Comparison of full-band Monte Carlo and Non-equilibrium Green's function simulations

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Collaboration with

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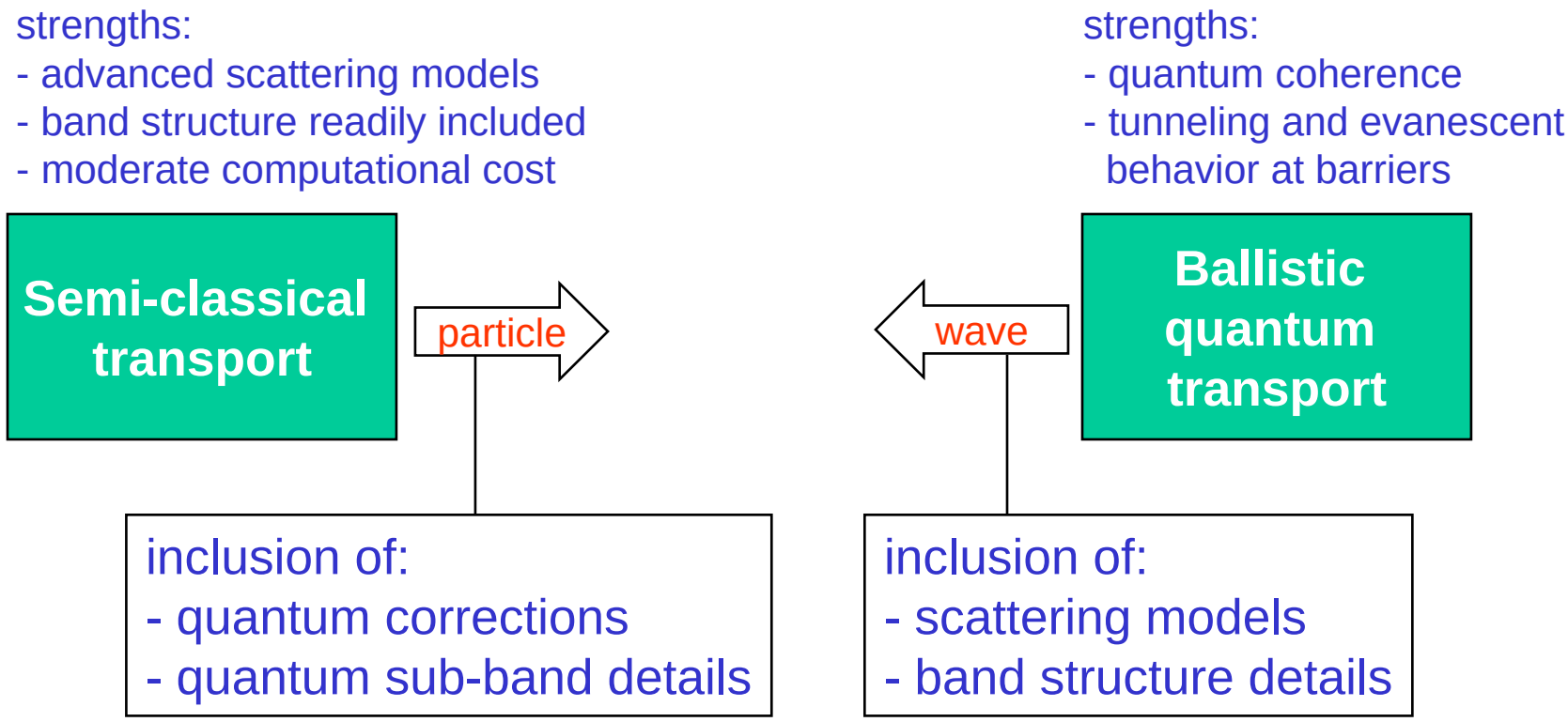
Purdue University

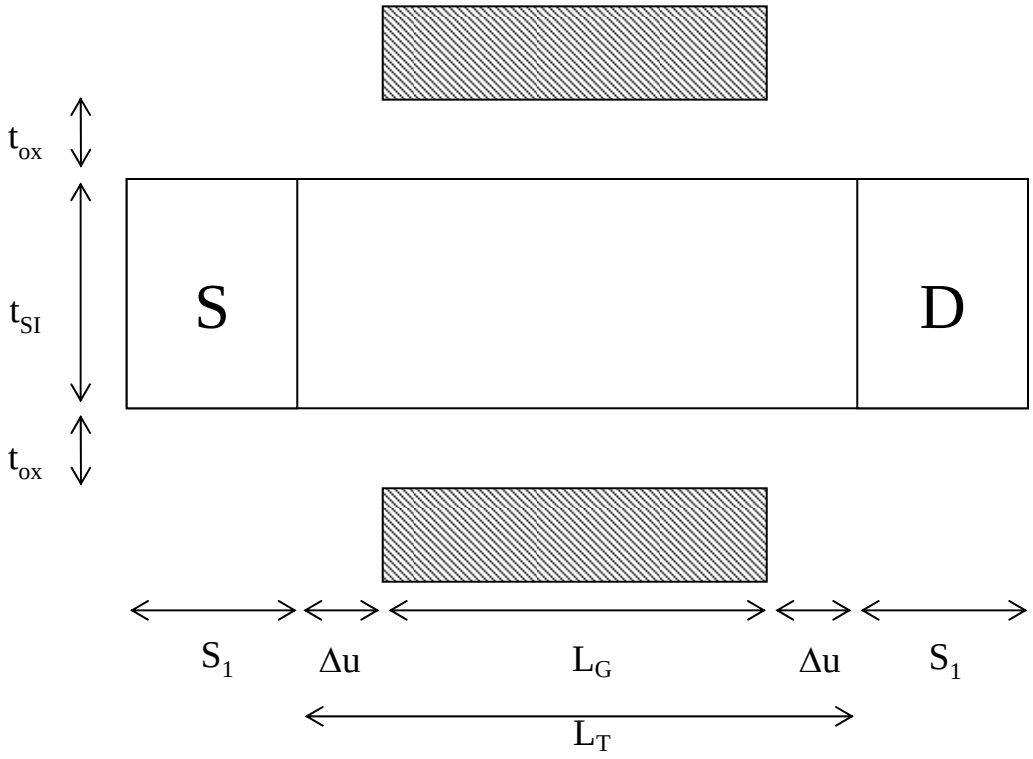
Motivation

- **There is still a considerable separation between semi-classical and quantum models in terms of physical detail**



Benchmark Model

- **We have considered a 2-D device model for the double-gate MOSFET performing simulations with MOCA 2-D (UIUC) NanoMOS (Purdue).**



Device parameters

t_{ox} = 1.0 nm (k = 1.0)

t_{Si} = 4.0 nm, 3.0 nm, 2.0 nm

S_1 = 6.0 nm

Δu = underlap = 4.0 nm

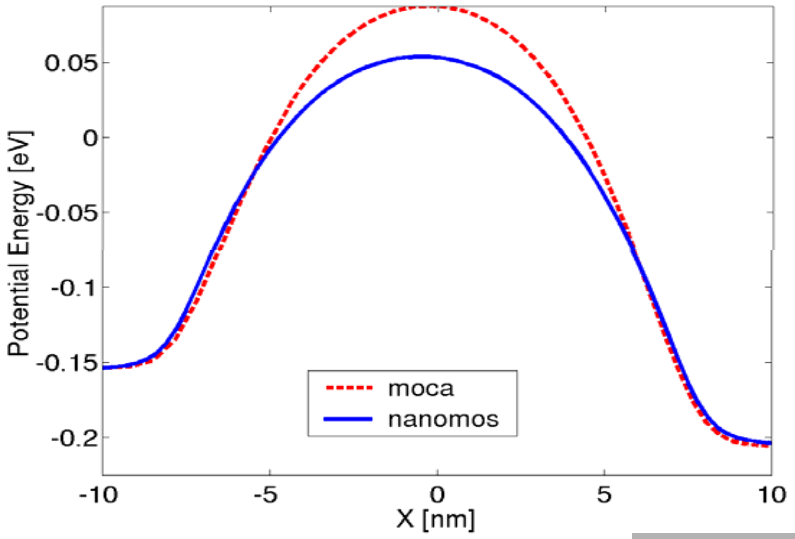
L_G = 9.0 nm (-4.5nm to 4.5nm)

