Experimental Observation of Thermal Transport of Surface Phonon-Polaritons over Hundreds Micrometers

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At nanoscale, enhancing heat propagating distance attracts intensive attentions for improving the thermal performance in micro- and nanoelectronics. However, the major heat carriers, phonons, propagate ballistically shorter than one micrometer above room temperature. To compensate this limited propagation, we propose a novel heat carrier, surface phonon polariton (SPhP), which generates from the hybridation of the optical phonons and the photons and propagates in the range of a few hundred micrometers. Here, we conduct a 3ω measurement of SiN suspended submicron films to investigate the thermal transport by SPhP in hundreds micrometers range.

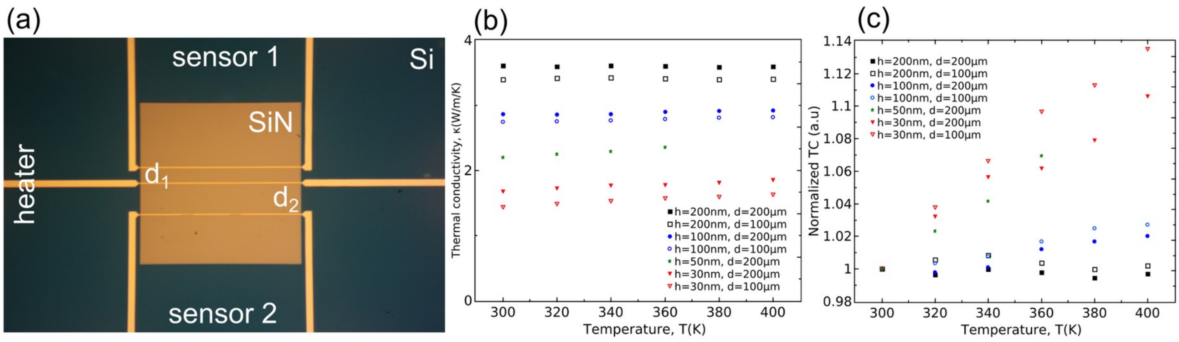

Fig. 1. (a) Schematic of a SiN sample: three metal wires deposited on top of suspended SiN membrane, one in the middle generates constant heat flux, and two detect the heat flux from different distances; (b) thermal conductivities (TC) of different thickness of membranes, the ones with longer distance have the higher TC (c) TC normalized by the ones at room temperature, demonstrating that higher SPhP contribution results from the thinnest membrane: 30 nm-thick.

Figure 1 shows the thermal conductivity (TC) of silicon nitride (SiN) films with different thicknesses (h=30, 50, 100 and 200 nm) measured from 300 to 400 K. We detect higher TC with the sensor further from the heater for different thickness. Since the range is in hundred of micrometers, this phenomenen can only be contributed by SPhP and in a good agreement with previous study [1]. When 30 nm-thick film heats up to 400 K, we detect 15% enhancement of TC. Meanwhile for 100 and 200 nm-thick membranes, TC is nearly independent from temperature and the detecting distance. The results presented here tackle the thermal issue at high temperature and have potenetial applications in the field of heat transfer, thermal management, near-field radiation and polaritonics.

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Reference [1] Y. Wu et al. “Enhanced thermal conduction by surface phonon-polaritons”, Science Advances 6, eabb4461 (2020)