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Network for Computational Nanotechnology (NCN)

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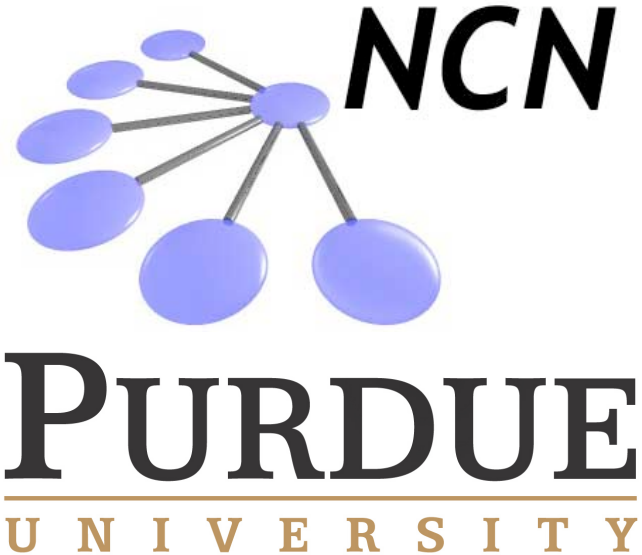
First-Time User Guide to MOSFET V1.2.2



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Electrical and Computer Engineering

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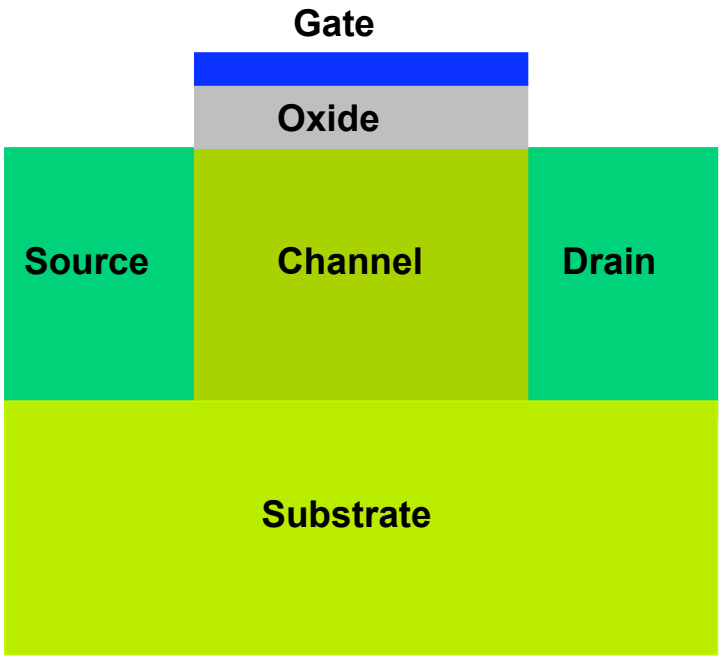
What is a MOSFET?

metal–oxide–semiconductor field-effect transistor:

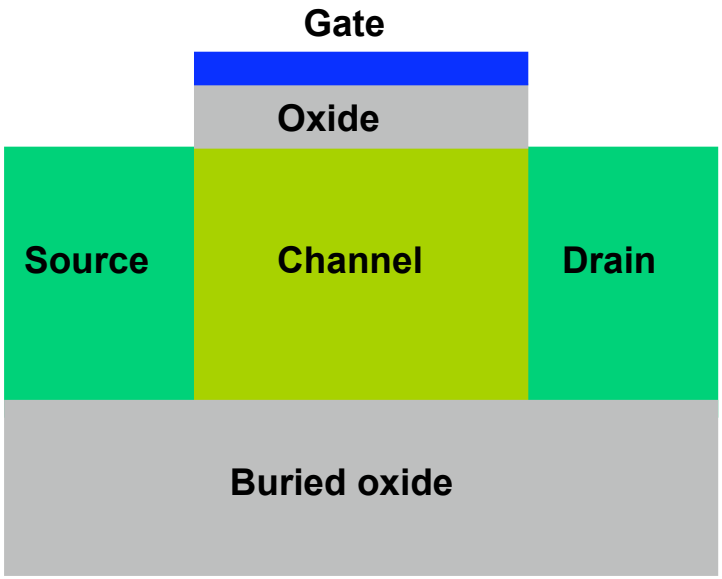
(**MOSFET, MOS-FET**, or **MOS FET**) is a device used to amplify or switch electronic signals.



- **Gate: Polysilicon or Metal (eV)**
- **Oxide: SiO_2 used as the dielectric (nm)**
- **Channel: n-type doped semiconductor for PMOS and p-type doped for NMOS**
- **Source/Drain: Heavily doped regions in contact with channel**
- **Substrate: Base semiconductor material**

What is a SOI MOSFET?