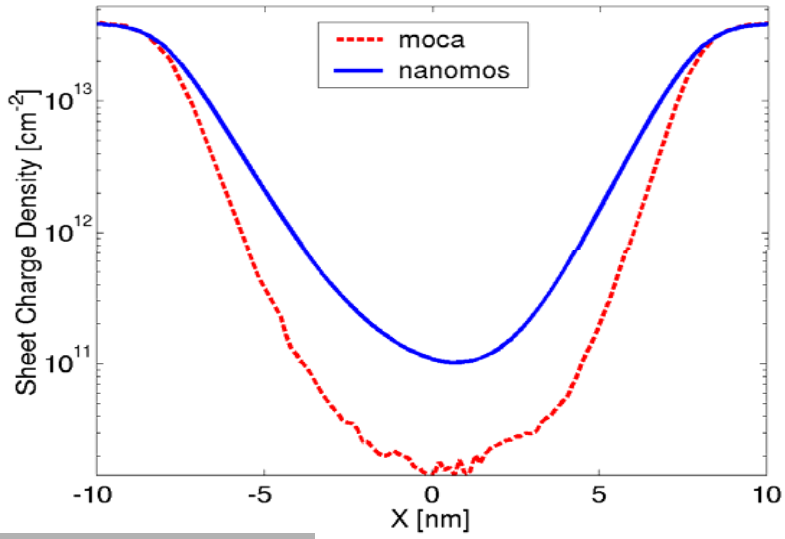
L_T = 17.0 nm (-8.5nm to 8.5nm)

$N_{S/D} = 10^{20}$ cm^{-3}
(gradient 1.0 nm/decade)

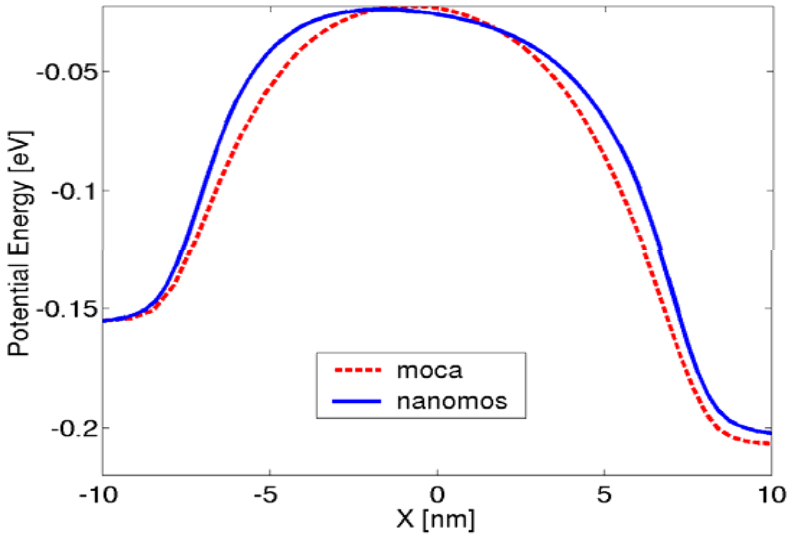
$N_{body} = 10^{10}$ cm^{-3}

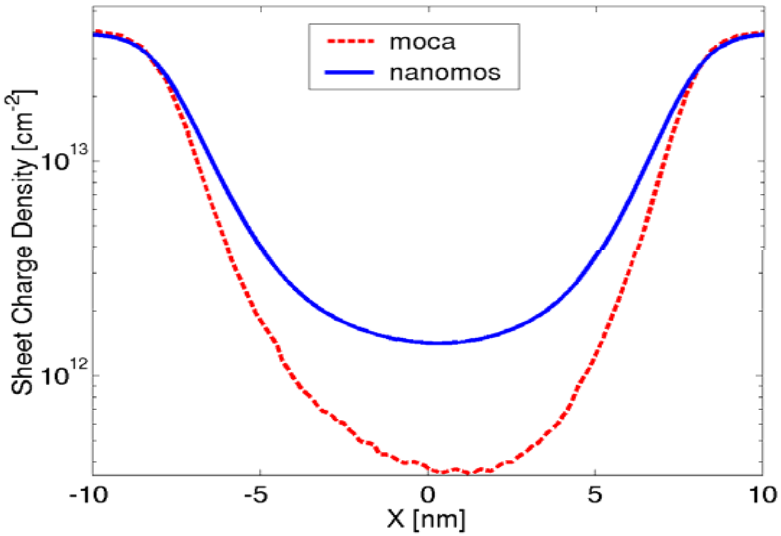
t_{Si} = 4nm, V_{ds} = 0.05V, Vg = 0.05V



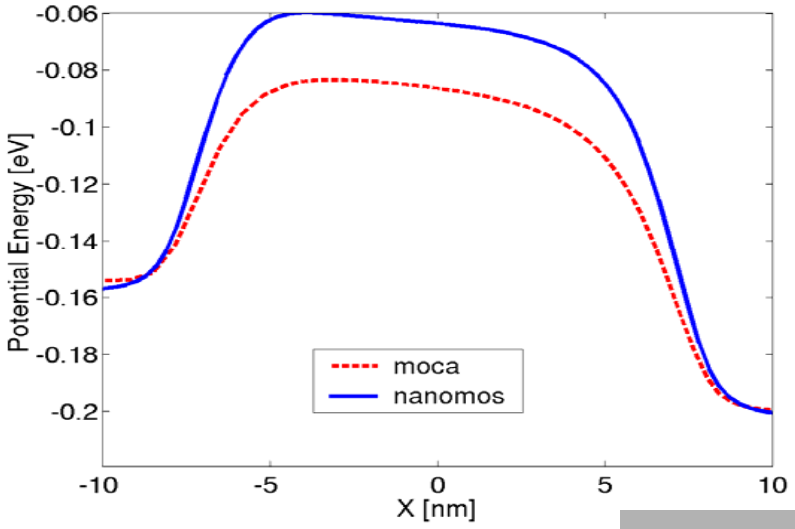


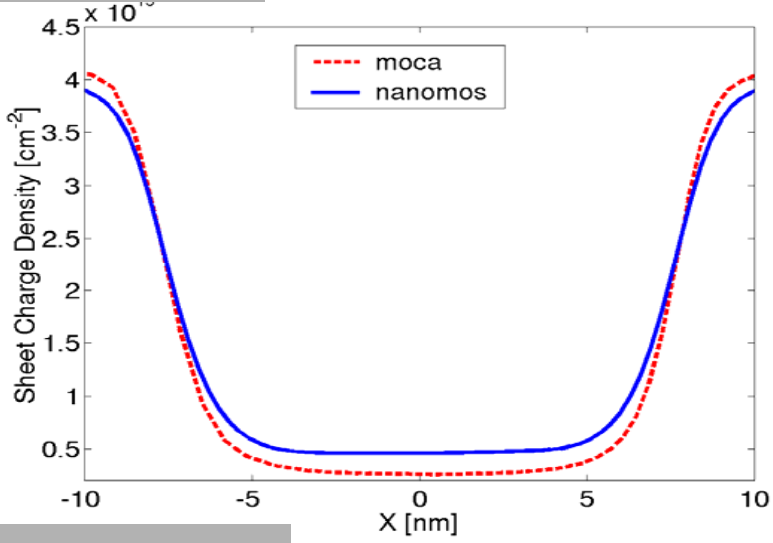
t_{Si} = 4nm, V_{ds} = 0.05V, Vg = 0.20V



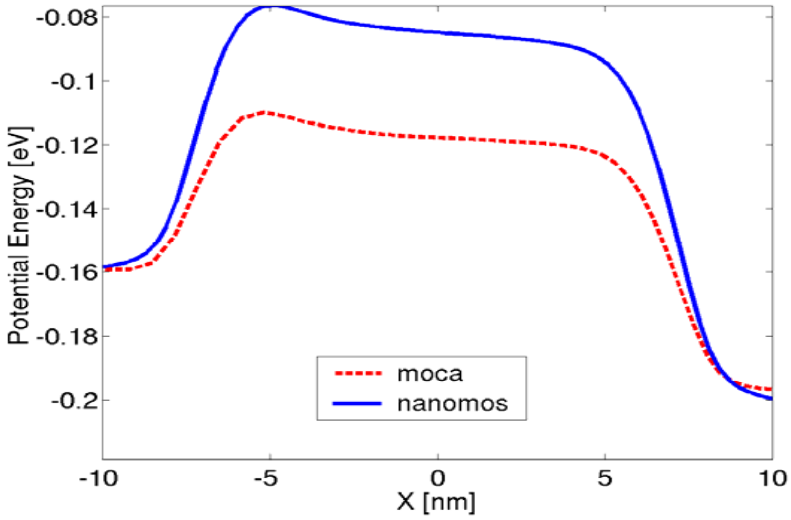


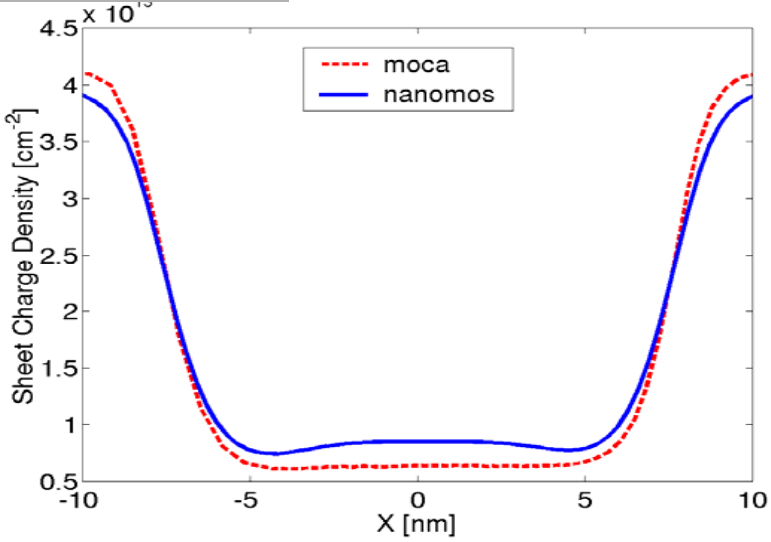
t_{Si} = 4nm, V_{ds} = 0.05V, Vg = 0.35V



