Engineering Thermal Energy Transport, Conversion and Storage with Nanostructured and Complex Materials

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Over 90% of world energy generation and consumption rely on thermal transport, conversion, or storage processes, the performance of which is often limited by materials thermal properties. These materials limitations have motivated us to investigate how thermal conductivity, thermoelectric coefficients, and heat of fusion may be modified at the nanoscale to exceed the current limits. One focus of our recent work is on two-dimensional (2D) layered materials where some of the highest thermal and thermoelectric properties have been reported. In one work, we found that reducing the thickness of graphite toward single or few atomic layer graphene can increase or decrease its record-high basal-plane thermal conductivity, depending on whether the obtained 2D materials are suspended or supported. Similar size effects are observed in 2D hexagonal boron nitride (h-BN), MoS2, and bismuth telluride, the latter of which also exhibits intriguing thickness dependence of the thermoelectric properties. Based on the understanding of these size-dependent, environment-sensitive properties, we have explored the use of h-BN thin layers and ultrathin graphite and h-BN foams as heat spreaders in flexible electronic devices and for thermal management of energy storage devices. In addition, we have recently discovered an unusually low-energy optical phonon polarization associated with the twisting motion of the one-dimensional substructure of complex higher manganese silicides. This discovery points to a potential approach to achieving phonon-glass-electron-crystal behavior and enhanced thermoelectric figure of merit of this class of materials containing only non-toxic and abundant elements.

Bio: Li Shi is the BF Goodrich Endowed Professor in Materials Engineering at the University of Texas at Austin (UT Austin). He received a bachelor degree in Thermal Engineering from Tsinghua University at Beijing in 1991, MS degree in Mechanical Engineering from Arizona State University in 1997, and PhD degree in Mechanical Engineering from University of California at Berkeley in 2001. Dr. Shi was an IBM Research Staff Member for about a year before joining the faculty at UT Austin in 2002. His scholarly works have been recognized by the CAREER Award from the National Science Foundation, the Young Investigator Award from Office of Naval Research, and the O'Donnell Award in Engineering from The Academy of Medicine, Engineering, and Science of Texas. Dr. Shi has served as the Editor-in-Chief for Nanoscale and Microscale Thermophysical Engineering since 2013. He is a fellow of American Society of Mechanical Engineering.