PHONON DYNAMICS IN NANOPHONONIC MATERIALS FOR ENERGY APPLICATIONS

LABORATORY : Institut Lumière Matière

LEVEL : M2
TEAM(S) : ENERGIE

CONTACT(S) : GIORDANO Valentina

CONTACT(S) DETAILS: valentina.giordano[at]univ-lyon1.fr / Tel. 0472431018

KEYWORD(S) : energy / nanophononic / thermal management

SCIENTIFIC CONTEXT :

In thermal science, nanostructuration allows to engineer thermal transport by directly acting on the heat carriers, the phonons, as the nanometric lengthscale becomes comparable with their characteristic lengths (wavelength and mean free path). This thermal engineering implies however new challenges, not only from the technological point of view, but also from the point of view of a fundamental understanding, as theories are still under development and can count only on very few experimental data. The aim of the project here proposed is to contribute at developing our knowledge in this field.

The introduction of interfaces at the nanoscale through nanostructuration is expected to scatter phonons and thus reduce their mean free path and ability in transporting heat. When nanostructuration is periodic, new phenomena come into play, which involve the wave nature of the phonon. Phonons may coherently interfere, when reflected, leading to the definition of a new Brillouin zone and a dramatic modification of phonon dispersions. The result is that these materials, said nanophononic, are extremely efficient in reducing thermal transport. The effects of coherent interference on phonon dynamics remain however not fully understood. We have measured phonon lifetime in the nanophononic SiN membrane reported in Fig. 1 at wavelengths 55-100nm, and shown that it is strongly reduced, due to the presence of coherent interference of the phonon with its reflections at the periodic interfaces.

MISSIONS :

Our calculations predict a maximum reduction of phonon lifetime at wavelengths comparable with the neck (250nm in our case), when phonons should be trapped between the pores. We offer an M2 internship (6 months) with the possibility of thesis funding, in which we propose to continue this investigation at larger wavelengths, between 300 and 1000nm, using the Surface Brillouin Light Scattering technique (sBLS), to identify phonon trapping at wavelengths resonant with the nanostructure and investigate the phonon lifetime reduction as a function of wavelength. To this aim, he/she will investigate a uniform SiN membrane and the nanophononic one as a function of temperature. A proposal has already been submitted to perform measurements in the 100-300 nm wavelength range at the free electron laser, and the beamtime could be allocated during the internship. In this case the trainee could also participate.

OUTLOOKS :

Requird: very good grades and strong knowledge in the domain of solid-state physics

Outlook: thesis

BIBLIOGRAPHY :

M. Nomura, Materials Today Physics 22, 100613 (2022)

G. Ma, Phonon Engineering of Micro- and Nanophononic Crystals and Acoustic Metamaterials: A Review , Small Science , 3, 2200052 (2023)

published on 08/09/2023