SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

19ECB311 -OPTICAL AND MICROWAVE ENGINEERING

UNIT 2 – MICROWAVE ACTIVE DEVICES

TOPIC– GUNN DIODE

MICROWAVE SEMICONDUCTOR DEVICES

- Microwave semiconductor devices include Microwave diode, point contact diode, varactor diode, Gunn diode, IMPATT, TRAPATT diode, Tunnel diode, microwave transistor and MMIC.
- At microwave frequencies conventional transistors and diodes do not function as desired due to following reasons:
  - length of the leads introduce significant inductance at microwave frequency.
  - high internal capacitance
  - high transit time of carriers through these device
- Time taken by electron or proton to travel from one node to the other is called transit time. In the case of diode for example from cathode to anode and in transistor from emitter to base or from emitter to collector or from source to drain.

GUNN DIODES

- Gunn diodes generate microwave signals anywhere from around 1 GHz up to frequencies of possibly 100 GHz.
- Gunn diodes are also known as transferred electron devices, TED.
- Although is referred to as a diode, the devices does not possess a PN junction. Instead the device uses an effect known as the Gunn effect (named after the discoverer, J B Gunn).
- Although the Gunn diode is normally used for generating microwave RF signals, the Gunn diode may also be used for an amplifier in what may be known as a transferred electron amplifier or TEA.
- As Gunn diodes are easy to use, they form a relatively low cost method for generating microwave RF signals, often being mounted within a waveguide to form a simple resonant cavity.

GUNN DIODES

- The Gunn diode or transferred electron device can be termed a diode because it has two electrodes.
- It does not contain a PN diode junction.
- Gunn diodes are fabricated from a single piece of n-type semiconductor. The most common materials are gallium Arsenide, GaAs and Indium Phosphide, InP.
- The device is simply an n-type bar with n+ contacts. It is necessary to use n-type material because the transferred electron effect is only applicable to electrons and not holes found in a p-type material.
- The central region is an active region, which is properly doped N-type GaAs and epitaxial layer with a thickness of around 8 to 10 micrometers.

GUNN DIODE CONSTRUCTION

- 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.