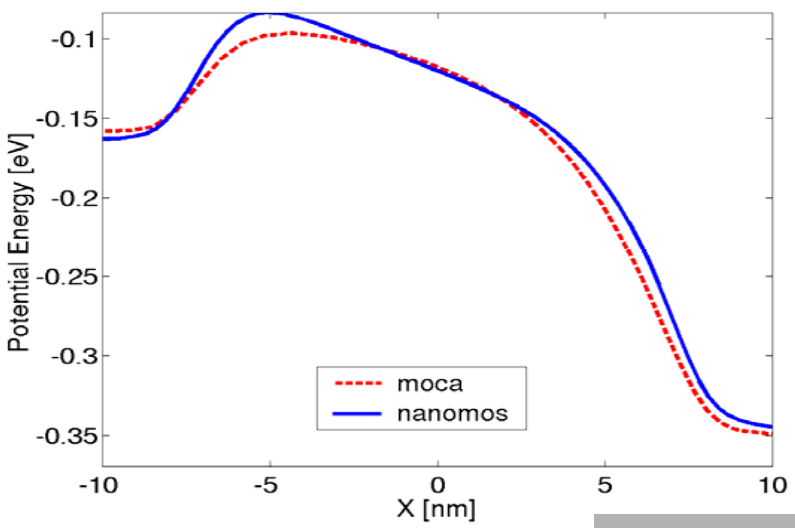


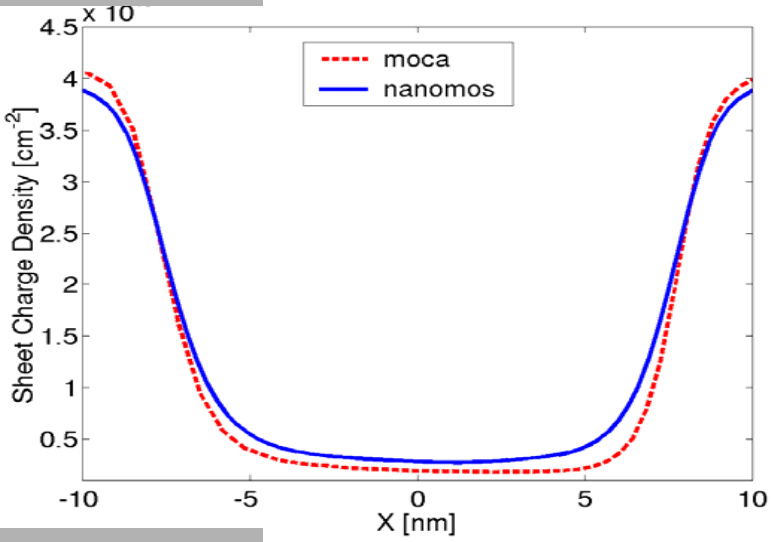
t_{Si} = 4nm, V_{ds} = 0.05V, Vg = 0.50V



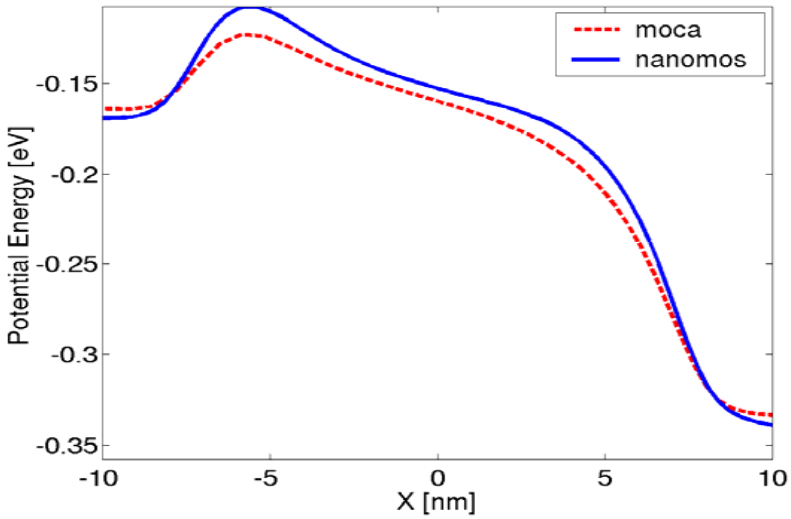


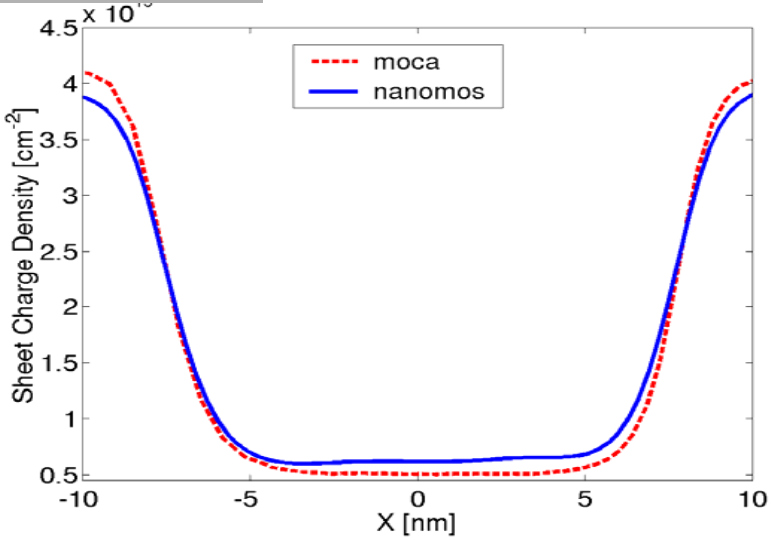
t_{Si} = 4nm, V_{ds} = 0.20V, Vg = 0.35V



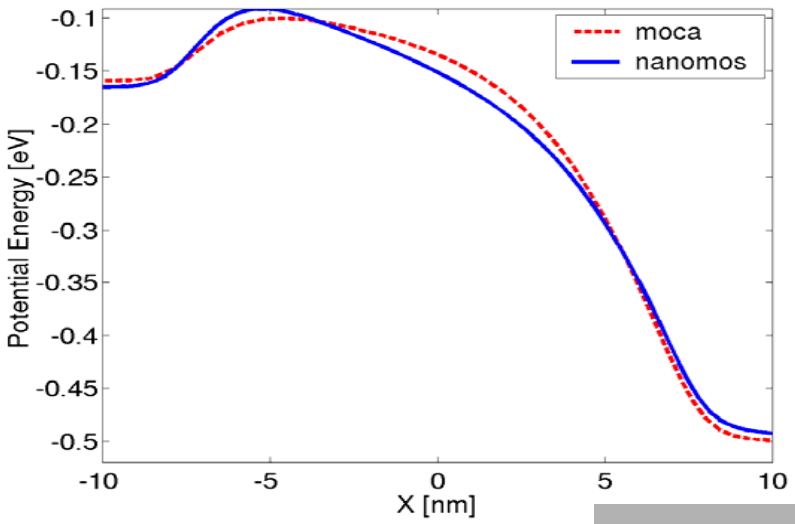


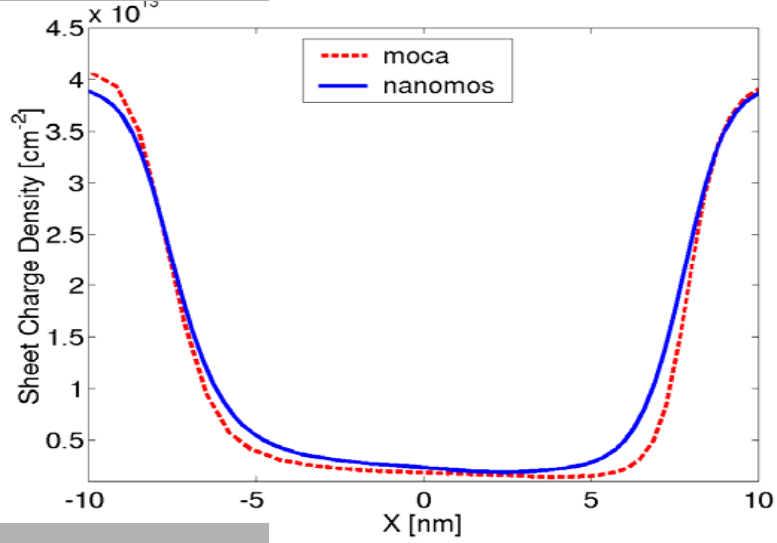
t_{Si} = 4nm, V_{ds} = 0.20V, Vg = 0.50V



