Probing Ballistic Thermal Transport Driven by Surface Phonon Polaritons in Dielectric Nanofilms

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Ballistic heat transport involving thermal conduction without heating up the system, has attracted great attention due to its potential applications for improving the thermal performance in nanoelectronics. However, ballistic heat transport was so far observed only due to non-diffusive heat conduction by phonons. As novel heat carriers, surface phonon polaritons (SPhPs) generated by the hybridation of optical phonons and photons, can ballistically propagate typical distances of a few hundred micrometers [Tranchant et al., Nano Lett. 2019, 19, 10, 6924; Wu et al., arXiv 1908.01247]. In this work, we conduct 3ω measurements on suspended SiN nanofilms to investigate the ballistic transport driven by SPhPs.

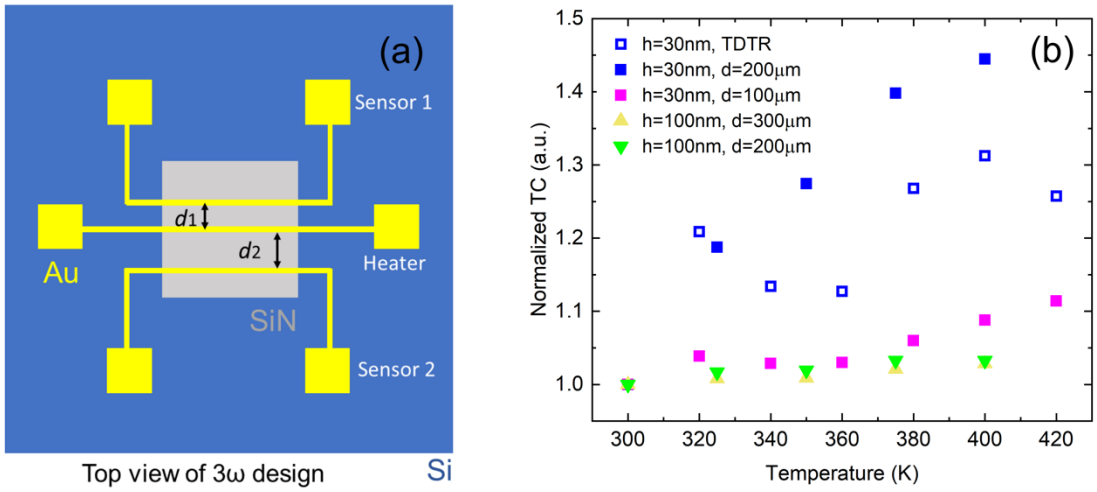

Fig. 1. (a) Scheme of a SiN sample with 3ω patterns and (b) its in-plane thermal conductivity (TC) normalized by the corresponding one at room temperature, as a function of temperature. The increase of TC with the heater-sensor distance of the 30 nm-thick film, represents the signature of the SPhPs contribution to the in-plane heat transport.

Figure 1 shows the temperature evolution of the thermal conductivity (TC) of SiN films measured for two thicknesses (h=30 and 100 nm) and different heat-sensor distances (d= 100, 200 and 300 μm). Note that for the 30 nm-thick film at 400 K, the sensor 2 (d_2=200 μm) and sensor 1 (d_1=100 μm) detect nearly 50% and 10% of TC enhancement, respectively. By contrast, the TC of the 100 nm-thick film, is nearly independent of temperature and the heater-sensor distance. These facts confirm that the SPhPs heat contribution has strong dependence on the propagation lengths and show only up for very thin nanofilms, as established by theory. The obtained results can thus have potential applications in thermal management, near-field radiation, and polaritonics.

Acknowledgements This work was supported by CREST JST (JPMJCR19Q3 and JPMJCR19I1) and Kakenhi (15H05869 and 17H02729).