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

1. Student name: Nathaniel Griggs

2. Faculty mentor name: David B. Go

3. Project title: Development of Apparatus and Conditions for μPECVD of Nanodiamond

4. Briefly describe any new skills you acquired during your summer research:

I learned to use the scanning electron microscope (SEM).

I redesigned and built a high vacuum system to be compatible with high temperature and high voltage.

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

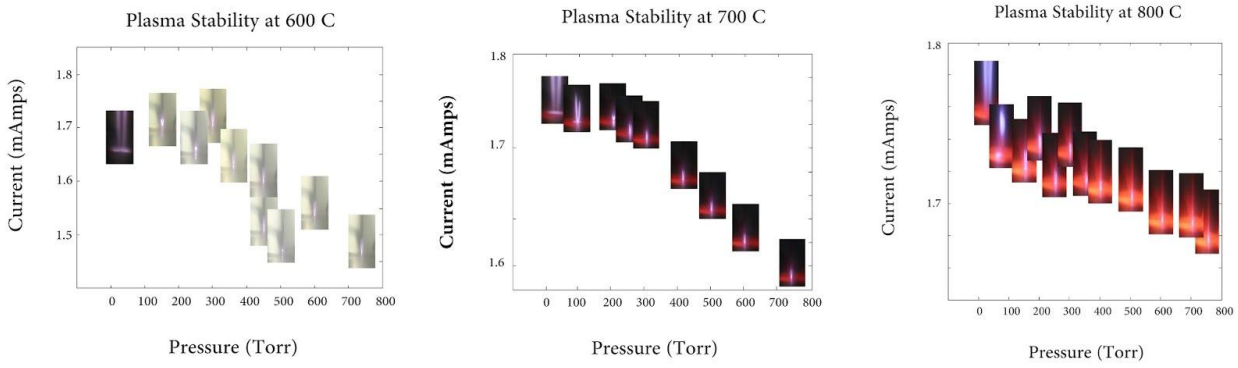
The end of this research is to achieve synthesis of carbon electrodes for direct conversion of heat to electricity via thermionic emission.

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

Given the properties of diamond, synthesis methods that offer control over its morphology and composition while being rapid and cost-effective can be advantageous. One such method of production includes chemical vapor deposition enhanced via a direct current microplasma (μPECVD). Though μPECVD has been shown to produce nanodiamonds under certain conditions, the exact mechanisms of nanodiamond growth and deposition are not precisely understood. The sheer number of parameters involved in μPECVD requires careful consideration of the apparatus and conditions needed to grow nanodiamond nonetheless control its morphology and composition. The primary objective of my work this summer was to develop this apparatus and these conditions for μPECVD of nanodiamond.

The apparatus consists of a vacuum chamber, a high voltage power supply, a substrate heater, and mass flow controllers. These components enable regulation of pressure, plasma behavior, substrate temperature, and gas flux. To safely incorporate all components, the apparatus needs vacuum compatible thermal and electrical insulation.

Conditions over which the plasma exhibits stable behavior have been documented visually through the use of videography and photography while all other conditions have been obtained from cited values. As shown in the three plots below, the chamber pressure affects the current at which the plasma operates. Taken as a measure of plasma stability, the plasma current exhibits a negative correlation with increasing pressure for all three temperates.

