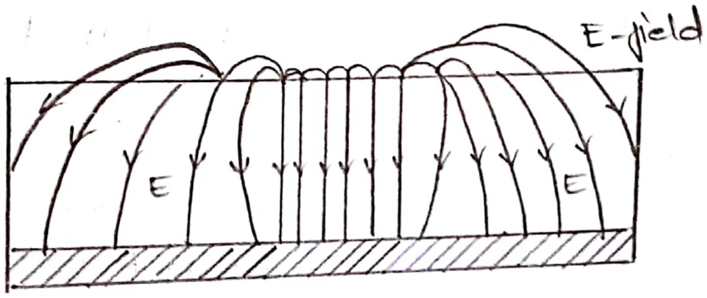
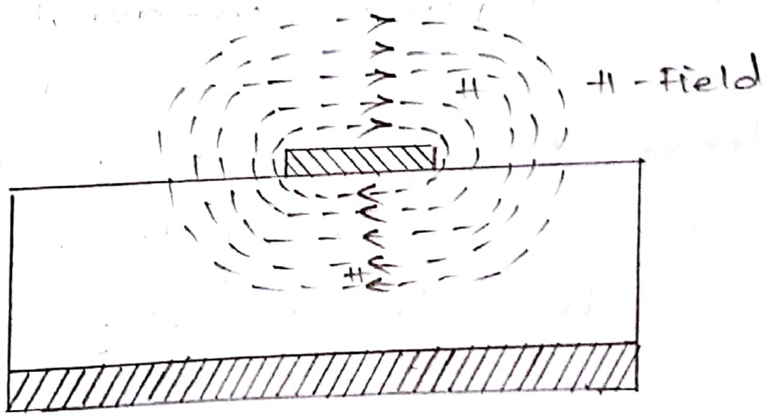


Fig: Microstrip line with a cover plate

The approximate distribution of electric and magnetic field is shown in fig. below.





Types of Microstrip Lines:

There are many varieties of microstrip lines that have been used in practise such as embedded microstrip, standard inverted microstrip, suspended microstrip and slotted transmission line. The cross sectional views of these are shown in fig. below.

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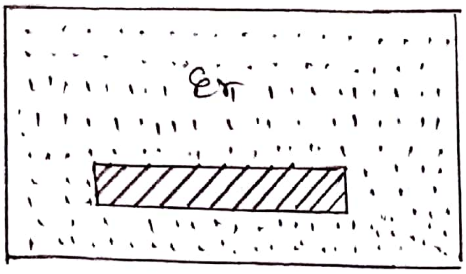
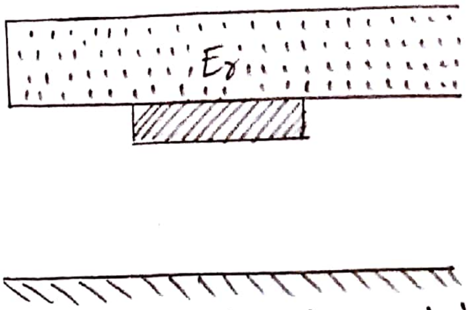
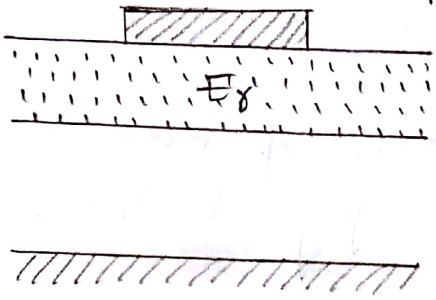


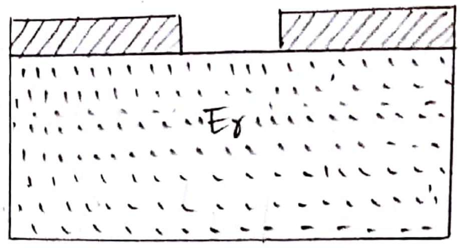
a) embedded microstrip



b) inverted microstrip



c) suspended microstrip



d) slotted microstrip

Advantages :-

1) The fabrication costs would be substantially lower than stripline, co-axial or waveguide circuits.