(Silicon on Insulator) metal–oxide–semiconductor field-effect transistor (SOI) MOSFET: semiconductor device formed above an insulator



Advantages

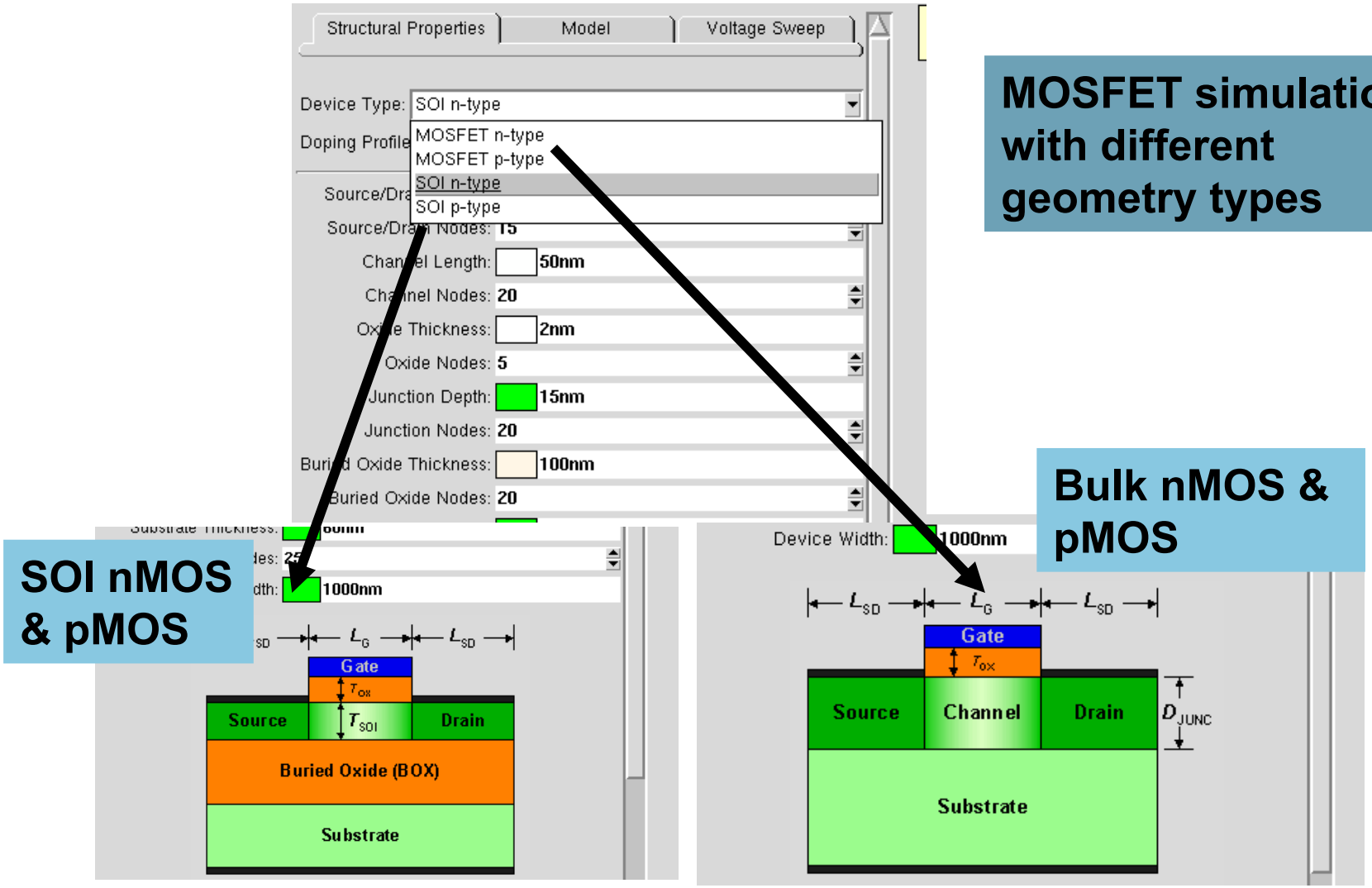
- Better gate control* over thinner channel
- Reduces short channel effects*

Disadvantages

- Increases parasitic resistance*
- Quantization effects come in leading to increasing (threshold voltage) V_t

Refer [1] https://nanohub.org/resources/5085 for detailed description of working of a MOSFET.

What Can Be Simulated by the MOSFET Tool?



