ND*nano* Undergraduate Research Fellowship (NURF)
2012 Project Summary

1) Student name: Ziqi Zhang
2) Faculty mentor name: Dr. Alan Seabaugh
3) Project title: Electrical Properties of Graphene Transistors

4) Briefly describe any new skills you acquired during your summer research:
I learned to use a Cascade Microtech Summit 11861 Probe Station to connect to devices and the Agilent B1500 Semiconductor Parameter Analyzer to collect and analyze current-voltage experimental data. I also learned how to use OriginLab to create and revise plots that satisfy different needs.

5) Please briefly share a practical application/end use of your research:
The data I collected on the probe station and analyzer and plots I made on OriginLab are being used to understand and develop better contacts to single layer materials (especially graphene) for transistors and future electron devices.

Project summary:

Graphene is a single-layer material consisting of carbon in a hexagonal lattice. It features useful electronic properties, which can be applied to future devices at the nanoscale. My goal is to measure and determine current-voltage characteristics of a graphene transistor on devices fabricated at Notre Dame from graphene prepared at IBM. This graphene, Fig. 1, was deposited by chemical vapor deposition on Cu and then transferred as a single layer onto 90 nm of silicon dioxide on Si. The graphene was patterned at Notre Dame into 10 micron wide strips. Metal contacts were patterned and deposited to form metal contacts consisting of a 5 nm Ti first layer followed by 100 nm Au. The separation between the metal contacts was systematically varied allowing the measurement of the resistivity of the graphene between the strips and the metal-to-graphene contact resistance. Using a contact to the backside of the wafer a gate contact was formed allowing the measurement of the current in the graphene as a function of the gate voltage. The current-voltage measurements of transistors with different source-drain separations have been used to determine the metal-graphene contact resistance and sheet resistance.

As the results of my research, I collected the experimental data and made OriginLab plots, which show the devices on this graphene transistor approximately obey Ohm's law, Fig. 2. The data for each contact separation corresponds to a single device and the backgate voltage is varied on each sweep from -20 to 20 V with a step of 5 V. The plot of the resistance versus separation is used to determine the contact resistance and sheet resistance of the graphene, Fig. 3. This device shows a negative contact resistance of -7839 Ω μm and a sheet resistance of 435 Ω/square, however there is significant scatter in the data. Ultra-low resistance ohmic contacts in graphene field effect transistors have been reported [1] with a contact resistance of 100 Ω μm. However negative contact resistance has also been recently reported [2]. My results are in support of future development of graphene transistors.

Pad dimensions: 100 x 100 µm
Separations: 4,5,6,7,8,9,10 µm
Graphene width:
Wafer number: IBM5/11
Materials: 5 nm Ti/100 nm Au, Graphene, 90nm SiO2, Silicon wafer (N+)
Substrate: SiO2
Contacts: : Ohmic
Kind of graphene: IBM graphene (CVD Chemical Vapor deposition graphene)

Fig. 1

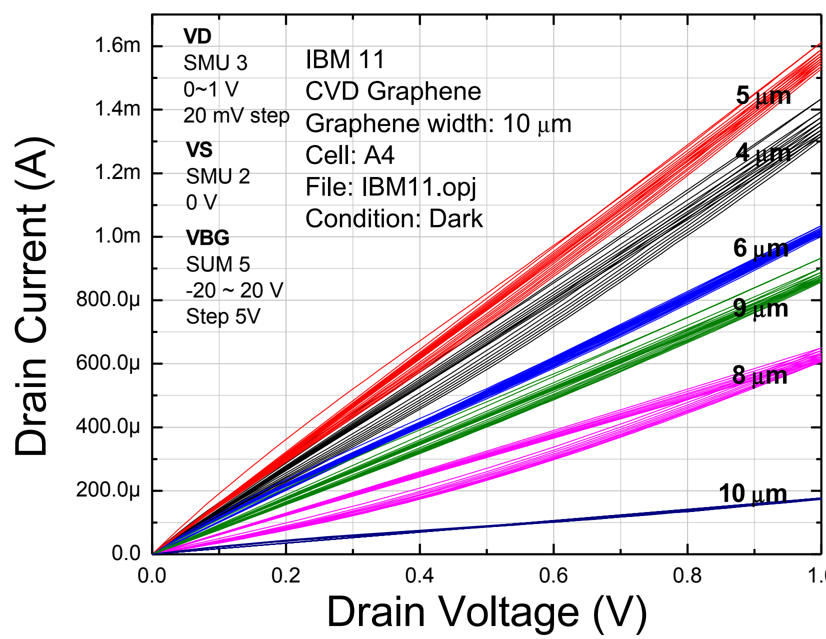

Fig. 2

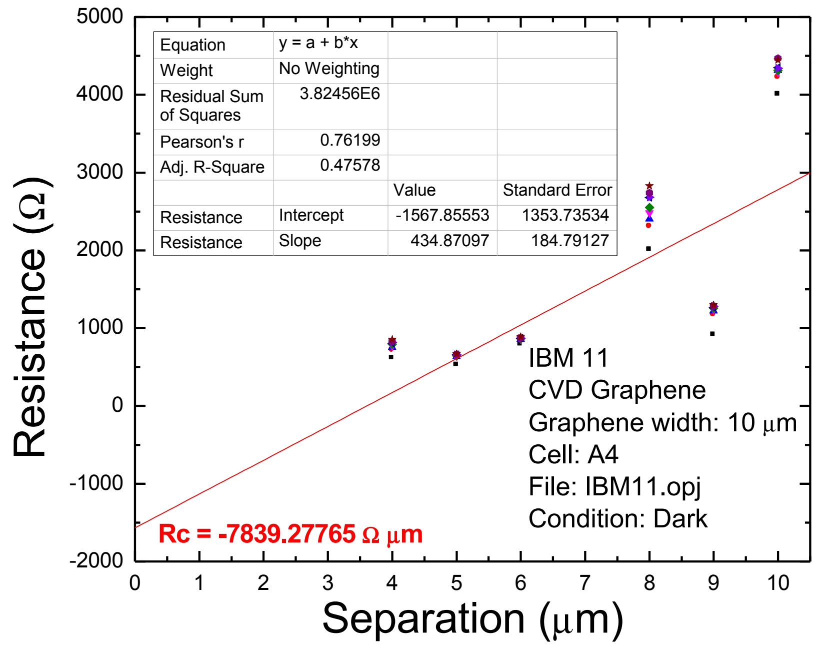

Fig. 3

Reference:

[1] J. S. Moon, M. Antcliffe, H. C. Seo, D. Curtis, S. Lin, A. Schmitz, I. Milosavljevic, A. A. Kiselev, R. S. Ross, D. K. Gaskill, P. M. Campbell, R. C. Fitch, K.-M. Lee, and P. Asbeck, "Ultra-low resistance ohmic contacts in graphene field effect transistors", Appl. Phys. Lett. 100, 203512 (2012)

[2] Ryo Nouchi, Tatsuya Saito, and Katsumi Tanigaki, "Observation of negative contact resistances in graphene field-effect transistors", J. Appl. Phys. 111, 084314 (2012)

Publications (papers/posters/presentations):

Poster: Electrical Properties of Graphene Transistors