2) Also there is an easy access to the top surface making it easy to mount passive or active discrete devices.

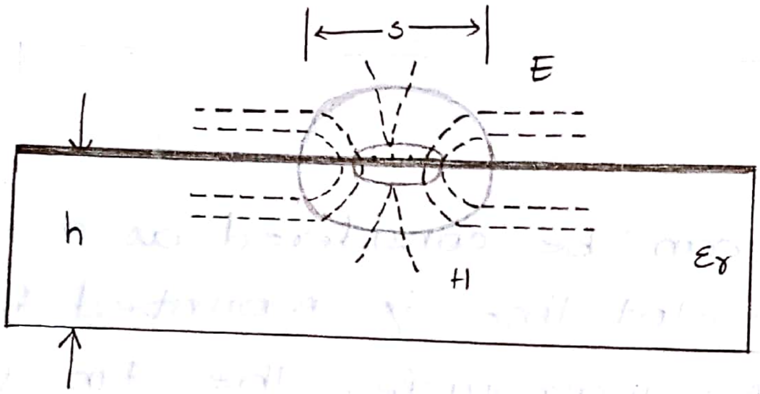
Limitations :

1) Due to the openess of the microstrip structure they have higher radiation losses or interference due to nearby conductors.

2) The variations of temperature may change the relative dielectric constant, which finally cause the change of impedance.

SLOT LINE :

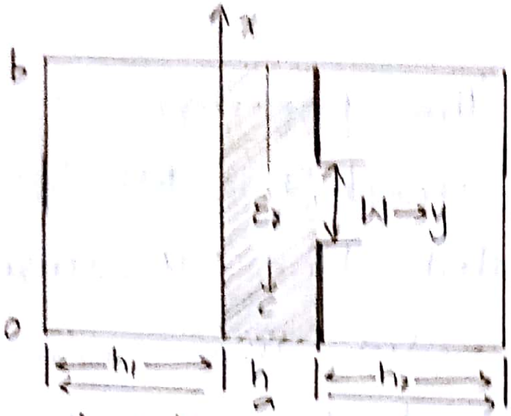
Slot line is one of the popular transmission line which are used in MIC's. The fabrication process of slot line is similar to that of microstrip line. Slot line consists of a gap or slot in a conducting coating on a dielectric substrate.



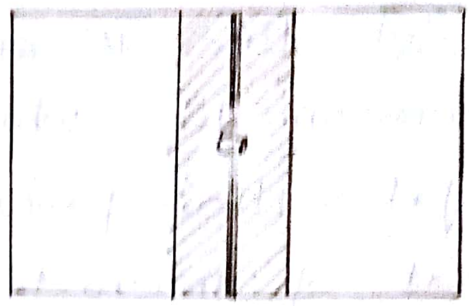
Here the conductor are in one plane on a dielectric substrate, Hence unlike strip line and microstrip lines active and passive components can easily be shunt mounted across the lines from the top.

FIN LINES :

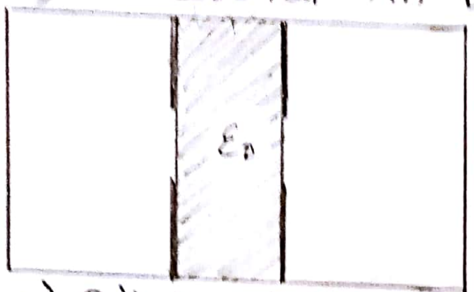
Fin lines are not exactly the planar structures but we may call them as quasi-planar. The main characteristics of Fin lines are their large bandwidth, compatibility with the planar circuit technology and absence of radiation.



