Nano-particle mass sensing using phononic pillars

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Background, Motivation and Objective

The development of biosensors is of crucial importance for multiple applications such as food processing, medical diagnosis and military [1]. A large set of acoustic sensors were proposed but they rapidly reached their limit in sensitivity. This work presents a sensing approach based on phononic micro-pillar resonators which display high mass sensitivity for single nano-particle detection and can be embedded in a lab-on-a-chip. This sensing mechanism presents a very promising mass sensitivity to increase the performance of Love waves based biosensors toward single molecule detection.

Statement of Contribution/Methods

We introduce a new acoustic sensing mechanism based on phononic micro-pillars, composed of successive tungsten and silica layers, and distributed on a substrate designed for Love waves propagation. These multilayered pillars allow the creation of band gaps, which lead to the existence of resonant modes with high elastic energy confinement within the free silica surface layer of each micro-pillar. To obtain this energy confinement, each micro-pillar is constructed by stacking tungsten and SiO_2 layers. We also study the variation of the mass sensitivity of the system by evaluating the resonant modes frequency shift induced by a mass perturbation using two theoretical approaches: the perturbation theory and a numerical method [2].

Results/Discussion

The Love waves interaction with the phononic micro-pillars appears in the surface wave's transmission spectrum as a narrow band sharp decay of the wave amplitude. Particularly, the Love wave can excite a torsional mode localized on the upper surface of the pillar depicted as a dip at 250 MHz with high quality factor of 83000 (fig1.(a) and.(b)). The minimum of the dip is at 20 dB in attenuation. This torsional mode displays high mass sensitivity in the surface area where the strain is maximum, i.e the free top surface of the micro-pillar (fig.1(a)). A mass perturbation of $\delta_m = 1.15$ fg at maximum sensitivity location induces a frequency shift of 2.7kHz to the torsional mode (fig.1(c)) Furthermore, the frequency shift is about 15 MHz for 3x10 ^{4} particles homogenously distributed in the pillar's surface.[2].

[1] K. Länge, *at al*. Anal. Bioanal. Chem. **391**, 1509 (2008)
[2] J. Bonhomme *et al.* Appl. Phys. Lett. **114**, 013501 (2019)

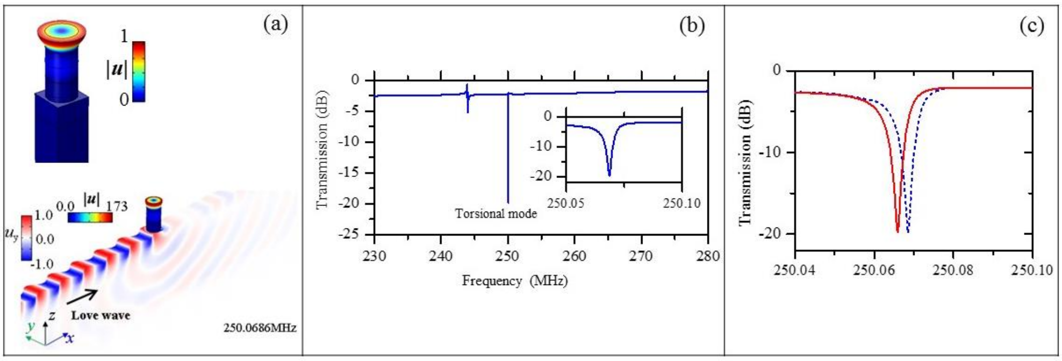

Figure 1: Normalized displacement for the torsion mode and the displacement field amplitude for the torsion mode at its resonance frequency as well as the u_y component in the silica guiding layer. (a), Transmission spectrum and a close look on the pic corresponding to the torsion mode, locate around 250MHz (b), Transmission spectrum for the torsion mode unperturbed (blue dashed line) and for a mass perturbation, δm=1,15 fg (red solid line) (c).