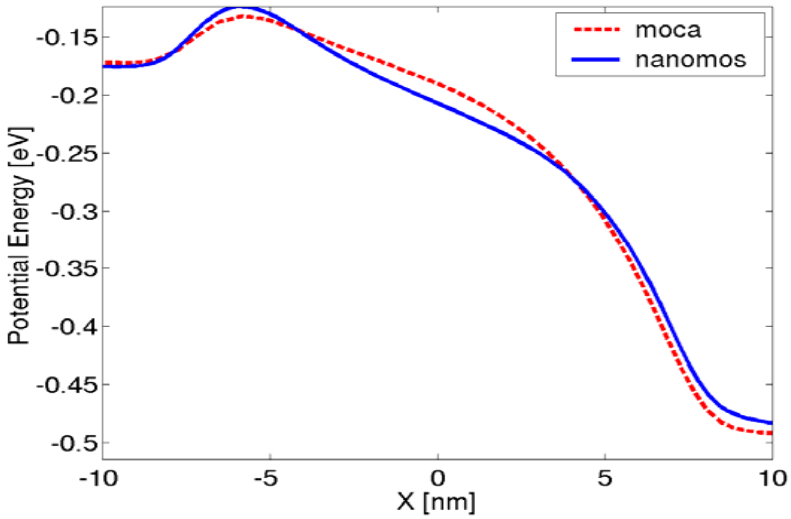


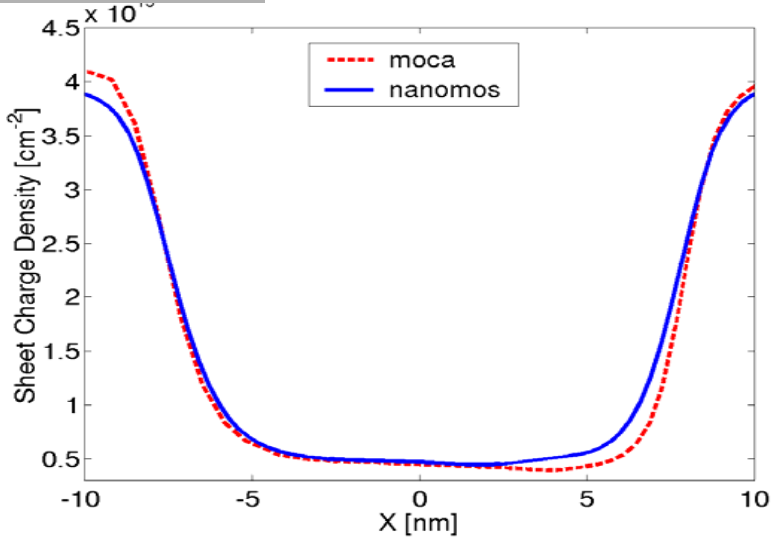
t_{Si} = 4nm, V_{ds} = 0.35V, Vg = 0.35V



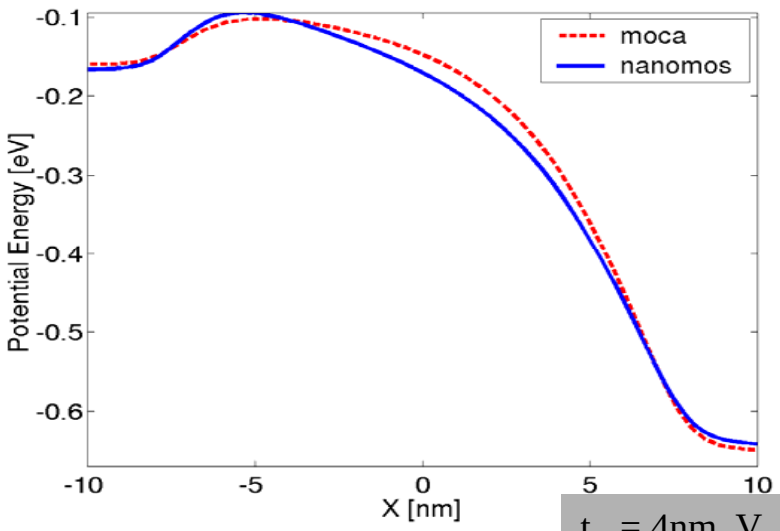


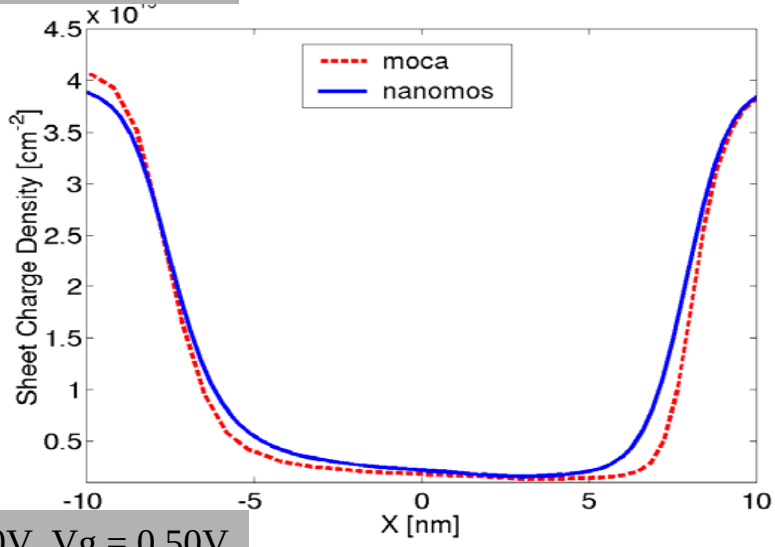
t_{Si} = 4nm, V_{ds} = 0.35V, Vg = 0.50V



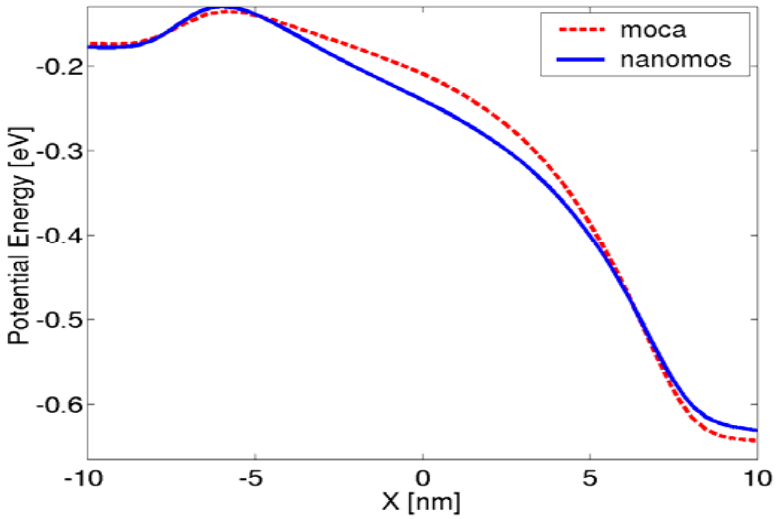


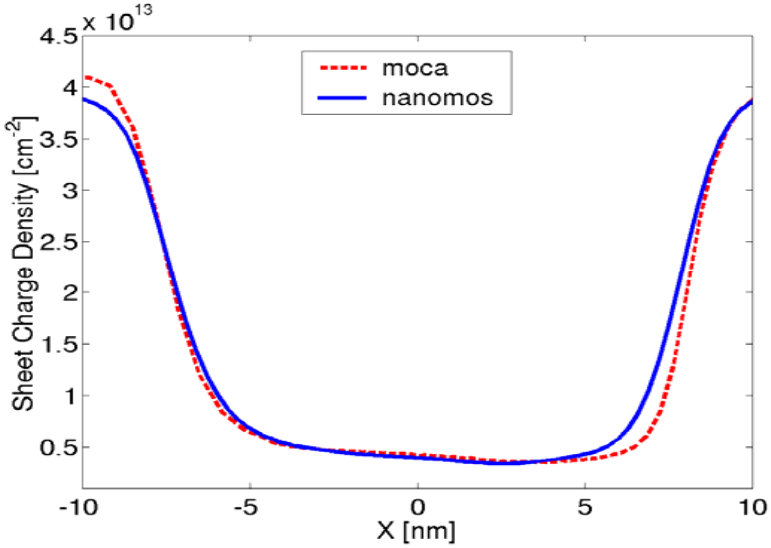
t_{Si} = 4nm, V_{ds} = 0.50V, Vg = 0.35V