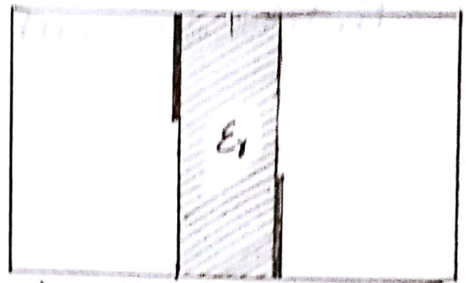
a) Unilateral fin line



b) Insulated fin line



c) Bilateral fin line

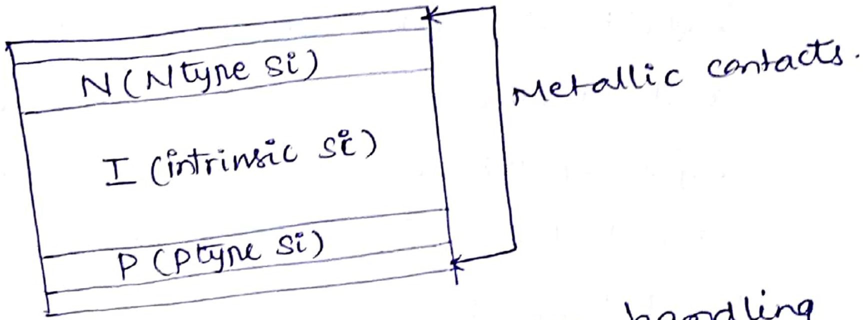


d) Antipodal FIN line.

→ A fin line can be considered as a shielded slot line. The slot line is mounted in the E-plane of the waveguide. The fin line structures are unilateral, bilateral and antipodal as shown in the fig. above.

PIN DIODE

- Pin Diode is a useful control element at microwave frequencies. These diodes are differ from an ordinary P-N Junctions.
- In a PIN (P-intrinsic-n) diode, the semiconductor wafer has heavily doped narrow layer of P-type material seperated from an equally heavily doped narrow layer of n-type material by a thick layer of high resistivity material that is intrinsic (or very lightly doped material).



- Si is widely used because of its power handling capacity and high resistivity in the intrinsic region and easy fabrication.
- PIN diodes are widely used for microwave power switching, limiting and modulation.
- The PIN diode acts as a low frequency rectifier that could rectify more power than an ordinary P-N Junction diode.
- upto 100 MHZ, the operation is similar to PN Jn diode, At high frequencies the PIN diode acts like a variable resistance.