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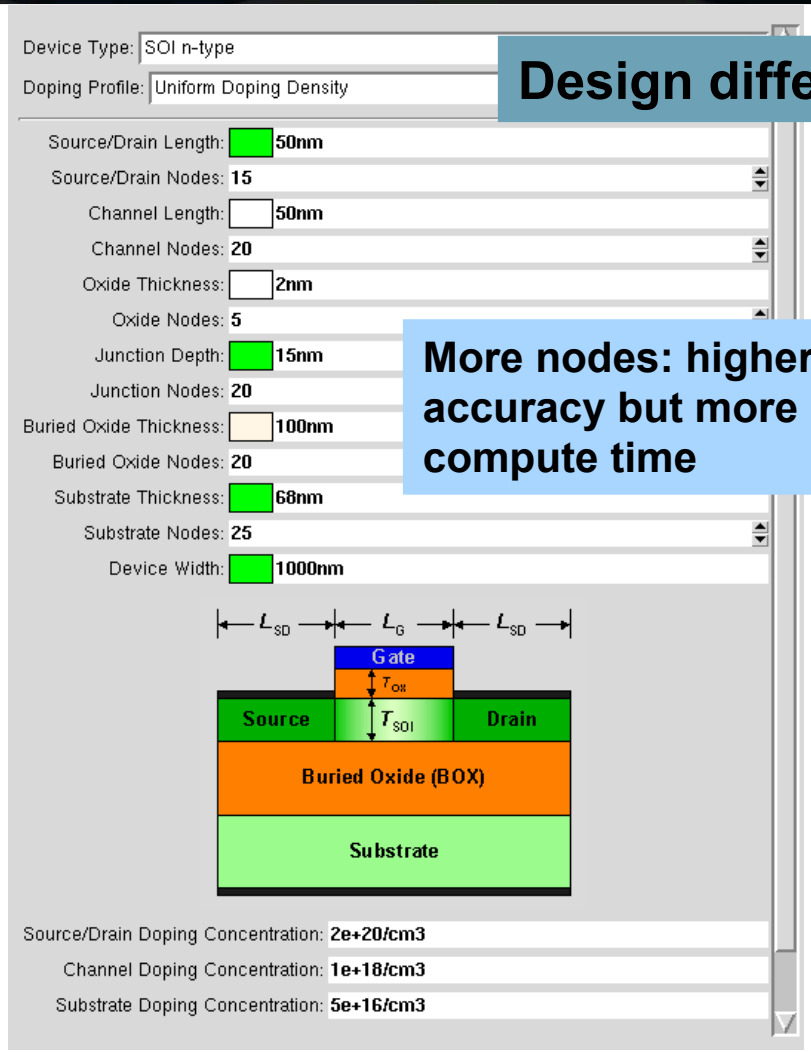
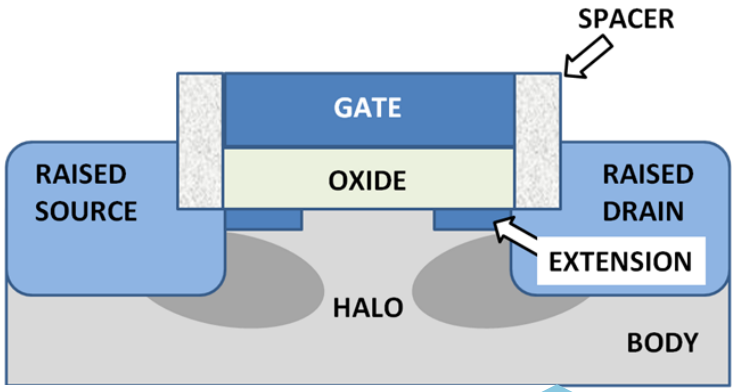


