# Using nanoHUB in the Electrical and Computer Engineering Curriculum

Stella A. Quiñones and Greg Lush

**Electrical and Computer Engineering**

**The University of Texas at El Paso**

**stellaq@utep.edu**

Arlington, Virginia
December 8, 2010

**Goal:**  Teach students how to use work space on nanoHUB to create tool.

**Rapturizer Tool:**   Writes the template to rappturize code.

**Homework:**   Includes a 5 minute tutorial and asks students to create code,
rappturize code, create tool on nanoHUB.org and test tool.

1. Download and import program commands.
2. Execute Rappurizer Program
3. Type in number for source of program and add comments.
4. Define variables
5. Set-up input layout:  #, name and range
6. Set-up output layout:  #, name and range

7. Enter plot range
8. Rappturize file
9. Input equation
10. Execute Program
11. Input Screen appears
12. Enter variables and Simulate
13. Results Screen appears
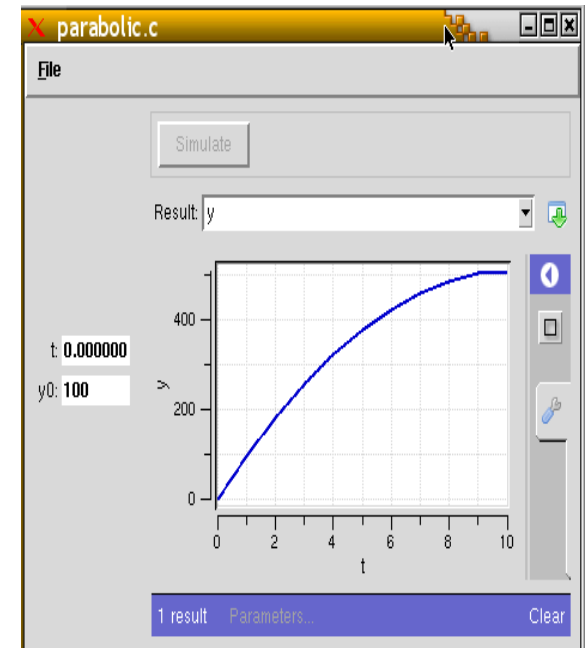
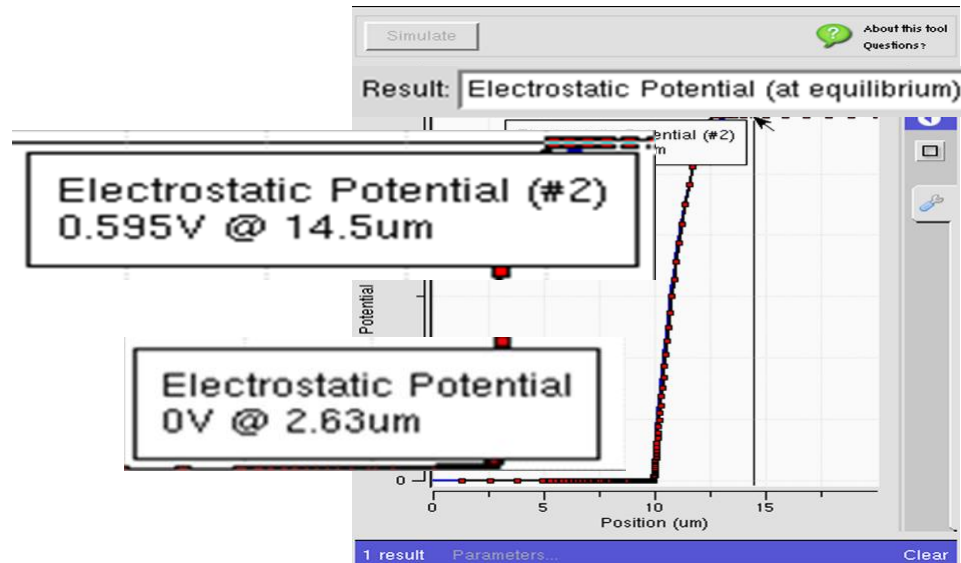**Goal:**  Examine effect of Doping on Electrostatic Characteristics

**PN Junction Tool:**  This tool simulates the electrostatic variables as a function of doping.

**Homework:**  (1) Calculate electrostatic variables ($V_{bi}$, $X_n$, $X_p$, $E_{max}$ at zero bias) and compare to similar values obtained from simulation.  (2)  Using simulation tool, examine the effect of applied bias on these variables.  (3) Examine the effect of increased doping on calculated and simulated values. (Includes an introduction to tool.)

$$V_{bi} = \frac{kT}{q} \ln\left[\frac{N_A N_D}{ni^2}\right]$$

$$V_{bi} = 0.0259V \ln\left(\frac{\frac{10^{16}}{cm^3} * \frac{10^{14}}{cm^3}}{\frac{10^{20}}{cm^6}}\right)$$

$$V_{bi} = 0.596V$$

Simulate

About this tool
Questions?

