ND*nano* Undergraduate Research Fellowship (NURF)
2013 Project Summary

1) Student name: Nicolas Martinez

2) Faculty mentor name: Dr. Tengfei Luo

3) Project title: Fabrication of polymer nanofibers with anomalous thermal conductivity

4) Briefly describe any new skills you acquired during your summer research:
I acquired the skills for using an optical microscope. I also acquired practical chemistry skills required for making reactions in an oxygen free atmosphere. I learnt the procedures for quoting and ordering parts and supplies. In addition, I learnt techniques for ultradrawing microfibers and nanofibers.

5) Please briefly share a practical application/end use of your research:
Polyethylene nanofibers have multiple applications in heat transfer. First of all the fibers have very high thermal conductivities, comparable to those of metals, making them ideal for substitutes for metals in heat sinks and similar devices. The fibers also present a huge drop in thermal conductivity after they reach a certain temperature (this temperature can be controlled by modifying the fiber morphology). This makes the nanofibers an ideal material for constructing thermal rectifiers, devices that allow heat transfer only in one direction.

Project summary:

Polyethylene nanofibers have shown very high thermal conductivities, comparable to those of many metals. This property makes the nanofibers very attractive for heat transfer applications such as heat sinks, given the low cost and eases of polymer manufacture. In addition, Dr. Luo's group has done molecular simulations of polyethylene nanofibers which show that they undergo a significant thermal conductivity drop at a given temperature and within a few degrees. This temperature can be tuned by controlling the morphology of the nanofibers. This characteristic makes them suitable to fabricate thermal rectifiers, devices that allow heat transfer only in one direction. The rectifiers could make efficient thermal storage and phonon computing viable. The objective of the NURF project was to develop a nanofiber drawing system that could produce the polyethylene nanofibers through mechanical drawing. The polyethylene nanofibers can be then used to validate the theoretical results of the group.

The first part of the project involved choosing a viable nanofiber drawing procedure. A survey of the available literature on polymer ultra-drawing and on polyethylene nanofibers was conducted. The survey concluded that the drawing process requires two main steps: the preparation of the polyethylene gel and the mechanical drawing of the fiber. After determining a suitable procedure for the gel preparation, the required materials were ordered. The design of the nanofiber drawing system required searching for mechanical parts with flexible operating parameters so that the drawing process could be carefully controlled and tuned.

The drawing process is very challenging because of the small size of the fibers which can only be seen through an optical microscope. Once all the parts were received the platform was constructed. Then the drawing process was tested multiple times trying to optimize the quality and size of the nanofibers. Our initial results have shown that fibers in the order of 10 microns can be repeatedly drawn. The drawing process is being further optimized to reduce the diameter of the fibers by two orders of magnitude.

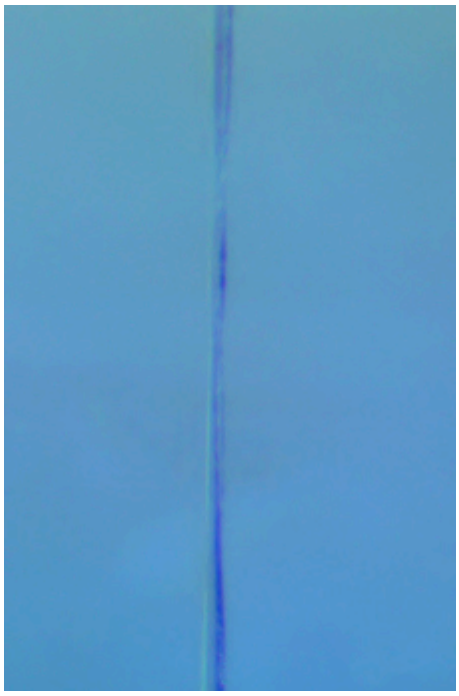

Figure 1. A polyethylene fiber with a 12 micron diameter. The picture was taken with an optical microscope with 270x zoom.