Macro Model for Drift/Diffusion Effects in Short-Channel Undoped Schottky Barrier DG-MOSFETs

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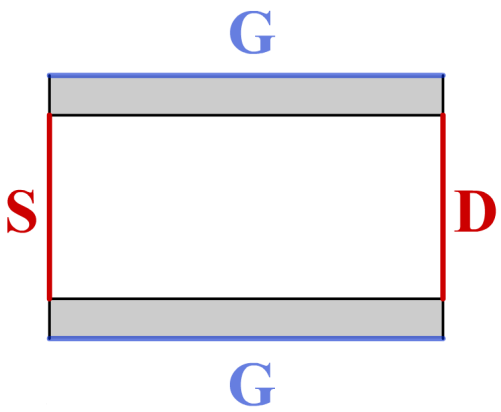
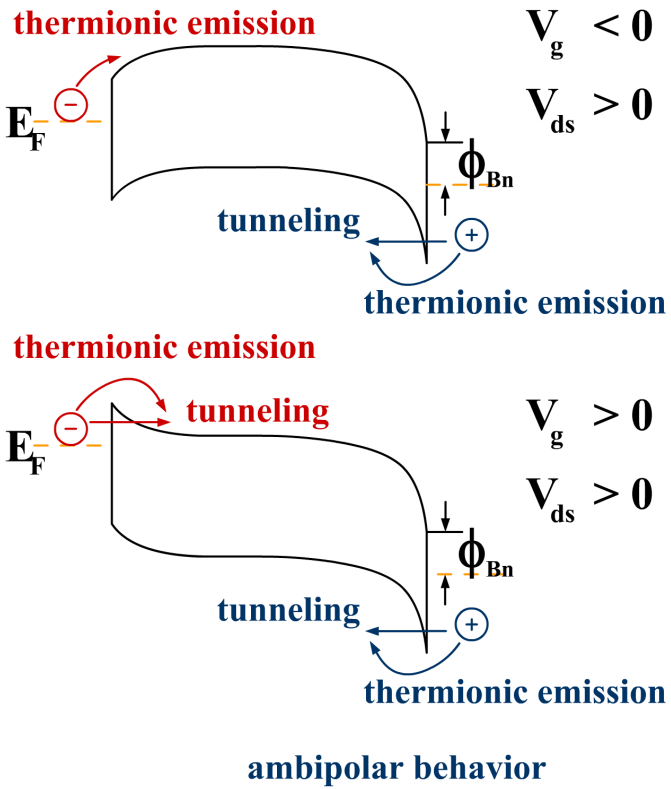
Contents

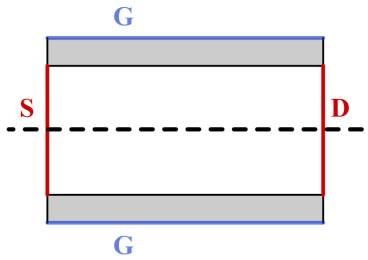
SB-DG-MOSFET

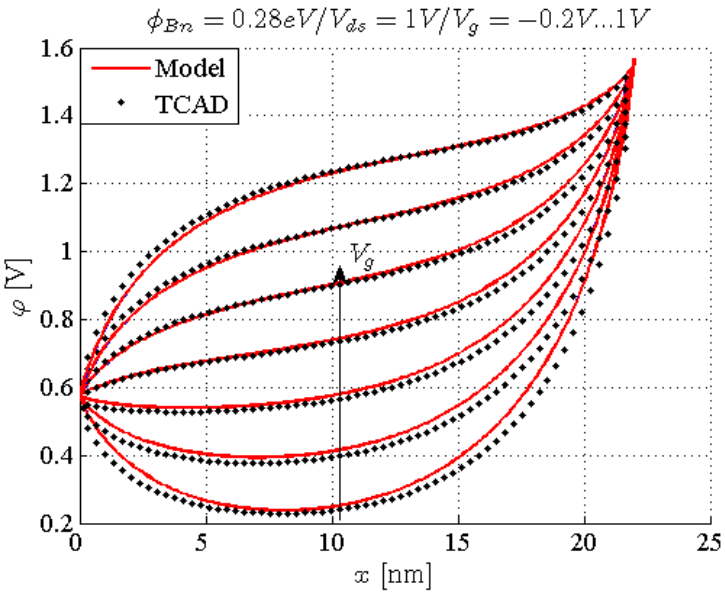


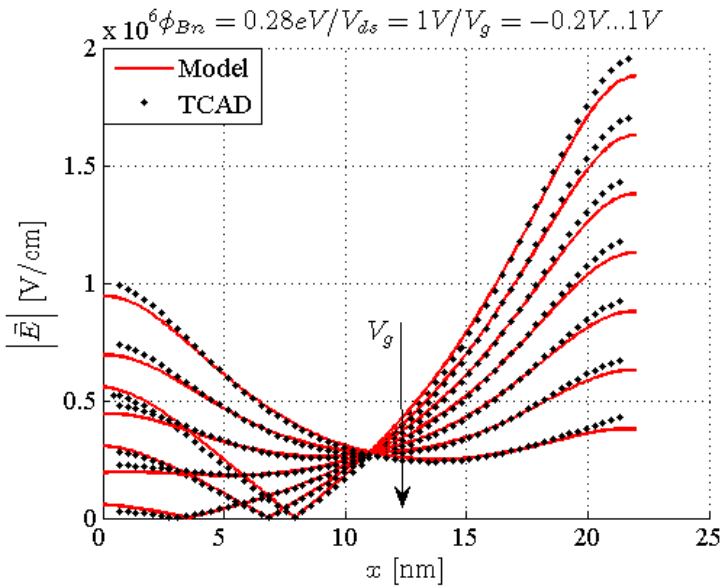
- High scalability
- Good process compability
- Low access resistances



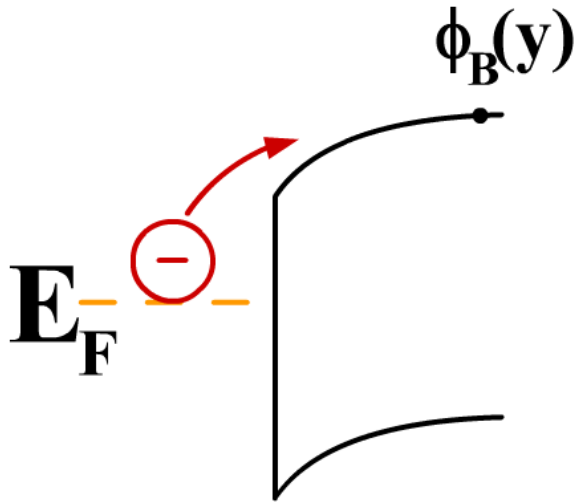
- Conformal Mapping technique
- Analytical framework for potential and electric field