Design different MOSFET structures

More nodes: higher accuracy but more compute time



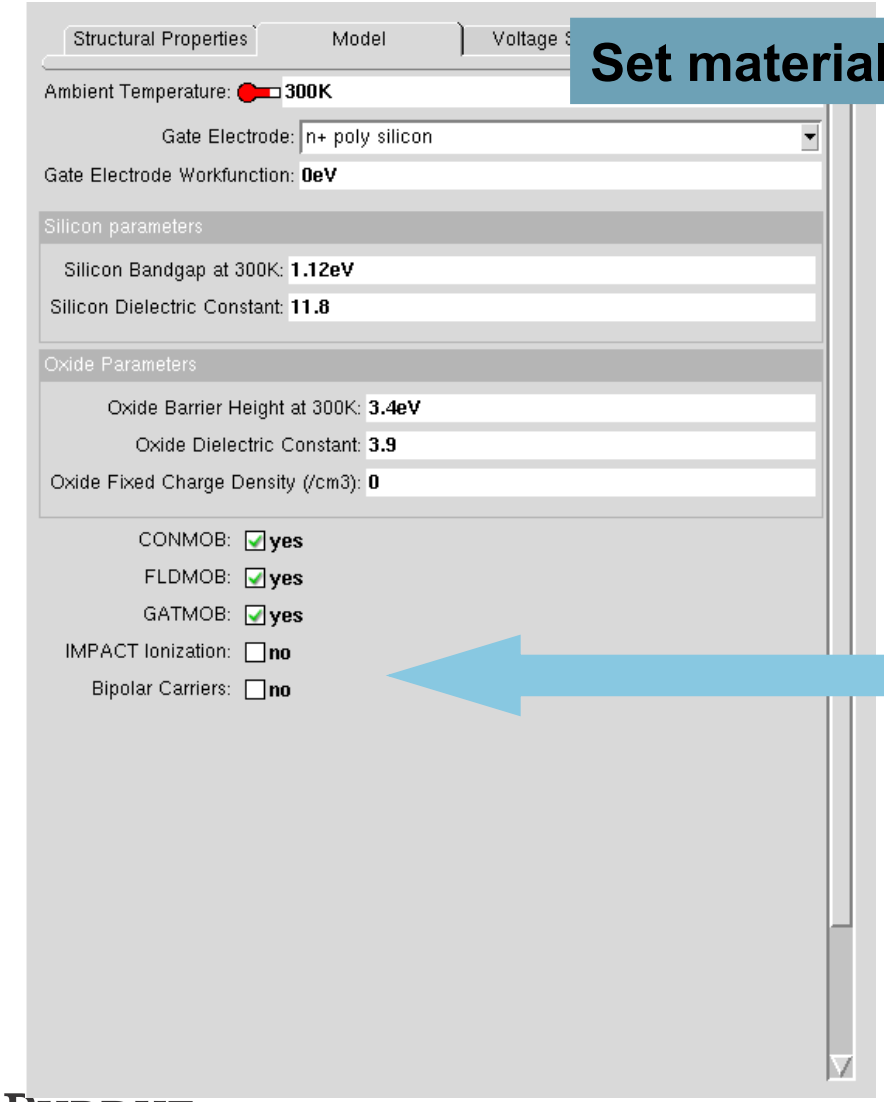
Modern MOSFET structure.[2]

3 different doping profiles to simulate real devices:

- Uniform
- Gaussian S/D
- Gaussian S/D + Halo

[2] http://en.wikipedia.org/wiki/File:MOSFET_junction_structure.png

What Can Be Simulated by the MOSFET Tool?



Set material parameters and model

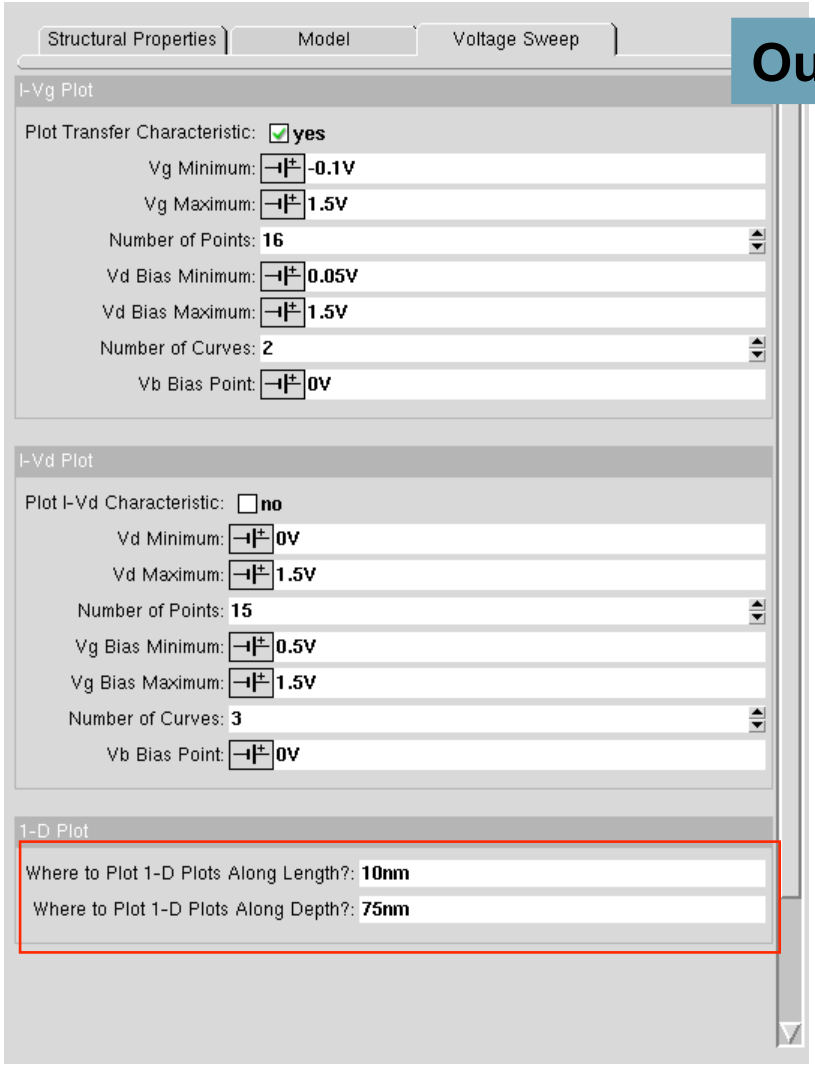
- No poly depletion included in simulations
- Bandgap, dielectric constant, and barrier height can be tuned to simulate another materials