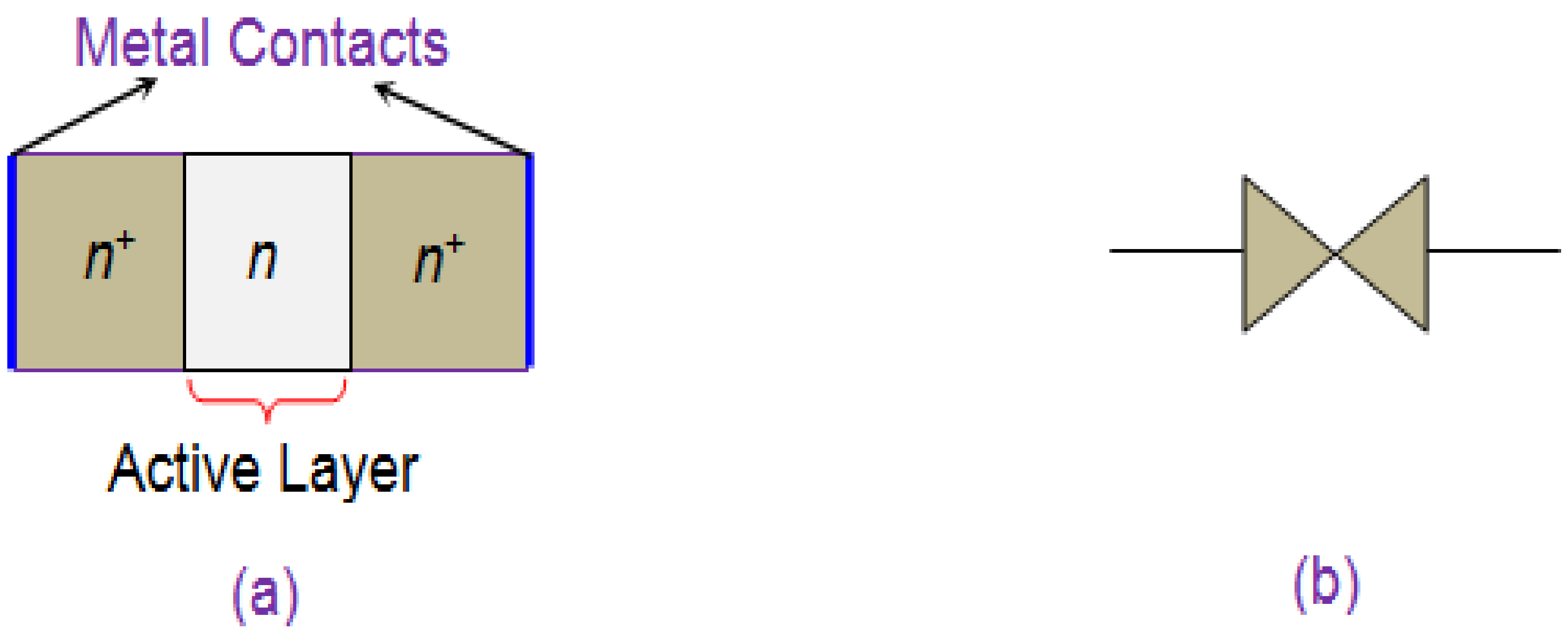
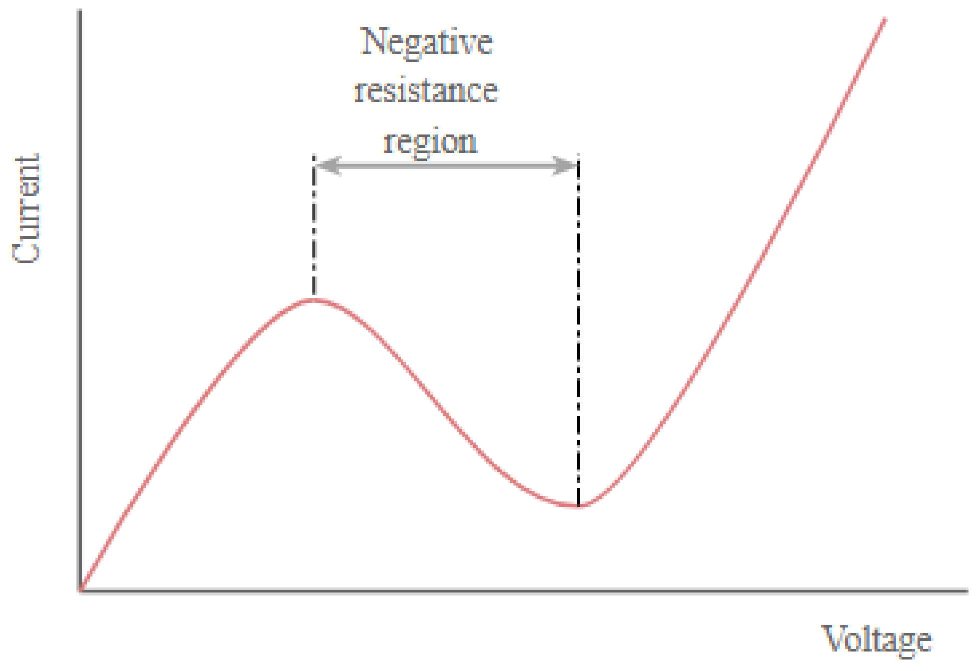