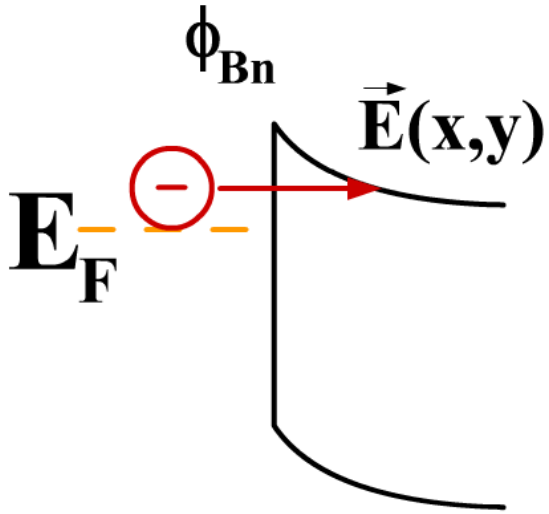
Thermionic Current SB-DG-MOSFET



$$J_{therm}(y) = A^* T^2 \exp\left(-\frac{q\phi_B(y)}{kT}\right)\left[1 - \exp\left(\frac{-qV_{ds}}{kT}\right)\right]$$

$$I_{therm} = \int_0^{w_{ch}} \int_{t_{ox}}^{t_{ox}+t_{ch}} J_{therm}(y) \cdot dy \cdot dz$$

Tunneling Current SB-DG-MOSFET

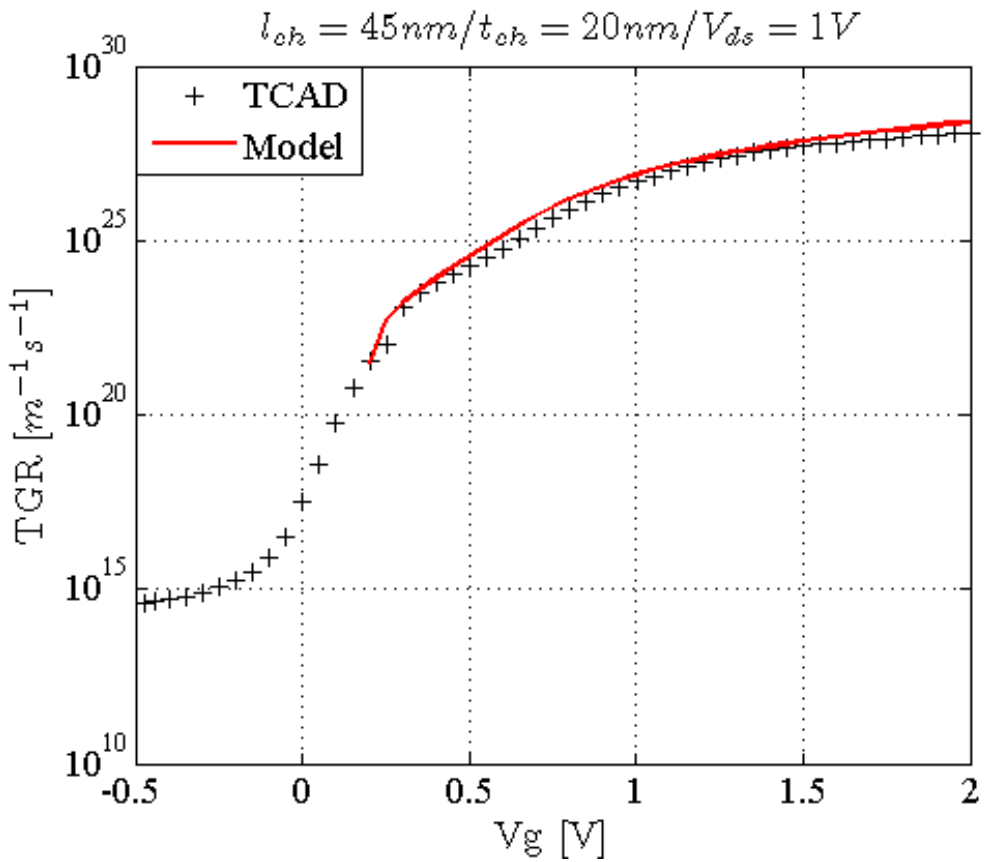


$$J_{tun}(y) = \frac{A^* T}{k} \int_0^{l_{ch}} T(\vec{E}, x, y) f_m(\xi(x)) \left[1 - f_s(\xi(x))\right] \frac{\partial \xi}{\partial x} dx$$

$$J_{tun}(y) = \frac{q\mu_n N_C}{kT} \int_0^{l_{ch}} \left|\vec{E}(x, y)\right| \cdot T(\vec{E}, x, y) \cdot f_m(\xi(x))[1 - f_s(\xi(x))] \frac{\partial \xi}{\partial x} dx$$

$$I_{tun} = \int_0^{w_{ch}} \int_{t_{ox}}^{t_{ox}+t_{ch}} J_{tun}(y) \cdot dy \cdot dz$$

