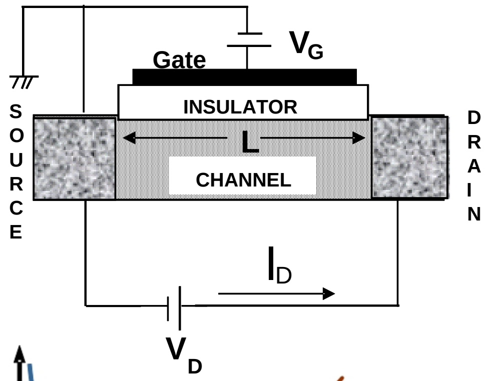
Fundamentals of Nanoelectronics

ECE495 - Session 29, Nov 4, 2009

Session 29 -Resistivity

Professor Supriyo Datta

Class notes taken by: Mehdi Salmani



Review

$M(E) \longrightarrow G_B$

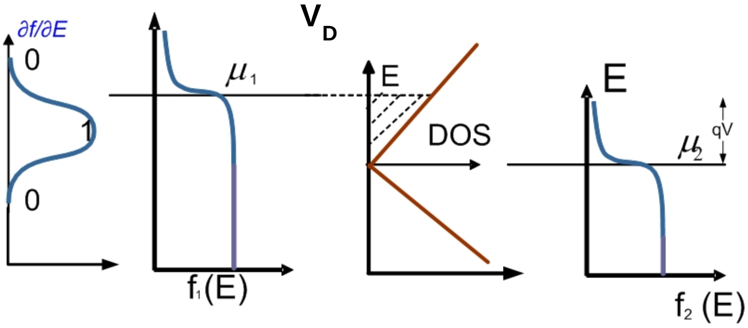
$D(E) \longrightarrow C_Q$

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

$$\bar{M} = \int dE M(E)\left(-\frac{\partial f}{\partial E}\right)$$

$$G = 2\frac{q^2}{h}\bar{M}\frac{\lambda}{L+\lambda} \qquad (I)$$

This is general answer for conductance. λ is mean free path (mfp). For long distance (L>> λ) λ from the denominator will be dropped.



$$G = 2\frac{q^2}{h}\frac{\bar{M}/A}{W/A}\lambda\frac{W}{L} \qquad (II)$$

For large devices

$$G = 2\frac{q^2}{h}\bar{M} \qquad (III)$$

For very small devices (λ>>L)

Based on (I) $R = \underbrace{\frac{h}{2q^2}}_{12.9k\Omega}\frac{1}{\left(\bar{M}/W\right)}\underbrace{\left(\frac{L+\lambda}{L\lambda}\right)}_{\frac{1}{L}+\frac{1}{\lambda}}\frac{L}{W}$

For long devices: $R = \underbrace{\frac{h}{2q^2}\frac{1}{\left(\bar{M}/A\right)}\left(\frac{1}{\lambda}\right)}_{\rho:\ resistivity}\frac{L}{A}$

ρ: for Cupper(Cu) and Silicon(Si):

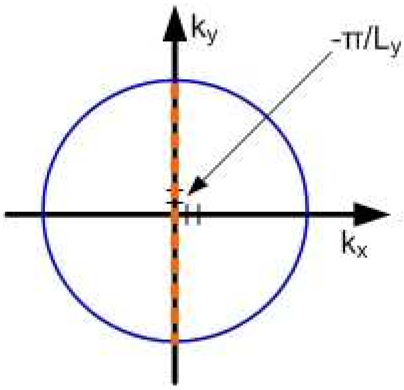
Cu: ρ=0.2 μΩ-cm λ=400Å

Si ($10^{18}/cm^2$): ρ=0.02 Ω-cm

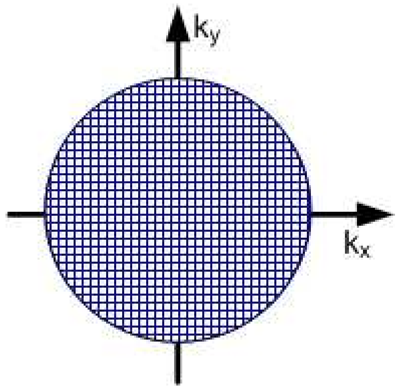
$$\rho = \frac{h}{2q^2}\frac{1}{\left(\bar{M}/_A\right)}\left(\frac{1}{\lambda}\right) \Rightarrow \frac{\bar{M}}{A} = \frac{\frac{h}{2q^2}}{\rho\lambda} \approx \frac{12.9\times 10^3\Omega}{0.2\times 10^{-6}\Omega\text{cm}\times 400\times 10^{-8}\text{cm}} \approx 10^{16}/cm^2 = \frac{1}{(10^{-8}cm)^2}$$

Modes for 2 and 3 Dimensional

$E = \varepsilon(k) = \frac{\hbar^2}{2m}k^2$ $\qquad\qquad$ $\varepsilon(k) = \pm atk \ \ for\ graphene$



$$M = \frac{k}{\pi/W} = \frac{kW}{\pi} \quad \text{for 2-D}$$



$$M = \frac{\pi k^2}{\frac{\pi}{W}\frac{\pi}{t}} = \frac{k^2 A}{\pi} \quad \text{for 3-D}$$

$e^{ikx}e^{-iEt/\hbar} \Rightarrow M_{2D} = \frac{2\pi}{\lambda_{DB}}\frac{W}{\pi} = \frac{W}{\left(\lambda_{DB}/_2\right)}$ k is wavenumber and $k = \frac{2\pi}{\lambda_{DB}}$where λ_{DB} is weave length.

$$M_{3D} = \frac{4\pi^2}{(\lambda_{DB})^2}\frac{A}{\pi} = \pi\frac{A}{\left(\lambda_{DB}/_2\right)^2}$$