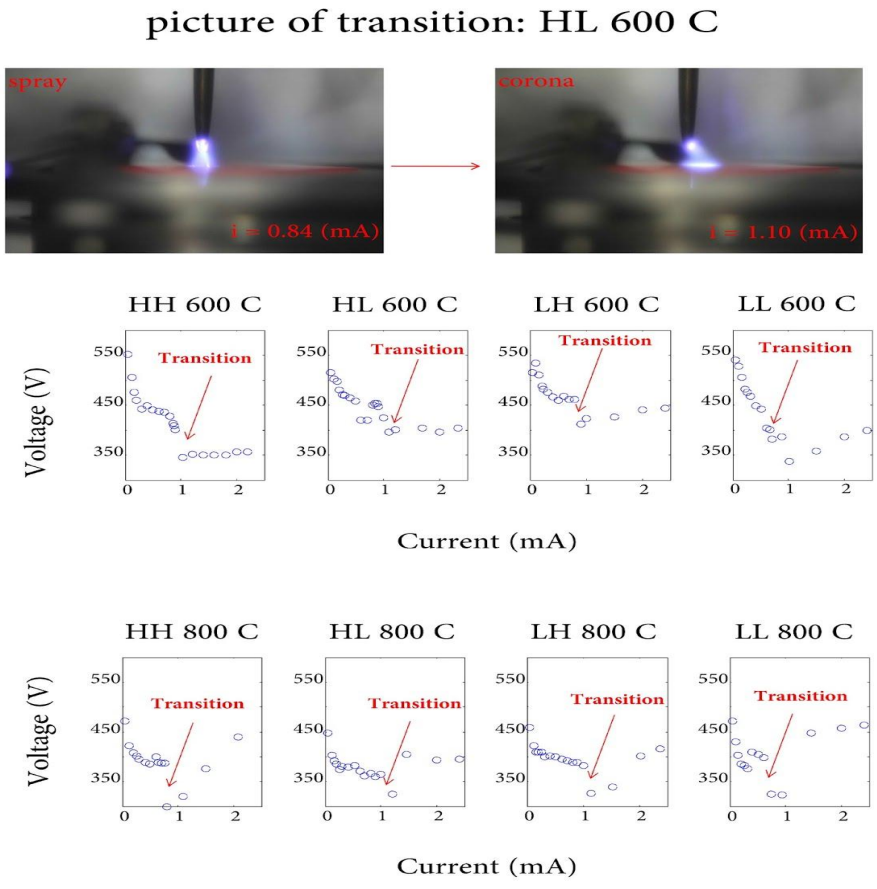


This decrease is accompanied by a change in the form of the discharge as seen in the superimposed images. The pressure at which the plasma changes form is dependent upon the temperature for two reasons. Directly, higher temperatures can further energize the electrodes

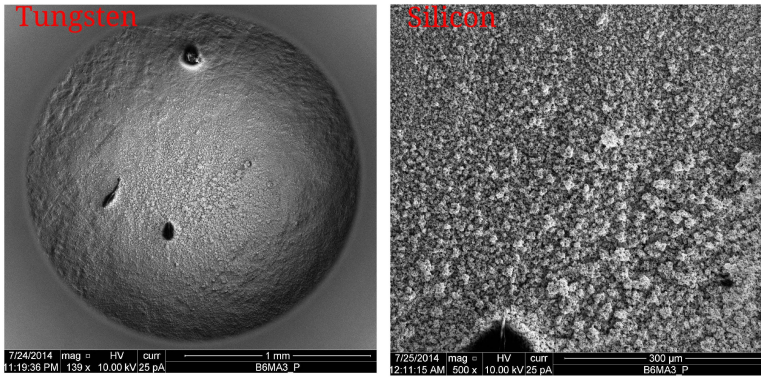
beyond the effects of the plasma. Indirectly, higher temperatures cause a decreased electrode distance.

The change in the form of the plasma was studied in further detail by focusing upon the role that the gas flux composition plays. Eight trials of different rations of argon, hydrogen, and methane gases all exhibited a similar transition in the plasma form accompanied by a sharp decline in voltage.

Label	Q_{Ar}/Q_H	Q_{CH4}/Q_H
HH	6/8	2.5%
HL	6/8	0.5%
LH	6/5	2.5%
LL	6/5	0.5%



Preliminary SEM images show that the synthesis successfully deposits particles on the substrate surface whether it be tungsten or silicon. It is clear that the plasma, not the substrate heater, has caused the deposition of particles upon the given substrate because no deposition was observed outside the region directly below the plasma.



This work demonstrates the development of an apparatus and conditions for μPECVD of nanodiamond. To ensure that the microplasma is truly enhancing the chemical vapor deposition, measures were taken to generate a stable, localized plasma. Chamber pressure, gas flux composition, electrode gap distance, and plasma current are important parameters in determining this plasma behavior. Future work includes relating synthesis parameters to deposition morphology and composition. Such work will rely upon further SEM imaging and analysis with Raman spectroscopy.

Publications (papers/posters/presentations):
Summer Undergraduate Research Symposium