Figure 1 (a) Internal Structure of a Gunn Diode (b) Symbol of Gunn Diode

CHARACTERISTICS OF GUNN DIODE

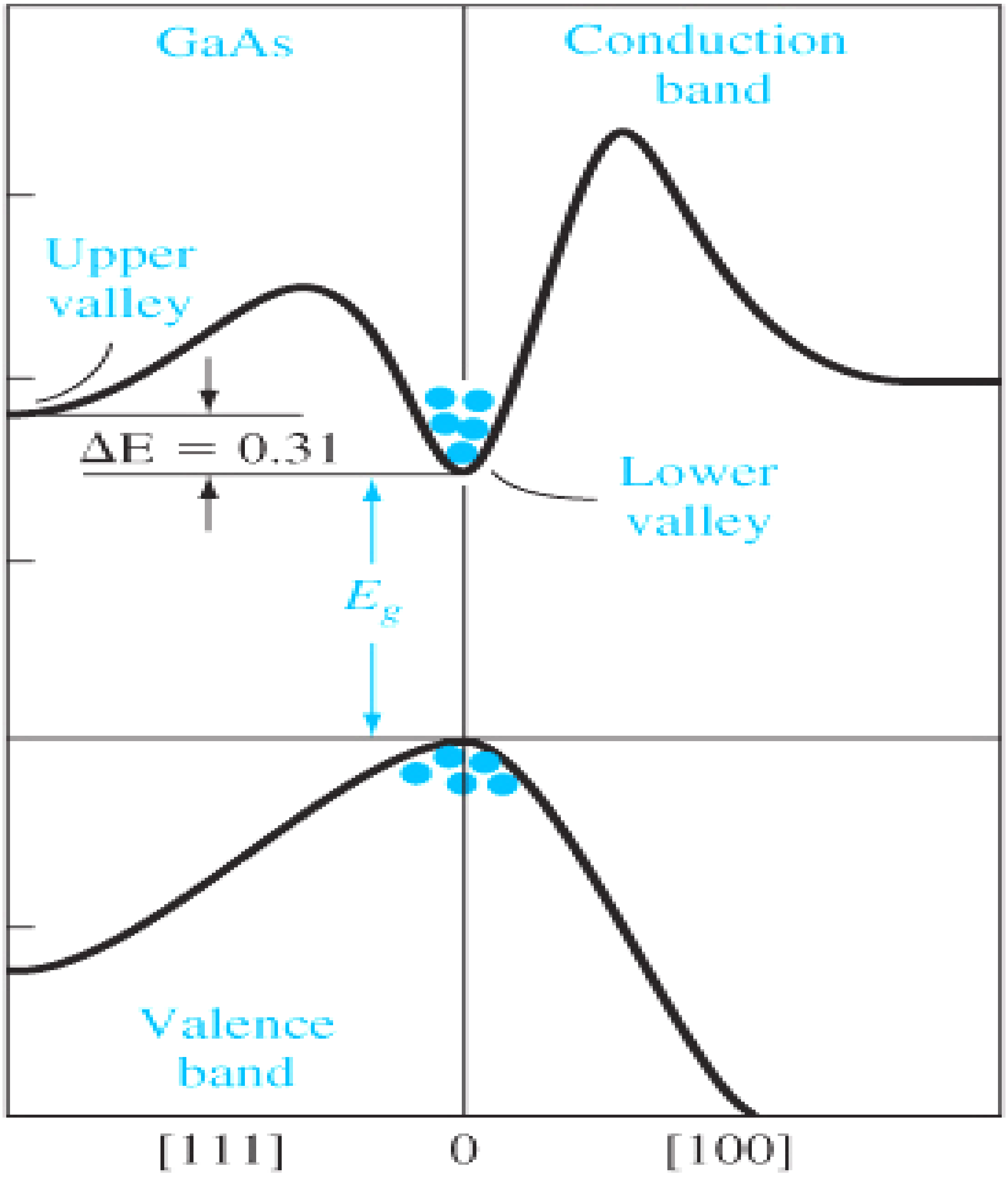
- The Gunn diode operation depends on the fact that it has a voltage controlled negative resistance
- this being dependent upon the fact that when a voltage is placed across the device, most of the voltage appears across the inner active region.
- This inner region is particularly thin and this means that the voltage gradient that exists in this region is exceedingly high.