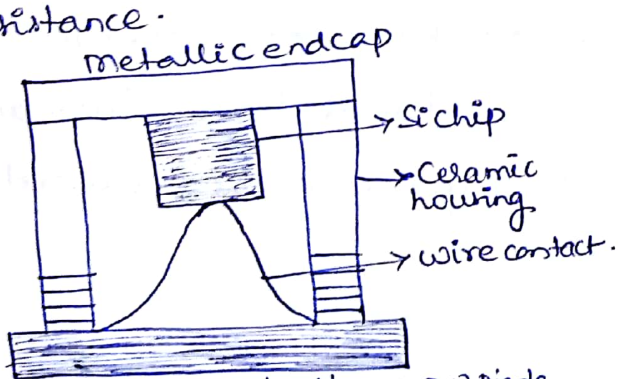


fig: Construction of PIN Diode

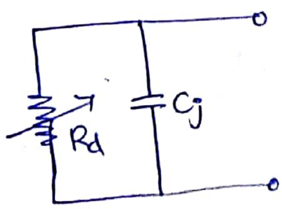


fig: equivalent ckt

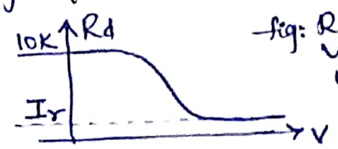
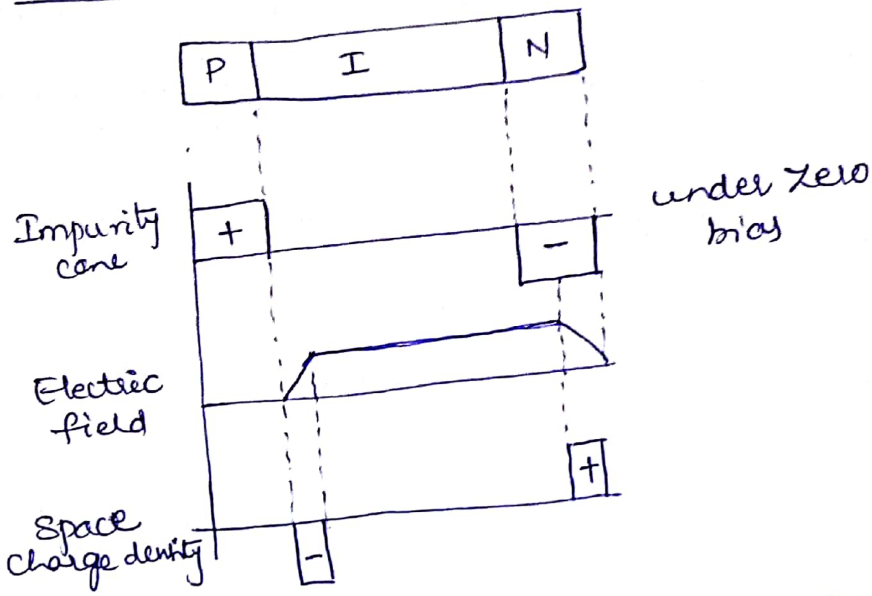


fig: Resistance variation with bias.

operation of PIN Diode



Zero Bias: At zero bias the diffusion of holes and electrons across the junction causes the space charge region of thickness inversely propotional to the impurity concentration. An ideal I layer has no depletion region i.e P layer has a fixed negative charge and n-layer has a fixed +ve charge under zero bias.

Reverse Bias: As reverse bias is applied the space charge regions in the P and n layers will become thicker. The reverse resistance will be very high and almost constant.

Forward Bias: with forward bias carriers will be injected into the 'i' layer and the 'p' and 'n' space charge regions will become thinner i.e. electrons and holes are injected into into the 'i' layer from p and n layers respectively. This results in the carrier concentration in 'I' layer becomes increases and resistivity decreases as forward bias increased. Thus low resistance is offered in the forward direction

Applications of PIN Diode:

1) PIN diode as a switch. ⟨ ON when FB. OFF when RB.
2) PIN diode as an amplitude modulator → Diode kept at low R.B
3) PIN diode as a phase shifter.
4) PIN diode as a limiter (clipper).
5) PIN diode as an attenuator.

It can be used as variable attenuator when operated in F.B mode.

Avalanche Transit Time Devices:

Microwave diodes exhibits −ve Resistance by having a delay between voltage and current.

There are 3 modes of avalanche oscillators

1) IMPATT : Impact Ionization Avalanche Transit Time device
2) TRAPATT : Trapped Plasma Avalanche Triggered - Transit device
3) BARITT : Barrier Injected Transit time device.

