5.3 Concept of Resonant Tunneling

An interesting phenomena occurs when two barriers of width a separated by a potential well of small distance L as shown in fig. This leads to the concept of resonant tunneling.

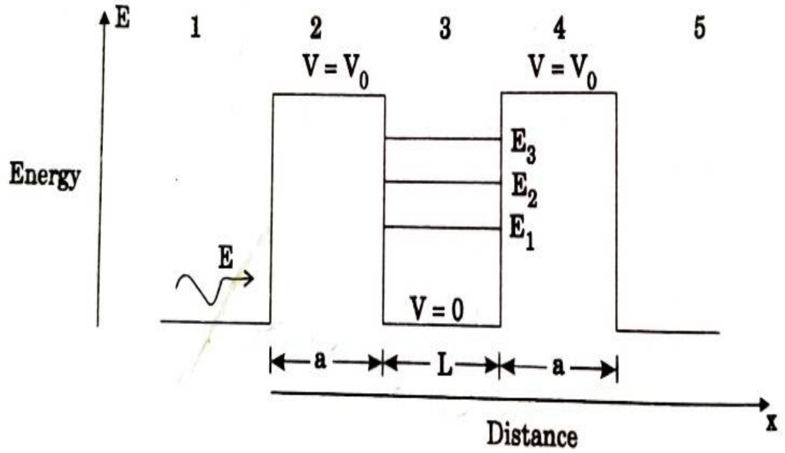


Fig.5.8 Double barrier junction with no applied bias.

The barriers are sufficiently thin to allow tunneling and the well region between the two barriers is also sufficiently narrow to form discrete (quasi-bound) energy levels.

The transmission coefficient of the double symmetric barrier becomes unity.

(ie.,T = 1), when the energy of the incoming electron wave (E) coincides with the energy of one of the discrete states formed by the well.

$$ie, \; E = E_n = \frac{n^2 h^2}{8mL^2}$$

where $n = 1,2,3 \ldots$

Thus, transmission probability of the double symmetric barrier is maximum and hence, the tunneling current reaches peak value when the energy of electron wave is equal to quantized energy state of the well. This phenomenon is known as resonance tunneling.

5.3.1 RESONANT DIODE

- It is a device that has two tunneling junctions. Its I-V characteristic shows negative differential resistance characteristic.

Definition

A resonant tunneling diode (RTD) is a diode with resonant tunneling structure. The electrons can tunnel through some resonant states at certain energy levels.

Principle

When electron (wave) incident with energy equal to energy level of a potential well of thin barrier, then the tunneling reaches its maximum value. This is known as resonant tunneling.

Structure of RTD

A typical resonant tunneling diode structure is made by using n-type GaAs for the regions to the left and right of both barriers (regions 1 and 5).

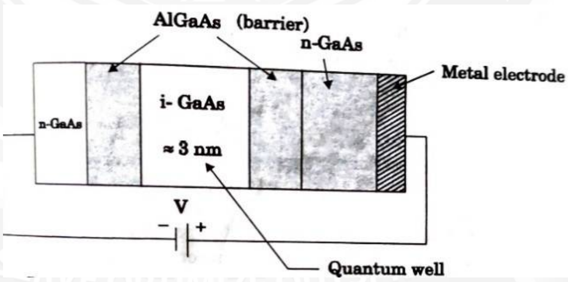


Fig.5.9 Structure of Resonant Tunnel Diode

The intrinsic GaAs is for the well region (region 3) and Al GaAs or Al As for the barrier material (regions 2 and 4). Tunneling is controlled by applying a bias voltage across the device.

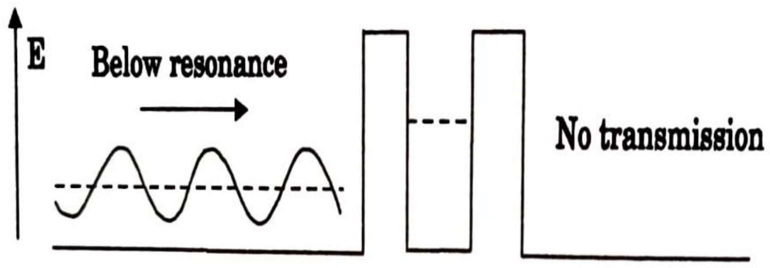
Working

Tunneling control

Tunneling is controlled by applying a bias voltage across the device.

Without applied bias

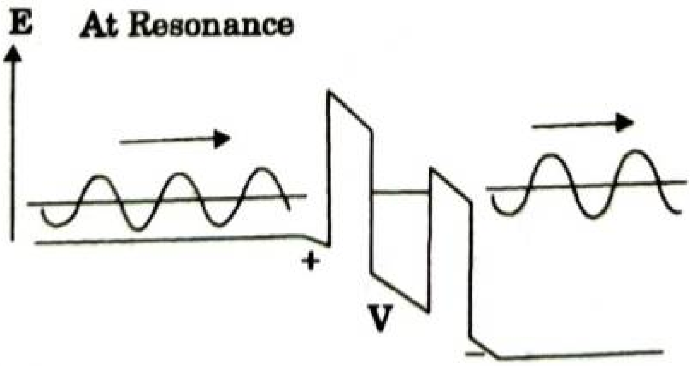
For the case of no applied bias, the energy band diagram is shown in fig. 7.15(a).



Practically it is very difficult to control the barrier height as well as the width of the potential well to match with the energy of the electron. This energy matching and hence resonant tunneling could be achieved by biasing the potential barriers.

With applied bias

When voltage is applied, the band diagram shifts and if the voltage is varied until the quantized discrete energy level corresponding to the potential well matches with the energy of the electron wave, resonant tunneling occurs.



Current - Energy characteristic for a resonant tunneling diode

When the incident electron energy E is very different from the energy of a discrete state E_n, transmission is low. As E tends to E_n, transmission will increase, becoming a maximum when $E = E_n$.

As E increases, tunneling will increase, reaching a peak when $E = E_1$. After that point, a further increase in E will result in a decreasing current, as shown in

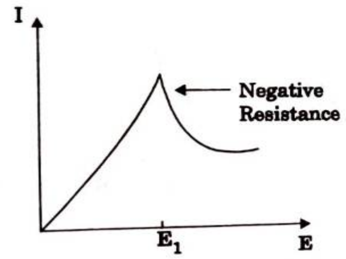


Fig.5.10 Current- energy characteristic for a resonant tunneling junction.

This decrease of current with an increase of bias is called negative resistance. Further peaks and valleys will occur as E approaches, and then moves across other discrete energy states.

Application and uses of Resonant Tunneling Diodes (RTD)

- One area or active application is building oscillators and switching devices that operate at tera hertz frequencies.
- RTDs are very good rectifiers.
- They are used in digital logic circuits.
- They also used in inverters, memory cells and transistors.

Advantages

- Resonant Tunneling diodes are very compact.
- They are capable of ultra-high-speed operations because the quantum tunneling effect through the very thin layers is a very fast process.