Gunn diode characteristic

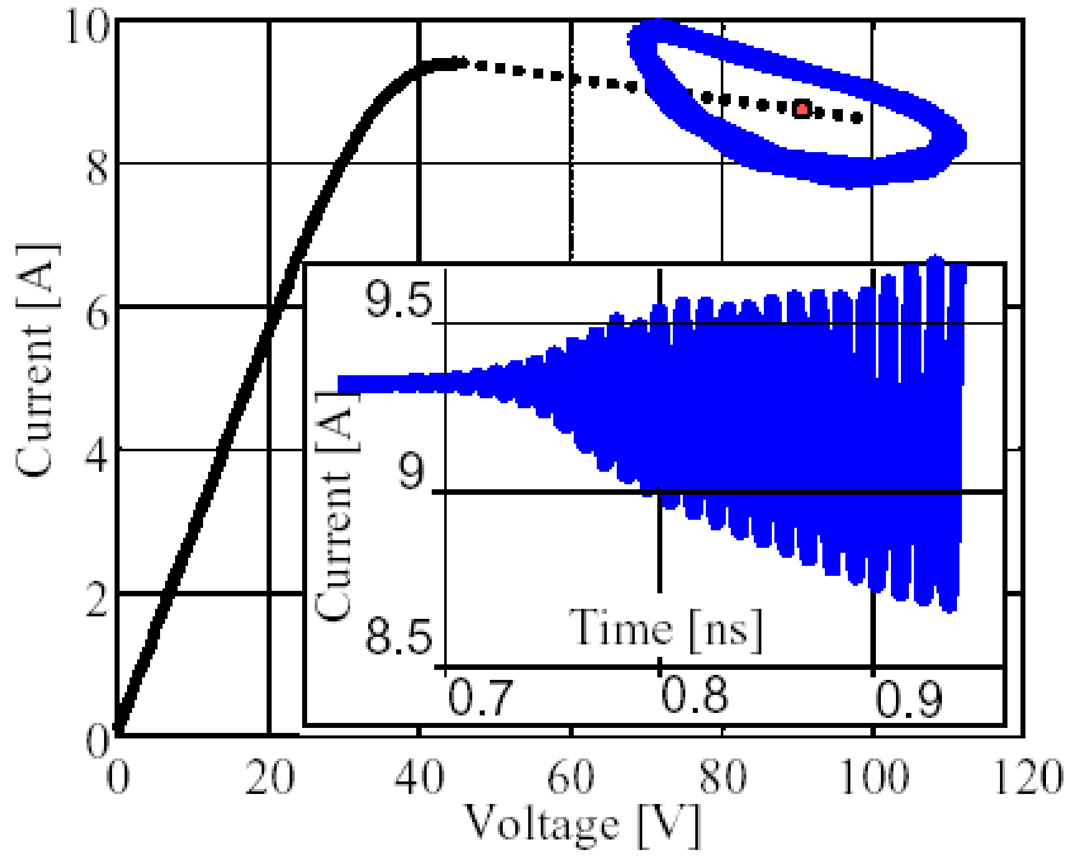
CHARACTERISTICS OF GUNN DIODE

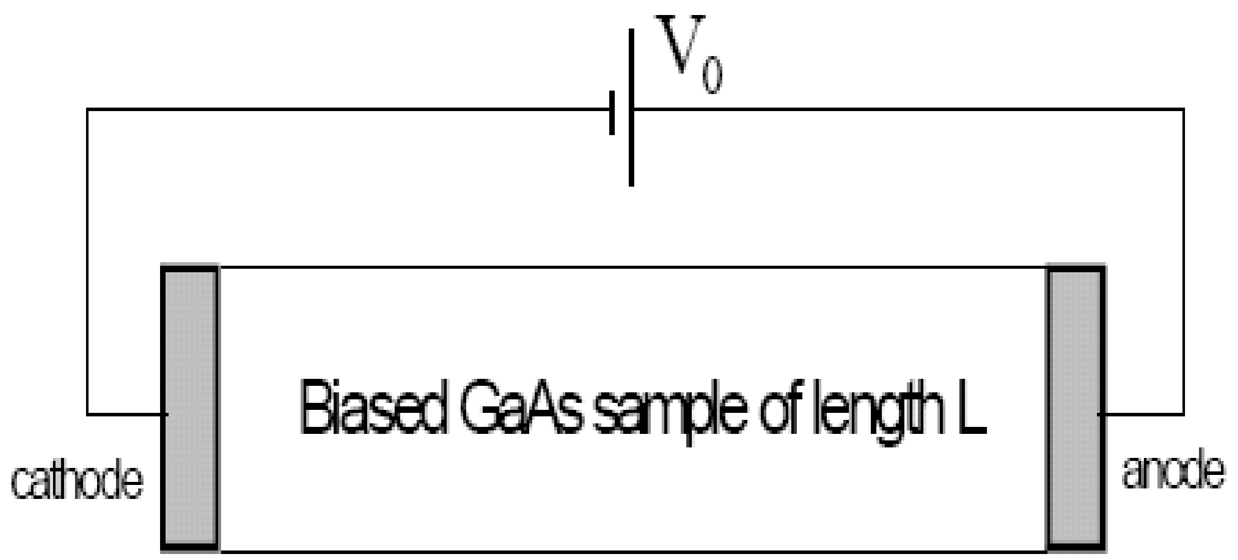
- ➢ The device exhibits a negative resistance region on its V/I curve.
- ➢ This negative resistance area enables the Gunn diode to amplify signals, enabling it to be used in amplifiers and oscillators.
- ➢ However it is the Gunn diode oscillators are the most commonly used
- As the field increases, the electron drift velocity in gallium arsenide ***reaches a peak and then decreases***.
- As the **E**-field increases, the energy of the electron increases & the electron can be **scattered into the upper valley**, where the density of states effective mass is **$0.55\ m_0$**



