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Nanoscale Material Approaches to Thermoelectric Energy Conversion[1]

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Nanoscale material approaches – superlattices, nano dots and second phase nano-inclusions – have become the dominant approach to enhancing the figure of merit (ZT) in thermoelectric materials for various energy conversion applications. The primary mechanism for improvement has been the significant reduction in lattice thermal conductivity through phonon scattering processes in nanoscale materials, which are not fully understood, without affecting the electron/hole transport. There has been considerable progress in ZT, of as much as 2.4 at 300K in Bi2Te3/Sb2Te3 superlattices, ZT>2 in PbTe-nano dot superlattice systems and in bulk PbTe with nano-inclusions. We will describe our recent studies and results in superlattice structural characterization including by X-ray absorption fine structure spectroscopy, coherent opical phonon property measurements using ultra-fast time resolved optical measurements, thermal conductivity reduction by 3-omega method and ZT enhancement in a couple of superlattice material systems. The work in low-temperature Bi2Te3-based superlattice thin-films have inspired us to develop 2-D and nano-dot superlattices in the mid-temperature PbTe-based systems and high-temperature SiGe-based material systems. These would be described along with progress in devices based on nanoscale materials. The implications of advanced thermoelectric materials and device development for energy efficiency in a variety of applications would be discussed as well.

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