ND*nano* Undergraduate Research Fellowship (NURF)
2013 Project Summary

1) Student name: Ashley Towne
2) Faculty mentor name: Prof. Patrick Fay
3) Project title: High-speed transistor characterization

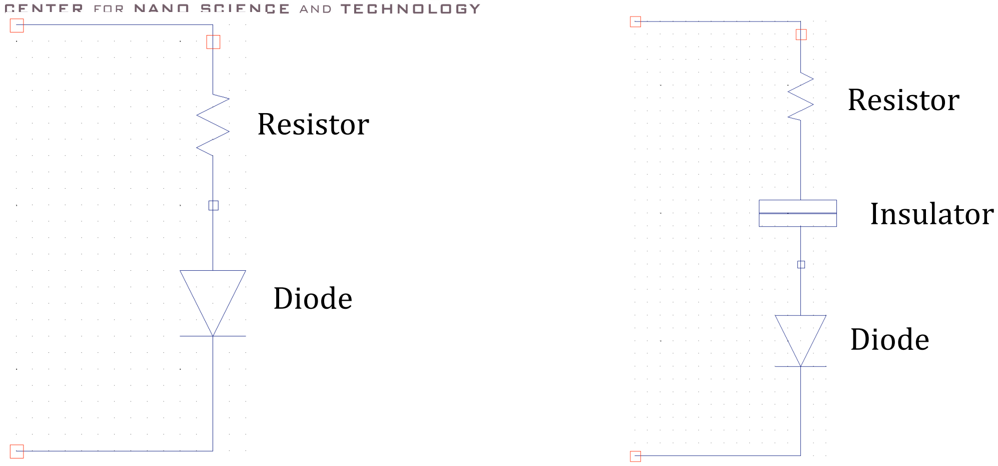
4) Briefly describe any new skills you acquired during your summer research:
I became familiar with the EEHEMT model for gallium nitride transistors and learned more about semiconductor science and its practical applications. I also learned how to calibrate and operate Agilent's Network Analyzer, use a microscope and probes to connect leads to a transistor on a wafer, and use and modify Agilent's IC-CAP software to model a GaN transistor using the EEHEMT model.

5) Please briefly share a practical application/end use of your research:
GaN transistors operate at high speeds and can be used for high power circuits. They operate efficiently at microwave frequencies. The EEHEMT model is used to design circuits that operate under these conditions. A more accurate model will facilitate better circuit design.

Project summary:

The EEHEMT model is a mathematical characterization of gallium nitride transistors. The model has many limitations because it was designed for gallium arsenide transistors, which can pose problems to successfully implementing GaN devices in high-speed circuits. This project's purpose was to improve the model by eliminating some of its limitations. Specifically, the focus was on improving the gate current parameter extraction process.

The original model treated the gate as a diode, but the initial extraction of the gate current parameters showed the limitations of this approximation, especially near the threshold voltage. The diode model was replaced with a model containing a resistor in series with a diode to address this problem (Figure 1a). The theory behind the added resistor was that, when the gate was etched, some of the material might have been roughened, adding a resistance that had been previously unaccounted for. The resistor marginally improved the fit of the graph of gate current versus gate voltage when the voltage was positive (there was no change when the voltage was negative). The difference was small enough to conclude that something was still missing from the model. The next attempt was a circuit consisting of an insulation layer, through which current could tunnel, in series with a resistor and diode (Figure 1b). The Fowler-Nordheim equation was used first for the relationship between current and voltage across the insulation layer. The form of this equation, coupled with Ohm's Law and the diode equation, is not conducive to solving for the gate current as a function of gate voltage, so the inverse was used, with the limitation that it is only valid for gate current greater than or equal to zero. This fit had less error than the previous two when comparing appropriate regions. Using the Poole-Frenkel relationship in place of the Fowler-Nordheim approach yielded marginally better fits, again with the inverse and the same limitations.



(a) (b)

Figure 1. (a) first modified equivalent circuit, (b) second modified equivalent circuit

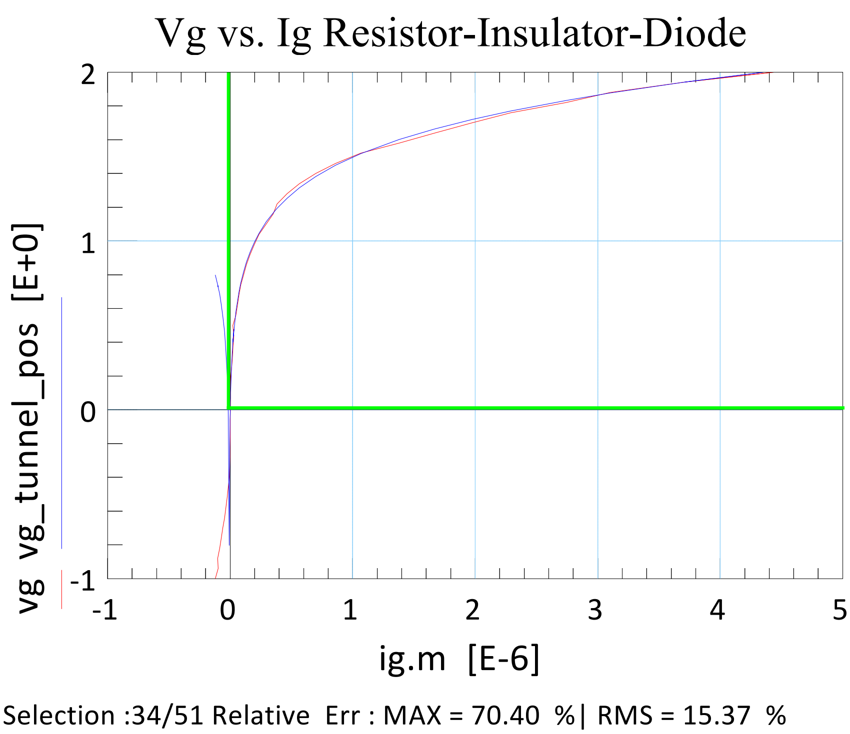


Figure 2. Equivalent circuit from Figure 1b – resistor, insulator, and diode in series; Poole-Frenkel equation

Publications (papers/posters/presentations):