Nano-optomechanical disk sensors

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Nano-optomechanical disks are excellent candidates for sensor development covering a wide range of applications. These devices simultaneously support very high quality optical and mechanical modes, making them advantageous for sensing. In the last decade, we have proposed their use for liquid characterization [1], environmental monitoring [2] and pathogen detection, characterization and identification [3, 4], among others.

Regarding liquid sensing, we have proved that nano-optomechanical disks can determine the density and viscosity of a liquid with precisions down to 1 part per million [1]. Regarding environmental sensing, we have proved that combining optical and mechanical sensing enables disentangle temperature and relative humidity changes, and have demonstrated temperature and relative humidity resolution of 1 mK and 0.1 %, respectively, even if both parameters change at the same time [2].

Besides, the use of nano-optomechanical disks for pathogen sensing is one of the most promising one. In this regard, we have recently demonstrated that these devices enable the optical and mechanical detection of virus-like-particles. Furthermore, we have also proved that they allow the detection of mechanical modes associated with individual microbiological entities [3]. The proposed method is based on coupling the mechanical modes of the sensor with the one of the analyte. An essential condition to achieve it, is that they resonate at close frequencies. This occurs for nano-optomechanical disk and micro-organisms (Figure 1). We have demonstrated the method for bacteria (Figure 2), but in the near future we plan to extent it for virus. This result paves the way for developing a novel and very promising technique, the mechanical spectrometry of microbiological entities [4]; which promises the detection, mechanical and morphological characterization, and univocal identification of many kind of microbiological entities, such as human cells, bacteria, virus and proteins.

Here, we review all of these applications, explain the operating principles of these sensors, and provide insight into their future potential [4].

References

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Figures

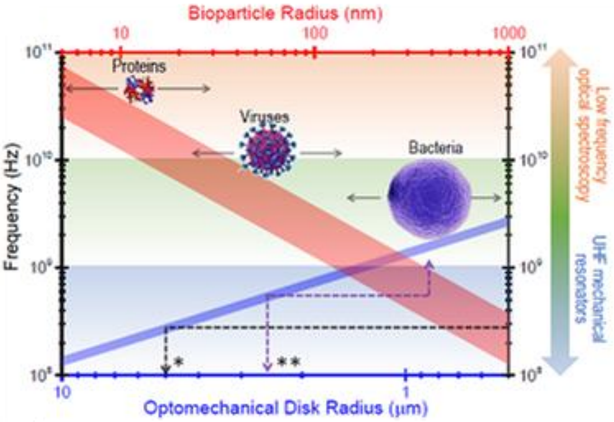

Figure 1. Resonant frequency of the first radial breathing mode of a nano-optomechanical disk (blue region) and of the fundamental mode of a quasi-spherical biological particle (bacteria, virus, protein, etc.) adsorbed on a rigid support (red region), as a function of their radii.

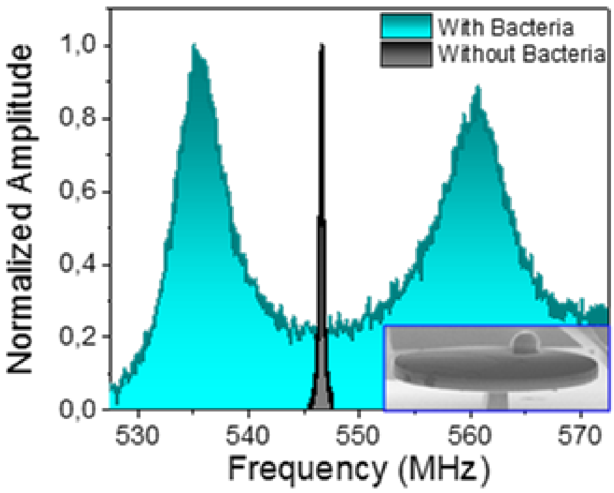

Figure 2. Mechanical spectra of a nano-optomechanical disk (2.5 μm in radius and 320 nm in thickness) before and after the adsorption of a Staphylococcus epidermidis bacterium. The inset shows a scanning electron microscopy image of the bacterium adsorbed on the disk. In particular, the graph shows the resonance associated to the first radial breathing mode of the disk, which couples with the first flexural mode of the bacterium, enabling its detection.