Accepted Manuscript

Fabrication of suspended microchannel resonators with integrated piezoelectric transduction

A. De Pastina, D. Maillard, L.G. Villanueva

PII: S0167-9317(18)30070-4
DOI: https://doi.org/10.1016/j.mee.2018.02.011
Reference: MEE 10738

To appear in: *Microelectronic Engineering*

Received date: 22 December 2017
Revised date: 24 January 2018
Accepted date: 10 February 2018

Please cite this article as: A. De Pastina, D. Maillard, L.G. Villanueva , Fabrication of suspended microchannel resonators with integrated piezoelectric transduction. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Mee(2017), https://doi.org/10.1016/j.mee.2018.02.011

Fabrication of suspended microchannel resonators with integrated piezoelectric transduction

A. De Pastina*, D. Maillard, L. G. Villanueva

Advanced NEMS Laboratory, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland

*annalisa.depastina@epfl.ch

ABSTRACT

Suspended microchannel resonators (SMRs) are resonant mass sensors that contain liquid within the mechanical structure, therefore minimizing damping associated with the fluidic viscous drag. In this paper, we present a novel fabrication process for transparent SMRs with integrated piezoelectric (PZE) transduction, based on thin film depositions and trench filling. Our method allows to finely tune the geometry and the dimensions of the embedded channels, through a short and well-controlled wet etching in KOH. After channel definition, the wafer has a flat surface that enables further microfabrication processing. Piezoelectric (PZE) electrodes are placed on top of each resonator, enabling independent transduction of the devices. Devices are fabricated with a yield higher than 95%, and characterized with and without fluids (water and IPA). PZE-transduced SMRs show a mass responsivity up to 1125 ± 0.06 mHz/pg and a non-monotonic dependence of the quality factor on fluidic viscosity. Besides PZE actuation and readout, our fabrication process is compatible with the integration of other types of transducers in close proximity to the fluid, broadening the spectrum of potential applications.

Keywords: suspended microchannel resonators, microfluidic channels, piezoelectricity, resonance frequency, quality factor, micromechanical sensors

1. Introduction

Micro- and Nano- mechanical sensors (M/NEMS) are mechanical transducers featuring micro- and nano- sized moving parts. Over the past two decades M/NEMS have been receiving growing attention in life-science applications, due to the *mechanical nature* of many fundamental biological processes [1, 2]. Their fabrication relies on standard semiconductor processing techniques, enabling efficient batch production.

Continuous advances in micro-fabrication techniques result in highly sensitive *mechanical responsivity* and outstanding *mass resolution*, in particular for sensors operating in resonance [3-5].

Fields of applications such as biological sensing [4], drug discovery [6] or food engineering [7], often require to operate with liquid samples. The mechanical performance of submerged resonating nanomechanical sensors is compromised by the viscous damping of the surrounding fluid [8]. One way of circumventing this limitation is to embed a micro-fluidic channel into the resonating sensor itself. This allows operating the device (also known as suspended microchannel resonator, SMR) in dry conditions, while viscous damping only occurs in the inside of the channel, and is thus almost completely suppressed [9]. Quality factors up to 15000 in vacuum and mass sensitivity down to 1 attogram in a 1 kHz bandwidth have been demonstrated [10].

One of the major limitations of suspended microchannel resonators is the costly and rather challenging fabrication. Previously reported fabrication processes rely on the etching of sacrificial materials [9, 11-13], or on Silicon self-assembly [14]. The main drawbacks of the above-mentioned techniques are slow channel emptying (several hours long), limited flexibility for fluidic channel and resonator dimensions, or incompatibility with integrated independent actuation.

In this paper, we present a novel wafer-level fabrication process for arrays of transparent SMRs with integrated piezoelectric (PZE) transduction. Our method allows to finely tune the geometry and the dimensions of microfluidic channels, providing a flat substrate that can be used for further processing. This allows for electrical transduction to be integrated on top of each resonator and in close proximity to the fluid. The resonating properties of the SMRs are characterized and their use as a mass sensor is demonstrated.

2. Design

PZE-transduced SMRs are designed to enable real-time sensing of picoliter fluidic samples and micron-size analytes dispersed in liquids. The mechanical properties of the analyte can be evaluated as they flow in the microchannels, by monitoring the frequency response of the resonators over time. The array configuration allows to reduce the analysis time, improving the experimental throughput.

The resonance frequency f_r of a mechanical resonator is directly proportional to the square root of the ratio between effective stiffness k and effective mass m of the vibrating structure. Mass responsivity, defined as the change in resonance frequency due to a change in mass, is given by [15]:

$$\Re_m = \frac{\partial f_r}{\partial m} \approx -\frac{1}{2}\frac{f_r}{m} \quad (1)$$

In order to achieve high mass responsivity, a beam should thus feature both high resonance frequency and