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Master internship proposal (+PhD) – Spring 2024

Elastic guided waves and local resonances in nano-porous silicon membranes

Host Laboratory: Institut Langevin, 1 rue Jussieu, 75005 Paris ; https://www.institut-langevin.espci.fr/
Supervisors: Claire Prada and Sylvain Mezil

This master subject is part of a franco-german research project dedicated to nano-porous silicon-elastomer hybrids. Nano-porosity in silicon leads to completely new functionalities in various fields. However, a difficult to assess elasticity significantly limited its mechanical application so far. The ultimate goal of the project is to develop a hybrid nano-material system with tunable elastic properties. To this end, we plan to confine liquid crystal elastomer (LCE) within the pores of the nano-porous silicon (pSi) membrane. As the mechanical properties of LCE change significantly as a function of stimuli, tunable properties of the hybrid are expected.

In order to comprehensively characterize the elastic behaviour of the hybrid system, broad band non-contact laser ultrasonic techniques will be used. A pulsed laser source excites elastic waves by thermo-elastic conversion. The propagating guided waves are then measured along the membrane with a laser interferometer. The elastic properties of the nano-porous silicon will first be evaluate following the procedure described in a preliminary study [1]. Two acoustic characteristics will be exploited: the local resonance frequencies obtained from the signal measured at the excitation point, and the dispersion curves of the guided elastic modes deduced from spatio-temporal measurements (figure). The first measurements performed in a 50% porosity pSi membrane, showed that the pore induced transverse isotropic anisotropy prevails over the cubic anisotropy of the bulk silicon.

We plan measurements in wafer of different porosities in order to understand the transition from cubic anisotropy (the one of silicon) to transverse isotropy (due to the porous network). The effective elastic properties of the dry pSi will be assessed based on inverse identification method developed in parallel. If time allows, we will study the elastic properties of the confined elastomer starting with the simpler case of 1D confinement between two silicon plates.

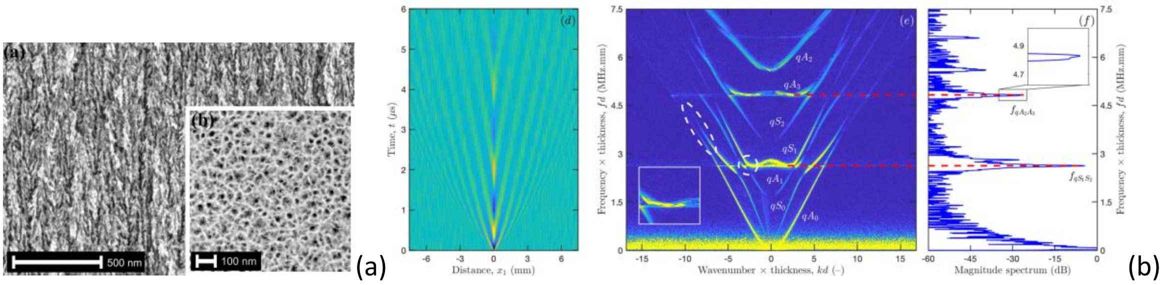

Figure (a) Scanning electron microscope images of nanoporous silicon membrane, (b) spatio-temporal measurement, dispersion curves and local elastic resonances measured by laser.

[1] M. Thelen, N. Bochud, M. Brinker, C. Prada, and P. Huber. "Laser-excited elastic guided waves reveal the complex mechanics of nanoporous silicon". Nature Commun. 12.1 (2021).

Requirements : The candidate should be motivated to continue with a PhD. A strong background in general physics and good knowledge in optic and waves are expected. Both experimental skills and an interest in numerical modelling are required.

Context : The HySiSound project entitled "Nanoporous Silicon-Elastomer Hybrids: From Liquid-Crystalline Functionalization to a Tunable Elasticity Assessed by Laser Ultrasonics" will start in spring 2024. It implies Nicolas Bochud who is assistant professor at the laboratory MSME at the Paris-Est Créteil University and the team of Patrick Huber, the german Principal Investigator, who is professor at the Hamburg University of Technology (TUHH) and the Deutsche Elektronen-Synchrotron (DESY). **A PhD grant** is secured at Institut Langevin.

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