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Master internship proposal (+PhD) – Spring 2024

Nano-Porous Silicon Membranes assessed by Laser Ultrasonic techniques

Host Laboratory: Institut Langevin, ESPCI, PSL, 1 rue Jussieu, 75005 Paris
https://www.institut-langevin.espci.fr/

Supervisors: Claire Prada and Sylvain Mezil

Nano-porosity in silicon leads to completely new functionalities in various fields. The goal of the project is to develop a hybrid nano-material system with tunable elastic properties. To this end, liquid crystal elastomer (LCE) will be confined within the pores of a nano-porous silicon (pSi) membrane (Figure (a)). As the mechanical properties of LCE change significantly as a function of stimuli, tunable properties of this hybrid material are expected. This holds great promise for diverse electromechanical applications, such as actuators or sensors. However, the difficulty to assess its elastic properties significantly limited its mechanical application so far.

In order to characterize the elastic behaviour of the hybrid material, broad band non-contact laser ultrasonic techniques will be used. A pulsed laser source will excite elastic waves by thermo-elastic conversion. The propagating guided waves will then be measured along the membrane with a laser interferometer. The elastic properties of the nano-porous silicon will first be evaluated following the procedure described in a preliminary study where first measurements were performed in a 50% porosity pSi membrane (Figure (b)). It was shown that the pore induced transverse isotropic anisotropy prevails over the cubic anisotropy of the bulk silicon [1].

During this internship, measurements in wafer of different porosities will be done to understand the transition from cubic anisotropy of bulk 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.

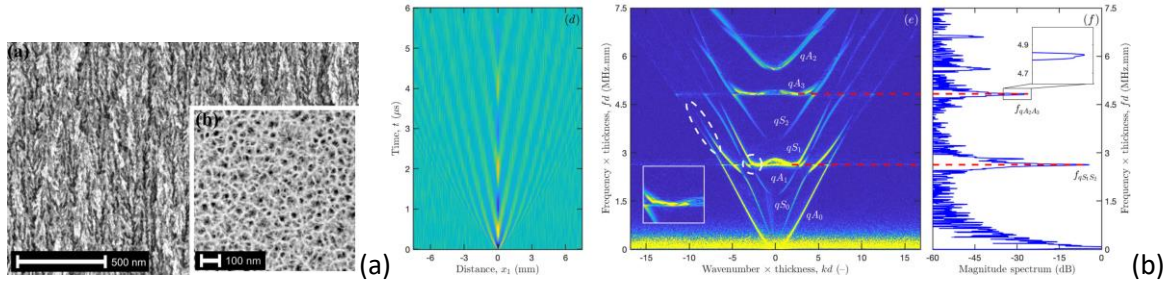

Figure (a) Scanning electron microscope images of nanoporous silicon membrane, (b) spatio-temporal wave measured by non-contact laser technique, local elastic resonances and dispersion curves obtained by 2D Fourier transform of the displacement field.

[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 welcome.

Context: This master subject is part of the franco-german research project entitled "Nanoporous Silicon-Elastomer Hybrids: From Liquid-Crystalline Functionalization to a Tunable Elasticity Assessed by Laser Ultrasonics". It involves 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). **A PhD grant** is secured at Institut Langevin.

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