Nano-optomechanical disk resonators operating in liquids

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Vibrating nano and micromechanical resonators have been the subject of extensive research for the development of ultrasensitive mass sensors for mass spectrometry, chemical sensing and biomedical analysis [1, 2]. By miniaturizing the devices and operating in high-vacuum conditions, mass detection down to the yoctogram (10^{-24} g; the proton mass) has been achieved [3]. Translation of these achievements to liquids, the natural environment for biology, has remained elusive because of the very high energy loss in viscous environments. Among the novel structures and approaches proposed to circumvent this problem, microchannels have been the most promising so far [4], because they mitigate energy losses in liquid. However, they can hardly be miniaturized, limiting the future improvement of their sensing capabilities.

Here we highlight the potential of semiconductor disk resonators in this context. They combine confined optical modes of high quality factor and giant optomechanical coupling, leading to displacement sensitivity down to 10^{-17} m/$\sqrt{\text{Hz}}$. This has allowed us to optically detect the Brownian motion of their GHz contour vibrations, even in the most dissipative liquids [5], and to finely test new fluid-structure interactions models at very high frequency. These disk resonators are potentially powerful sensors, thanks to their low mass (pg), very high frequency, and low dissipation in liquid environments, and can be miniaturized to the nanoscale. Nano-optomechanical disks emerge as probes of rheological information of unprecedented sensitivity and speed (Figure 1). In water, thermodynamical limits of detection in mass, density and viscosity are respectively of 14 yoctogram, $2\cdot10^{-7}$ kg/m^3 and $5\cdot10^{-9}$ Pa·s (for 1 s integration time). This represents a 3 orders of magnitude improvement over current state-of-the-art techniques. While putting miniature disk fluidic sensors on a firm ground, our results also provide a first frame to depict nano-optomechanical dissipation in liquids. This will be of importance for future optomechanical applications in aqueous environments, in biology or chemistry.

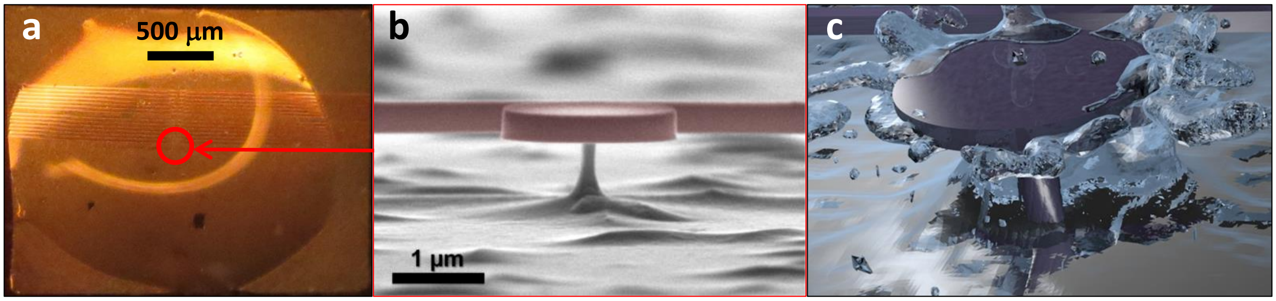

Fig. 1 a. Optical micrograph top view of a chip with an array of disk resonators, together with their optical coupling waveguides, immersed in a liquid droplet. **b.** Scanning electron microscope image (side-view) of a 1 μm radius GaAs disk with a tapered waveguide. **c**. Artistic illustration of the disk-liquid interaction.

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