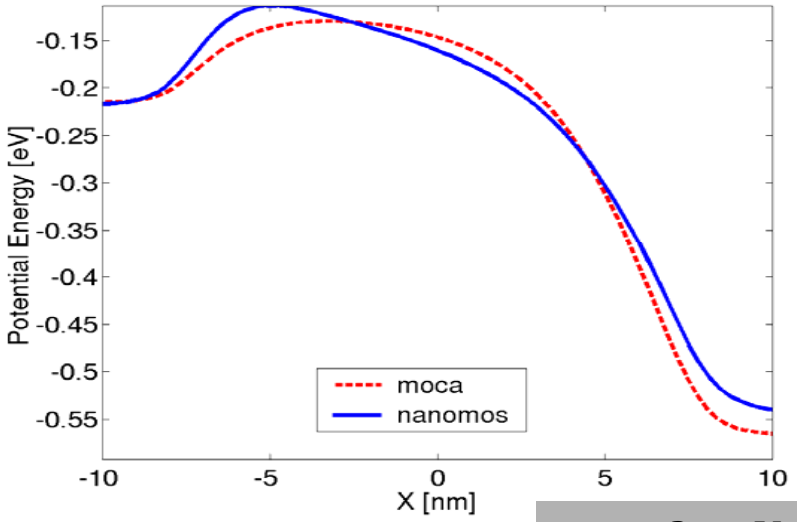


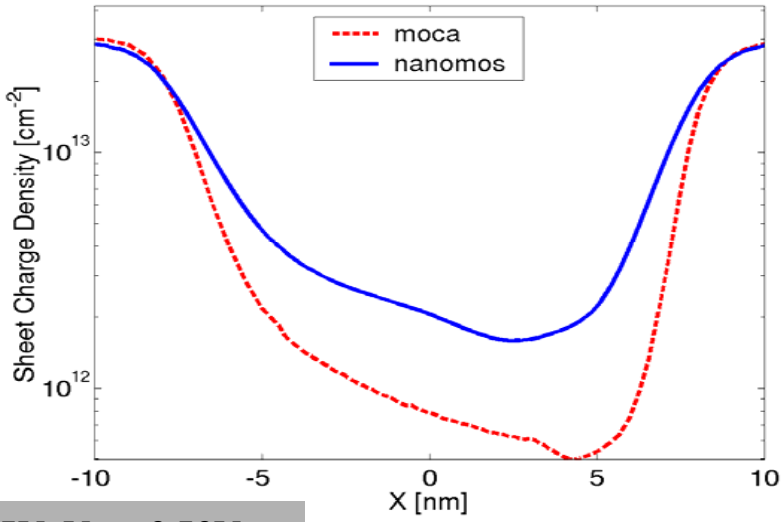
t_{Si} = 4nm, V_{ds} = 0.50V, Vg = 0.50V



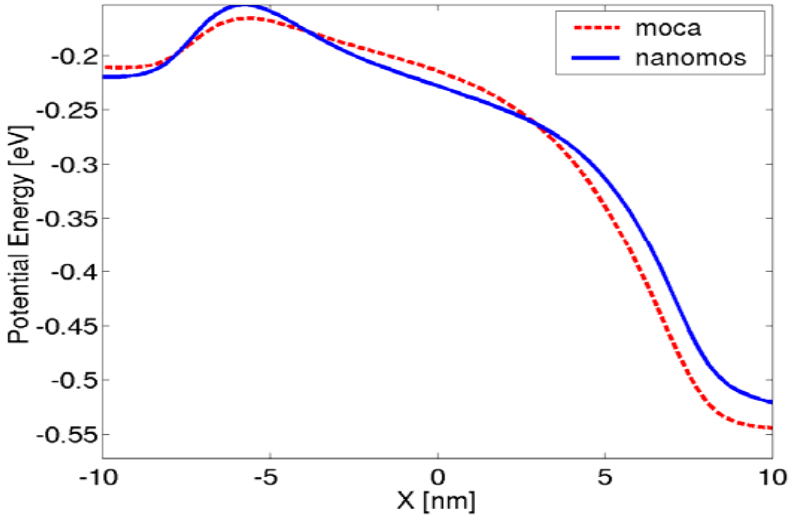


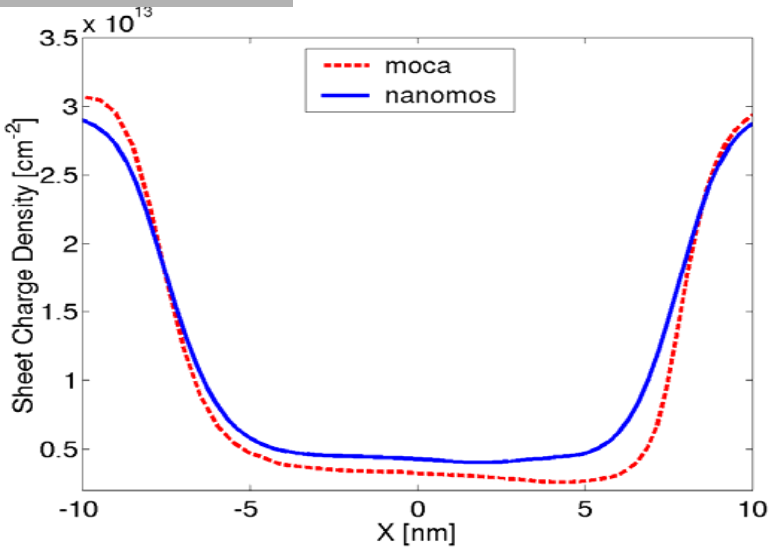
t_{Si} = 3nm, V_{ds} = 0.35V, Vg = 0.35V



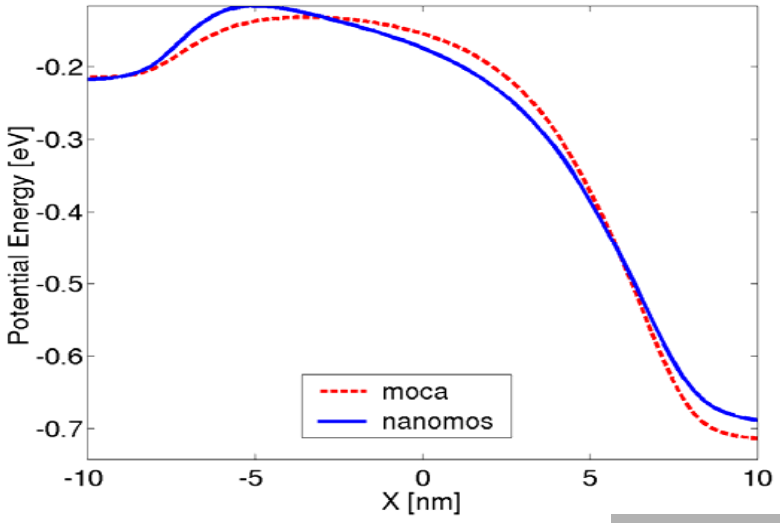


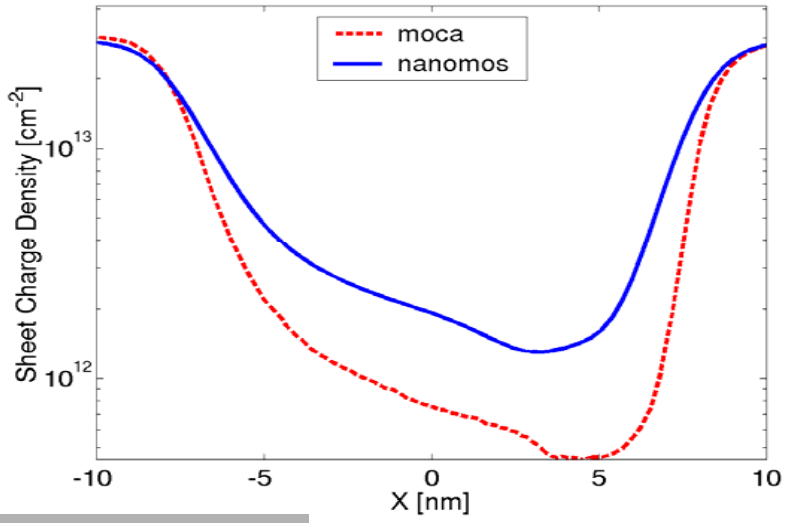
t_{Si} = 3nm, V_{ds} = 0.35V, Vg = 0.50V



