Fundamentals of Nanoelectronics

ECE495 - Session 28, Nov 2, 2009

Session 28 –Ballistic Regime Conductance

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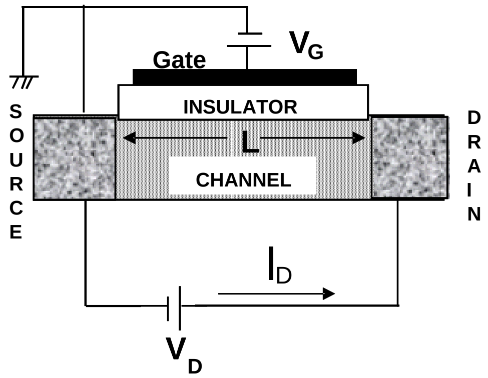
Review



Ballistic: means like a bullet an electron enters and directly goes out.

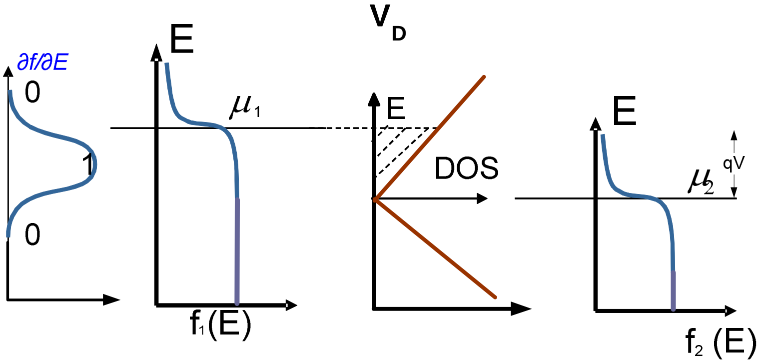
$R = \rho \frac{L}{A}$ Ohm's law

$R = \rho \frac{(L+\lambda)}{A}$ Ballistic regime

$$G_B = \frac{I}{V} \cong \underbrace{\frac{2q^2}{h}}_{\frac{1}{12.9\,k\Omega} \approx 80\mu\mho} \int dE M(E)\left(-\frac{\partial f}{\partial E}\right)$$

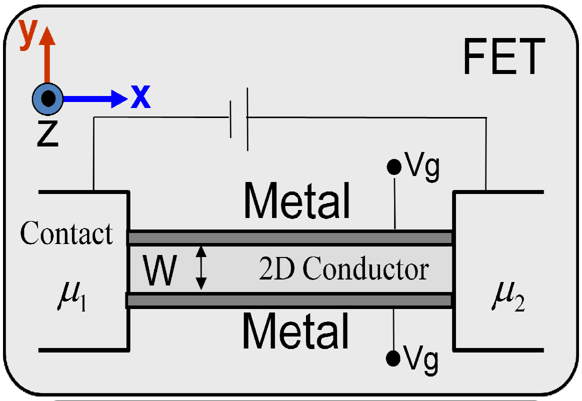
$$= 2\frac{q^2}{h}\overline{M}\int dE\left(-\frac{\partial f}{\partial E}\right)$$

$$\Rightarrow G_B = 2\frac{q^2}{h}\overline{M}$$



For very small devices $M = \pi D \gamma$

Minimum Resistance of a FET



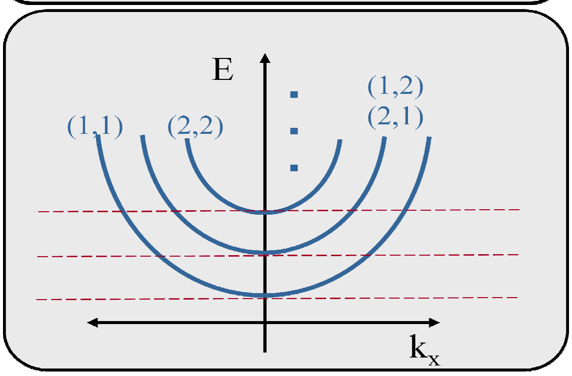
Let's now think about a 2D conductor:

What is the minimum resistance of this device?

Let Lz to be very small. So

$\varepsilon(k_x, k_y) = E_C + h^2/2m_C\,(k_x^2 + k_y^2)$ and $k_y = \frac{\pi}{L_y}\upsilon_y$

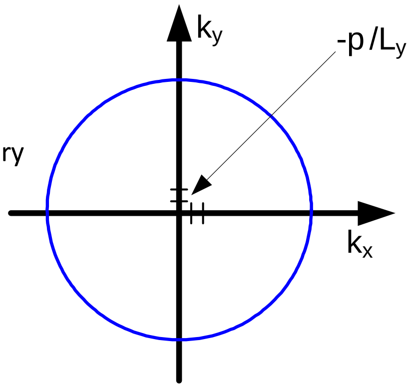
We want to the number of sub bands "M" for a given μ.



If we draw E-k diagram it would be as below. If L_y be bigger, then, these curves would be closer and number of modes (M) will increase.

$$M(E) = \sum_{k_y}\sum_{k_x}\delta(E-\varepsilon(\vec{k}))\frac{\pi\hbar v_z}{L} = \sum_{k_y} 2\int_0^{\infty}\frac{dk_x L}{2\pi}\delta\left(E-\varepsilon(\vec{k})\right)\frac{\pi\hbar v}{L} = \sum_{k_y}\theta(E-\varepsilon_y)$$

$$E - E_c = \frac{\hbar^2}{2m}k^2$$



L_y=W then $M = \frac{2k}{2\pi/W} = \frac{kW}{\pi}$

There is no difference between periodic or box boundary conditions.

$$N = \frac{\pi k^2}{2\frac{\pi}{L}\times 2\frac{\pi}{W}}$$

$$n_s = \frac{N}{LW} = \frac{k^2}{4\pi} \Rightarrow k^2 = 4\pi n_s$$

$$\Rightarrow \mathrm{G_B} = 2\frac{q^2}{h}\ \underbrace{\frac{kW}{\pi}}_{\sqrt{2\pi n_s}\frac{W}{\pi}}$$