Analysis Components



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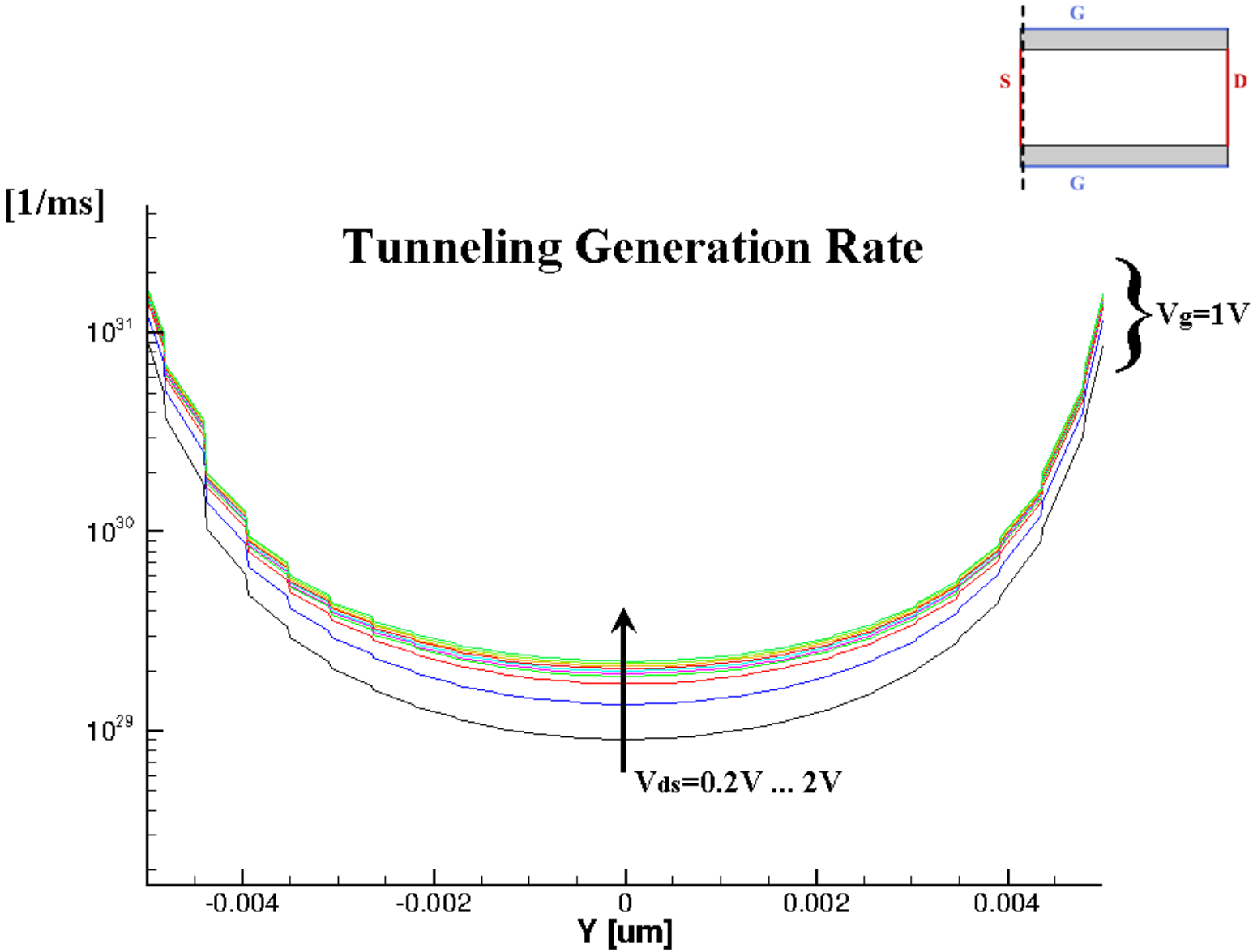
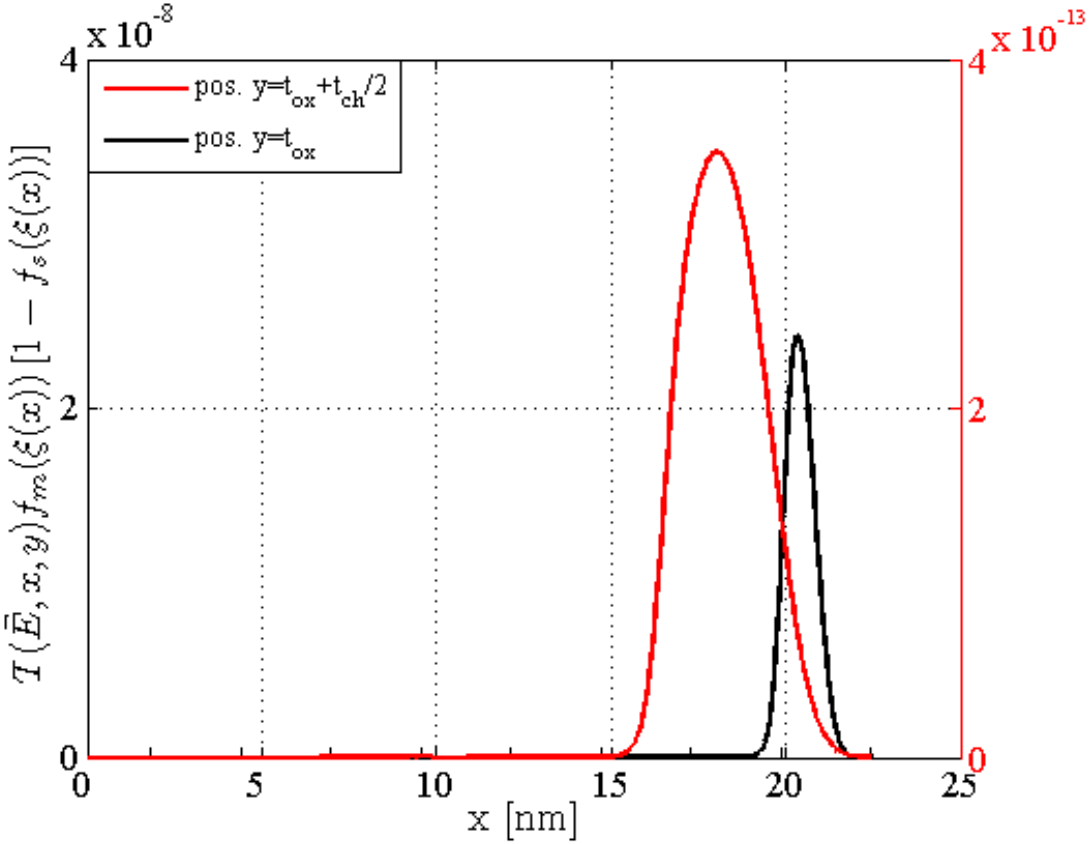
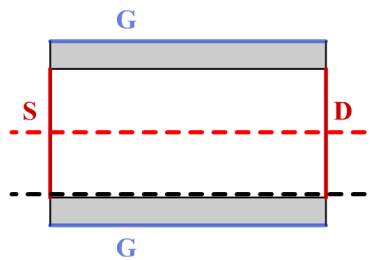


Analysis Components

$\phi_{Bn} = 0.28eV / l_{ch} = 45nm / t_{ch} = 20nm / V_{ds} = 1V / V_g = 0V$





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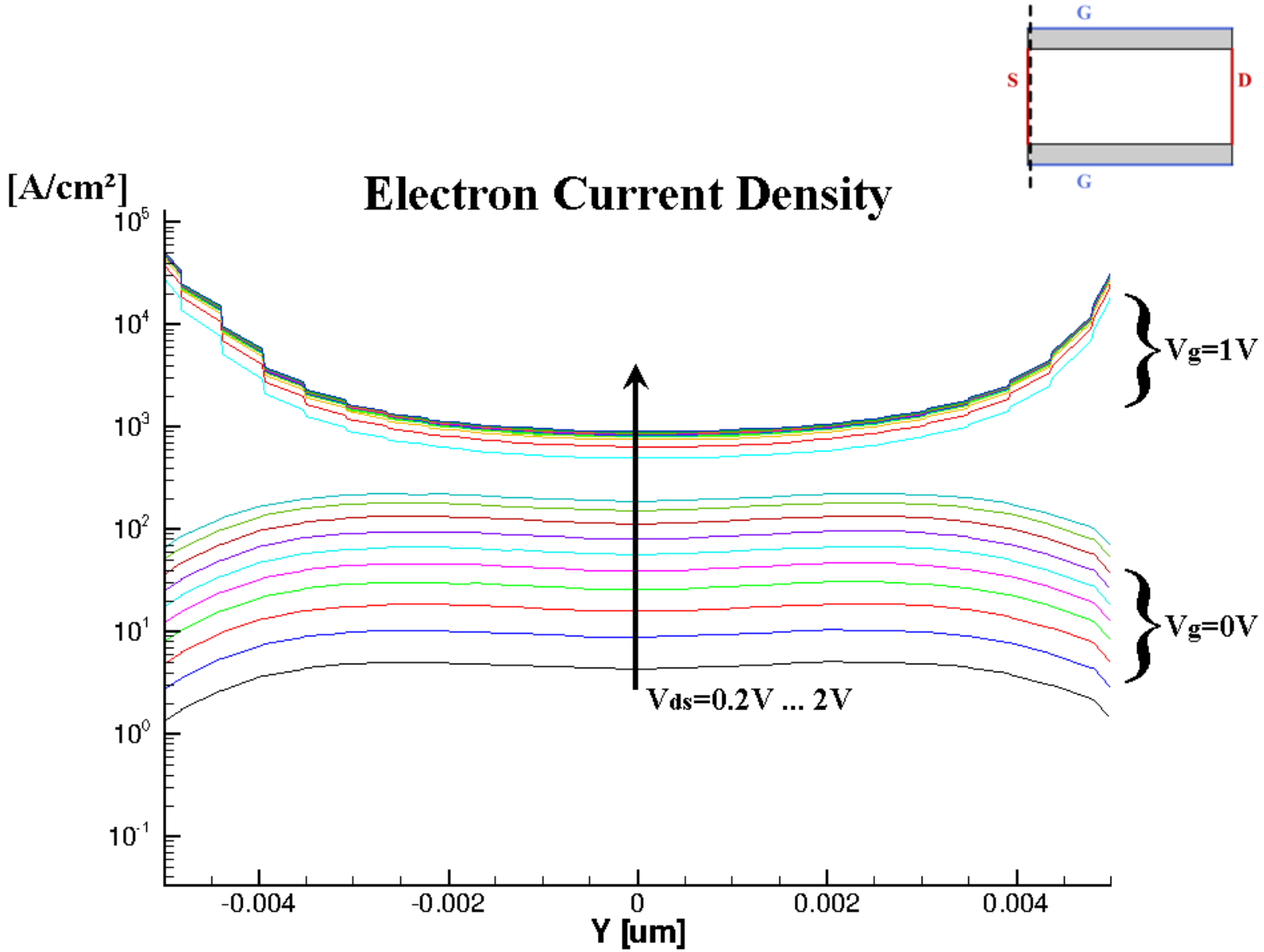

