

Thermoelectric Characterization of Nanostructured Bismuth Telluride and Carbon Nanotube Nanomaterials

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Quantum and size effects experienced by charge and energy carriers in nanostructures raise challenges and create novel opportunities for heat transfer and energy conversion in low-dimensional systems. For instance, the increased boundary and interface scattering of thermal carriers leads to a reduction in thermal conductivity, which is detrimental for thermal management applications but beneficial for thermoelectric energy conversion. In contrast, novel nanostructures such as carbon nanotubes have been shown to have among the largest thermal conductivity of any materials. Understanding key aspects of the transport in nanomaterials and nanodevices brings potential breakthroughs in designing efficient thermoelectric power generators and reliable carbon-nanotube based nanoelectronics.

This work presents studies of thermal and thermoelectric transport in aligned carbon nanotube nanomaterials (multiwalled carbon nanotube arrays, carbon alumina composites, carbon nanotube-polymer composites, carbon nanotube strands), and Bi₂Te₃ nanostructured films obtained by controlled assembly from nanoscale building blocks. The talk emphasizes the development of experimental techniques able to perform measurements in a passive configuration or in-situ when electrical current is passing through the samples. Several techniques are exemplified. For instance anisotropic thermal diffusivity and thermal interface resistance measurements in aligned carbon nanotube materials are performed using a photothermoelectric technique. A 3ω based technique is used to determine the thermal properties along carbon nanotube strands. Thermoelectric transport measurements in the nanostructured bismuth telluride films are performed by depositing the films on substrates instrumented with microelectrodes for thermoelectric characterization. An AFM based scanning hot probe technique is employed for simultaneous characterization of Seebeck coefficient and thermal conductivity of thermoelectric thin-films. Techniques currently under development for characterization of individual nanowire/nanotube structures will be presented. The talk will also discuss the effects of the structure, growth conditions, and temperature annealing on the thermoelectric transport properties.