Temperature Dependence of the Thermal Boundary Resistance at Metal-Dielectric Interfaces

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As micro- and optoelectronic device sizes decrease, precise knowledge of the thermal boundary resistance (TBR) at the interface of two materials is crucial for device performance and design. The primary energy carriers in dielectric materials are acoustic phonons, so the TBR associated with systems that are comprised of dielectric materials is often associated with the reflection of phonons at the interface. For non-perfect interfaces, the Diffuse Mismatch Model (DMM) is often used to predict phonon scattering and relate the phonon transmission probability to the TBR. This transmission probability is related to the density of phonon states at either side of the interface, which is temperature dependent up to the Debye temperature. Molecular Dynamics Simulations (MDS) have shown temperature dependence in the TBR even at temperatures higher than the Debye temperature. This dependence cannot be accounted for by the DMM, and implies some inelastic phonon scattering at higher than Debye temperatures. To experimentally test this phenomenon, a variety of samples with varying Debye temperature ratios are fabricated, and the TBR's are measured using the pump-probe Transient Thermo Reflectance (TTR) technique utilizing a sample heater that can achieve temperatures of 600 K. Chromium, Au, and Pt films are grown on GaAs, InSb, Si, AlN, and Al_2O_3 substrates, and the TBR is measured at various sample temperatures. The combination of these film/substrate systems allows the TBR to be studied at interfaces with film/substrate Debye temperature ratios from 0.15 to 3.8. The TBR dependence of the interface temperature is observed, and information about phonon scattering processes is discussed.