Thermal Conductivity of Wide Band Gap Semiconductors Measured by Time Domain Thermoreflectance

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The development of wide bandgap (WBG) semiconductor devices has led to unprecedented advancement of electronics that operate at high power and high frequency. However, the performance and reliability of these systems rely on the ability to efficiently dissipate thermal energy from the devices during operation. Accurately measuring the thermal conductivity of WBG semiconductors is crucial for achieving thermal management. However, WBG materials like GaN and SiC are highly sensitive to the doping level, leading to scattered thermal conductivity by measurement and first principles calculation. Besides, the anisotropic thermal transport in WBG materials like SiC and Ga_2O_3 are usually not well articulated by the steady state measurement available in the literature which only measure the thermal conductivity in a certain direction. In this work, we have used time-domain thermal reflectance to measure the temperature dependent thermal conductivity of the WBG semiconductors including GaN, SiC, and Ga_2O_3. We have separately measured the in-plane and through plane thermal conductivity of 4H- and 6H- SiC using variable-spot size TDTR. For the monoclinic Ga_2O_3 with three-dimensional anisotropy, beam-offset TDTR is combined with the concentric TDTR to obtain the thermal conductivity tensor. More interestingly, the GaN thermal conductivity is observed to depend on modulation frequency, which is attributed to the non-equilibrium transport between high frequency and low frequency phonons separated by the large phonon bandgap.