- **CONMOB: Ionized Impurity scattering**
- **FLDMOB: Velocity Saturation model**
- **GATMOB: Gate-field mobility model**

Refer [3] below to know more about the models.

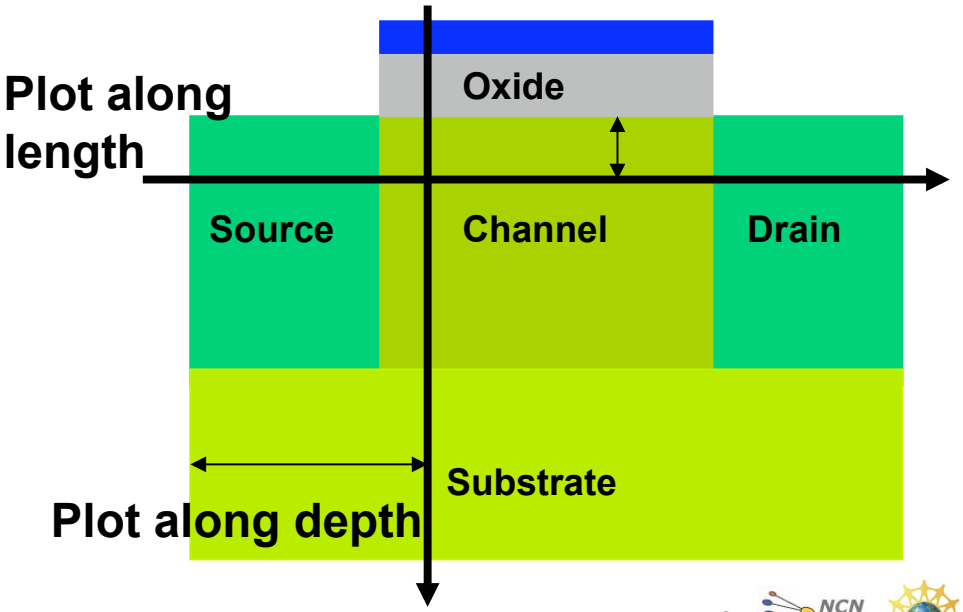
[3] http://nanohub.org/resource_files/tools/padre/doc/padre-ref/mater.html

What Can Be Simulated by in the MOSFET Tool?



Output from MOSFET tool

- Both Id-Vg and Id-Vd curves can be simulated during the same run
- Keep number of bias points at 0.1 V spacing for better convergence



