Fabrication of suspended micro-resonator integrated with PZE electrodes

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The mechanical nature of many fundamental biological processes is the reason of the increasing development of nano-mechanical tools to sense and actuate on biological systems. In particular recent results have illustrated the importance of cell mechanical properties in many cellular processes related to cancerous diseases and such properties have already been used as a new biomarker for cancer detection [1].

In order to provide real-time detection mechanical biosensors are usually immersed in liquid, which lowers their quality factor and hence deteriorates frequency stability. An elegant solution is the fabrication of hollow structures (suspended micro-resonators - SMRs) (Figure 1) with the liquid and the analytes flowing inside them instead of around them, therefore reducing dissipation [2]. SMRs were originally developed for high-resolution mass sensing applications. However they have also been successfully applied to the evaluation of other physical properties that are related with energy dissipation as the viscosity of a fluidic sample [3].

The objective of this project is the fabrication of hollow piezoelectric micro electric mechanical systems (PZE-MEMS) arrays with suspended micro-channels integrated with a microfluidic network. The ultimate goal is to demonstrate the feasibility of characterizing viscoelastic fluids and cell mechanical properties using such system. We herein propose an application of SMRs as micro-rheological and biological sensors for real time analysis, using mainly the stiffness effect and not only mass-loading. A platform made of a microfluidic network and SMRs with PZE self-actuation and detection will allow multiplexing.

The fabrication of these devices represents an important challenge as it consists of 7 lithography levels and more than 40 process steps. Here we propose a suspended micro-channel fabrication based on the definition of high aspect ratio trenches in PolySilicon, which is used as sacrificial material (Figure 2 and 3). Low stress Silicon Nitride is the constitutive material of channel walls, its transparency and biocompatibility make it suitable for biomedical real time analysis. Inlet and outlet are opened by deep dry and wet etching from the backside of the wafer. In this way the top surface of the micro-channels remains transparent allowing for visual inspection during experiments. Platinum electrodes and the active PZE Aluminum Nitride are defined through sputter deposition and photolithography. The sacrificial PolySilicon inside the channels is removed through 24 hours etching in KOH (Figure 4 and 5). Our preliminary measurements revealed that this device is able to withstand an applied pressure of 165 mbar before breaking. This allows for a flow up to 1.5 µl/min that is comparable with data in literature [4].

References

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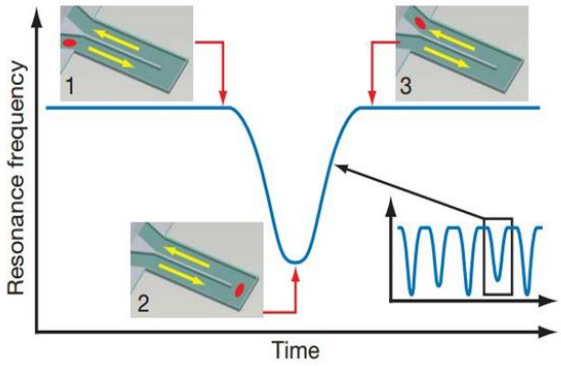

Figure 1: Schematic of a suspended micro-resonator with a u-shaped embedded micro-fluidic channel. As the analyte flows inside the channel a drop in the resonance frequency is observed [4].

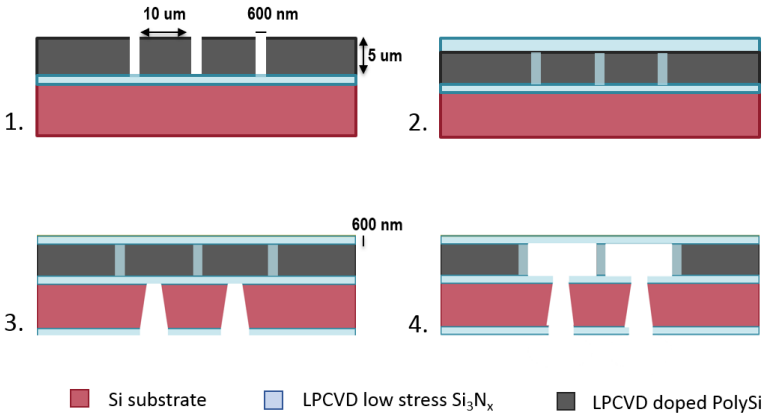

Figure 2: Suspended micro-channel fabrication: process flow in cross section (not the right scale).

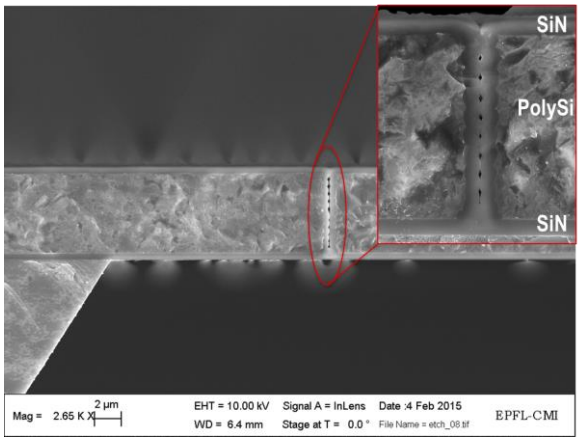

Figure 3: Trench in PolySilicon filled with Silicon Nitride. This is a cross section of the suspended micro-channel before emptying.

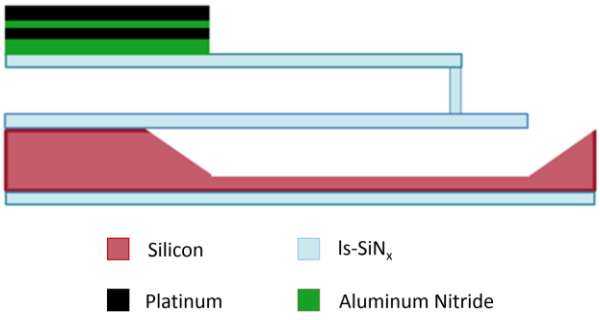

Figure 4: Lateral section view the completed device.

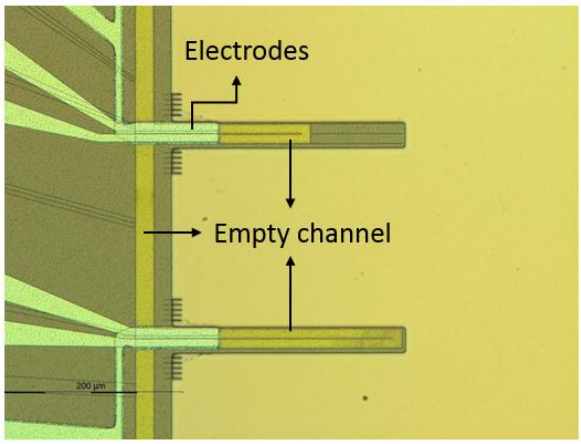

Figure 5: Optical microscope image of the SMR before releasing. Channels have been emptied in a 24 hours etching in 20% KOH at 90°C.