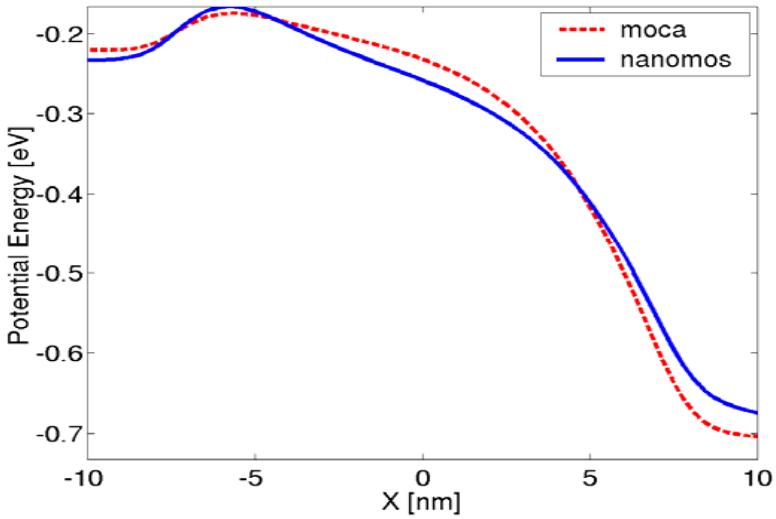


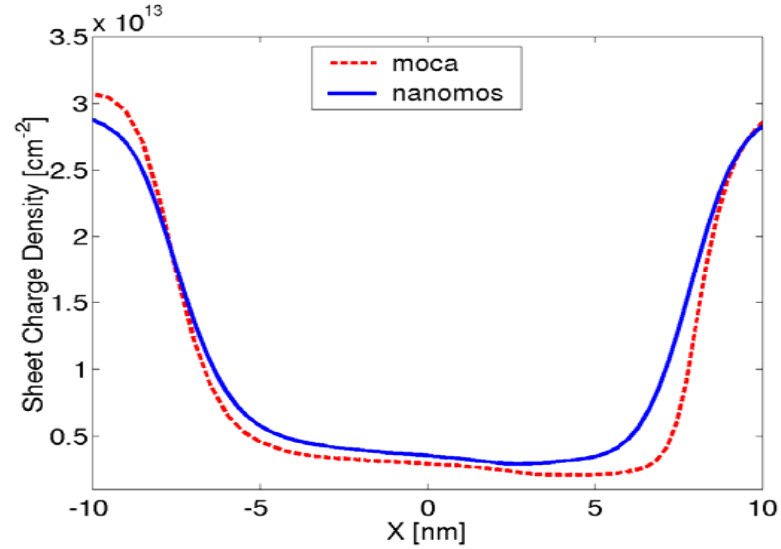
t_{Si} = 3nm, V_{ds} = 0.50V, Vg = 0.35V



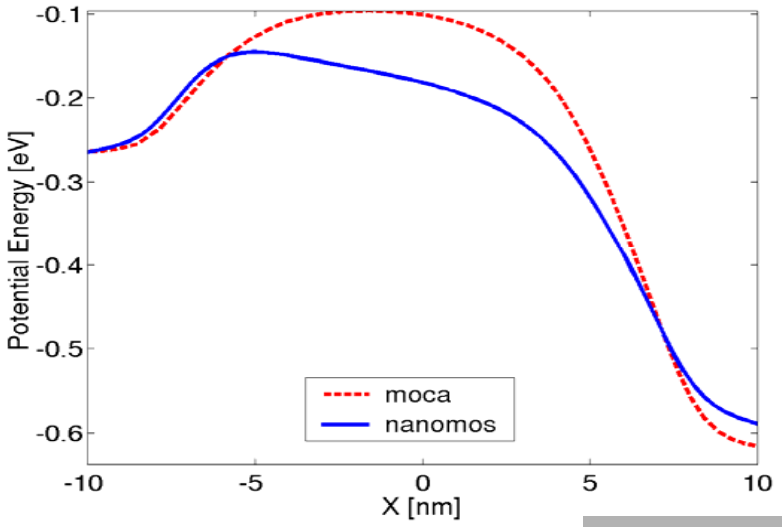


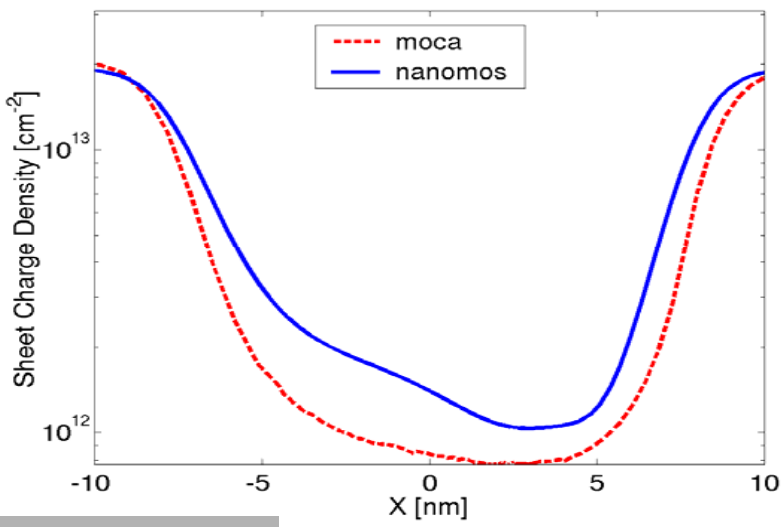
t_{Si} = 3nm, V_{ds} = 0.50V, Vg = 0.50V



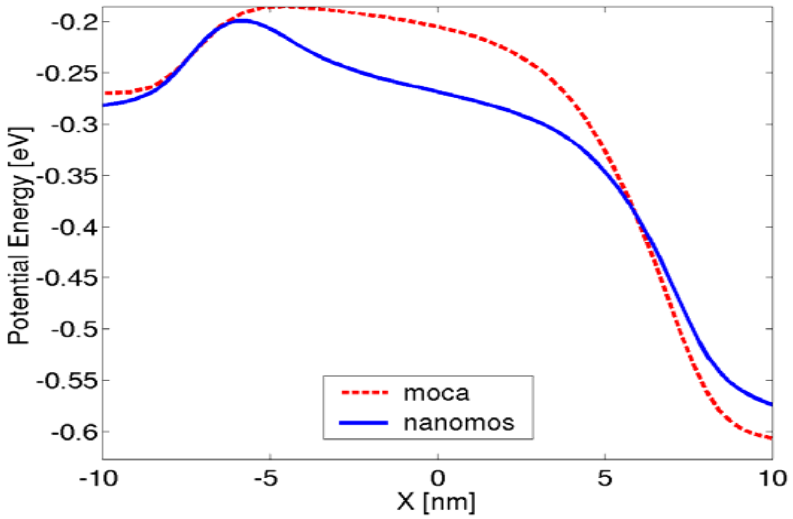


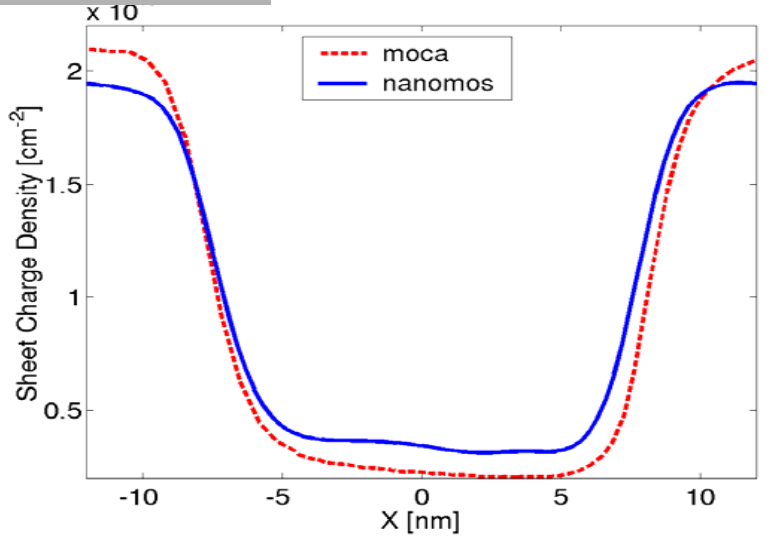
t_{Si} = 2nm, V_{ds} = 0.35V, Vg = 0.35V