Result:  Electrostatic Potential (at equilibrium)

Electrostatic Potential (#2)
0.595V @ 14.5um

Electrostatic Potential
0V @ 2.63um

Potential

Position (um)

1 result     Parameters...                    Clear

COLLEGE OF ENGINEERING
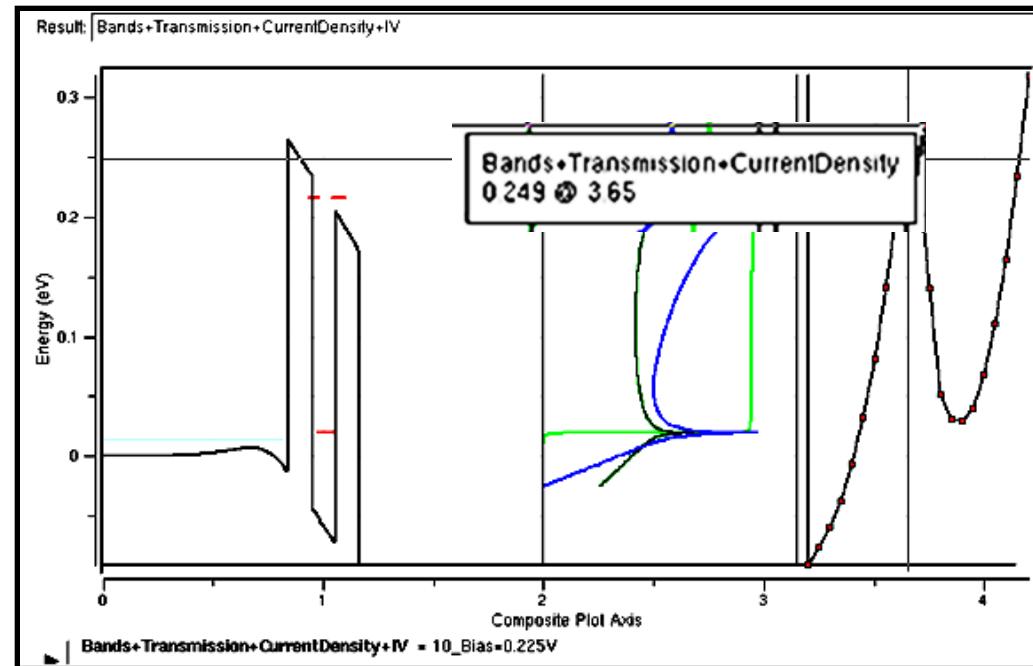THE UNIVERSITY OF TEXAS AT EL PASO

**Goal:** Examine effect of quantum well length on quantization of energy, tunneling and device physics by simulating a RTD.

**Resonant Tunneling Diode Tool:** This tool simulates the peak current and peak bias for a 2-barrier or multi-barrier device.

**Homework:** Examine the change in quantized energy levels in QW, peak bias and peak current as a function of well length.

Identify peak current at 100% tunneling



Result: Bands+Transmission+CurrentDensity+IV

Bands+Transmission+CurrentDensity
0.249 ⊗ 3.65

Energy (eV)

Composite Plot Axis

Bands+Transmission+CurrentDensity+IV = 10_Bias=0.225V

**Goal:** Examine effect of doping, oxide thickness, channel length, and scaling on NFET transistor operation.

**MOSFET Tool:** This tool simulates the I-V characteristics and electrostatic variables associated with an n-channel and p-channel MOSFET transistor.

**Homework:** Identify $V_T$, $I_{on}$, $I_{off}$, $I_{DSAT}$ and $V_{DSAT}$ as a function of doping, and examine the effect of scaling on the performance of a short channel MOSFET.

$I_D$-$V_D$
Characteristics
before and after
scaling
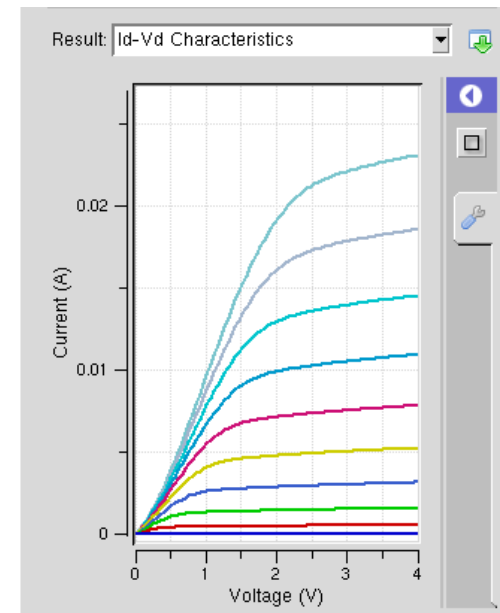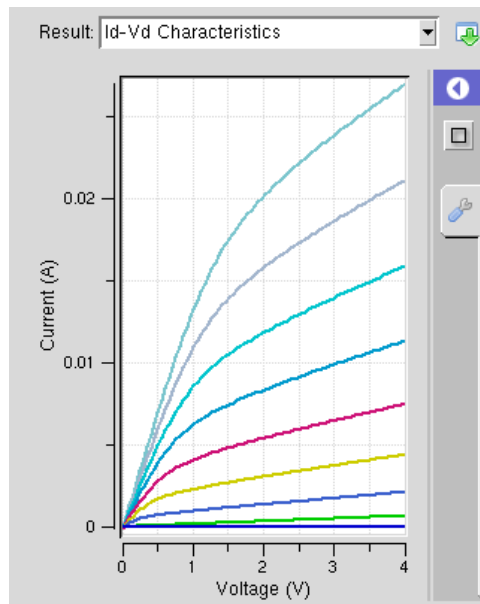
## Instructional Tools

1. Tools are user friendly.

2. Simulations help students visualize effect of design parameters on performance.

3. Students can connect theoretical calculations to simulated values as a function of doping.

4. As students become familiar with the operation of the device, they can skip calculations and focus on designing MOSFETs with performance in mind.

## Student Response (AQM Course)

1. 80 – 88% of students reported that the nanoHUB.org simulations/animations were important/critical to their learning of the course material

   "*The visual online computer simulations and java applets really helped visualize what was going on in class.*"

2. 67% of students reported that the nanoHUB.org simulations helped them feel more confident about the course material.

3. 56 – 71% of students reported that the nanoHUB.org simulations increased their interest in quantum mechanics and semiconductor devices