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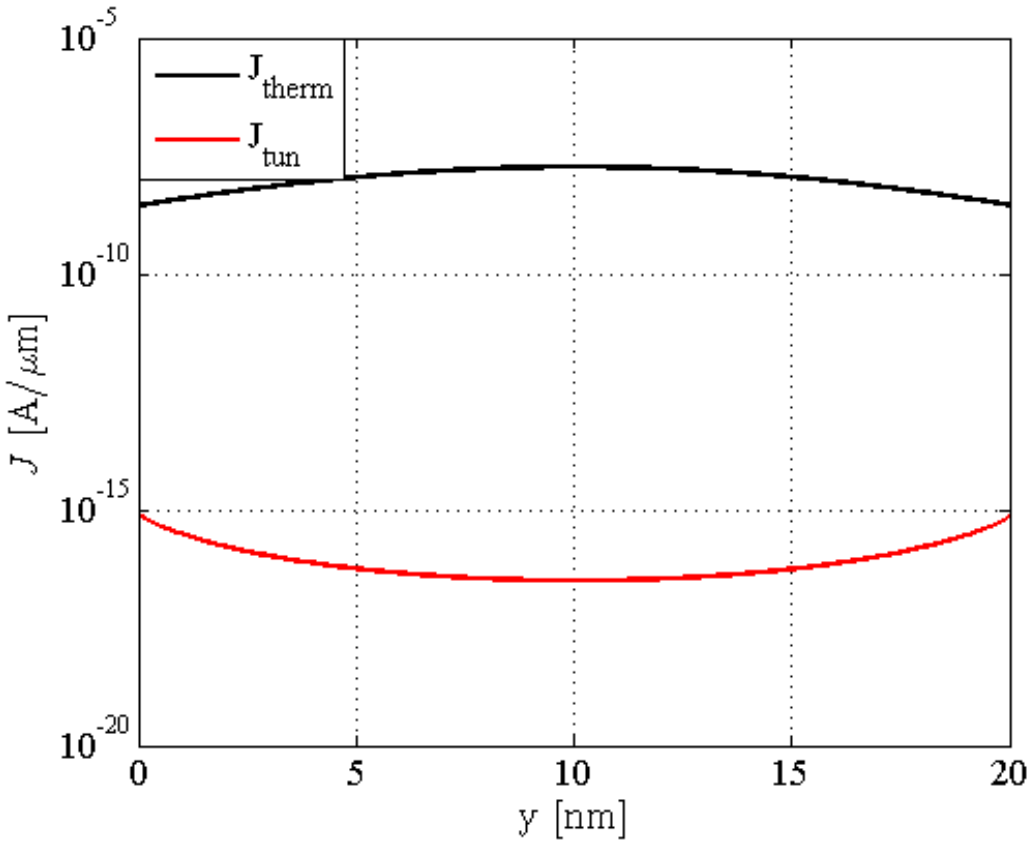