IMPATT Diode

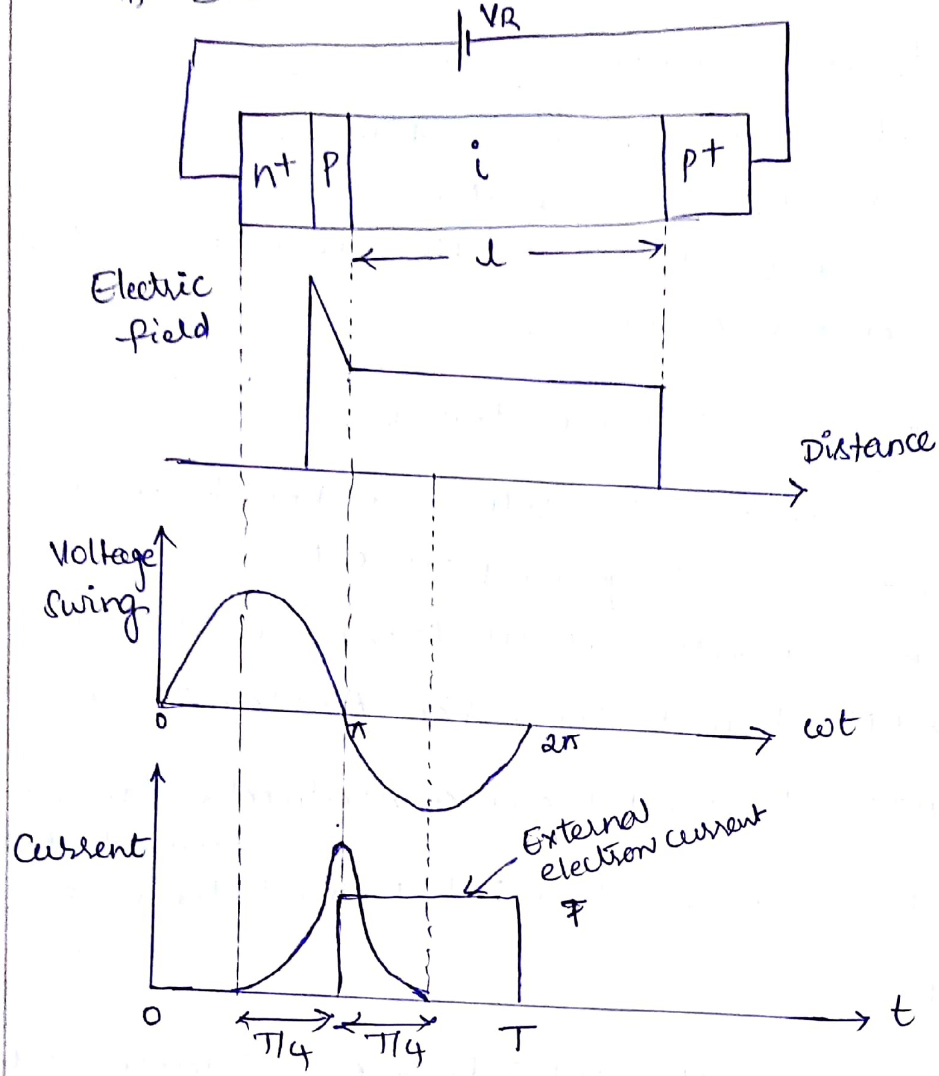
Any device which exhibits −ve resistance for dc will also exhibit it for ac i.e. If an ac voltage is applied current will rise when voltage falls at an ac rate.

Hence −ve resistance can also be defined as that property of a device which causes the current through it to be 180°.out of phase with the voltage across it. Thus this kind of −ve resistance exhibited by IMPATT diode i.e. if we show voltage and current have a 180° phase difference, then −ve resistance in IMPATT diode is proved.

IMPATT operation has two effects are important.

i) Impact ionization

ii) Slow transit velocities.



– When a large Reverse Bias voltage is applied some electrons and holes in the region of peak field gain enough energy, and this makes them impact and knock electrons off, are ionize atoms in the crystal lattice. Thus an impact ionization mechanism creates an electron hole pair. The electrons and the holes, thus created are accelerated by the field in the opposite direction and can cause additional impact.

Advantages of IMPATT Diode

(i) It is very noisy because avalanche is a noisy process.

(ii) Noise figures for IMPATT being 30dB are not as good as klystron.

