Nanomechanical resonators for multiplexed physical characterization of cells and other biological analytes

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Characterizing the physical properties of single living cells is essential for a wide range of applications going from increasing our understanding of the processes governing life to unraveling the mechanisms behind the development of different pathologies as well as for the development of personalized therapies. In the last decades many efforts have been directed towards developing innovative techniques that allow characterizing physicochemical properties of cells under physiological conditions using different approaches such as microfluidics [1], Raman spectroscopy [2], impedance spectroscopy [3], holographic microscopy [4] or nanomechanics [5]. Nevertheless, despite the success of those techniques biological entities are so rich and complex physicochemical systems that it is necessary a more global approach to obtain a comprehensive characterization of these analytes.

In this context, the development of multiplexed techniques is gaining weigh so the combination of different physicochemical processes can draw a more accurate image on the processes happening in the cell (or other microbiological entity). Moreover, this kind of characterization techniques have also been revealed as tools with potential for being used in diagnostic application. On one hand, they have the advantage of offering a label-free approach, while, on the other hand, the combined measurement of physical properties helps to overcome the typical low sensitivity offered by measuring single biophysical properties.

In this line, nanomechanical resonators and, more specifically, suspended microchannel resonators (SMR) [6], have been revealed as a powerful technique for this multiplexed biophysical characterization: not only for they high accuracy transducing different physical phenomena (Fig. 1), but also for its high versatility for being combined with other analysis techniques in the micro and nanoscale as microfluidics [7], optics [8] or electrical heating [9].

In this work we present different approaches for transduction and characterization of different phenomena using nanomechanical resonators (especially SMR) and its eventual application to the detection and characterization of different samples of microbiological interest. More specifically, we will show how different hydrostatic and hydrodynamic phenomena in SMR devices can be used to obtain mechanical properties of cells as mass or stiffness [10,11] as well as for trapping them at specific positions of the integrated channel (Fig. 2). Eventually, we will show how different thermal effects [12] can be transduced using nanomechanical resonators (Fig. 3) for its eventual application to the characterization of microbiological entities.

References

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Figures

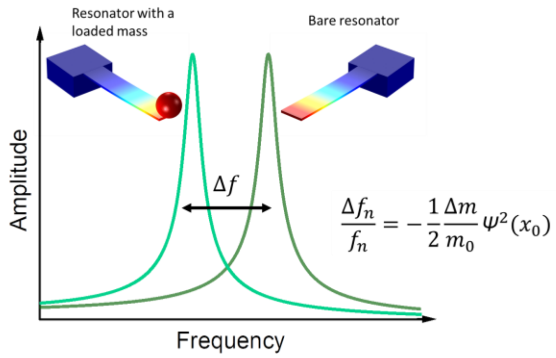

Figure 1. Schematic of the working principle for the measurement of physical parameters using

nanomechanical resonators: the resonace frequency is compared with and without that parameter (an added mass in this case) and this parameter can be inferred by this frequency difference (Δf).

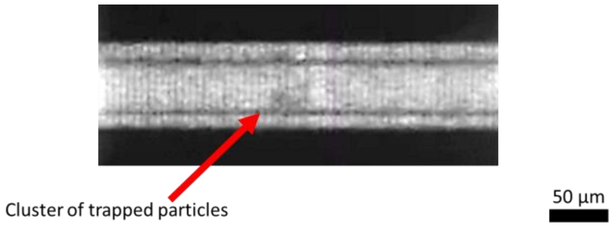

Figure 2. Optical micrograph of a cluster of particles trapped in a SMR device by means of hydrodynamic forces. (The oscillation of the SMR happens in the out-of-plane direction).

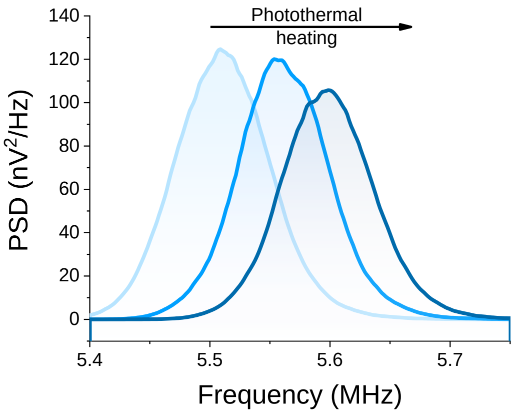

Figure 3. Evolution of the mechanical resonance frequency of a nanomechanical resonator as a function of the photothermal heating.