A Circuit Compatible Analytical Device Model for Nanowire FET Considering Ballistic and Drift-Diffusion Transport

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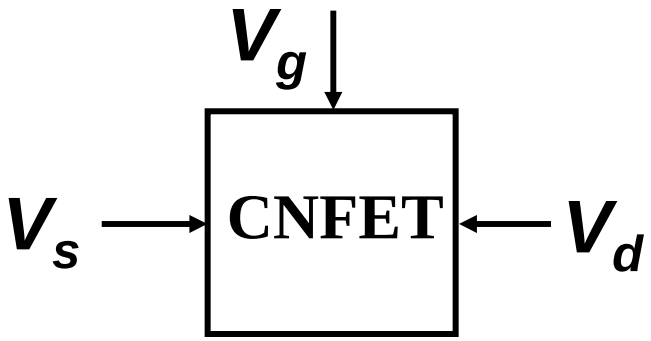
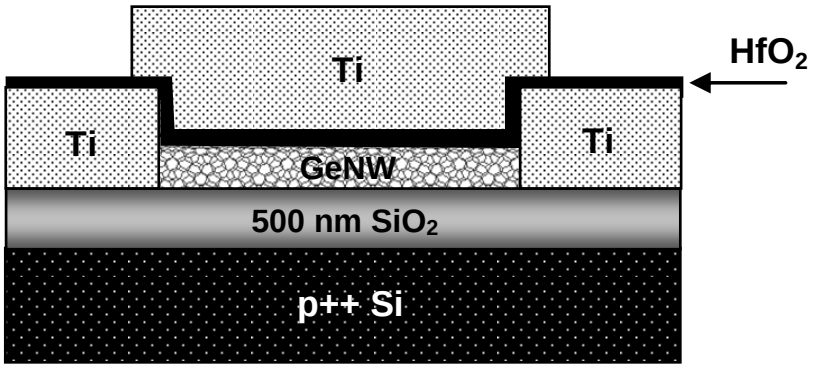
Objective

To achieve *ANALYTICAL* expression for device electrostatics



$$I_D = f_1(V_g, V_d, V_s)$$

$$C = f_2(V_g, V_d, V_s)$$



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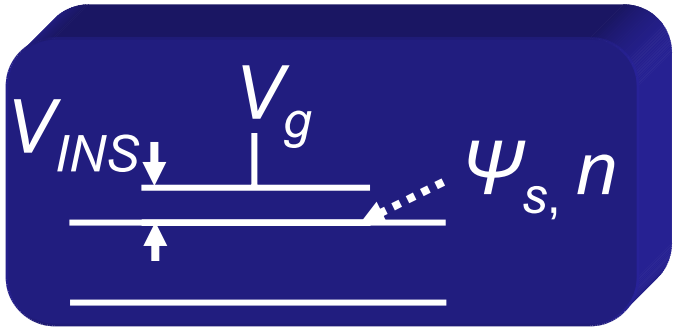
Challenges

- To obtain CLOSED form integral

$$Q_{NW} = \frac{q\sqrt{2k_BT}}{2\pi\hbar}\sum_n\sum_\upsilon g_\upsilon\sqrt{m_d^\upsilon}\left\{\int_0^\infty \frac{E^{-1/2}dE}{1+e^{\left[\frac{E+E_\upsilon^n-q\psi_s}{k_BT}\right]}} + \int_0^\infty \frac{E^{-1/2}dE}{1+e^{\left[\frac{E+E_\upsilon^n-q(\psi_s-V_{ds})}{k_BT}\right]}}\right\}$$

- Solving SELF- CONSISTENT equations

$$\psi_s = V_{gs} - V_{INS} = V_{gs} - \frac{Q_{NW}}{C_{INS}}$$



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Analytical Solution

$$Q_{NW} = \alpha e^{(\psi_s / \beta)}$$

for $V_{gs} < V_T$

$$Q_{NW} = \lambda_0 + \rho_1 \lambda_1 (\psi_s - \psi_T) + \rho_2 \lambda_2 (\psi_s - \psi_T)^2$$

for $V_{gs} > V_T$

Drift-diffusion current:

$$I_{ds} = \frac{\mu}{L_{eff}} \int_0^{V_{ds}} Q_{NW}(V_{gs}, V_{ds}) dV$$

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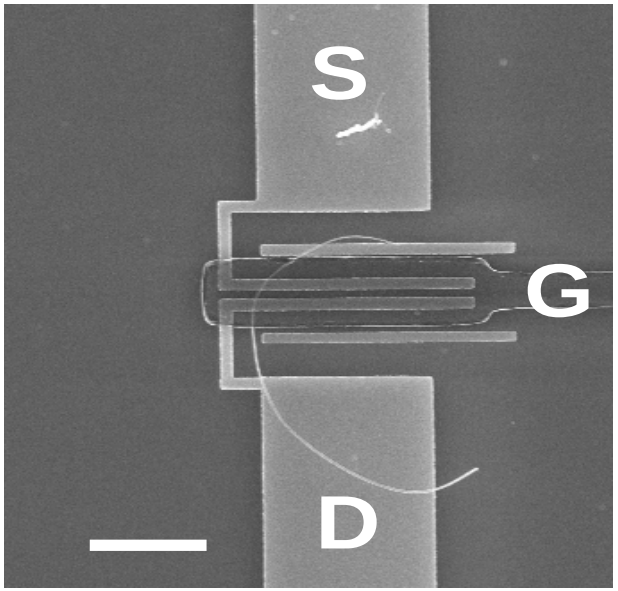
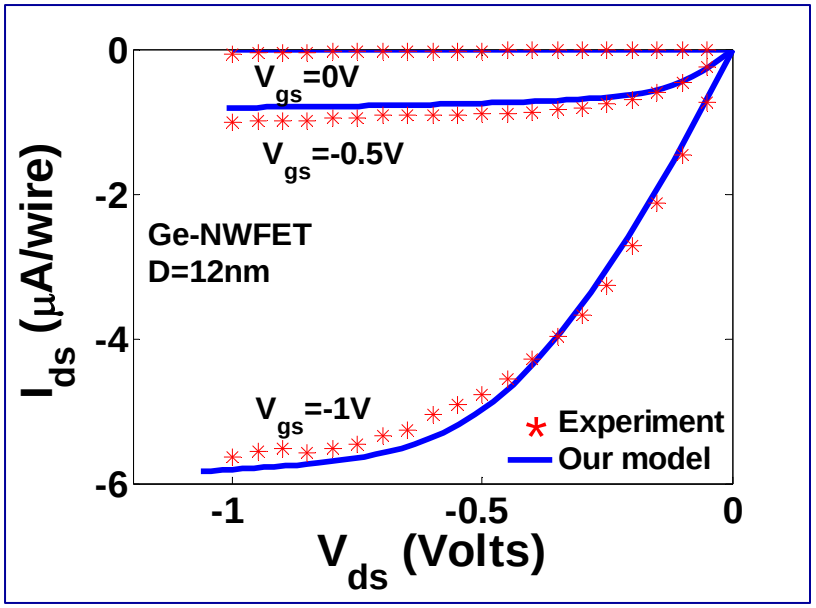
Experimental Verification

Ge-Nanowire PFET, diameter=12nm,
L_{eff} = 250nm, T_{ox}=8nm(HfO_2)





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