GUNN DIODE

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Gunn diode:- The microwave devices that operates with transferred electron mechanism are often known as gunn diode.
J.B ~~Gunn~~ Gunn who in 1963 discovered that when a high electric field is applied to n-type GaAs, there is a periodic fluctuations in the current when it exceeds a certain critical value (2-4 kV/cms). this effect is known as gunn effect or bulk transferred electron effect. The other materials (semiconductor) that exhibit this property are indium phosphide (InP), ~~~~ cadmium tellurride and indium arsenide (InAs).
The below figure shows the energy band diagram of GaAs.

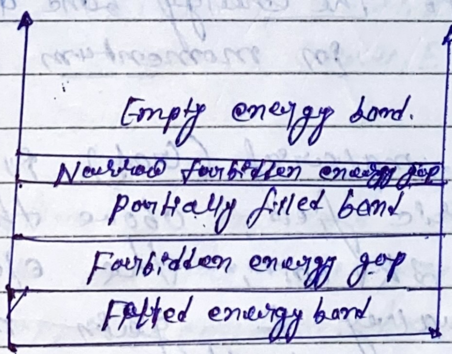

Fig: Energy band diagram of GaAs showing important energy bands.

The curvature of 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 U valley m_2 (1.2 m_0). The different effective mass means different mobilities for the L-valley.

and the U-valley respectively. The ratio of density of states in the U-valley to that in the L-valley is about 60. Then the upper valley has a very high density of states compared with lower as shown below.

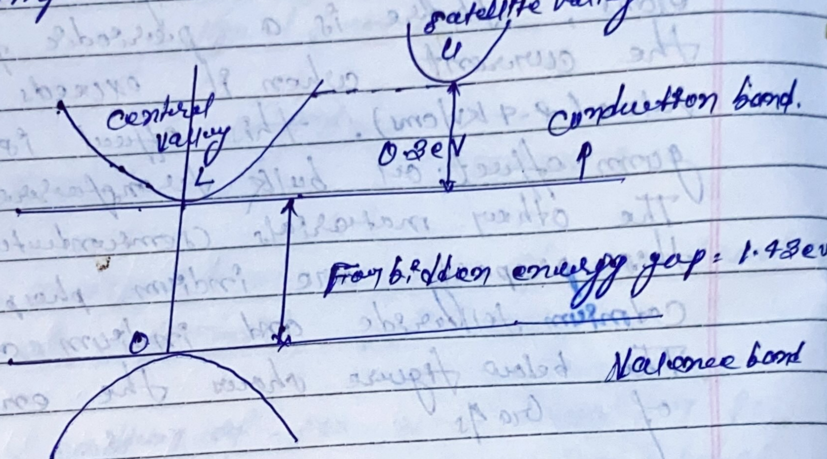

Fig: The energy band diagram of GaAs in momentum space.

When the material (GaAs) is subjected to a high electric field, above the critical value of about 3KV cm⁻¹, the electrons in the lower valley L gain more energy than 0.3eV and this pass to the satellite valley at U. These electrons remain in the higher energy so long as the applied field is greater than the critical value.

Since the density of states in the satellite valley is much higher than in the central valley, therefore, the electrons scattering takes place from satellite to central valley.

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On further increasing the field, the electron instead of moving faster, actually slow down due to very low mobilities in the satellite valley, resulting the current falls and device exhibit negative resistance.

Let n_1 and μ_1 be the density of electrons and their mobility in the lower central valley. and
n_2 and μ_2 are the respective values in the upper satellite valley.

At low temperature,
The density (current).

$$J = \sigma E$$
$$= e n_1 \mu_1 E$$
$$= e n_0 \mu_1 E \quad [\because \sigma = e n_1 \mu_1]$$

also
$[n_1 = n_0]$

When the field is increased above the critical value, almost all the electrons get transferred to the upper conduction band (satellite valley) by acquiring a high velocity, and hence energy. These energetic electron are referred to as hot electrons. Once an electron gets transferred to the satellite valley its mobility decreases but its effective mass ~~decreases~~ increases, resulting in decreased current density resulting the device they offer negative resistance.

During the electron transfer process, the current density is given by

$$J = \sigma E$$
$$= e n_1 \mu_1 E + e n_2 \mu_2 E$$
$$= eE(n_1\mu_1 + \mu_2 n_2)$$

put $\bar{\mu} = \dfrac{n_1\mu_1 + n_2\mu_2}{n_0}$ is the average mobility of the electron in the two valleys.

$$= eE n_0 \bar{\mu} \quad \text{—— (2)}$$

At sufficient high field, almost all electrons get transferred to satellite valley from C valley and then current density of the electron in the satellite valley.

$$J = \sigma E$$
$$= e n_2 \mu_2 E \quad \text{—— (3)}$$

The below figure shows the variation of current density with electric field.

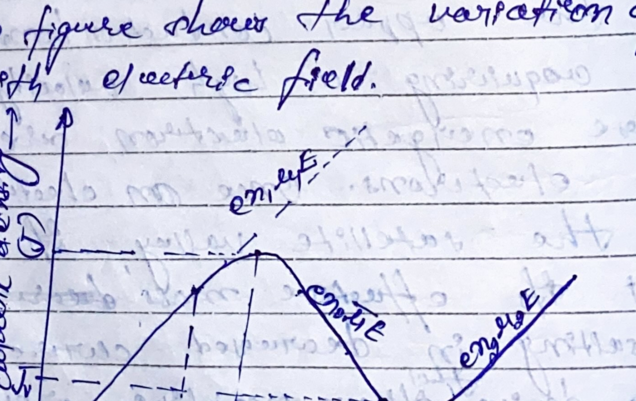

Fig: Variation of current density with electric field

It also show the variation of current w.r.to voltage
The region between E_m and E_V is ~~one of~~ the -ve resistance region. i.e current in this region decreases with applied potential. This effect is first observed by Watkins and by Hilsum for a GaAs based Gunn diode.