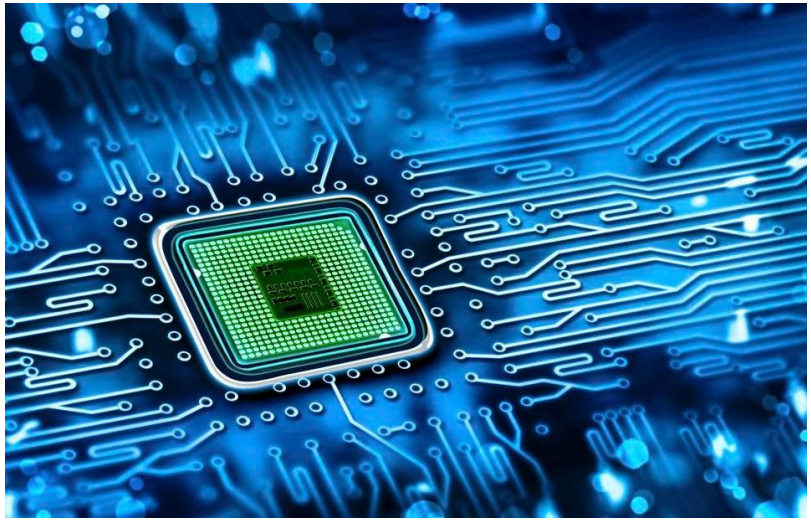
GUNN DIODE



Gunn Diode

- A Gunn Diode is considered as a type of diode even though it does not contain any typical PN diode junction like the other diodes, but it consists of two electrodes.
- A Gunn diode, also known as a transferred electron device (TED), is a form of diode, a two terminal passive semiconductor electronic component, with negative resistance, used in high-frequency electronics.
- This diode is also called as a Transferred Electronic Device. This diode is a negative differential resistance device, which is frequently used as a low-power oscillator to generate microwaves.
- It consists of only N-type semiconductor in which electrons are the majority charge carriers. To generate short radio waves such as microwaves, it utilizes the Gunn Effect.

Gunn Effect

- It was invented by John Battiscombe Gunn in 1960s; after his experiments on GaAs (Gallium Arsenide), he observed a noise in his experiments' results and owed this to the generation of electrical oscillations at microwave frequencies by a steady electric field with a magnitude greater than the threshold value.
- It was named as Gunn Effect after this had been discovered by John Battiscombe Gunn.
- The Gunn Effect can be defined as generation of microwave power (power with microwave frequencies of around a few GHz) whenever the voltage applied to a semiconductor device exceeds the critical voltage value or threshold voltage value.

Gunn Diode Oscillator

- Gunn diodes are used to build oscillators for generating microwaves with frequencies ranging from 10 GHz to THz. It is a Negative Differential Resistance device – also called as transferred electron device oscillator – which is a tuned circuit consisting of Gunn diode with DC bias voltage applied to it. And, this is termed as biasing the diode into negative resistance region.
- Due to this, the total differential resistance of the circuit becomes zero as the negative resistance of the diode cancels with the positive resistance of the circuit resulting in the generation of oscillations.

Gunn Diode's Working

- This diode is made of a single piece of N-type semiconductor such as Gallium Arsenide and InP (Indium Phosphide). GaAs and some other semiconductor materials have one extra-energy band in their electronic band structure instead of having only two energy bands, viz. valence band and conduction band like normal semiconductor materials.
- These GaAs and some other semiconductor materials consist of three energy bands, and this extra third band is empty at initial stage.
- If a voltage is applied to this device, then most of the applied voltage appears across the active region. The electrons from the conduction band having negligible electrical resistivity are transferred into the third band because these electrons are scattered by the applied voltage. The third band of GaAs has mobility which is less than that of the conduction band.
- Because of this, an increase in the forward voltage increases the field strength (for field strengths where applied voltage is greater than the threshold voltage value), then the number of electrons reaching the state at which the effective mass increases by decreasing their velocity, and thus, the current will decrease.
- Thus, if the field strength is increased, then the drift velocity will decrease; this creates a negative incremental resistance region in V-I relationship. Thus, increase in the voltage will increase the resistance by creating a slice at the cathode and reaches the anode. But, to maintain a constant voltage, a new slice is created at the cathode. Similarly, if the voltage decreases, then the resistance will decrease by extinguishing any existing slice.

