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Nanoscale Phonon Transport as Probed with a Microfabricated Phonon Spectrometer for the Study of Nanoscale Energy Transport

RICHARD ROBINSON, OBAFEMI OTELAJA, JARED HERTZBERG, MAHMUT AKSIT, Department of Materials Science and Engineering, Cornell University, DEREK STEWART, Cornell Nanoscale Science and Technology Facility —

Phonons are the dominant heat carriers in dielectrics and a clear understanding of their behavior at the nanoscale is important for the development of efficient thermoelectric devices. In this work we show how acoustic phonon transport can be directly probed by the generation and detection of non-equilibrium phonons in microscale and nanoscale structures. Our technique employs a scalable method of fabricating phonon generators and detectors by forming Al-Al_xO_y-Al superconducting tunnel junctions on the sidewalls of a silicon mesa etched with KOH and an operating temperature of 0.3K [1]. In the line-of-sight path along the width of these mesas, phonons with frequency $\sim$100 GHz can propagate ballistically The phonons radiate into the mesa and are observed by the detector after passing through the mesa. We fabricated silicon nanosheets of width 100 to 300 nm along the ballistic path and observe surface scattering effects on phonon transmission when the characteristic length scale of a material is less than the phonon mean free path. We compare our results to the Casimir-Ziman theory. Our methods can be adapted for studying phonon transport in other nanostructures and will improve the understanding of phonon contribution to thermal transport. The work was supported in part by the National Science Foundation under Agreement No. DMR-1149036.

[1] J. B. Hertzberg et al, Rev. Sci. Inst. 82, 104905 (2011).

Obafemi Otelaja
Department of Materials Science and Engineering, Cornell University

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