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Thermal and Thermoelectric Transport in Two-Dimensional Materials and Devices beyond Graphene

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Besides the switching speed and on-off ratio, the hot spot temperature is one important performance metric of novel electronic devices fabricated from two-dimensional (2D) materials beyond graphene. This performance metric depends sensitively on the largely unknown thermal transport properties of various 2D materials. In addition, it still remains a grand challenge to experimentally verify the theoretical predictions of enhanced thermoelectric figure of merit in 2D systems and by topologically protected surface states. Following our prior works on thermal transport measurements of graphene, we have recently studied thermal transport in few-layer h-BN, MoS2, and germanane, and the thermoelectric properties of bismuth telluride nanoplates. The results reveal that surface perturbation suppresses the in-plane lattice thermal conductivity of these 2D materials. The thickness needed for recovery to the bulk lattice thermal conductivity scales with the bulk phonon mean free path. In addition, we have observed decrease in both the electrical conductivity and thermal conductivity with decreasing thickness of bismuth telluride nanoplates. While the electrical conductivity is still within the bulk range, the thermal conductivity is reduced to below the bulk range for nanoplates thinner than 20 nm. These results are explained by the presence of surface band bending and diffuse surface scattering of electrons and phonons in the nanoplates, where pronounced n-type surface band bending can yield suppressed and even negative Seebeck coefficient in unintentionally p-type doped nanoplates. Sb doping and surface functionalization are employed in our works to tune the Fermi level and surface band bending and modify the thermoelectric properties.