UNIVERSITY OF NOTRE DAME
NDnano
CENTER FOR NANO SCIENCE AND TECHNOLOGY

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

1. Student name: Rose Doerfler

2. Faculty mentor name: Dr. Marya Lieberman, Dr. Valerie Goss

3. Project title: DNA Origami

4. Briefly describe any new skills you acquired during your summer research:
In addition to completing cleanroom training and developing skills working with small-scale samples, I learned to use a Nanoscope Atomic Force Microscope to obtain images of DNA origami and analyze the results. I can get data from a contact-angle goniometer. I can operate the tube furnace in the Materials Characterization Facility (MCF) and set up an oxygen-free environment. I learned to use microscopy software, such as Nanoscope Analysis, Gwyddion, and ImageJ, and I gained programming skills with image analysis using MATLAB.

5. Briefly share a practical application/end use of your research:
Since this project focuses on controlling surface chemistry at the nanoscale, and investigates what happens when those surfaces are heated, it has potential applications to nanoelectronics and lithography. It is also an interesting result from a scientific perspective, since the DNA adhered to solid surfaces is stable at much higher temperatures than its stability limit in solution.

Begin two-paragraph project summary here (~ one type-written page) to describe problem and project goal and your activities / results:
DNA origami consists of single-strand viral DNA and short oligonucleotide staple strands, which self-assemble into nanoscale shapes and adhere to solid surfaces. It is known that DNA origami are more thermally stable when adhered to a solid mica surface than when in solution, but the temperature limits of this stability, and the effects of heating in different environments, were previously unknown. Previous studies had shown stability of DNA in air up to 250°C, but this project investigated higher temperatures, and whether heating in an environment free of oxygen could further increase the stability. One goal was to determine the upper temperature limit at which DNA origami can maintain their structure. DNA origami on mica were heated to temperatures up to 500°C in oxidative and inert environments, using a tube furnace that can heat the samples either in air or nitrogen. After heating, the samples were analyzed using Atomic Force Microscopy (AFM) and X-ray Photoelectron Spectroscopy (XPS).

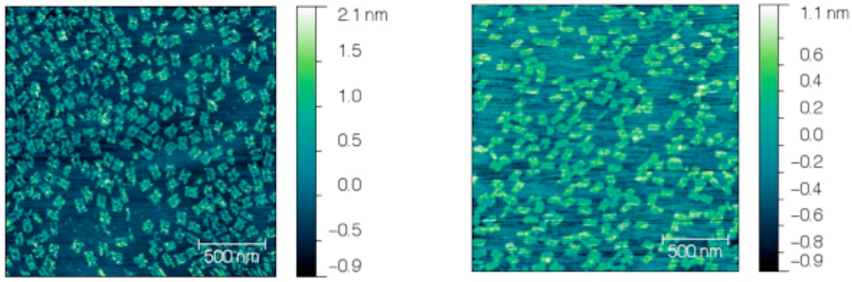

Figure. DNA Origami on mica heated to 500°C in air (left) and in nitrogen (right).

Preliminary XPS results show that when DNA origami are heated to high temperatures, some of the carbon in the DNA is oxidized. The higher the temperature, the more carbon is oxidized. If the DNA is exposed to only nitrogen when it is heated, oxidation cannot occur as it does in air, and the DNA maintains its original structure better than in air. The origami in both nitrogen and air maintain their physical structures as they are heated, up to the point where holes form in the origami. For the DNA in air, there were holes at 500°C, but the DNA in nitrogen remained intact even at this temperature. I also found that the area of the DNA nanostructures remains constant with increasing temperature, and the height of the DNA nanostructures decreases with increasing temperature, up to the point where holes form. Once the DNA are sufficiently oxidized to form holes, there is an apparent increase in height as the DNA forms ridges around the holes, and a decrease in area. Nevertheless, even after heating at 500°C in air, the shapes of the origami are clearly visible. Further experiments will investigate the binding of DNA to semiconductors, and the chemical changes that occur in DNA at high temperatures, in order to move towards practical use in nanoelectronics.

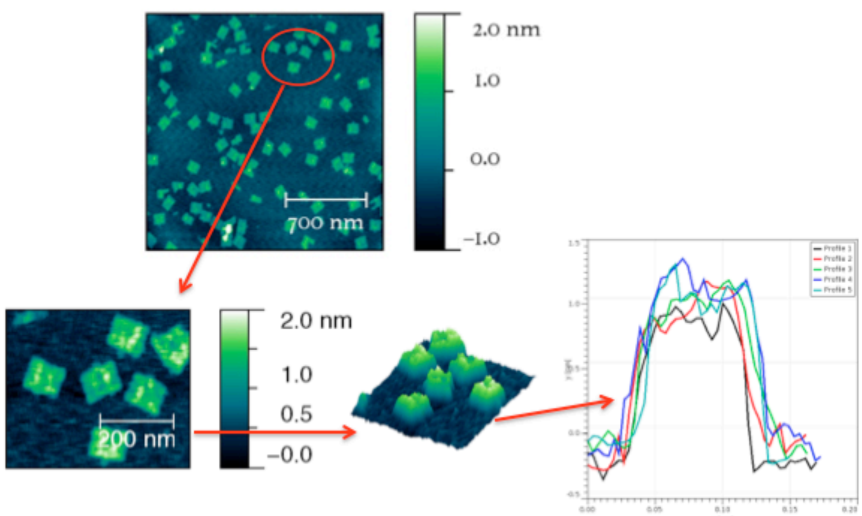

Figure. Visualizing the dimensions of DNA origami using Gwyddion software.

Publications (papers/posters/presentations):

Michelle Pillers, Rose Doerfler, Adam Farchone, Valerie Goss, Keenan Linder, and Marya Lieberman "Thermal Stability of DNA Origami at 500C on Silicon or Mica," mss in preparation 2014.

Research poster (attached)