THERMAL ENERGY TRANSPORT IN A SURFACE PHONON-POLARITON CRYSTAL

Jose Ordonez-Miranda$^{1,2}$, Karl Joulain$^1$, Sebastian Volz$^2$

$^1$ Institut Pprime, CNRS, ISAE-ENSMA, Université de Poitiers, F-86962 Futuroscope Chasseneuil, France. $^2$ Laboratoire EM2C, CNRS, CentraleSupélec, Université Paris-Saclay, Grande Voie des Vignes, 92295 Chatenay-Malabry cedex, France.

Surface phonon-polaritons (SPhPs) are coupled states of optical phonons and electromagnetic waves, which can enhance the thermal energy transport along the interface of polar nanomaterials. Theoretical results showed that the SPhP contribution to the thermal conductivity of nanofilms [1,2] and the thermal conductance of nanowires [3] could be comparable to or even higher than the corresponding ones of phonons, especially at room temperature.

In this work, we demonstrate that the SPhP energy transport can be efficiently observed in SPhP crystals made up of a three-dimensional assembly of spheroidal nanoparticles of silicon carbide. The ultralow phonon thermal conductivity of these structures along with their high surface area-to-volume ratio allows the predominance of the SPhP energy transport over that generated by phonons. The SPhP thermal conductance is numerically determined, as a function of the size, shape, and temperature of the nanoparticles. It is shown that the SPhP energy transport along the minor axis of prolate nanoparticles is higher than the corresponding one for spherical and oblate nanoparticles. The SPhP thermal conductance of nanoparticles at 500 K, with a minor axis of 50 nm, and a major axis of 5 μm is 0.5 nW/K$^1$, which is comparable to the quantum of thermal conductance of polar nanowires [3]. Furthermore, the conditions for minimal absorption, longest propagation length, and highest group velocity are analytically derived, for both the longitudinal and transverse polarizations. The proposed structure of the SPhP crystal is analogous to that of the phononic one and its relatively high thermal conductance is expected to enable the experimental quantification of the SPhP energy transport.

Keywords: Surface phonon-polariton crystal, Thermal conductance, Quantum of thermal conductance

References:


Presenting author’s email: jose.ordonez@cnrs.pprime.fr