Gunn Diode's Characteristics

- Because of this, an increase in the forward voltage increases the field strength (for field strengths where applied voltage is greater than the threshold voltage value), then the number of electrons reaching the state at which the effective mass increases by decreasing their velocity, and thus, the current will decrease.
- Thus, if the field strength is increased, then the drift velocity will decrease; this creates a negative incremental resistance region in V-I relationship. Thus, increase in the voltage will increase the resistance by creating a slice at the cathode and reaches the anode. But, to maintain a constant voltage, a new slice is created at the cathode. Similarly, if the voltage decreases, then the resistance will decrease by extinguishing any existing slice.

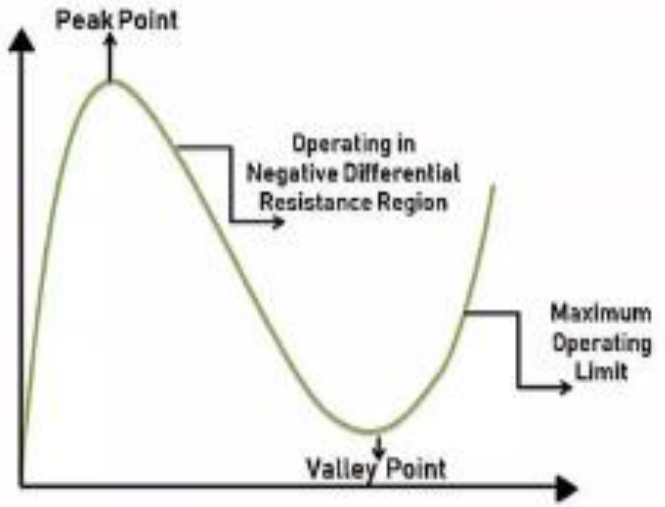


Figure: Characteristics of Gunn Diode

Gunn Diode's Applications

- Used as Gunn oscillators to generate frequencies ranging from 100mW 5GHz to 1W 35GHz outputs. These Gunn oscillators are used for radio communications, military and commercial radar sources.
- Used as sensors for detecting trespassers, to avoid derailment of trains.
- Used as efficient microwave generators with a frequency range of up to hundreds of GHz.
- Used for remote vibration detectors and rotational speed measuring tachometers.
- Used as a microwave current generator (Pulsed Gunn diode generator).
- Used in microwave transmitters to generate microwave radio waves at very low powers.
- Used as fast controlling components in microelectronics such as for the modulation of semiconductor injection lasers.
- Used as sub-millimeter wave applications by multiplying Gunn oscillator frequency with diode frequency.

GUNN DIODE

Definition:

Such type of semiconductor device which have only N type doped (semiconductor) material, is called "Gunn Diode."

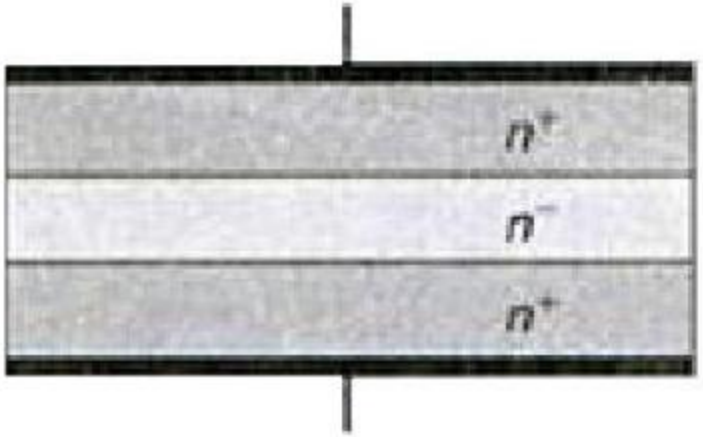
It's a unique component.

Gunn Diode is also known as:

Transferred Electron Device (TED).
Microwave Semiconductor Device.

GUNN DIODE

Symbols for Circuit Diagram:



GUNN DIODE

Construction:

Gunn diodes are fabricated from a single piece of n-type semiconductor,

Source Material:

