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ECE 495N, Fall'09 GRIS 280 MWF 1130A-1220P

Fundamentals of Nanoelectronics

HW#1: Due Friday Sept.4 in class.

Please turn in a copy of your MATLAB codes for all problems.

This HW involves calculating the current-voltage (I-V) characteristics of a nanoscale device from the relation

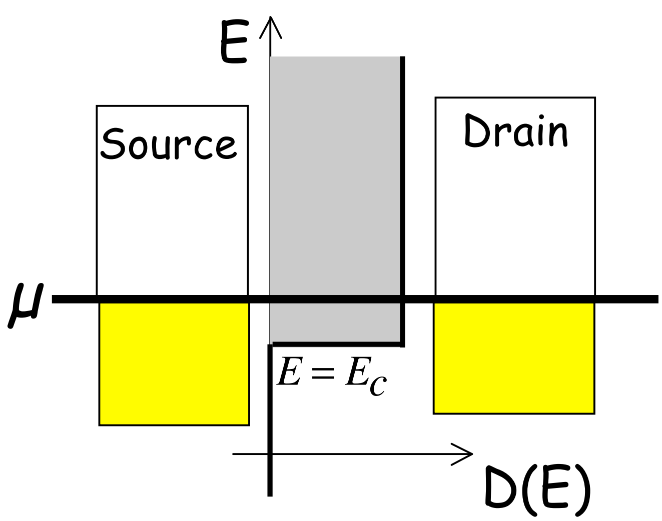
$$I = \frac{2q}{\hbar}\int_{-\infty}^{+\infty} dE\; D(E-U)\,\frac{\gamma}{2}\left[f_1(E)-f_2(E)\right] \qquad (1)$$

with $$N = 2(for\ spin)\int_{-\infty}^{+\infty} dE\; D(E-U)\,\frac{f_1(E)+f_2(E)}{2} \qquad (2)$$

and $$U = U_L + U_0(N-N_0) \qquad (3)$$

Fermi functions : $f_1(E) = \dfrac{1}{e^{(E-\mu_1)/kT}+1}$ and $f_2(E) = \dfrac{1}{e^{(E-\mu_2)/kT}+1}$ (4)

A channel has a density of states as shown, namely a constant non-zero value for $E \geq 0$ and zero for $E < 0$, that is, $D(E) = D_0\,\vartheta(E)$, where ϑ represents the unit step function. The equilibrium electrochemical potential is denoted by μ. Assume the escape rate γ (same for both contacts) to be equal to 100 meV, and the density of states (for E<0) D_0 to be 100 / eV.



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Problem 1: Calculate the current (I) versus drain voltage (V_D) for –0.4V < V_D < +0.4V assuming $U_0 = 0$, μ = 0.1 eV, and

(a) $U_L = 0.5 * (U_{source} + U_{drain})$,
(b) $U_L = U_{source}$,
(c) $U_L = U_{drain}$.

Note that $U_{drain} = U_{source} - qV_D$, $\mu_1 = \mu + U_{source}$, $\mu_2 = \mu + U_{drain}$.

For comparison also plot the linear approximation discussed in class: $I = (2q^2/h) * \pi D\gamma * V_D$.

Do the results depend on your choice of U_{source} ?

The current should saturate for positive voltages in case (b). Explain why and obtain an expression for the saturation current.

Problem 2: Calculate the current (I) versus drain voltage (V_D) for –0.04V < V_D < +0.04V assuming $U_0 = 0$, μ = 0 and

(a) source and drain have the same temperature: $k_B T_1 = 0.025\ eV = k_B T_2$,
(b) $k_B T_1 = 0.025\ eV, k_B T_2 = 0.02\ eV$,
(c) $k_B T_1 = 0.025\ eV, k_B T_2 = 0.03\ eV$.

In each case find the open circuit voltage and the short circuit current. If non-zero, indicate their polarity: For open circuit conditions is the drain positive or negative relative to source? For short circuit conditions does the current flow from source to drain or from drain to source in the *external* circuit?

Problem 3: Calculate the current (I) versus drain voltage (V_D) for –0.4V < V_D < +0.4V assuming $U_0 = 0.2$ eV, μ = 0.1 eV and $U_L = U_{source}$. Note that this problem requires a self-consistent solution of Eqs.(2) and (3) for each drain voltage.

Again, for comparison also plot the linear approximation discussed in class: $I = (2q^2/h) * \pi D\gamma * V_D$.

Is the saturation current (for positive voltages) larger or smaller than that for Problem 1b. Explain why.