Extended Abstract

Mass Spectrometry 2017: High frequency nano-optomechanical disk resonators in liquids - Eduardo Gil Santos - University of Paris

Abstract

Vibrating nano and micromechanical structures have been the subject of extensive research for the development of ultrasensitive mass sensors for spectrometry, chemical sensing and biomedical analysis. In short, the minimum detectable mass is proportional to the effective mass of the resonator and sensitivity improves if mechanical dissipation is reduced. Device miniaturization and dissipation control are therefore crucial. In liquids, the energy losses are high and therefore the mass sensitivity is usually diminished dramatically. To circumvent this problem, novel structures are proposed, like micro-channels or micro-capillars where the liquid flows directly inside the resonators. While these structures indeed show lower mechanical dissipation, they will hardly be miniaturized. Here we demonstrate the potential of nano-optomechanical disk resonators during this context, especially that specialize in high-frequency radial breathing modes of those structures. Miniature semiconductor mechanical disks, with their high mechanical Q even in air (>103), their Low Mass (pg) and high mechanical frequency (GHz), present clear assets for mass sensing applications. However, they have not been operated in liquids so far. Here, we experimentally, numerically and analytically investigate the interaction of such vibrating disk resonators with arbitrary liquids, and propose models for both the frequency shift and dissipation of their mechanical modes. Nano-optomechanical disk resonators finally emerge as probes of rheological information of unprecedented sensitivity and speed, opening applications in high frequency sensing and fundamental science

The development of ultrasensitive mass sensors for biological applications like early disease detection has recently generated a great deal of effort. In this context, micro and nanomechanical resonators with low inertial mass appear as a key technology, as exemplified by their capability to sense down to individual atoms in vacuum. In short, the minimum detectable mass is proportional to the effective mass of the resonator and sensitivity improves if mechanical dissipation is reduced. Device miniaturization and dissipation control are therefore crucial. In liquid -typical of biological environments-, energy losses are high and therefore the mass sensitivity diminishes dramatically. Furthermore, viscous damping in a liquid also increases when standard mechanical devices such as cantilevers or membranes are miniaturized.

To circumvent these problems novel structures and techniques have been developed. An efficient approach is to use vibrating micro channel cantilevers where the liquid flows directly inside the resonator in order to reduce the induced dissipation. Fibered micro capillaries adopt this approach too with a more integrated optical detection. Since both types of devices need to embed fluidic channels, their size varies from a few tens to few hundreds of microns, leading to masses above the nanogram and mechanical frequencies at most in the MHz range. These channel devices can hardly be miniaturized to the nanoscale. Other geometries have been investigated, including the case of a partially immersed resonator, which faces similar size limitations and has demonstrated lower integration capabilities.

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