Tri-methylgallium and arsenic **(10% in H2).**

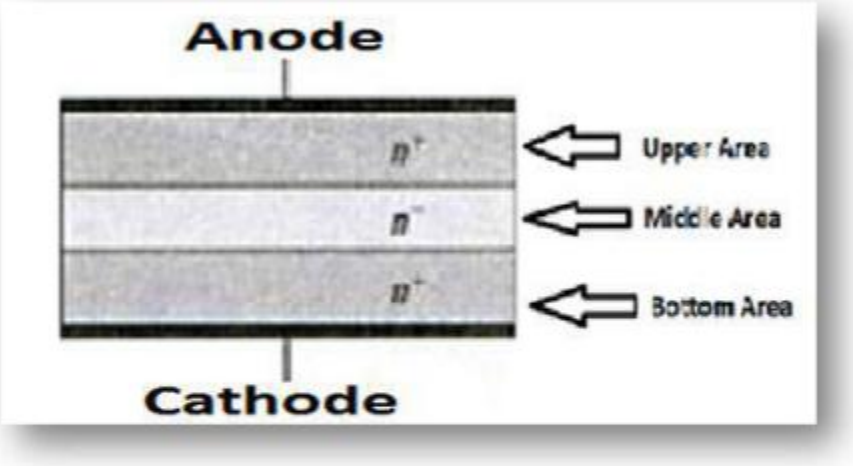
Most Common Materials :

Gallium Arsenide (GaAs)
and Indium Phosphide (InP).

GUNN DIODE

Three main areas:

Top/Upper Area,
Middle Area,
Bottom Area.



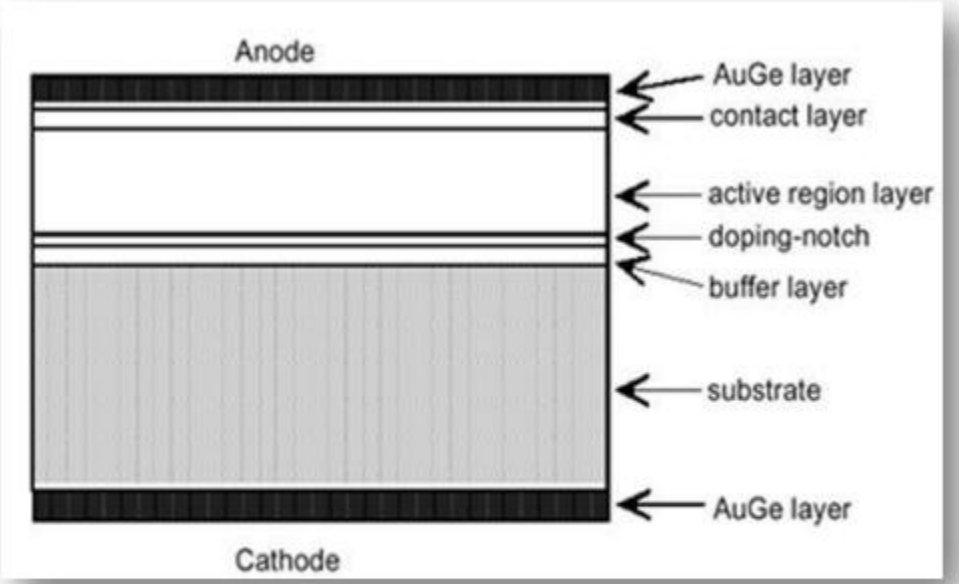
Middle area (Active layer) has a doping level between

10^{14} cm^{-3} to 10^{16} cm^{-3} .

GUNN DIODE

Substrate has doping density

n = 1.3x10 ^18 cm-^{3}.



Thickness varies according to the frequency required.

