As an experimental physicist it is important to investigate problems that are both physically fundamental and impact people's daily lives. One such problem is the cost and efficiency of computers and the accessibility of information to people around the world. Although the drive for ever smaller transistors, the well known "Moore's law," has lead to greater accessibility to information, there are fundamental limits to the size of standard electronics, that are associated with the heat generated in diffusive transport devices. As standard CMOS technology is reaching nanometer length scales the need for alternative methods to control charge transport and heat generation on molecular and atomic length scales is becoming necessary. The field of molecular electronics is developing as one such alternative. In this case, single molecules are used as electronic components, and already it has been demonstrated that individual molecules can have the functions of transistors, diodes or wires. However, to date there has is very little development in the understanding of heat generation and dissipation in molecular systems. To understand these properties I have been working with Dr. Nongjian Tao to study the effect of phonons on the electrical transport of single molecule devices.

To study phonons, discrete vibrations of the constituent atoms in single molecules, it is necessary to connect a molecule to some sort of electrode. To do this we have built a low temperature scanning tunneling microscope (STM), which measures the tunneling current through a molecule covalently bonded to a metallic tip and substrate. Working at low temperatures suppresses thermally excited phonons and allows us to study only electrically excited phonons. The electrons traversing the molecule will be able to excite a vibration on the molecule when the applied bias is greater than the frequency of the phonon times Planck's constant, $\hbar\omega$. This inelastic scattering of electrons on the phonon will cause an increase in the conductance of the molecule, since now electrons can either tunnel across the molecule elastically or can tunnel inelastically and lose energy to the molecule in the form of a phonon, heat. This effect is a deviation from the classical Ohm's law, and is seen because the molecular device is a quantum mechanical system. By measuring the rate of change of the current as the bias is swept it is possible to determine which constituent atoms in the molecules are vibrating due to the electron transport.

Using this technique, called inelastic electron tunneling spectroscopy, we are able to study how heat is generated and dissipated on single molecules. Also, with the help of chemists who can synthesis the molecules, we can see which how different molecular configurations and geometries effect transport as only the atoms that are involved in transport should be capable of being excited to vibrate. Doing this technique on many different molecules will thus give us a greater understanding of how vibrations are excited on single molecules and allow us to relate nanoscale and bulk heat generation. In addition, using the STM to form molecular junctions gives us the ability to investigate how the phonons created on the molecule dissipate onto the metallic electrodes, i.e. the tip and substrate, illuminating the mechanisms of heat transport on molecular scales.

The study of electrical and heat transport on molecular and atomic length scales will help to drive the development of technology in the future. In addition, the types of fundamental studies of electrical behavior in molecules that we do in Dr. Tao's group require extensive interdisciplinary collaboration with both theorists and experimentalists in chemistry and engineering. These attributes of the research have influenced my planned career of becoming a university professor. Teaching and research in a university setting gives a professor the opportunity to help train the next generation of scientists while improving and driving technology.