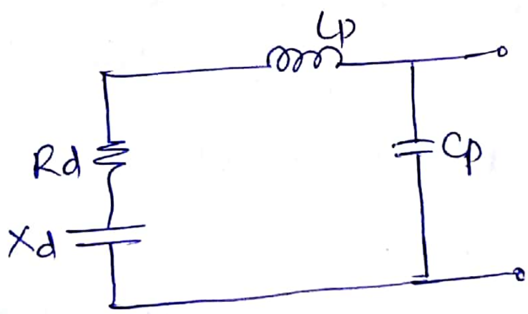
iii) Tuning rate is not as good as gunn diodes, amplifiers

Applications of IMPATT Diode:

1) microwave generators
2) modulated o/p oscillators
3) Receiver local oscillator
4) parametric amplifier pumps.
5) suitable for negative resistance amplification.

High Q IMPATT are used in instruction alarm network, police radar and low power transmitter.
Low Q IMPATT are useful in fm Tele communication transmitter and cw doppler radar transmitter.

equivalent ckt:



Rd → -ve resistance
Cp → Shunt capacitance
Lp → series inductance.

Planar Transmission Lines

Planar transmission lines are those in which the entire transmission line components can be fabricated in one step by thin film or photolitho-graphic techniques similar to a printed circuit board.

This allows the characteristic impedance of the line to be controlled by defining the dimensions in a single plane.

The various configurations available in planar transmission lines are

- Strip line
- micro strip
- slot line
- coplanar lines etc.

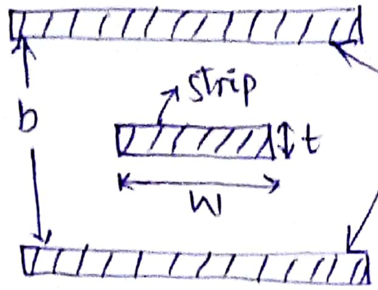
Strip lines :

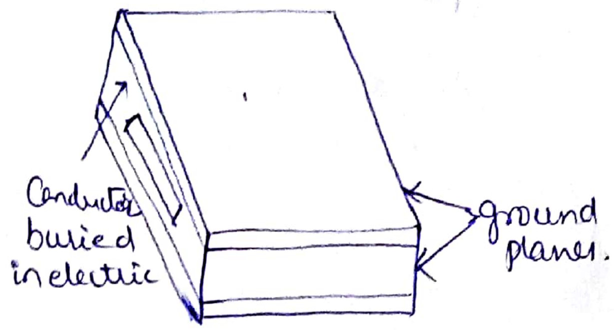
It is basically a three conductor TEM mode transmission line consisting of a thin conductor supported on a dielectric sheet with an earthed metallic backing.

The width (W) of the strip is normally greater than its thickness (t) as shown in fig. with two ground planes in the dielectric medium.

The thickness is normally 1.4 to 2.8 mils.

The symmetrical strip lines are these which have two dielectric sheets and earthed conductors also termed as "triplates".





Mode propagation in a stripline

TEM is the mode of propagation in a strip line. Grounded planes will be at zero potential with field lines concentrated near the central conductor shown in fig.

The phase velocity and characteristic impedance are given by the following relation

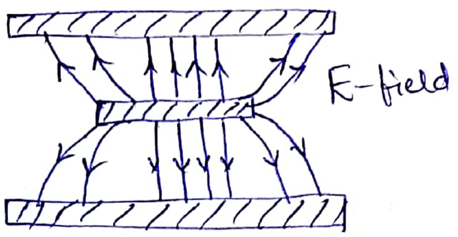
$$V_p = \frac{V_c}{\sqrt{\varepsilon_r}}$$

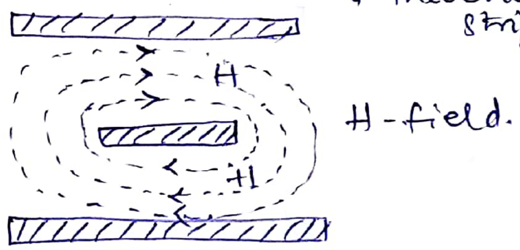
$$Z_0 = \frac{1}{V_p C}$$

$V_p \rightarrow$ phase velocity.

