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

1. Student name: Keenan P Linder

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

3. Project title: DNA origami

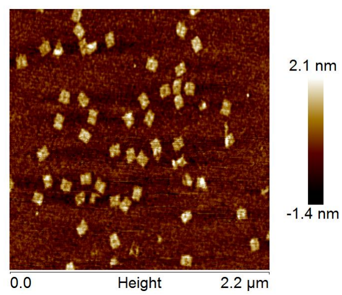

Figure 1. 2.0 nM DNA Origami on APTES treated silicon

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

I am a proficient user of the Veeco Multimode with NanoScope V Controller, Atomic Force Microscope (AFM), one of the foremost tools for imaging, measuring, and manipulating matter at the nanoscale. A representative image from my collection is shown in Figure 1. I operated the Thermo Scientific Lindberg/Blue M™ 1100 °C Tube Furnace, which was used to heat APTES and DNA samples on silicon at various temperatures, conducted in the Material Characterization facility. I used the contact angle goniometer on APTES treated silicon to obtain angle data conventionally measured through a liquid drop, where the liquid interface comes into contact with the solid surface. I am a user of CMOS bench in Dr. Lieberman's laboratory. I learned the technique to chemically clean silicon via etching to create a nice smooth surface for DNA binding, under the right chemical conditions. I also received cleanroom training. Quantitative analysis on images was performed using programs such as Nanoscope, and ImageJ.

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

The control of DNA (deoxyribonucleic acid) on silicon substrates is an important step for the application in the computer and semiconductor industry. Being able to pack a lot of information onto smaller sized microelectronic chips with 10x the current processing power is a challenging demand in computer manufacturing.

My research problem involved answering the question, "Can chemically modified silicon surfaces with bound DNA origami survive under extreme heating?" DNA origami, involves two main components: one long strand of DNA called a scaffold that contains roughly 7000 bases, and smaller staple strands that have between 30 and 50 bases. As the bases that make up the staple strand hybridize to the bases on the scaffold, they fold the scaffold into two- and three-dimensional shapes such as rectangles, stars, and smiley faces making many different shapes.

The folded structures are called DNA origami. APTES, which is a cationic self-assembled monolayers (SAMs), can easily be formed on silicon dioxide, and these SAMs provide robustly attached surface charges that anchor DNA nanostructures and origami. My project explored the use of biological molecules in the semiconductor industry, and to quantify data on the limits of determining the thermal stability and versatility of DNA origami from 150-250 °C, and APTES from 150-650 °C on chemically modified, cleaned silicon surfaces. Results are in Figure 2.

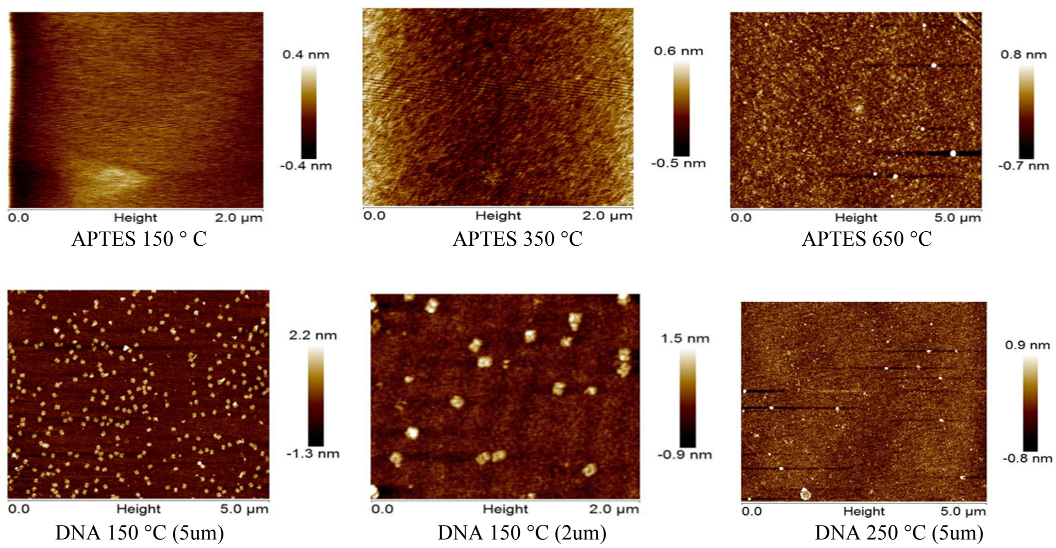

Figure 2. AFM images of Si surfaces with APTES monolayers, and with DNA origami deposited on APTES both survive at 150 °C. At 250 °C, DNA origami is not observed on APTES treated silicon.

Silicon wafers were cleaned using RCA bath procedures and HF etching, and then were derivatized with APTES by brief immersion in an aqueous solution of APTES. Water contact angles were measured to determine whether the surfaces were hydrophilic (low contact angles) or hydrophobic (high contact angles). AFM imaging was done to determine the topography of the surface. Results show that the DNA origami folded correctly with an average height of 2.57 nm ± 0.75 nm. The APTES samples were smooth and clean with an average of 2.23 nm in roughness. The thermal stability of APTES did not decrease until 350 °C. The DNA was stable at 150 °C, and was not stable at 250 °C. This data show the advantages and applicability of silicon chips that have been processed with CMOS (complementary metal oxide semiconductor) compatible processes as solid support for measurements of thermal stability in molecular films at extreme temperatures.

Pillers, M., Goss V., et al. (2014). "Electron-Beam Lithography and Molecular Liftoff for Directed Attachment of DNA Nanostructures on Silicon: Top-down Meets Bottom-up." Accounts of Chemical Research.

Pillers, M., Lieberman, M., et al. (2014). "Thermal stability of DNA origami on mica." Journal of Vacuum Science & Technology.

Linder, K. P. and Lieberman, M.(2014). "Thermal Stability of DNA Origami Bonded to APTES Monolayers and Silicon Surfaces." Poster Presentation.