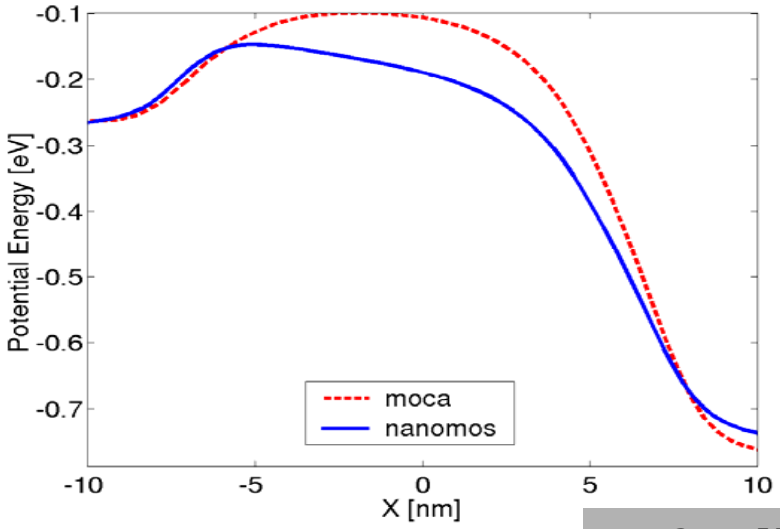


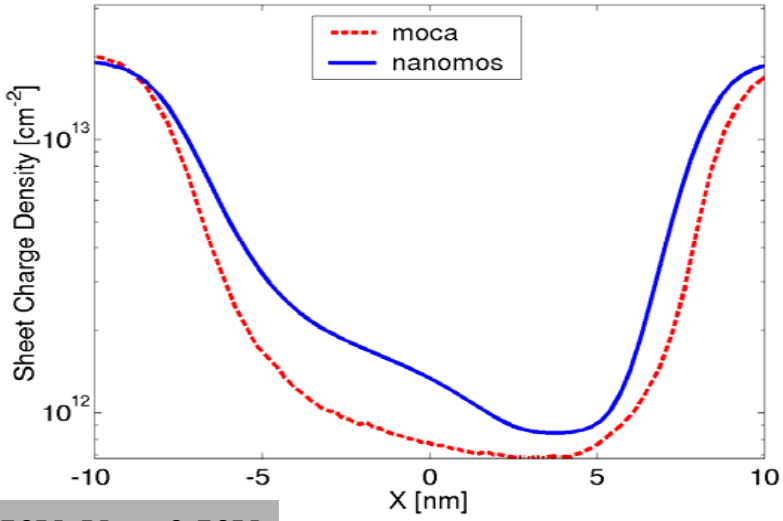
t_{Si} = 2nm, V_{ds} = 0.35V, Vg = 0.50V



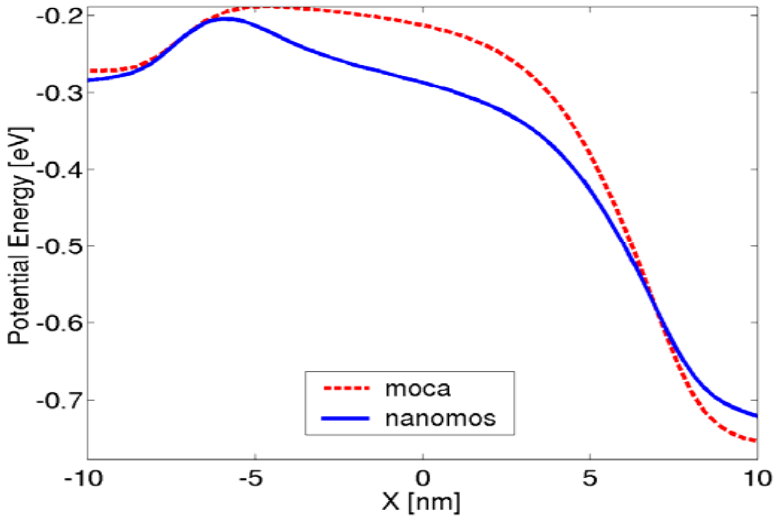


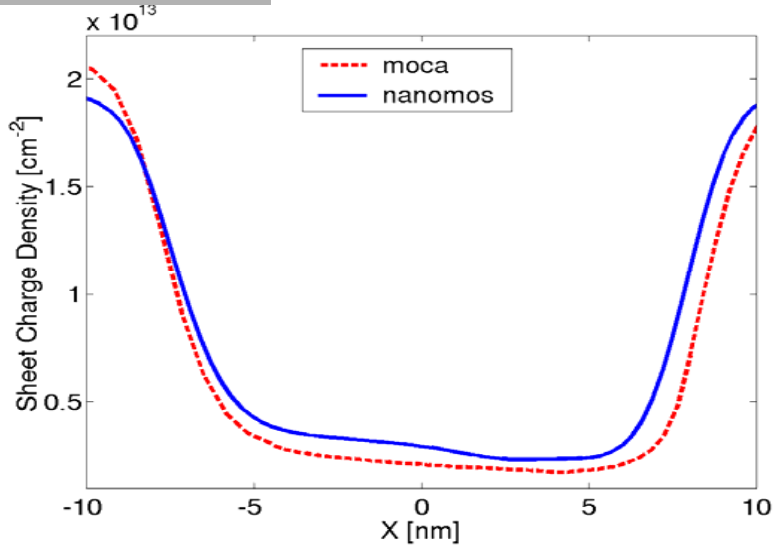
t_{Si} = 2nm, V_{ds} = 0.50V, Vg = 0.35V