$C \rightarrow$ Shunt capacitance

The value of 'c' depends on width & thickness of strip lines.

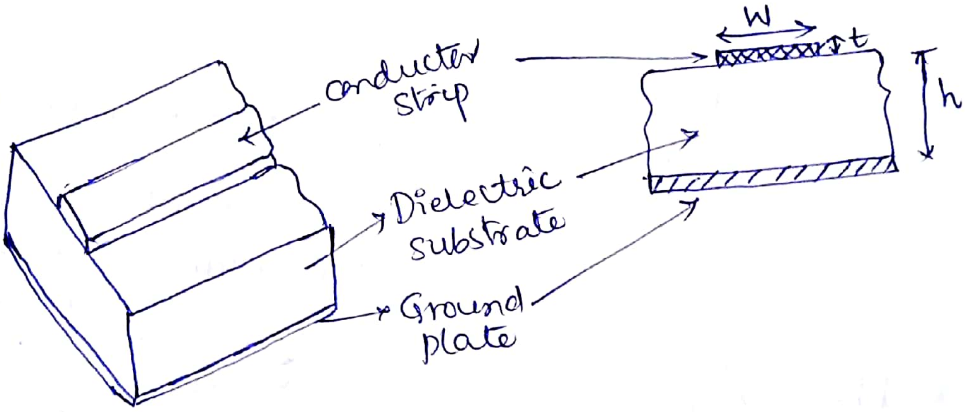




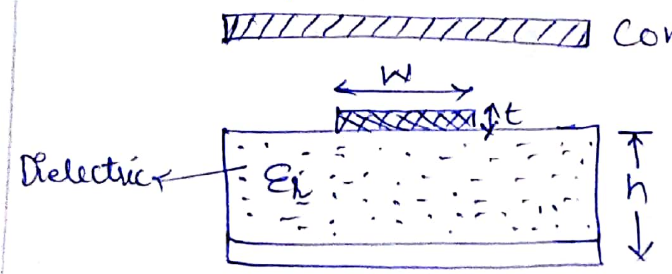
Microw Strip Line :

Micro strip line is an unsymmetrical strip line that nothing but a parallel plate transmission line having dielectric substrate, the one face of which is metallised ground and the other (top) face has a thick conducting strip of certain width (w) and thickness 't'.

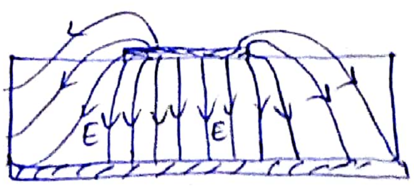
- The top ground plane is not present in a microstrip as compared to a strip line.
- Sometimes a cover plate is used for shielding purposes but it is kept much far away than the ground plane so as not to effect the microstrip field lines shown in fig.



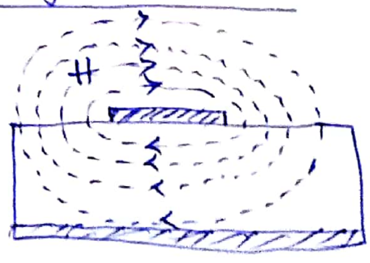
Micro strip line with a cover plate



Distribution of electric and magnetic field on micro strip



E-field



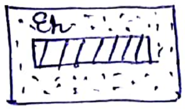
H-field

Losses in microstriplines

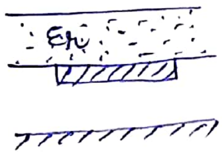
1) Dielectric losses
2) Ohmic losses → This is major microstrip conductor contributes major part of ohmic loss.
3) Radiation losses. → depends on substrate thickness & dielectric constant & its geometry.

