Fundamentals of Nanoelectronics

ECE495 - Session 6, Sept 4, 2009

I-V characteristics II

Ref: Chapters 1.3 and 1.4

Professor Supriyo Datta

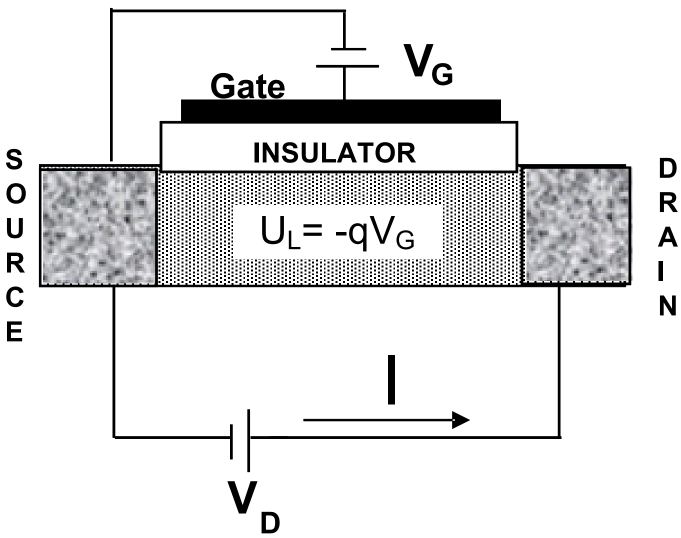
Class notes taken by: Mehdi Salmani

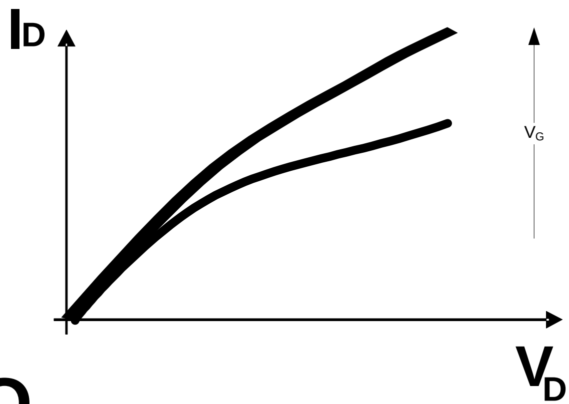
Review

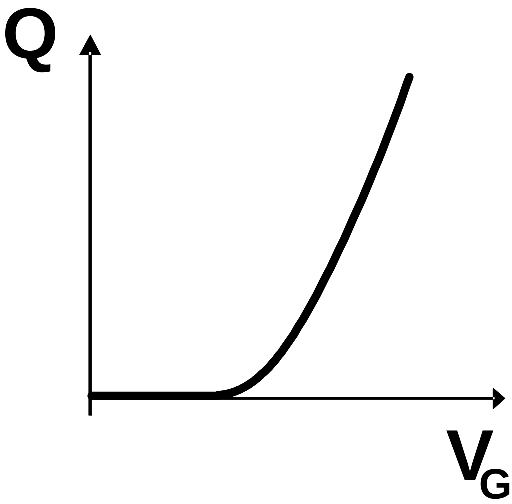
$$I = \int \frac{q}{\hbar} dE D(E-U) \frac{\gamma}{2} (f_1(E) - f_2(E)) \quad (I)$$

$$N = \int dE D(E-U) \frac{f_1(E) + f_2(E)}{2} \quad (II)$$

$$U = U_L + U_0 (N - N_0) \quad (III)$$





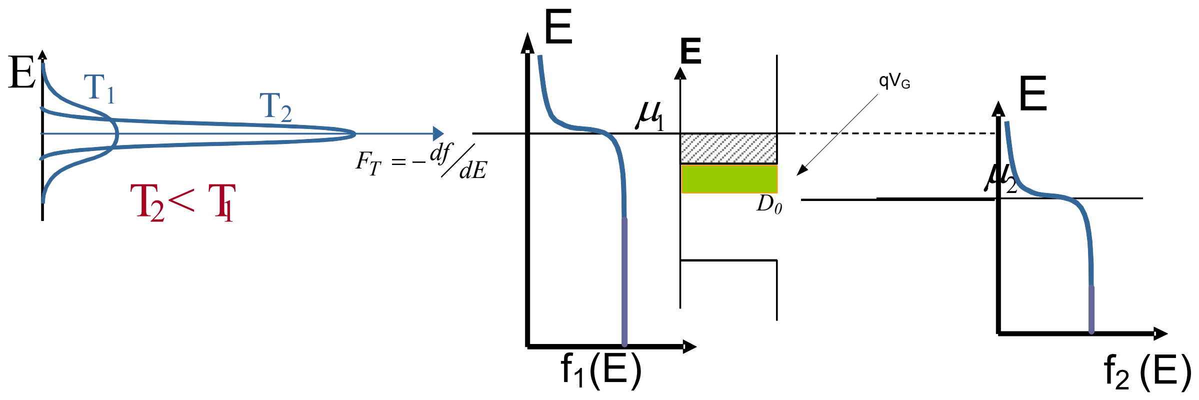


C_Q Calculation

$$N = 2\int dED(E)\, f_0(E-U)$$

$$C_Q \Rightarrow -\frac{\partial N}{\partial U} = 2\int dED(E)(-\frac{\partial f_0}{\partial E}) = 2D_0 \quad \& \quad (-\frac{\partial f_0}{\partial E}) = \delta(E-\mu)$$

