Fundamentals of Nanoelectronics

ECE495 - Session 25, Oct 26, 2009

Modes

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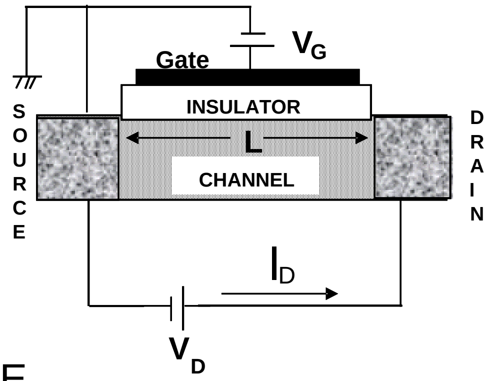
Review



$$h(\vec{k}) = \sum_m [H_{nm}] e^{i\vec{k}(\vec{d}_m - \vec{d}_n)}$$

$$D(E) = \sum_{\vec{k}} \delta(E - \varepsilon(\vec{k}))$$

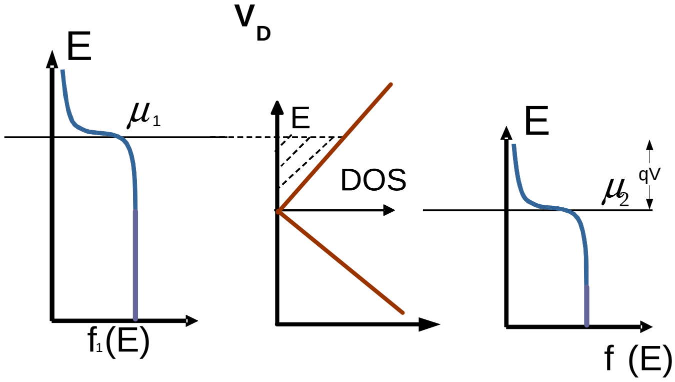
$$M(E) = \sum_{\vec{k}} \delta(E - \varepsilon(\vec{k})) \underbrace{\frac{\pi\hbar v_z}{L}}_{\pi D\gamma}$$

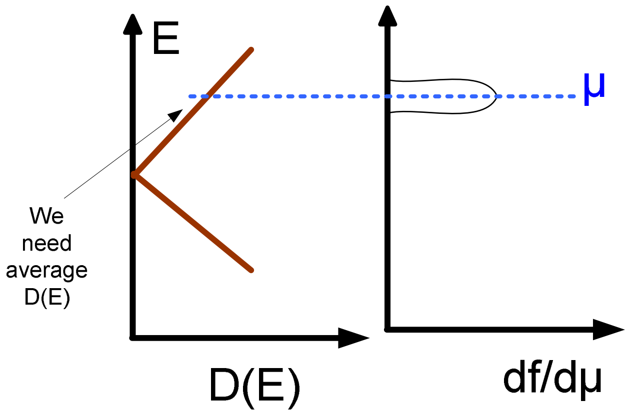
$$N = \int dED(E)f(E)$$

$$I = \frac{q}{h}\int dEM(E)\big(f_1(E) - f_2(E)\big)$$

$$\approx \frac{q}{h}\int dEM(E)\frac{\partial f}{\partial \mu}\underbrace{(\mu_1 - \mu_2)}_{qV} \qquad (I)$$

$$\Rightarrow \frac{\partial N}{\partial \mu} = \int dED(E)\left(\frac{\partial f}{\partial \mu}\right) = \int dED(E)\left(-\frac{\partial f}{\partial E}\right)$$





$\frac{\gamma}{\hbar}$ is very important for very small devices but for large devices $\frac{\gamma}{\hbar} \propto \frac{v_z}{L}$.

