ND*nano* Undergraduate Research Fellowship (NURF)
2014 Project Summary

1. Student name: Katrina Magno

2. Faculty mentor name: Dr. Grace Xing

3. Project title: Ohmic Contacts to Semiconductors with High Work Functions

4. Briefly describe any new skills you acquired during your summer research:
Throughout this summer I gained many skills involving the fabrication of nano devices, specifically metal-semiconductor contacts. I am now independent on a wide variety of machines within the cleanroom and better understand the physical concepts behind the growth, properties, and applications of semiconductor materials. Furthermore, I obtained experience in the acquisition and interpretation of Raman spectra and photoluminescence measurements.

5. Briefly share a practical application/end use of your research:

In the field of nanotechnology, recent efforts have focused on optimizing the fabrication of field effect transistors (FETs) for a variety of optoelectronics. By improving the performance of these devices through the use of atomically thin transition metal dichalcogenides (TMDCs) and III-nitrides (Gallium Nitride (GaN) and Aluminum Nitride (AlN)), advances can be made in the fields of low power fast switching and high power and UV light emission applications, respectively. My main project focuses on optimizing ohmic contacts onto p-GaN using high work function metals, specifically MoO_x and NiO_x. Interestingly, after oxidation Ni becomes translucent, which can be translated to a more efficient light emitting diode (LED) as more area of the diode is capable of emittance. Though these structures have already been optimized in other labs, in-house fabrication would be significantly beneficial for many other projects in the Xing lab at Notre Dame. We also plan on analyzing the electronic properties of different structural designs using NiO_x and Au that has not been presented before.

Begin two-paragraph project summary here (~ one type-written page) to describe problem and project goal and your activities / results:

The lack of in-house fabrication of ohmic contacts onto p-type Gallium Nitride (p-GaN) was mainly focused on this summer. When optimized, this fabrication process may produce more efficient n and p-type field effect transistors (FETs) and benefit many other projects within the Xing lab. However, high performance hole injection devices are difficult to realize in III-Nitrides and 2D material systems using conventional metals. For large bandgap III-Nitrides the high contact resistance and low current injection into valence band is due to the large Schottky barrier height of the metal-Semiconductor junction. For 2D materials, Fermi-level pinning close to conduction band has been observed for even large work function metals. By using a larger work function material for III-Nitrides and an unconventional large work function metal for 2D Semiconductors, hole injection at the source and drain contacts can be improved. Two materials were chosen for ohmic contact to p-GaN including, MoO_x and NiO_x due to their high work functions of ~6.6 eV and 5.50 eV, respectively. For the former, a procedure was adopted from a paper by Professor Ali Javey's group at the University of California Berkeley, in which they demonstrated optimized fabrication of ohmic contacts onto MoS_2 for p-type transistors using MoO_x capped with Pd. After attempting these steps and depositing an equal ratio of both metals, we were not able to obtain good ohmic contact onto p-GaN. However, annealing in forming gas did improve contact resistance. The overall poor behavior may be due to a lack of higher purity MoO_3, surface contaminants, or an overestimation of the valence band depth of the metal.

Alternatively, significant progress was made in the optimization of NiO_x contacts capped with Au. After oxidation, Ni becomes translucent, making the material an excellent choice for increasing the efficiency of optoelectronic devices, such as UV light emitting diodes (LEDs). It was determined that increasing the ratio of Au:Ni whilst maintaining a thinner overall metallic layer and annealing at a lower temperature helps to obtain ohmic behavior. The latter is implicated through linear I-V measurements. Though we did not achieve definite linear trends, there was a significant reduction in the resistance throughout the research period. With further optimization between thicknesses, annealing time, and temperature, we can also focus on decreasing the Au to a point that maximizes translucency and minimizes contact resistance. Aside from my work on the high work function metal contacts, I also acquired and interpreted Raman spectra measurements of mechanically exfoliated $NbSe_2$. This work is part of a larger project to understand how the changes in the thickness of the flakes effect the charge density waves. Previous studies on $TiSe_2$ have suggested through Raman spectra that a decrease in thickness may cause an increase in the transition temperature, offering superconductivity properties at higher temperatures. Finally, I also obtained photoluminescence (PL) measurements of hexagonal boron nitride (h-BN) samples grown by collaborators. This data provides an excellent indication of the quality of the material, as the PL system is extremely sensitive to defects, traps, and impurities.

Publications (papers/posters/presentations):

A power point presentation of this project, “Ohmic Contacts to Semiconductors with High Work Functions”, was submitted to the NDConnect Competition.