$$\frac{\partial (qN)}{\partial (U/q)} = q^2 \frac{\partial N}{\partial U}$$



Conductance

$$G = \frac{I}{V_D}$$

$$f_0(E) = \frac{1}{1+e^{\frac{E-\mu}{kT}}}$$

$\frac{I}{V_D} = \frac{2q}{\hbar}\int dED(E)\frac{\partial f_0}{\partial \mu}(\mu_1 - \mu_2)$ *and* $(\mu_1 - \mu_2) = qV_D$ for small potential using tailor series for $f_0(\mu_1)$- $f_0(\mu_2)$ it is correct

$G = \frac{2q}{\hbar}\int dED(E)\frac{\partial f_0}{\partial \mu}$ *and* $\frac{\partial f_0}{\partial \mu} \equiv -\frac{\partial f_0}{\partial E}$ this is equivalent with a minus sign

$$\xrightarrow{yields} G = \frac{2q}{\hbar}\int dE\,\frac{\gamma}{2}D(E)\left(-\frac{\partial f_0}{\partial E}\right) \text{and } 2\pi\hbar = h \xrightarrow{yields} G = \frac{2q}{h}\int dE\;\pi\gamma D(E)\;\left(-\frac{\partial f_0}{\partial E}\right)$$

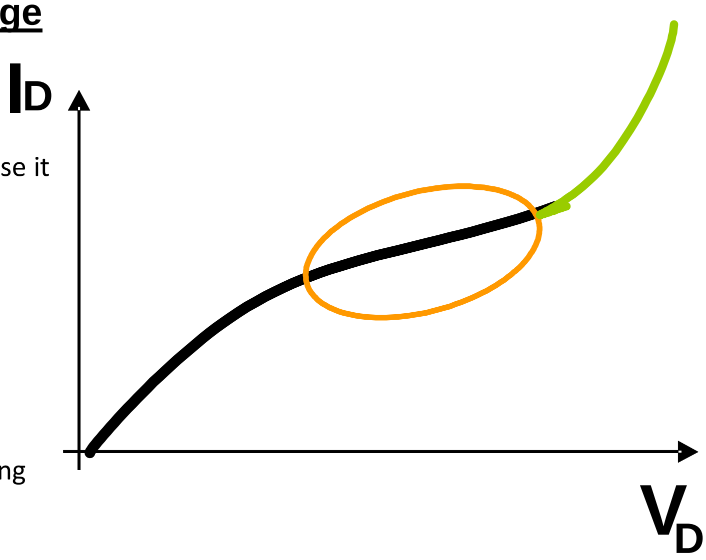
In the achieved equation $\pi\gamma D(E)$ is called number of ***Modes***, M(E).

For charge calculation D(E) was enough but for current calculation we need the speed of electrons come in and out.

If we know the D(E) and M(E) then we could easily calculate I-V.

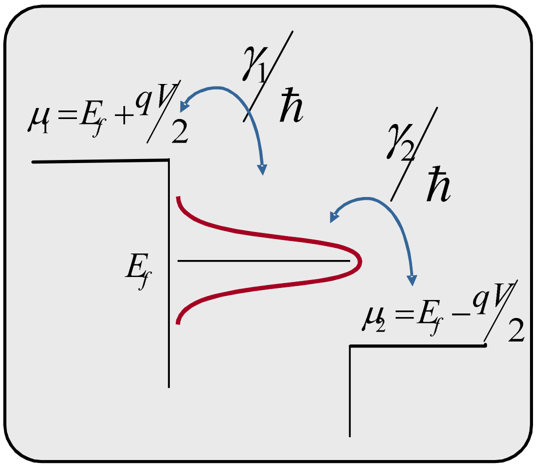
Current equation for higher voltage

In I-V graph, in circled part, if we have enough voltage the $f_2(E) \approx 0$ then we can drop f_2 from current equation. We can assume $f_2(E) \approx 0$ because it is very lower than where DOS is greater than 0.



$$I = \int \frac{q}{\hbar} dE D(E-U) \frac{\gamma}{2} f_1(E)$$

In this part also current is not fixed due to lowering the D(E).



When we put a voltage, then half will be on source side and the other half will be on drain. And DOS is assumed fixed.

N α $f_1/2$ → $N_0/2$