GUNN EFFECT

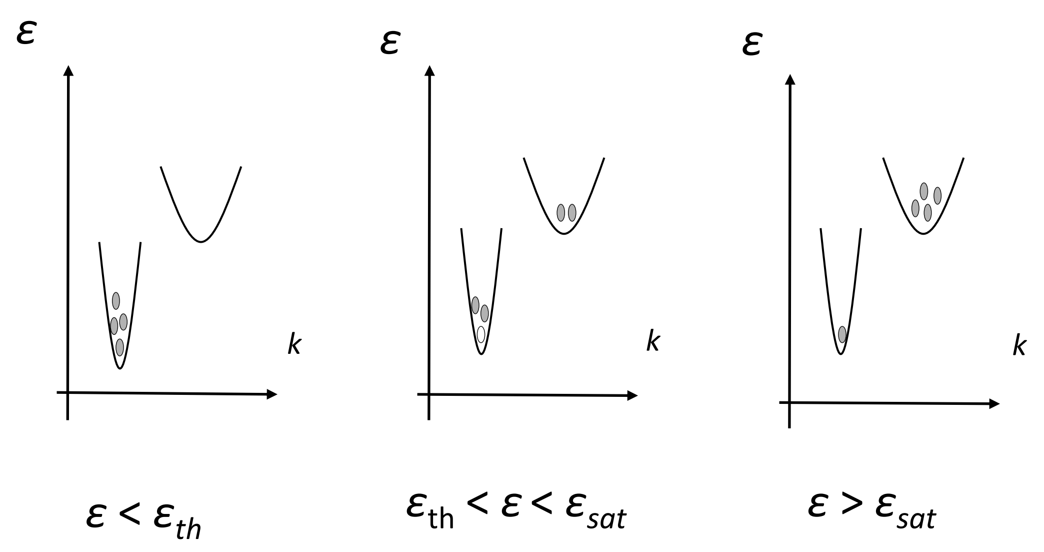
- JB Gunn discovered the Gunn-effect in February 1962. He observed random noise-like oscillations when biasing n-type GaAs samples above a certain threshold. He also found that the resistance of the samples dropped at even higher biasing conditions, indicating a region of negative differential resistance.

