CTS Award Achievements

Notable Accomplishments from CTS Awards

CAREER: Thermal Transport and Thermoelectric Measurements of Nanotransistors, Nanowires, and Superlattices

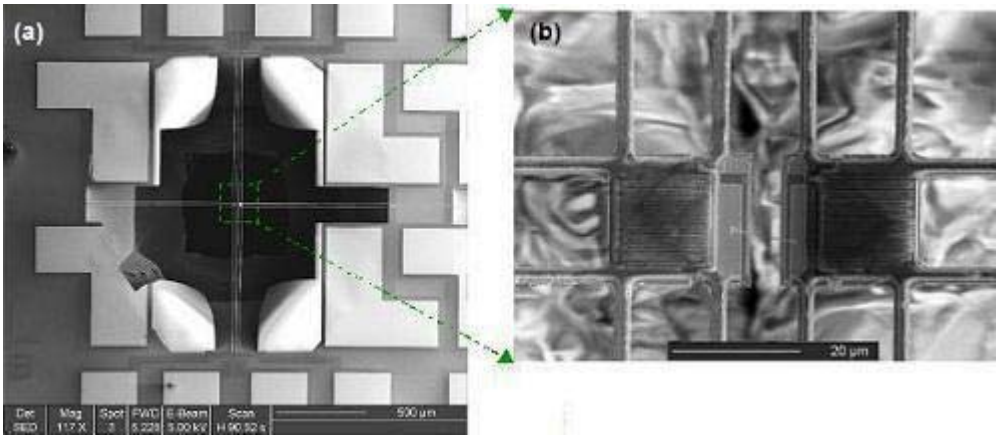
Li Shi - University of Texas at Austin

Background: With increasing miniaturization in microelectronics, one of the challenges to maintaining device performance is the management of excess heat. A researcher at the University of Texas at Austin has developed unique experimental tools to identify potentially promising new materials for addressing this problem. His findings may have broad applications in electronics and energy conversion.

Results: The researcher developed a device to characterize the crystal structure and chemical composition of nanowires and single carbon nanotubes. He also used a specialized microscope that he had developed previously under the award to characterize how nanowires respond to different temperatures and their ability to conduct heat and be thermoelectic. Thermoelectric materials pump across a temperature jump when an electric current passes through them and generate electric currents when heat is applied. These properties are important in a wide range of applications from cooling of high power chips, power conversion, and chemical sensing.

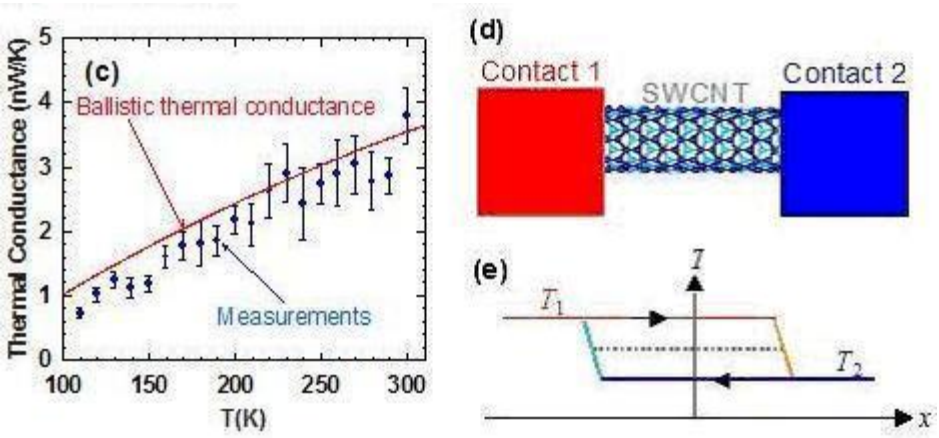
He identified one type of bismuth telluride nanowire with high thermoelectric properties that may provide the basis for energy-efficie on-chip spot cooling of electronic devices. He also found single-wall carbon nanotubes to have high thermal conductivity--higher tha diamonds, which are one of the best conductors. This suggests that single-wall carbon nanotubes might be used in thermal interface materials in electronic packaging to enhance the efficiency of microchips in a variety of applications.

A powerful new design of a device for nanowire characterization was developed in this project. The new device can be used to characterize the crystal structure and the chemical composition of the nanowire together with the thermal and thermoelectric proper so as to establish the structure-property relationship of nanowire materials. The new device for nanowire characterization and the Scanning Thermoelectric Microscope that was developed earlier as a result of this award constitute a set of unique tools for thermal thermoelectric characterization of nanomaterials for electronic and energy applications.



(a-b) A micro-device for characterization of structure-thermal/thermoelectric property relationships of nanotubes and nanowires

Credit: Li Shi, University of Texas at Austin



(c) The measurement results of the thermal conductance of a single-wall carbon nanotube (SWCNT) is very close to the calculated ballistic thermal conductance of a 1-nm-diameter SWCNT; (d-e) Schematic showing two opposite phonon flows at different temperatures transported ballistically in a SWCNT

Credit: Li Shi, University of Texas at Austin

Broader Impacts: For the past year, one Hispanic-American graduate student and one female undergraduate student have been supported to participate in this research, and an experimental module based on a miniaturized thermoelectric cooler was demonstra in the 'Introduce a Girl to Engineering Day'. For the past three years, two Ph.D. and five B.S. students supported in part by this awa have graduated. One of the two graduated Ph.D. students is continuing post-doctoral study at Lawrence Berkeley National Lab, and other has joined Applied Materials, Inc. One of the B.S. students graduated with highest honor, while three of the other four B.S. students are continuing graduate study at UT Austin and two of them have received M.S. degree under the P.I.?s supervision.

This work is notable because this work has resulted in a set of unique experimental methods for measuring thermal and thermoel properties of nanoelectronic devices and nanostructured materials, as well as the first measurement results of thermal conductance single-wall carbon nanotubes, thermoelectric figure of merit of bismuth telluride nanowires, and local thermopower profile in p-n junctions and thin film superlattices.

This work involves multidisciplinary research. This work impacts the fields of thermal sciences, electronic devices, and nanomaterials.

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