Low temperature phonon boundary scattering in slightly rough Silicon nanowires

MARC GHOSSOUB, KRISHNA VALAVALA, MYUNGHOOON SEONG, BRUNO AZEREDO, JYOTHI S. SADHU, SANJIV SINHA, Department of Mechanical Science and Engineering - University of Illinois at Urbana-Champaign — Nanostructured materials [1-3] have lower thermal conductivities than the bulk and are promising candidates for thermoelectric applications. In particular, measurements on single silicon nanowires show a reduction in thermal conductivity below the Casimir limit. This reduction increases with surface roughness [4] but the trend and its connection to phonon boundary scattering are still elusive. Here, we measure the thermal conductivity of single silicon nanowires fabricated using metal-assisted chemical etching. High resolution TEM imaging shows crystalline wires with slightly rough surfaces. Their statistical correlation lengths (5-15 nm) and RMS heights (0.8-1.5 nm) are in a range where perturbation-based wave scattering theory is still applicable. We use the thermal conductivity data to extract the frequency dependence of phonon boundary scattering at low temperatures (10-40 K) and show agreement with multiple scattering theory. This work provides insight into enhancing the thermoelectric performance of nanostructures. 1-A. I. Hochbaum et al, Nature Lett. 451, 163-167 (2008). 2-A. J. Minnich et al, Energy Environ. Sci. 2, 466-479 (2009). 3-L. Shi, Nanoscale Microscale Thermophys. Eng. 16, 79–116 (2012). 4-J. Lim et al, Nano Lett. 12, 2475–2482 (2012).