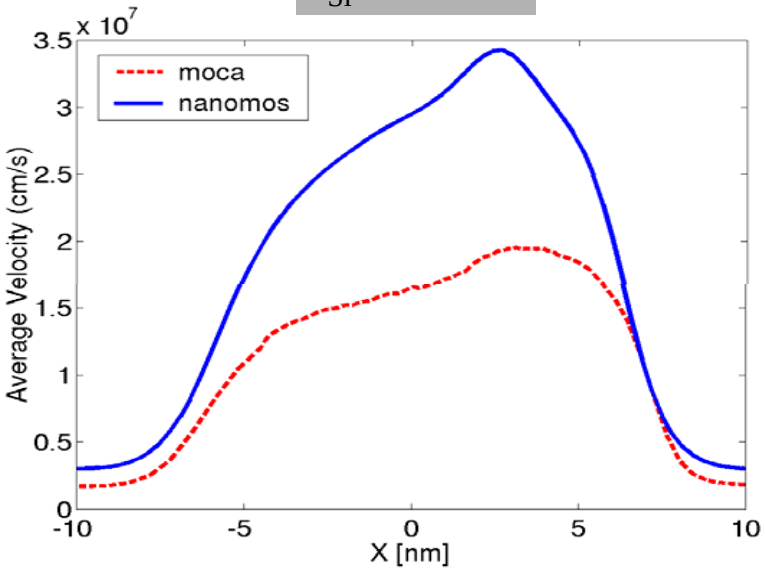


t_{Si} = 2nm, V_{ds} = 0.50V, Vg = 0.50V

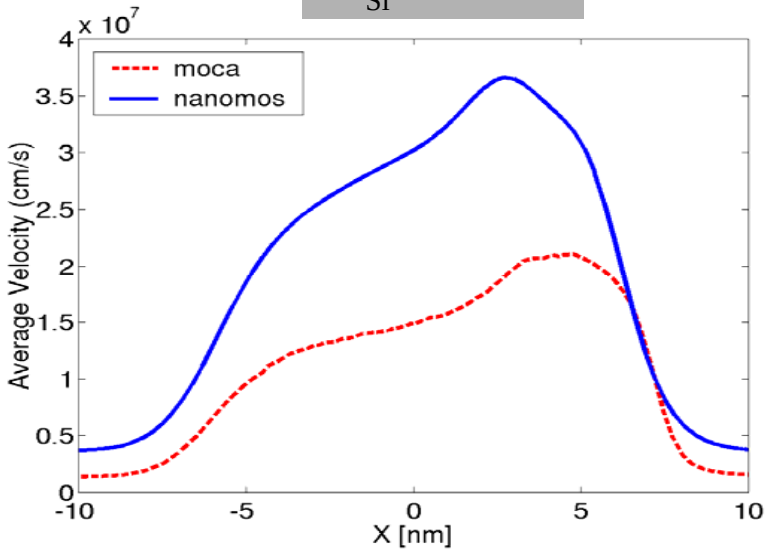




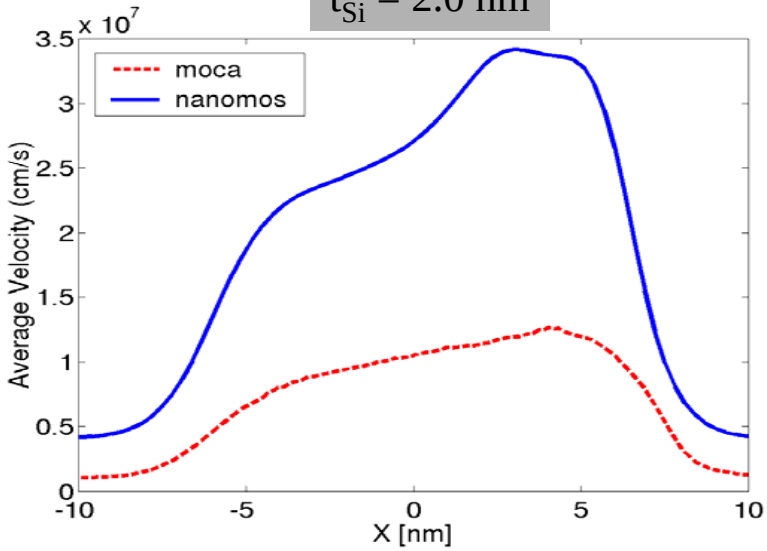
t_{Si} = 4.0 nm



t_{Si} = 3.0 nm



t_{Si} = 2.0 nm

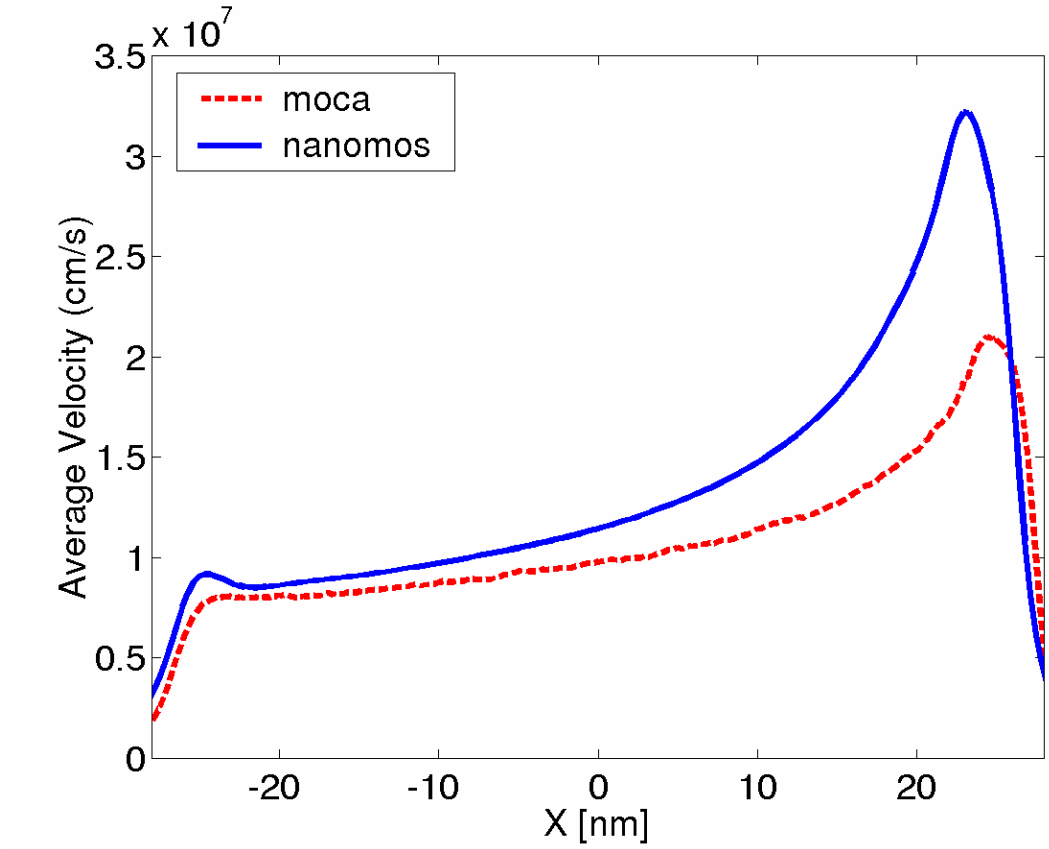


Velocity Profiles

V_{ds} = 0.50V, Vg = 0.50V

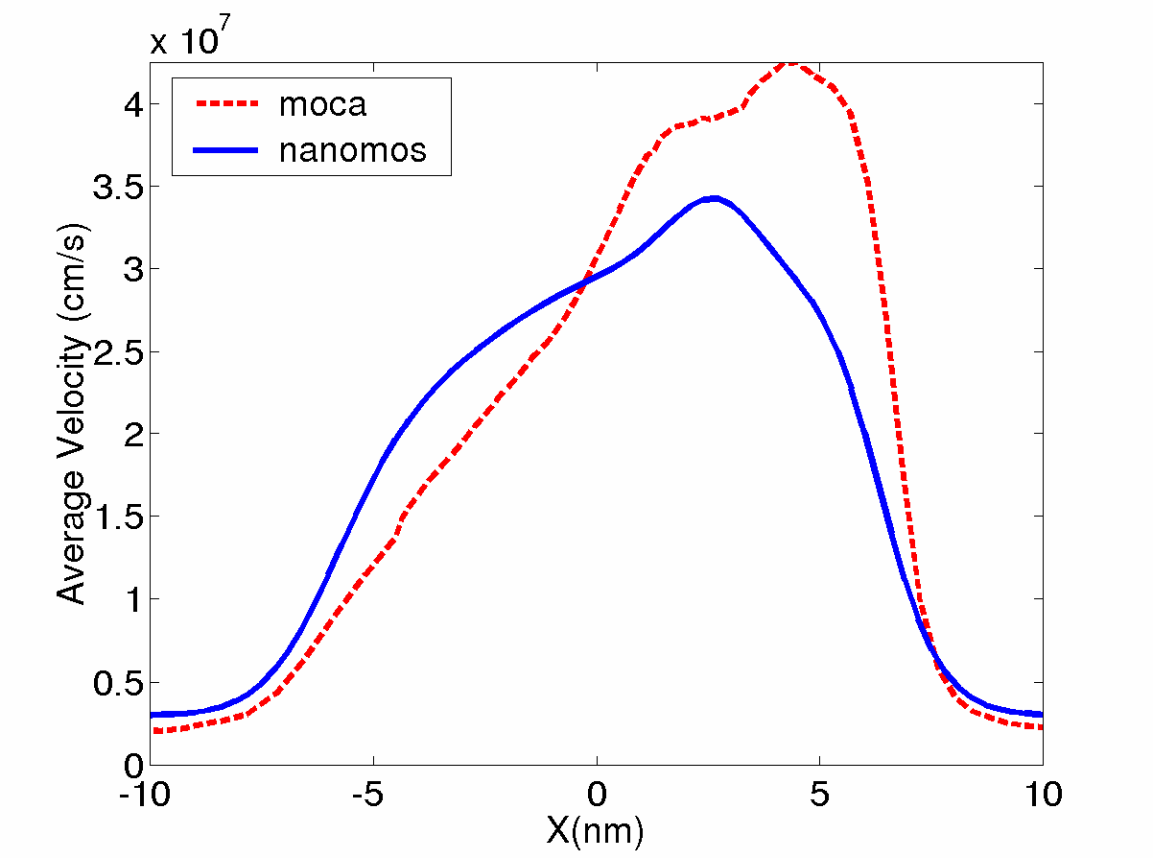
Long Channel benchmark

t_{Si}= 3.0 nm L_G = 50 nm, V_{ds} = 0.50V, Vg = 0.50V



Velocity comparison for a ballistic device

t_{Si}= 4.0 nm L_G = 9 nm, V_{ds} = 0.50V, Vg = 0.50V



Conclusions

- **The present benchmark comparison indicates that Monte Carlo and NEGF simulations give potential and density profiles that agree well in a range of conditions and silicon slab thicknesses.**
- **Discrepancies are noticed at low bias, explained by the granular nature of Monte Carlo as opposed to the continuum nature of NEGF.**
- **For thinner silicon slab thickness, size quantization is emphasized, and we are looking for the limits of validity of the quantum correction potential approach in Monte Carlo.**
- **At high fields, NEGF tend to give a much more prominent velocity overshoot. This is understood by considering that the present model of nanoMOS has parabolic bands, where velocity is not constrained as in a realistic band.**