* Current flow mechanisms through the Schottky barrier :-

Reference!

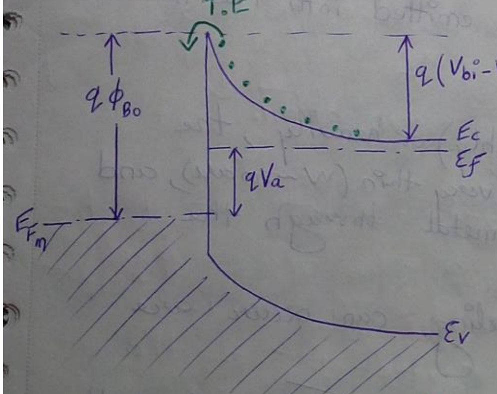

fig 8a) Thermionic emission

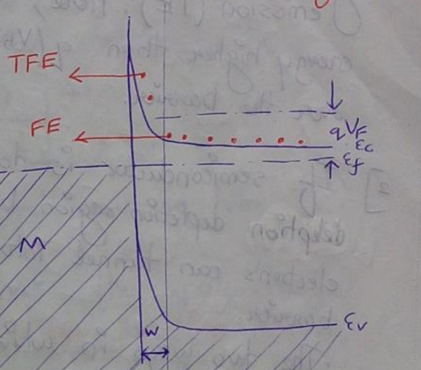

fig 8b) Tunneling mechanism

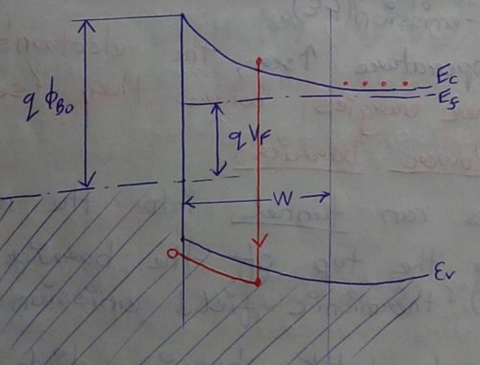

fig 8c) Electron-Hole pair (EHP) recombination in depletion region.

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fig 8: EBD showing different current transport processes in metal-n type semiconductor Schottky barrier diode

Reference!

1] Fig 8a), illustrates the process of Thermionic emission (TE). Here, an electron that has energy higher than $q(V_{bi}-V_a)$ is emitted into the metal over the barrier.

2] If semiconductor is doped (highly) or heavily, the depletion region becomes very thin (W-small), and electron's can tunnel into the metal through the barrier.

· The two ways in which tunneling can occur are shown in fig 8c).

a) At low temperature, electrons near fermi-level in the semiconductor can tunnel into the metal. This process is known as field-emission (FE).

b) As the temperature ↑ses, the electron's are excited to higher energies where they 'see' a thinner and lower barrier.

These electrons can tunnel into the metal before reaching the top of the barrier. This is known as 'thermionic field emission (TFE).

3] In a forward schottky barrier diode, electrons are injected into the depletion region from the neutral semiconductor and holes are injected from the metal. These EHP recombine in the depletion region to cause a forward current fig (8c).

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* Tunneling Current: (Refer fig 8b) / Tunneling Barrier:-

- Space-charge width (W) for a metal-ntype SC,

$$W = x_n = \left[\frac{2\varepsilon_s (V_{bi} + V_a)}{q N_d} \right]^{1/2} \quad — (1)$$

where, Va represents the applied reverse bias.

From expression (1), it is clear that the space-charge width (W) of a metal-semiconductor junction is inversely proportional to the square-root of the semiconductor doping level (Nd).

- When the semiconductor doping level (Nd) ↑ses, the space-charge width (W) ↓ses.
- For a sufficiently heavily doped semiconductor, tunnelling current becomes the dominant carrier transport process.

→ Tunneling current J_t can be expressed as,

$$J_t \propto \exp\left(-\frac{q\phi_{Bn}}{E_{00}}\right) \quad — (2)$$

where the parameter E_{00} is given by,

$$E_{00} = \frac{q\hbar}{2}\sqrt{\frac{N_d}{\epsilon_s m_n^*}}$$

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Thus, tunneling current can be seen to ↑se exponentially with the semiconductor doping concentration.

→ The dominance of tunnelling current at high-doping levels is of extremely high significance for semiconductor devices.

Reference!

- Nearly all semiconductor devices require metal contacts and almost everywhere the need is to have as small a voltage drop across the contact region as possible.
- Putting metal contacts on heavily doped semiconductors then offers an important route to provide contacts for accessing the semiconductor device.

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* Schottky barrier I-V Characteristics:-

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a] Forward characteristics:

- Schottky barrier diodes have been made on a number of semiconductors and most of the devices follow the I-V relation of the form,

$$I = I_s \left[\exp\left(\frac{qV_a}{\eta KT}\right) - 1 \right]$$

where, η is ideality factor

- For an ideal schottky barrier diode, $\eta = 1$.

→ Factors that make η to exceed unity are
1) The bias dependence of barrier height.
2) The tunneling of electrons through the barrier.
and 3) EHP recombination in depletion region.

- Tunneling occurs for concentration in excess of doping concentration $> 10^{17}/cm^3$.

b] Reverse characteristics:-

- According to thermionic emission theory, the reverse current of a Schottky barrier diode should saturate to a value I_s given by,

$$I_S = A^{*} T^2 \exp\left(\frac{-q\phi_B}{KT}\right)$$

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- In actual schottky barrier diode, reverse current is always found to ↑se with the bias.

→ Most common cause of an ↑se in current is the ↓se in barrier height with an ↑se in reverse-bias.

$$\text{ie } I_S = A^{*} T^2 \exp\left(-\frac{q(\phi_{B_0} - \Delta\phi_B)}{KT}\right)$$

∴ As $\exp\left(\frac{\Delta\phi_B q}{KT}\right)$ ↓ses, I_S ↑ses.

- Primary cause of barrier lowering is the image force on the electron emitted from the metal into the semiconductor.

- Other mechanism's that cause I_S to ↑se are
  a) Tunneling of electron's from metal into the semiconductor.
  b) EHP recombination in depletion region.

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