Thermal Energy Transport and Conversion in Nanostructured and Complex Materials

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Reducing or recovering the large amount of waste heat lost by transportation vehicles and electronic devices has gained increasing interest. High and low thermal conductivity values, respectively, are desirable for increasing the energy efficiency of electronic and thermoelectric devices, both of which require high electron mobility. Recently, ultrahigh electron mobility and thermal conductivity have been reported in mechanically exfoliated small flakes of monolayer graphene. Here, we have developed a micro-Raman spectroscopy method to show that large-area graphene grown using chemical vapor deposition possesses thermal conductivity comparable to the highest values found in graphite and diamond. We have further fabricated a suspended micro-thermometer device to reveal that the thermal conductivity of mechanically exfoliated graphene is reduced by the contact with a dielectric support because of phonon leakage across the interface, but is still considerably higher than the values of common electronic materials. In the other end of the thermal conductivity spectrum, we find that the lattice thermal conductivity of nanowire structures is suppressed considerably for III-V semiconductors with long anharmonic phonon scattering mean free paths, but only slightly for bismuth telluride with already low bulk thermal conductivity and good thermoelectric figure of merit (*ZT*). In contrast, the thermal conductivity of higher manganese silicide (HMS) nanowires can be suppressed from the already low bulk values to a level as low as the so-called minimum thermal conductivity. This finding is attributed to the combined effect of a complex crystal structure and phonon-interface scattering in the HMS nanowires, and points to a potential approach to enhancing the *ZT*.