NEGATIVE RESISTANCE IN GUNN DIODE

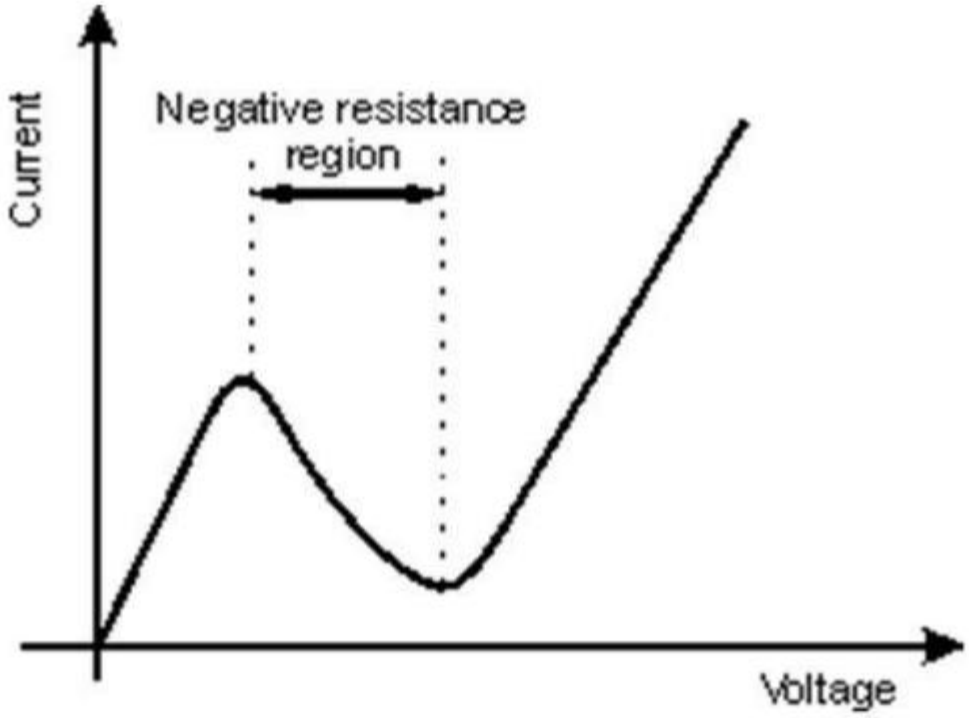
- GaAs (Galliam Arsenide) has a property of negative resistance.
-) The negative resistance in Gunn diode is due to

(a) electron transfer to a less mobile energy level

(b) high reverse bias

(c) electron domain formation at the junction

EFFECT OF NEGATIVE RESISTANCE ON CURRENT



GUNN DIODE

(a)

How electron move into low mobility ?

According to Einstien Equation

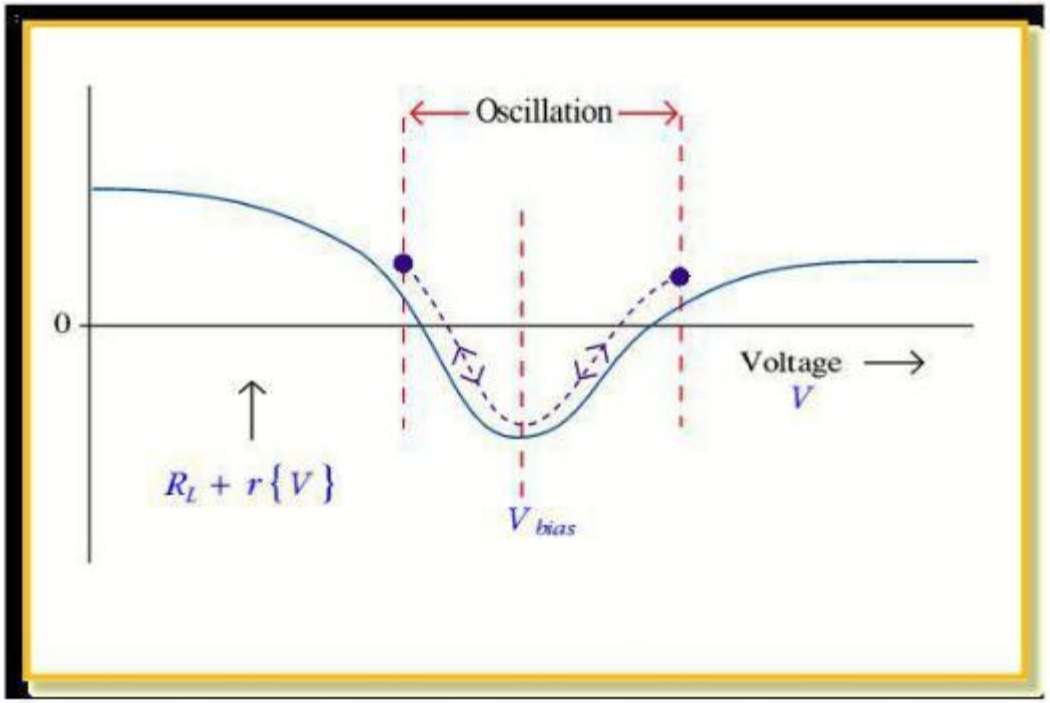
$E=mc^2$

GUNN DIODE

WHEN R < 0

- The oscillation energy tends to be increased.
- According to law of conservation of energy
- The amount of energy at r > 0 = The amount of energy at r < 0

GRAPH BETWEEN RESISTANCE AND VOLTAGE



APPLICATION OF GUNN DIODE

A Gunn diode can be used to amplify signals because of the apparent "negative resistance". Gunn diodes are commonly used as a source of high frequency and high power signals


Thank
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