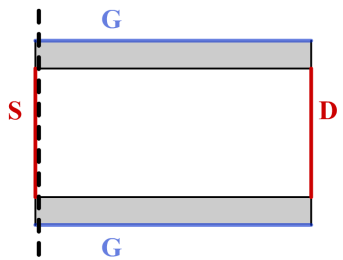

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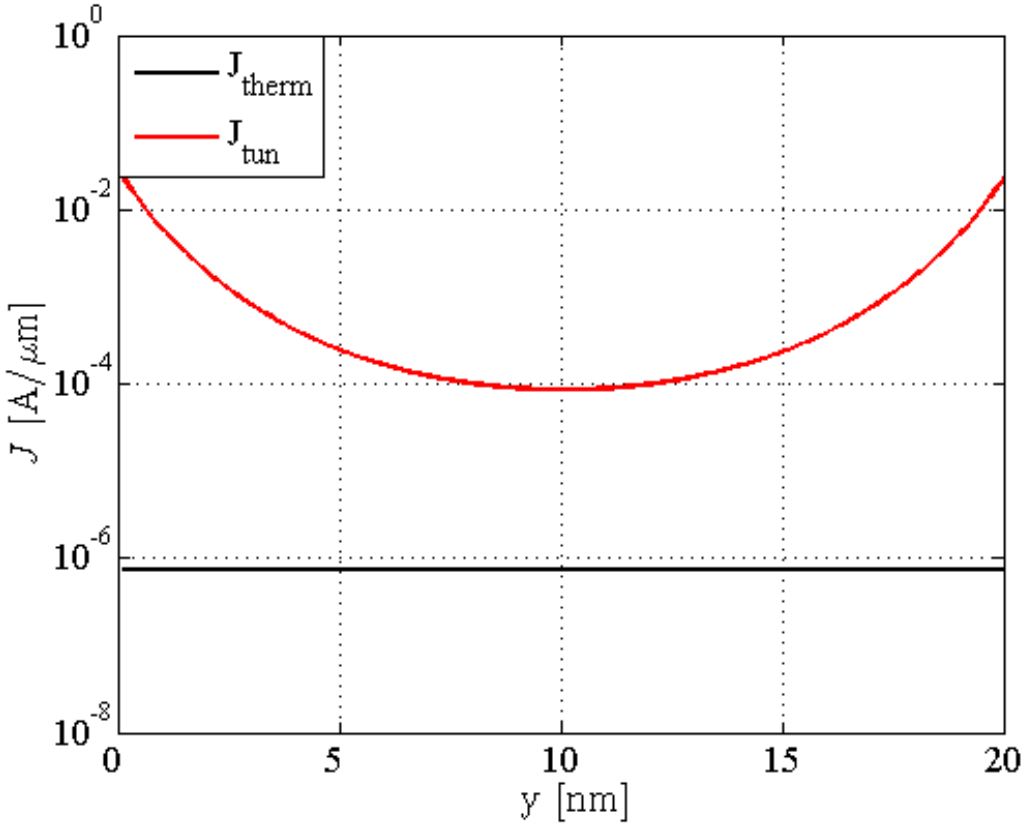
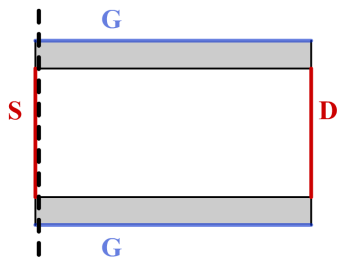
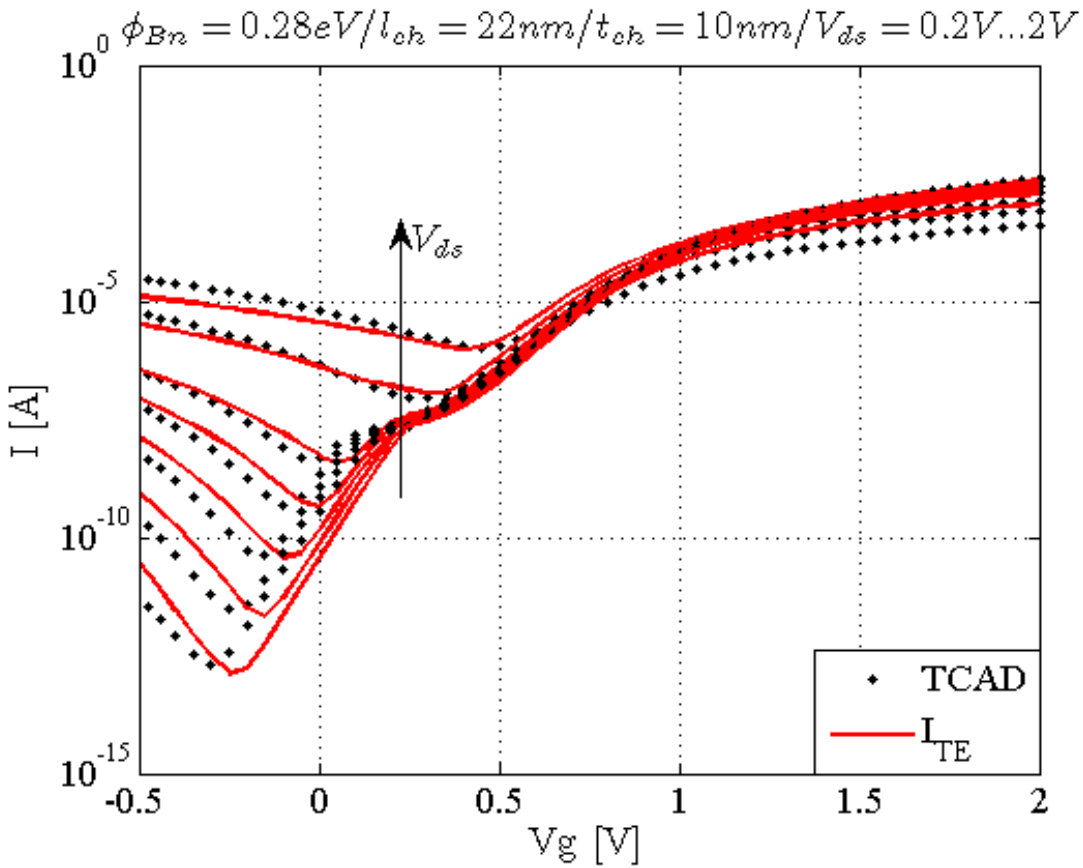




