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DIRECT MEASUREMENTS OF THERMAL PHONON TRANSMISSIVITY AT ROUGH INTERFACES

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Abstract: Energy transport across solid-solid interfaces is a fundamental process of both scientific and practical interest. For example, electronic transport across metal- semiconductor and pn-junctions forms the basis for modern microelectronics. While electron and photon transport across interfaces is well understood, the microscopic interfacial transport processes for thermal phonons are largely unknown. In fact, the transmissivity of thermal phonons across any interface has never been directly measured. At present, interfacial transport is studied using macroscopic measurements of interface conductance, a procedure that leaves substantial ambiguity in the actual transmissivity profile. Here, we demonstrate that the spectral phonon transmissivity at a metal-semiconductor interface is contained in measurements from a widely-used experimental technique, time-domain thermoreflectance (TDTR). Using our recent advances in solving the phonon Boltzmann equation to interpret TDTR measurements, we are able to directly measure how much heat is carried by each phonon mode across the interface and hence directly extract the spectral phonon transmissivity. Our measurements reveal that, like other waves, thermal phonons are capable of tunneling across disordered interfaces with thickness smaller than their wavelength. This work represents a major advance in our understanding of thermal phonon transport at interfaces and could impact numerous applications ranging from thermoelectric waste heat recovery to heat dissipation in electronic devices.