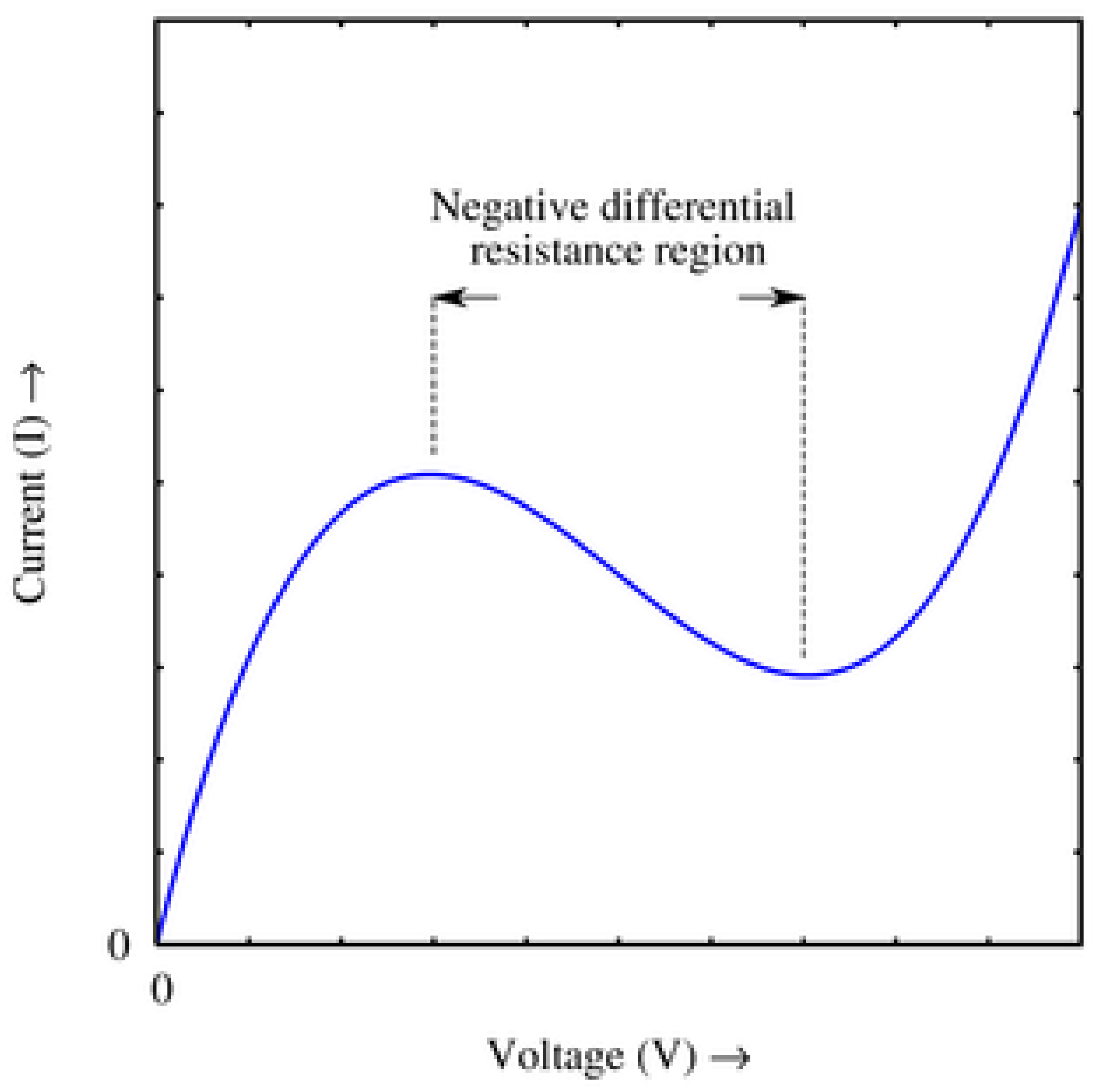




GUNN EFFECT

- Materials which have the Gunn Effect, such as GaAs, InP, GaN, must be direct bandgap materials that have more than one valley in the conduction band & the effective mass & the density of states in the upper valley(s) must be higher than in the main valley.