Transfer Characteristics

$$I_{TE} = I_{tun} + I_{therm}$$



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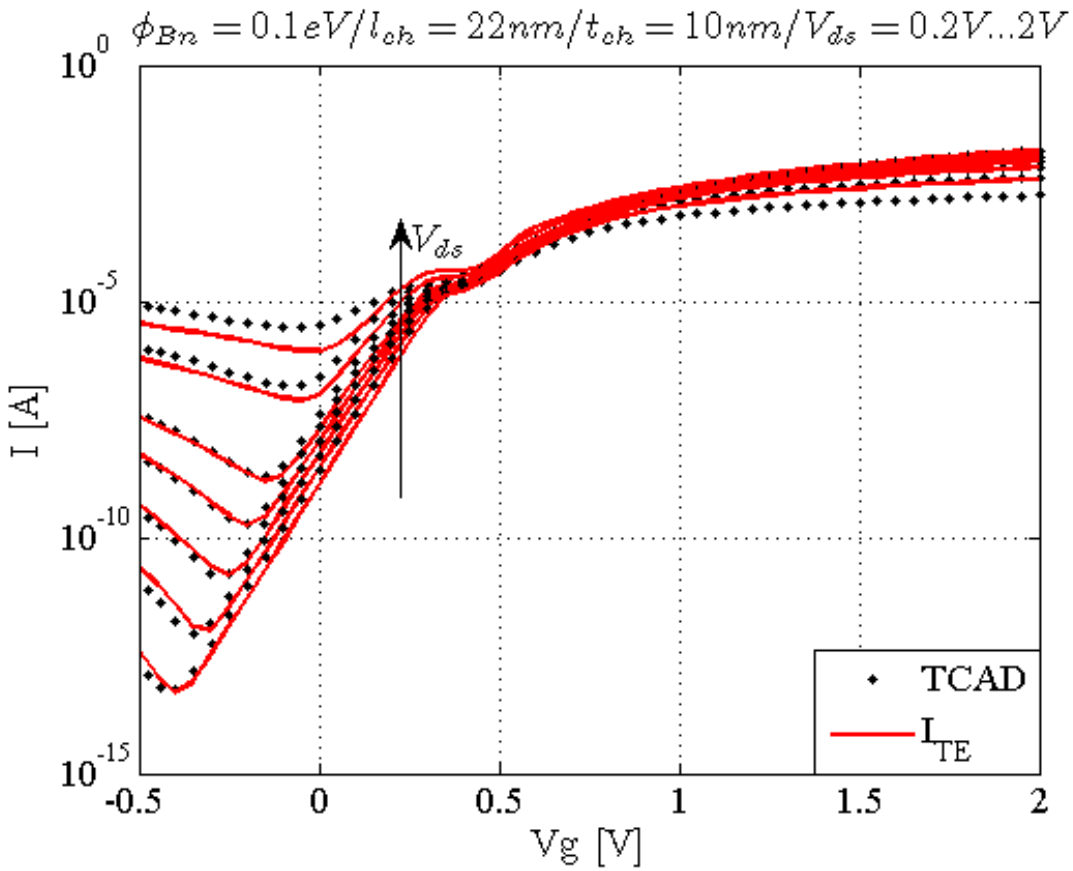
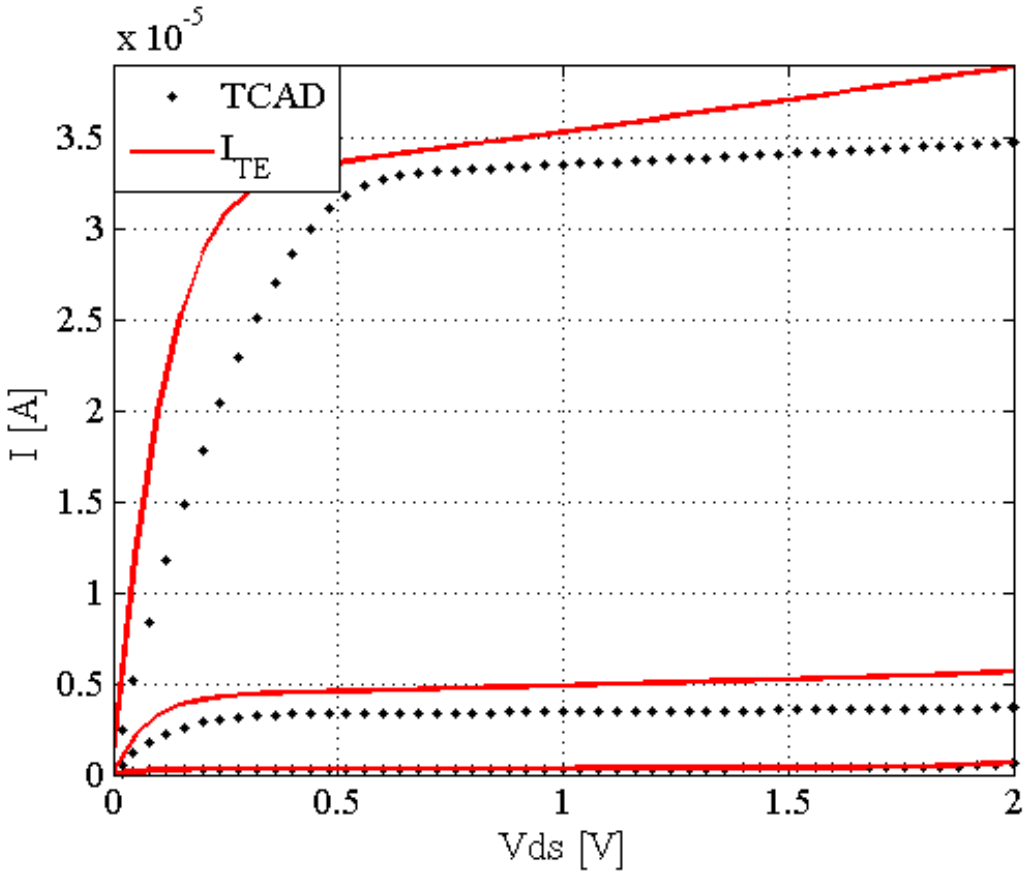


