MAR12-2011-000779

Abstract for an Invited Paper
for the MAR12 Meeting of
the American Physical Society

Nanostructured Thermoelectrics and the New Paradigm[1]

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A comprehensive and stable energy strategy would require proportionate attention to all three legs of the "energy stool"; supply (sources), demand (efficiency) and storage/transport (delivery). Thermoelectric materials, that convert waste thermal energy into useful electrical energy, have an important role to play in any and all these three legs. The efficacy and efficiency of thermoelectrics is reflected in the figure of merit ZT, which is directly proportional to the power factor (comprising electrical conductivity and Seebeck coefficient) and inversely proportional to thermal conductivity (comprising carrier and lattice contributions). The recent emergence of nanostructured thermoelectrics has ushered in a new era for bulk thermoelectrics, which show considerable promise to enhance the "contra-indicating" parameters of high electrical conductivity and low thermal conductivity. This is achieved by introducing nanostructures in bulk thermoelectric host materials to significantly reduce lattice thermal conductivity via effective scattering of heat carrying phonon through hierarchical architecture of nanostructured thermoelectrics. The presentation will cover recent developments, current research in our EFRC and future prospects for high performance bulk materials. Systems based on lead chalcogenides (e.g., PbTe, PbSe, PbS) present key science challenges with promising properties and are given particular emphasis. We have achieved excellent control of synthesis and crystal growth of such materials resulting in record enhancements in the figure of merit. These enhancements derive from very large reductions in lattice thermal conductivity possible with nanostructuring. We have experimentally realized concurrent synergistic effect of phonon blocking and charge transmission via the endotaxial placement of nanocrystals in thermoelectric material host. In particular, we have shown that the enhanced performance is due to nanostructuring of thermoelectric host matrix, with a compelling influence of hierarchy of length-scales associated with these systems. The presentation will outline possible future strategies for enhancing the thermoelectric figure of merit of bulk thermoelectric materials.

[1]This work is supported as part of the Revolutionary Materials for Solid State Energy Conversion, an Energy Frontier Research Center funded by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Award Number DE-SC0001054