Thermal Transport in Nanoscale Materials: From Ordered to Disordered

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Thermal properties of nanoscale materials are strongly influenced by material microstructure. In my talk, I will describe our studies on the thermal properties of two different material systems, which represent extreme cases of microstructural ordering. In the first part, I will focus on heat conduction in highly-ordered lattice-matched superlattices of InGaAs/InAlAs, where we find that the closely matched acoustic phonon properties of the constituent layers and the high degree of interface specularity lead to negligibly small values for the interfacial thermal resistance. This work utilizes time domain thermoreflectance (TDTR) for measurements of cross-plane thermal conductivity, and phonon Boltzmann transport simulations for modeling of transport in the quasi-ballistic regime. In the second part I will focus on measurements of the anisotropic and non-homogeneous thermal conductivity of nanocrystalline diamond films with thicknesses down to a few micrometers. The higher density of grain boundaries in the lateral direction as compared to the vertical direction leads to a large anisotropy in thermal conductivity with the cross-plane value being a factor of 6-8 times higher than the in-plane value, for a 6 micron thick film. Besides being of fundamental interest to understanding the impact of grain boundary scattering on thermal conductivity, this study has implications for the design of heat sinks utilizing CVD diamond substrates in high heat-flux applications.