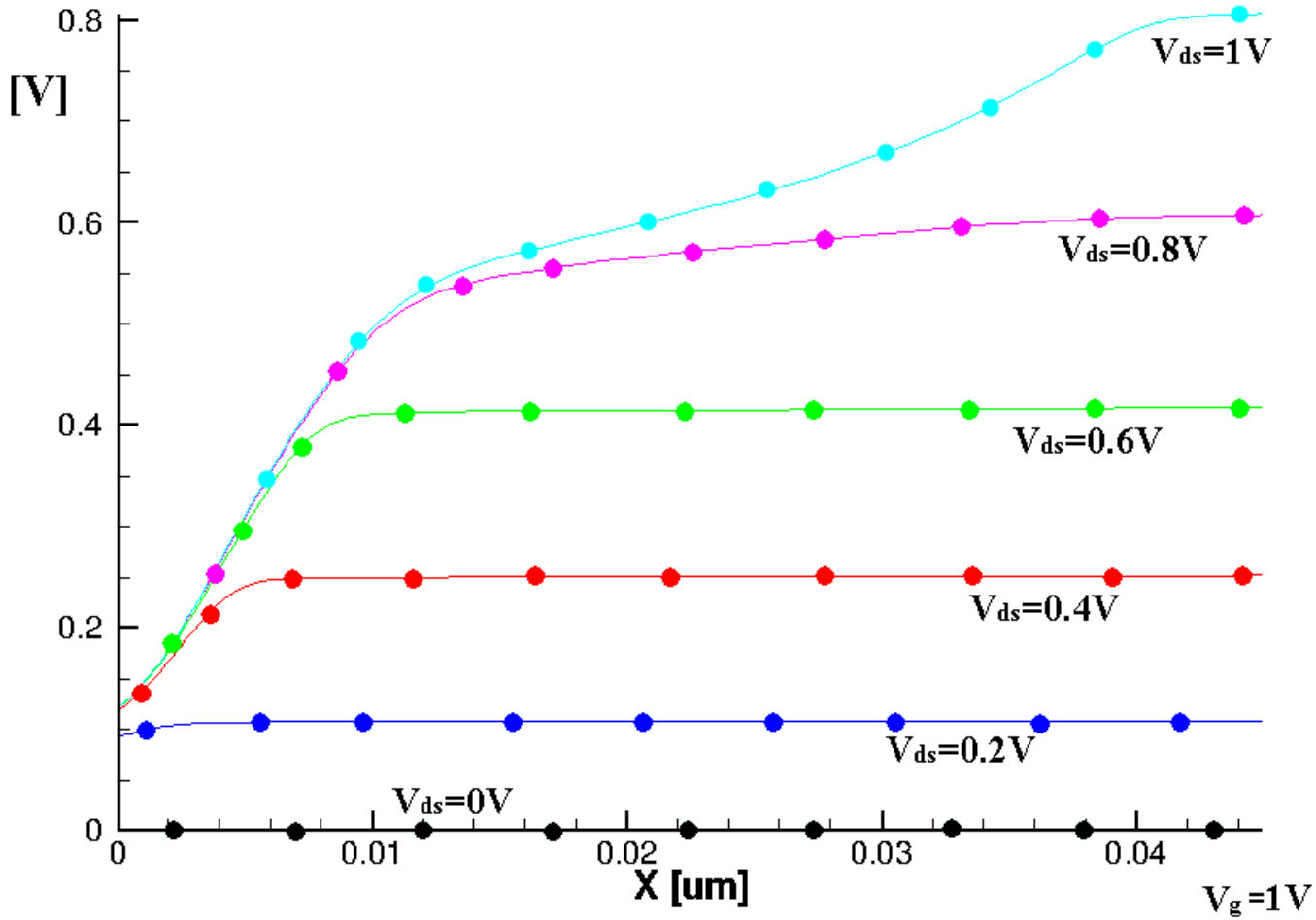
Problem Output Characteristics

$$I_{TE} = I_{tun} + I_{therm}$$

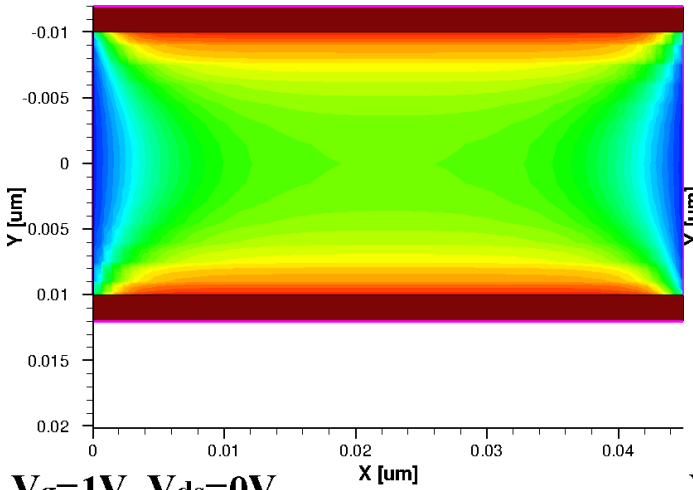
$$\phi_{Bn} = 0.28eV / l_{ch} = 45nm / t_{ch} = 20nm / V_g = 0.5V...0.9V$$