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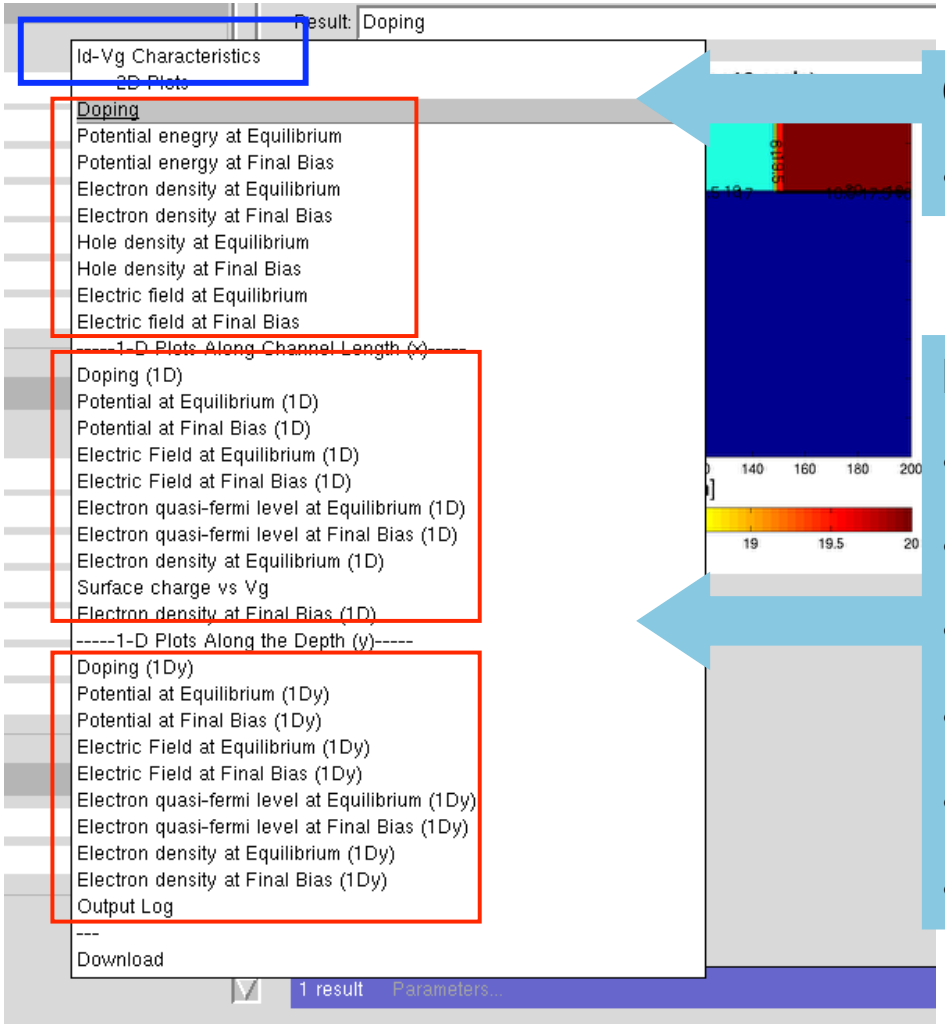


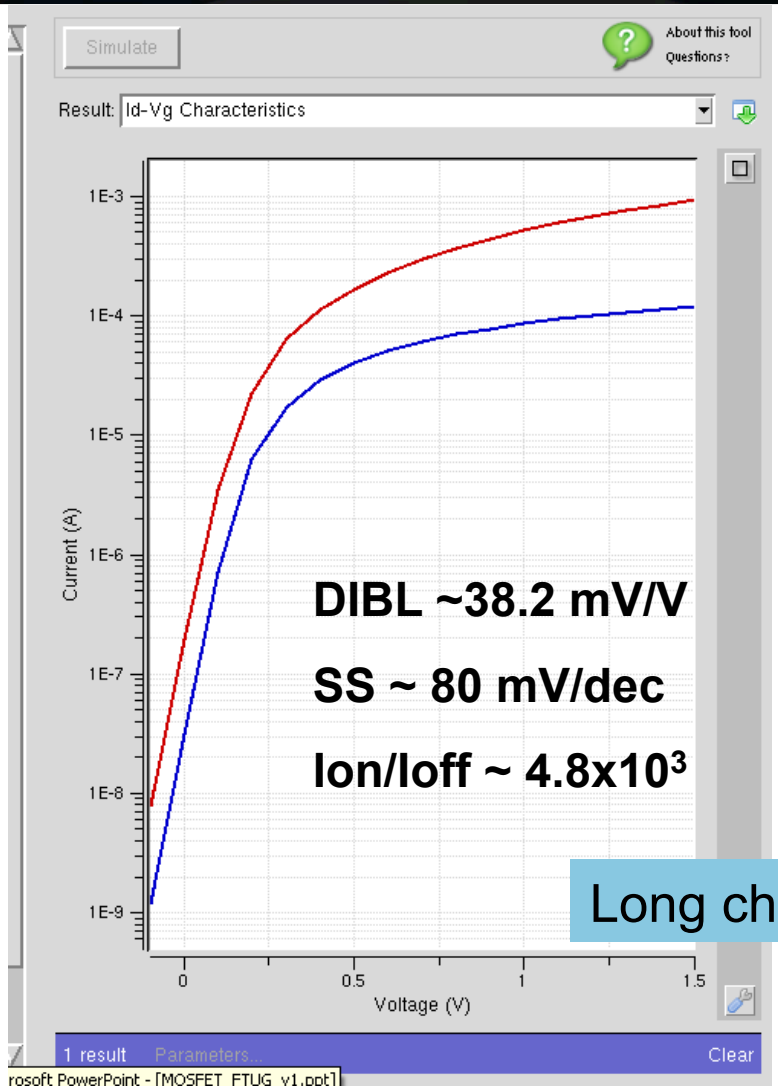
Output Characteristics:

- **Id-Vg & Id-Vd**

In 2D,1D(along x) and 1D(along y)

- **Doping profile (/cm3)**
- **Potential profile (V)**
- **Electron density (/cm3)**
- **Hole density (/cm3)**
- **Electric field (V/cm)**
- **Quasi-Fermi level (eV)**

What If You Just Hit Simulate?



