Collective and Extrinsic Effects on Phonon Transport in 2D Materials

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Two-dimensional (2D) materials have tremendous potential for next-generation nano- and optoelectronics. However, heat dissipation and its removal from hot spots in the monolayer remains a critical concern to the design of 2D-based devices. Thermal currents flowing in an atomic layer can either dissipate through source/drain contacts in a transistor configuration, or through a supporting substrate via van der Waals (vdW) coupling to it. When a 2D material is supported by a substrate, the interfacial area formed between it and the substrate is often far larger than the lateral source/drain contact area. Thus, the majority of waste heat is removed across the 2D-substrate interface and then via the substrate. The thermal boundary conductance (TBC) between the 2D layer and substrate should be well characterized for reliable 2D device performance. Interfaces formed between 2D vdW materials and 3D substrates are fundamentally different than same-dimension 3D-3D and 2D-2D interfaces due to the presence of a vdW gap and the different dimensionalities of the phase spaces on either side of the interface. In this talk, I will review the progress in understanding lattice thermal transport, both in-plane and cross-plane, in 2D mono and few-layer materials. Next, I will introduce my recent work aimed to tackle the question of selecting the best substrate for each 2D material from the point of view of heat dissipation. Then my talk will review some recent work in length scaling of thermal conductivity in long graphene ribbons, caused by collective phonon hydrodynamics, as well as thermal transport between graphene and amorphous substrates.