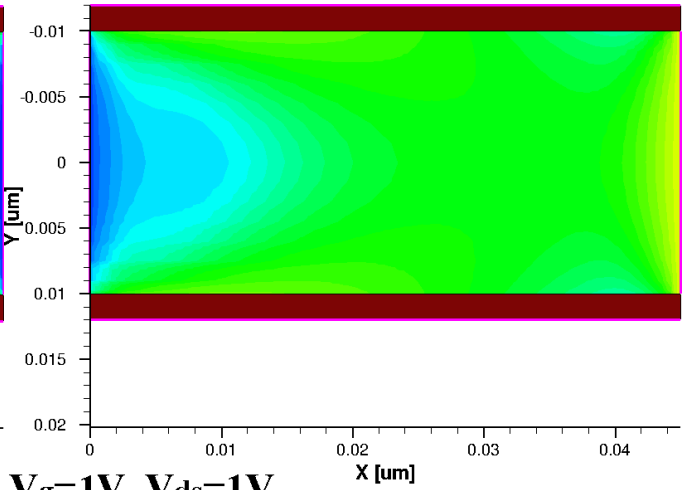
Analysis eQuasiFermiPotential



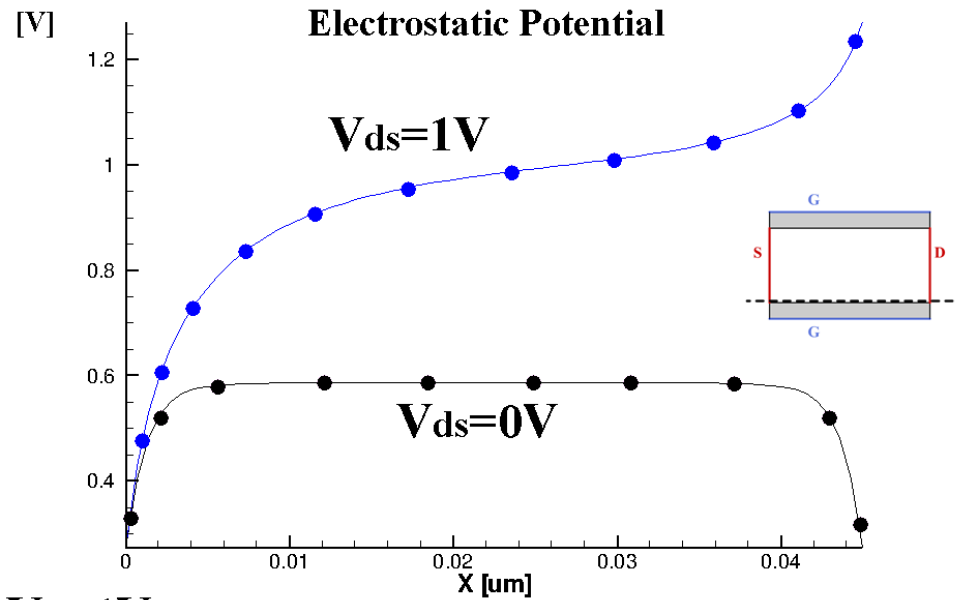
Analysis eDensity



Vg=1V, Vds=0V



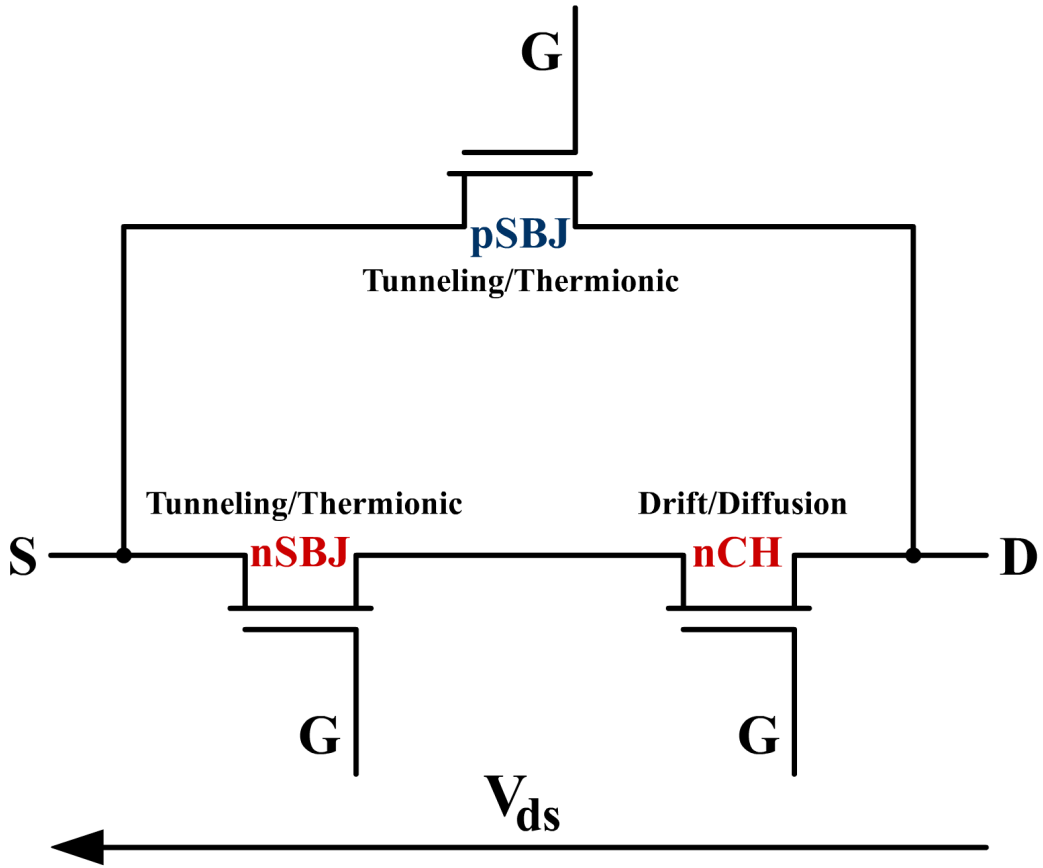
Vg=1V, Vds=1V



Vg=1V

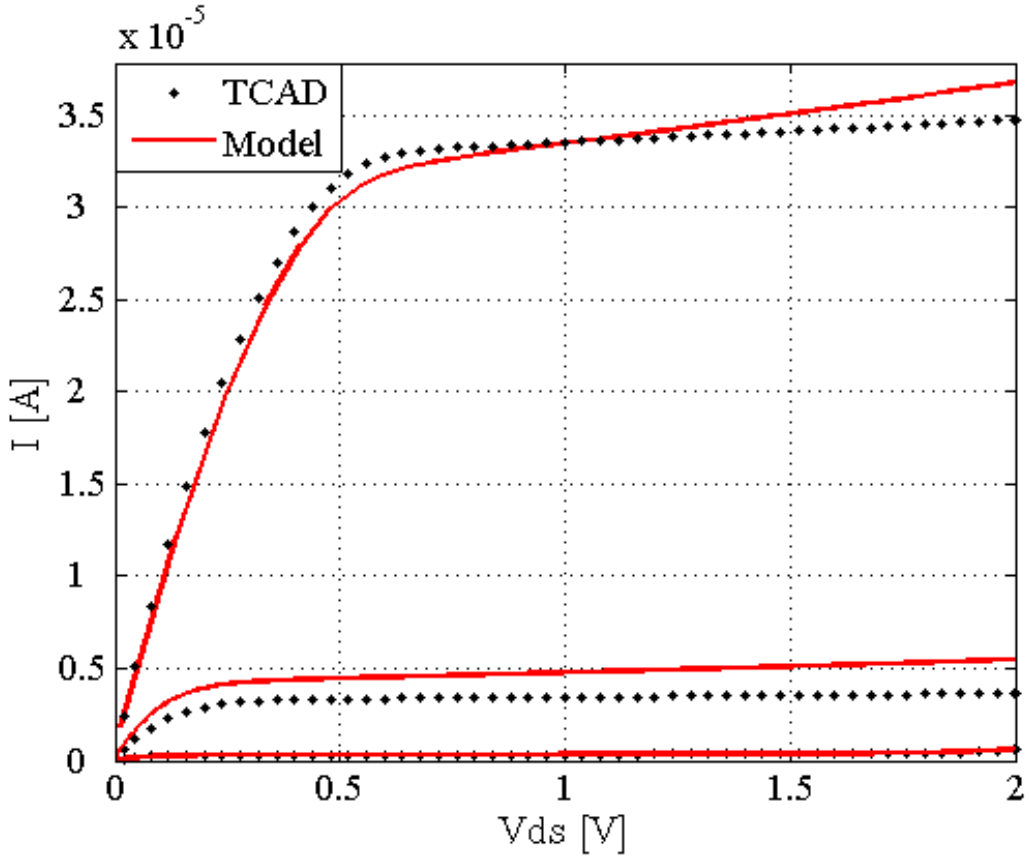
Approach Macro Model

$$I_{Drift/Diff} = \mu C_{ox} \frac{2W}{L} \left(V_g - V_{th} - \frac{V_{ds}}{2} \right) V_{ds}$$



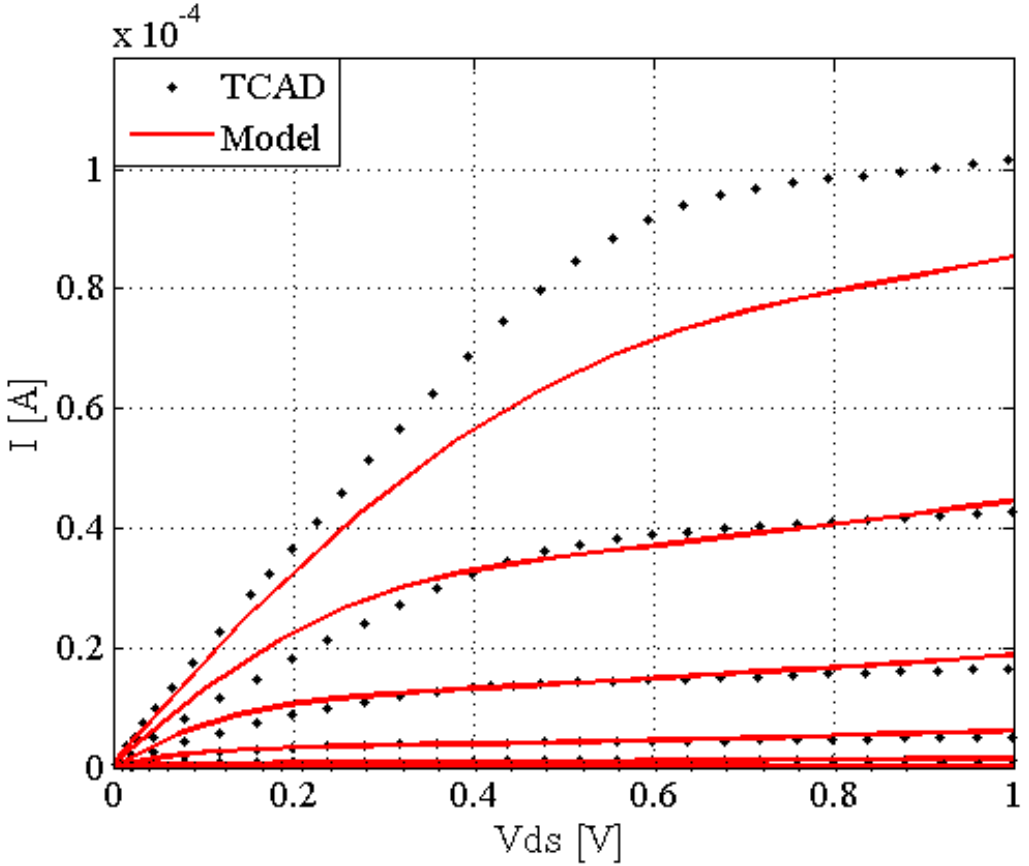
Solves Problem Output Characteristics

$\phi_{Bn} = 0.28eV / l_{ch} = 45nm / t_{ch} = 20nm / V_g = 0.5V...0.9V$



Solves Problem Output Characteristics

$\phi_{Bn} = 0.28eV / l_{ch} = 22nm / t_{ch} = 10nm / V_g = 0.5V...1V$



Conclusion & Take Aways

- 2D analytical solutions of the electrostatics are used for calculating tunneling probability and carrier distributions
- Quasi 2D approach is used for the estimation of tunneling and thermionic current
- Enhanced tunneling current calculation with electric field
- Analysis of current densities show 2D influence
- Macro model introduced to account for Drift/Diffusion effects in the channel
- Results of the model compared to TCAD show an accurate agreement for channel lengths down to 22nm

Acknowledgment

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