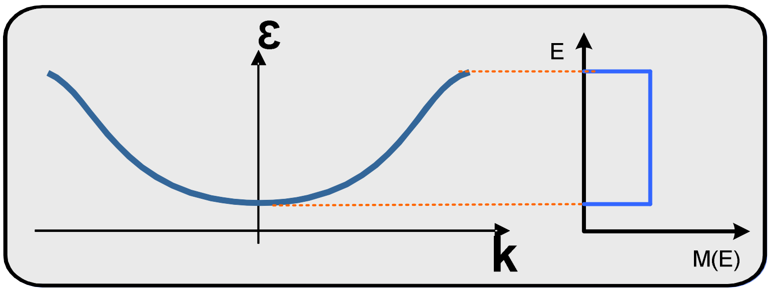
D(E) is related to capacitance and M(E) is related to conductance.

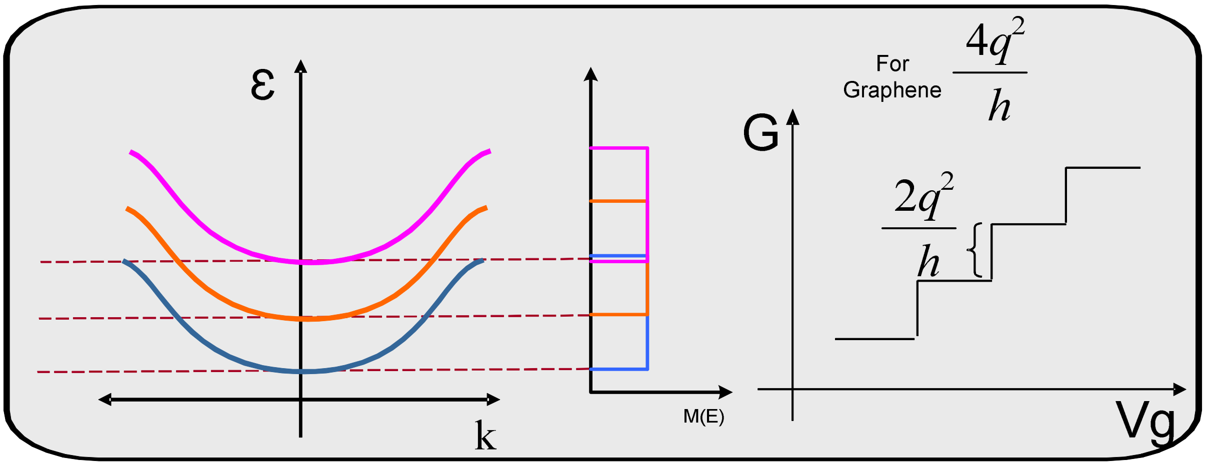
$$(I) \;\Rightarrow\; G = \frac{I}{V} \cong \underbrace{\frac{q^2}{h}}_{\approx 40\mu\mho}\int dEM(E)\left(-\frac{\partial f}{\partial E}\right) = \frac{q^2}{h}\int dE\,\frac{hD(E)v_z}{2L}\left(-\frac{\partial f}{\partial E}\right)$$

For one dimensional device

$$M(E) = \sum_{\vec{k}} \delta(E - \varepsilon(\vec{k})) \frac{\pi\hbar v_z}{L} = 2\int_0^{\infty} \frac{dkL}{2\pi} \delta\left(E - \varepsilon(\vec{k})\right) \frac{\pi\hbar v}{L} \quad and \quad \hbar v = \frac{d\varepsilon}{dk}$$

$$M(E) = \int_0^{\infty} d\varepsilon\, \delta\left(E - \varepsilon(\vec{k})\right) = 1 \Rightarrow G = \frac{q^2}{h}$$





$$\varepsilon(k_y, k_z) \Rightarrow \varepsilon_v = (k_z) \quad where \quad k_y = v\frac{2\pi}{W}$$

$$\Rightarrow M(E) = \sum_{k_x k_y} \sum_{k_z} \delta(E - \varepsilon_{xy} - \varepsilon_z) \frac{\pi\hbar |v_z|}{L}$$