Types of microstrip lines

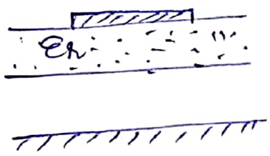
1) Embedded microstrip



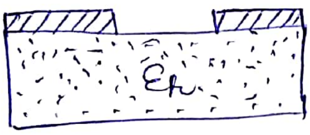
2) Standard inverted microstrip



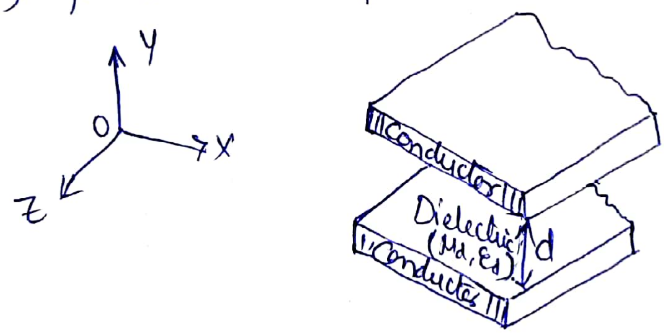
3) Suspended microstrip



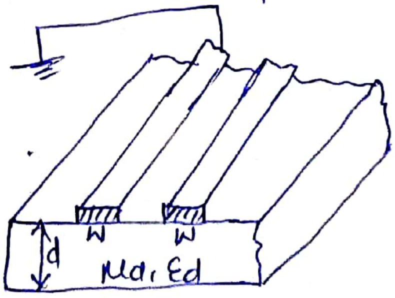
4) Slotted Transmission line



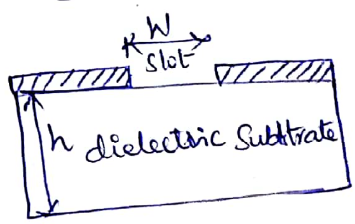
5) parallel strip lines



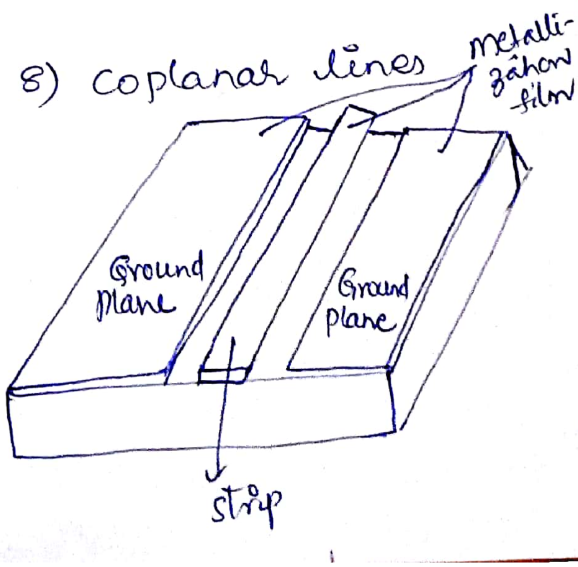
6) Coplanar striplines



7) Slot line



8) coplanar lines



Advantage of microstrip over striplines

1) Construction is simple
2) Integration is easy
3) Both Q and power handling ability are lower with microstrip

Advantages of strip lines over waveguides

1) Reduced Bulk
2) Greater bandwidth
3) Greater Compatability.

Disadvantages of strip lines

1) Greater losses
2) Lower Q
3) Lower power handling capacity.

— Microwave transistor are fabricated by using a technology called planar technology.

Comparision between strip lines & microstriplines

strip lines	micro striplines
1) Dielectrics are used are teflon, polystyrene	1) Dielectrics are Alumina, Quartz ~~stice~~ Silica.
2) suitable for design of only passive circuits	2) suitable for passive ckts and series mounting of active components across a gap in strip
3) Strip lines losses are mainly in conductors	3) microstrip line losses are in dielectric
4). It has 3 conductor transmission system. i.e. two ground plates & strip line.	4) It has 2 conductor system. i.e. one ground plane & microstrip.
5) propagation mode is pure TEM	5) propagation mode is quasi TEM.