GUNN EFFECT

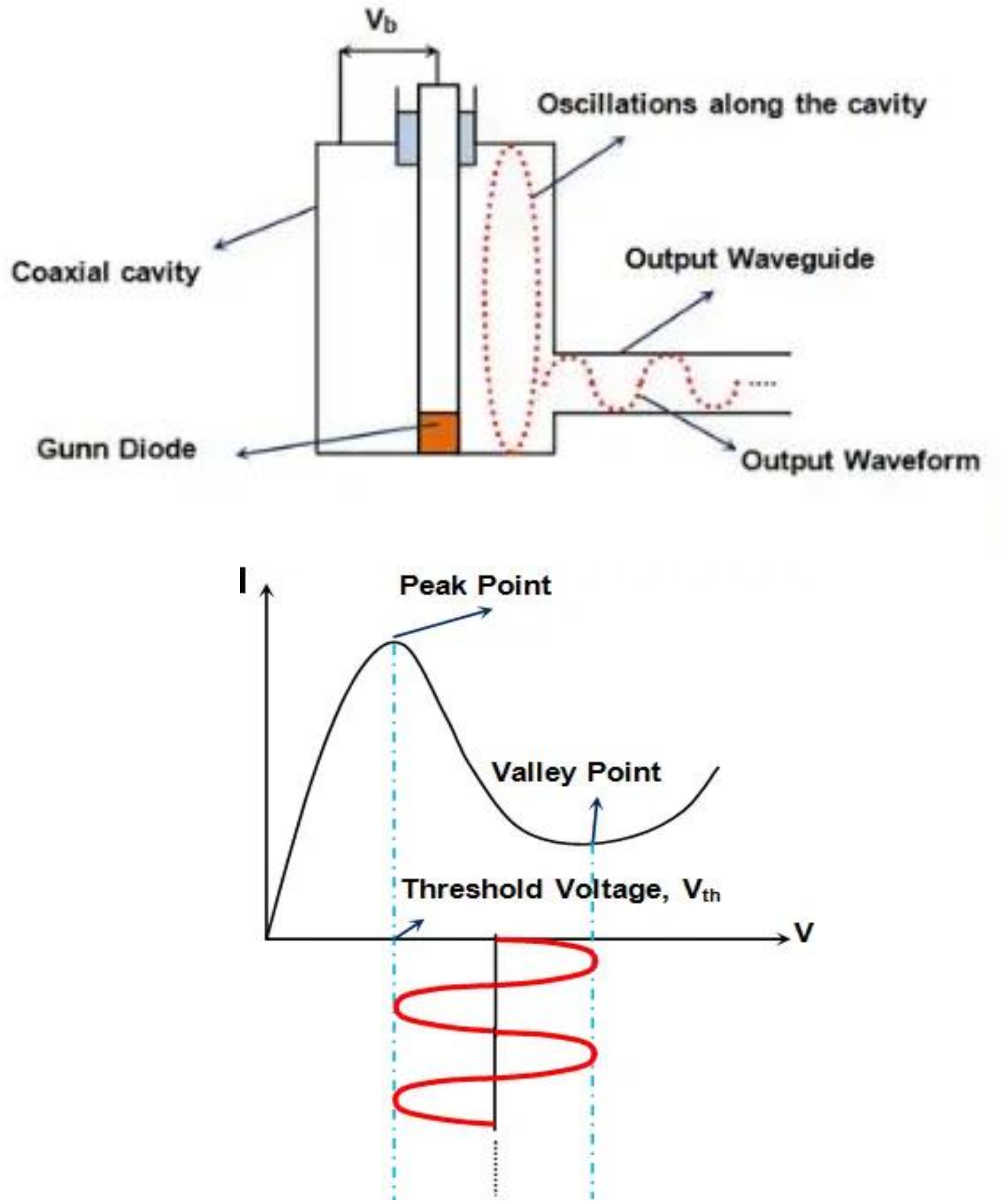
- It is important to note that the sample had to be biased in the NDR region to produce a Gunn-domain.
- Once a domain has formed, the electric field in the rest of the sample falls below the NDR region & will therefore inhibit the formation of a second Gunn-domain.
- As soon as the domain is absorbed by the anode contact region, the average electric field in the sample rises & domain formation can again take place.
- The successive formation & drift of Gunn-domains through the sample leads to ac current oscillations observed at the contacts.
- In this mode of operation, called the Gunn-mode, the frequency of the oscillations is dictated primarily by the distance the domains have to travel before being annihilated at the anode. This is roughly the length of the active region of the sample, L.

GUNN DIODE OSCILLATOR

- In Gunn oscillators, the Gunn diode will be placed in a resonant cavity. A Gunn oscillator is comprised of two major components:
- (i) A DC bias and (ii) A tuning circuit.
- property of the Gunn diode along with its timing properties cause it to behave as an oscillator provided an optimum value of current flows through it. This is because, the negative resistance property of the device nullifies the effect of any real resistance existing in the circuit.
- This results in the generation of sustained oscillations till the DC bias is present while preventing the growth of oscillations. Further, the amplitude of the resultant oscillations will be limited by the limits of the negative resistance region

GUNN DIODE OSCILLATOR

- Tuning Circuit
- In the case of Gunn oscillators, the oscillation frequency primarily depends on the middle active layer of the gunn diode. However the resonant frequency can be tuned externally either by mechanical or by electrical means. In the case of electronic tuning circuit, the control can be brought about by using a waveguide or microwave cavity or varactor diode



APPLICATIONS

- Low power oscillator at microwave frequencies
- Used in Radar transmitters
- Pulsed Gunn diode oscillators in Transponders for air traffic control
- Low and medium power oscillator Microwave receivers
- As Gunn Diodes can be built using semiconductors with very high electron mobility and frequency response, terahertz oscillators have been built using this technology.
- Gallium Arsenide (GaAs) and gallium nitride (GaN) semiconductors are commonly used to make Gunn diodes that operate into the gigahertz to terahertz.
- Gunn diode oscillators are known for being able to produce extremely high energy levels at high frequencies. Hence, their common use in microwave, millimeter-wave, and terahertz systems.

ASSESSMENT

1. GaAs is used in the fabrication of GUNN diodes because:
   a) GaAs is cost effective
   b) It less temperature sensitive
   c) it has low conduction band electrons
   d) less forbidden energy gap

Answer: d

2. When the electric field applied to GaAs specimen is less than the threshold electric field, the current in the material:
   a) increases linearly
   b) decreases linearly
   c) increases exponentially
   d) decreases exponentially

Answer: a

THANK YOU