Energy Conversion and Transport in Nanostructures

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Solid-state energy conversion technologies such as thermoelectric and thermionic refrigeration and power generation require materials with low thermal conductivity but good electrical conductivity and Seebeck coefficient, which are difficult to realize in bulk semiconductors. Nanostructures such as superlattices, quantum wires, and quantum dots provide alternative approaches to improve the solid-state energy conversion efficiency through size and interface effects on the electron and phonon transport. In this presentation, we will discuss both theoretical and experimental aspects of energy conversion and transport processes in nanostructures.

Interrogating the mechanisms of solid-state energy conversion in nanostructures raises many fundamental and interesting questions on the energy conversion and transport processes. Examples on both the energy conversion and transport will be discussed. For the energy conversion between electrons and phonons, we will show that in nanostructures electrons and phonons can easily be driven out of equilibrium. Such nonequilibrium processes can potentially be used to improve the energy conversion

efficiency. The transport of electrons and phonons in nanostructures is significantly affected by both quantum and classical size effects. Modeling approaches describing these effects in both electron and phonon systems will be discussed. Key questions for improving the device performance are which effects are dominant: electrons or phonons, and classical or quantum size effects. Answers to these questions will be explored by comparing modeling with experimental results. Approaches for establishing unified transport models that include both quantum and classical size effects will also be discussed.

Experimental characterization of energy conversion and transport properties in nanostructures has proven to be very challenging. We will discuss experimental techniques and results on the thermal conductivity, electrical conductivity, and Seebeck coefficient of superlattices. Recent thermal measurements on nanowire arrays will also be presented.