Default setting simulates Id-Vg characteristics for N-type MOSFET:

Channel length, L=100nm

Oxide thickness, T_{ox}=2nm

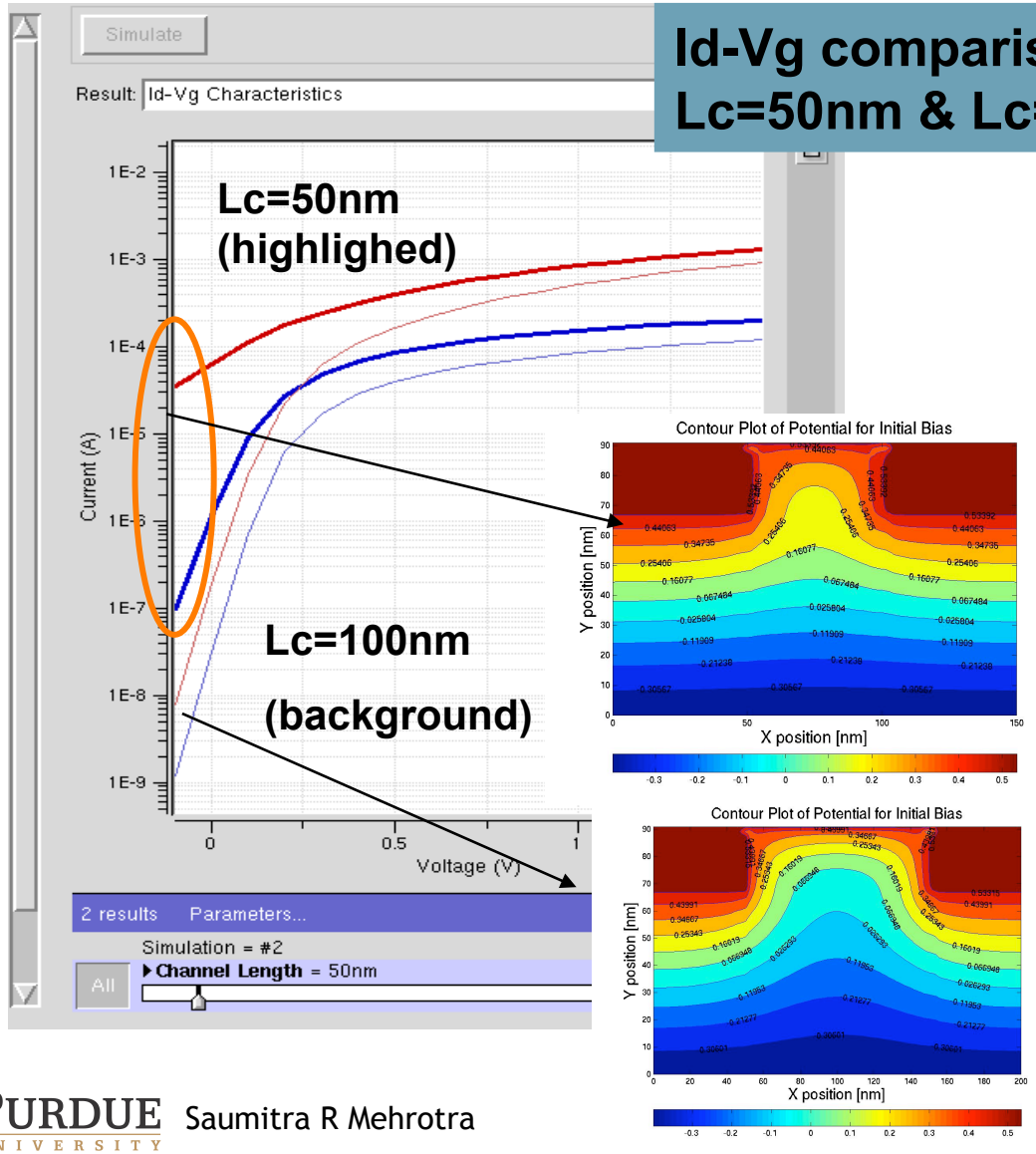
Channel doping, N_{ch}=1e18/cm3

Id-Vg simulated are at

Vd=0.05V (low) & Vd=1.5V (high)

Long channel device behavior

Example: What if the Channel Length is Changed?



