Thermoelectric Energy Conversion: Materials and Devices

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Thermoelectric devices based on Peltier effect and Seebeck effect use electrons as a working fluid for energy conversion. These solid-state energy conversion devices have important applications in refrigeration and electrical power generation. Our work follows two directions: nanostructured materials and microdevices.

The efficiency of thermoelectric devices is characterized by the nondimensional thermoelectric figure of merit $ZT = S^2\sigma T/k$, where $S$ is the Seebeck coefficient, $\sigma$ the electrical conductivity, and $k$ the thermal conductivity of their constituent materials, and $T$ is the average device temperature. Identifying materials with a large $ZT$ has been challenging because of the interdependency of those three properties. With both quantum size effects on electrons and classical size effects on phonons, nanostructures provide an alternative way to engineer thermoelectric properties.\(^1,^2\) Our current effort is focused on designing, synthesizing, and characterizing nanostructures in bulk form that can be produced for mass applications. Figure 1 illustrates ballistic phonon transport in a unit cell of a nanocomposite, which leads to low thermal conductivity.\(^3\) We are also working on fabricating micro thermoelectric devices, first using thin film devices such as SiGe alloy and Si-Ge superlattices,\(^4\) and more recently on thick films to reduce parasitic heat losses.\(^5\) In addition, we are also exploring novel microdevice configurations that can improve energy conversion efficiency, by utilizing the hot electron concepts.\(^6,^7\)

Figure 1: Temperature distributions in one unit cell of two-dimensional periodic structure made of Si nanowires embedded in a Ge matrix.

REFERENCES: