Electron and phonon thermal conductivity and scattering rates in metal and non-metal thin films and multilayers

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The progressive reduction in the characteristic length scales of logic technology nodes in very-large-scale integration (VLSI) has led to the need to find replacements for copper being used as interconnects. Both the thermochemical and thermomechanical stability of Cu at these length scales, along with the strong reduction in both electrical and thermal conductivity due to length scales reducing to those less than its electronic mean free path has led to underperformance, which in part can be ascribed to deleterious heating effects.[1] While Ru and W interconnects are currently being evaluated, a range of additional metals and metallic systems (alloys, eutectics and multilayers) are also of note due to their potential mechanical and thermal properties that are superior to Cu at the < 100 nm length scale. In this presentation, I will discuss our recent efforts in measurements of thermal conductivity and electron-phonon scattering rates of thin metal films for interest as next-generation metal interconnects, including Ru, W, Ir, Pt, Mo, Co and Ta. First, I will discuss the use of various thermoreflectance techniques – including time-domain thermoreflectance (TDTR), steady state thermoreflectance (SSTR),[2,3] and time resolved magneto-optical Kerr effect (TR-MOKE) – to measure the thermal properties of thin films, including the in-plane a cross plane thermal conductivity of thin films of metals, dielectrics, multilayer metals and multilayer chalcogenide phase change materials. I will then discuss how the measurement of in-plane thermal conductivity allows for direct comparison to k derived from electrical resistivity measurements and application of the Wiedemann-Franz (WF) Law. We find that in most cases, the application of the WF law with the low temperature value of the Lorenz number does not sufficiently predict the total thermal conductivity. To understand the mechanisms that drive the thermal transport of these metal films, we use infrared variable angle spectroscopic ellipsometry (IR-VASE) the measure the electron scattering rates, demonstrating the relatively thickness independent scattering processes in these films, providing strong promise in the scaling of these metals to technology node length scales.

References
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