ECE 495N

Fundamentals of Nanoelectronics

Fall 2008

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Lecture: 5
Title: Quantitative Model for Nanodevices II
Date: September 5, 2008

Video Lectures posted at:
https://www.nanohub.org/resources/5346/

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Quantitative Model for Nanodevices II

- If \( V_D = 0 \) then \( U = U_L + f(N) \) and hence these two equations are decoupled.
- Intuition solution of the above system.
- Two contact voltages with two different roles:
  - \( V_D \) drives the current between D and S.
  - \( V_G \) allows us to control that current.

If \( V_D \) is very small then \( \mu_2 \approx \mu_3 \Rightarrow f_1 \approx f_2 \) and hence \( N = \int dE \cdot D(E-U) f_2(E) \)
If now we write the $\gamma$ as
$$\gamma = \frac{\hbar v}{L} \frac{\Lambda}{\Lambda + L}$$
then it's like interpolation between diffusive and ballistic. Let's check it:
- if $L \ll \Lambda$, then $\frac{\Lambda}{\Lambda + L} = 1 \Rightarrow \gamma = \frac{\hbar v}{L} \Rightarrow$ ballistic
- if $L \gg \Lambda$, then $\frac{\Lambda}{\Lambda + L} \approx \frac{\Lambda}{L} \Rightarrow \gamma = \frac{\hbar v}{L} \Rightarrow$ diffusive

$$I_{ON} \quad \text{(very high $V_D$)}$$

$$I_{ON} = \frac{q}{\hbar} \int d\varepsilon \cdot D(\varepsilon - U) \frac{\gamma}{2} f_{1}(\varepsilon)$$

$$N = \frac{q}{\hbar} \int d\varepsilon \cdot D(\varepsilon - U) \frac{f_{1}(\varepsilon)}{2}$$

$$\Rightarrow I_{ON} = N \frac{q}{\hbar} \frac{\gamma}{2}$$

For the ballistic limit:
$$I_{ON} = qN \frac{U}{L} = W \cdot L \cdot C_{ox} \cdot (V_{G} - V_{T}) \frac{U}{L}$$

$$\Rightarrow I_{ON} = WC_{ox}(V_{G} - V_{T})U$$

On current per unit length
$$\Rightarrow I'_{ON} = C_{ox}(V_{G} - V_{T})U$$

Oxide capacitance per unit area
$$\Rightarrow I_{ON} = \frac{C_{ox}(V_{G} - V_{T})U}{L}$$
If we have a channel with low density of states then $C_q$ in the important capacitance, if the density of states is high then $C$ is important.

For very small conductor (in our days) $C_q$ should be taken into account.