Id-Vg comparison between MOSFET with Lc=50nm & Lc=100nm

Severe short channel effects [3] at Lc=50nm.Vd=1.5V(red) & Vd=0.05(blue)

- High OFF state current*
- High DIBL*
- High Subthreshold slope*

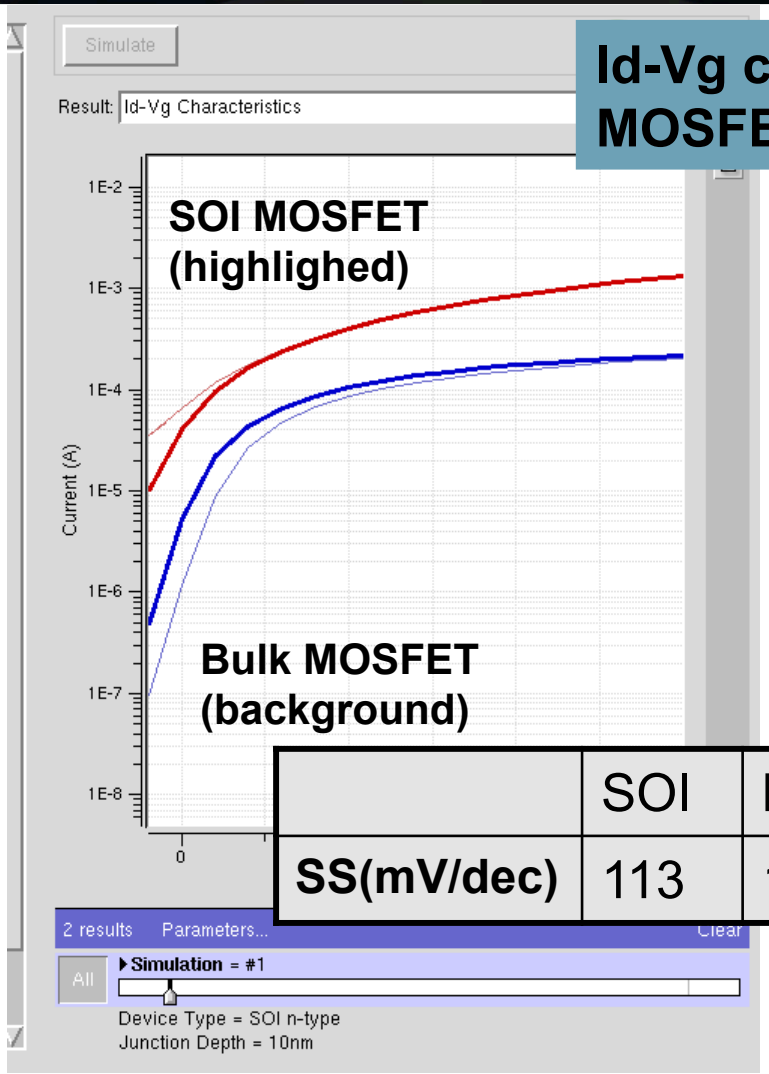
***Please refer to reference [3] for more information about short channel effects in MOSFETS**

DIBL: Drain Induced Barrier Lowering

https://nanohub.org/resources/5085

Barrier lowered for Lc=50nm

Example: SOI versus Bulk MOSFET



Id-Vg comparison between bulk and SOI MOSFET with Lc=50nm

	SOI	Bulk
SS(mV/dec)	113	162

Improved short channel effects [3] for SOI-MOS (10 nm body thickness) over bulk-MOS at Lc=50nm.

Vd=1.5V(red) & Vd=0.05(blue)

- Lower Ioff
- Lower DIBL
- Lower subthreshold slope

Please refer [3] for more information about Short Channel Effects in MOSFETS
https://nanohub.org/resources/5085

Tool Limitations and General Comments

- No polydepletion effects are included in the simulations.
- Quantum effects are not present in the simulations.
  - » This is important for SOI simulation with very thin (<5nm) body thickness
- Few bias points during the large bias sweep (Vg or Vd sweep) might lead to non convergence.
- Take note of the location of 1D output plots while running the simulation (i.e. output profile should lie in the desired region of interest).

Please use the following link to submit any issues/comment:

- https://nanohub.org/resources/3/reviews?action=addreview#reviewform

If you reference this work in a publication, please cite as follows:

- Matteo Mannino; Shaikh S. Ahmed; Gerhard Klimeck; Dragica Vasileska; Xufeng Wang; Himadri Pal (2006), "MOSFet," DOI: 10254/nanohub-r452.7.

References

[1] MOSFET OPERATION DESCRIPTION:
https://nanohub.org/resources/5085

[2] MODERN MOSFET STRUCTURE (image)
http://en.wikipedia.org/wiki/File:MOSFET_junction_structure.png

[3] PADRE DEVICE SIMULATOR MANUAL:
http://nanohub.org/resource_files/tools/padre/doc/padre-ref/mater.html

[4] PADRE SIMULATOR: https://nanohub.org/resources/941/