Using second harmonic on cantilever based mass sensors to increase sensitivity to the pico-gram level

Gabriel Abadal[1], Jordi Teva[1] , Francesc Torres[1], Francesc Pérez-Murano[2], Núria Barniol[1]

[1] Dept. Enginyeria Electrònica. Universitat Autònoma Barcelona. E- 08193 Bellaterra. Spain
[2]Institut de Microelectrònica Barcelona (IMB-CNM) Campus UAB. 08193 Bellaterra Spain

Devices based on micrometer and nanometer scale cantilever configurations are especially attractive as transducers for chemical and biological sensors [1]. In this work, we demonstrate that mass sensitivity of a cantilever is increased by operating the sensor at the second harmonic. Glycerine mass measurements on cantilevers operated at first and second harmonic are performed to experimetaly demosntrate such a mass sensitivity improvement. Two different kinds of experiments were carried out with two different devices: i) cantilevers excited electrostatically with capacitive read-out and ii) cantilevers excited mechanically at the first and the second resonance harmonic modes, with optical read-out. For both experiments the mass measurements were performed measuring the change on the resonance frequency [2]. Measurements corresponding to the second harmonic exhibits a high quality factor (Q) and a higher mass resolution, derived from its higher resonance frequency.

Experiments performed with micro-cantilevers fabricated on silicon oxide with dimensions L=200μm (length), w=30μm (width) and t=3.55μm (thickness), consisted on measuring the change on the resonance frequency due to the mass change of the system (i.e cantilever plus glycerine drop). These cantilevers were mechanically driven to its resonance frequency by a piezoelectric stage system. It consists on an external shear mode piezoelectric driver coupled to the sensor chip which excites the on-plane lateral vibration of the cantilever. The design of a specific electronic circuit for driving the piezoelectric element to its lateral vibration mode will be described [3]. In order to measure more precisely the lateral amplitude of the cantilever oscillating movement, a system consisting on a beam laser and a photodetector connected to a network analyzer is used. Mechanical resonance curves are obtained for the first and the second harmonic: figure 1.a and figure 1.b.

In order to perform the mass measurements, a drop of glycerine of approximately 6μm in diameter has been added to the free end of the cantilever, figure 2 by using an STM tip. After adding the glycerine drop, resonance curves for the first and the second harmonic have been measured, and the change on the resonance frequency is then determined.

The change on the resonance frequency is measured from the shift of the read-out signal phase. Figure 3 shows the change on the phase before and after adding the glycerine drop, corresponding to the second harmonic. The resonance frequency of the first mode shifts 300Hz while the second mode shifts its resonance frequency on 1500Hz. Then, bigger changes on the second resonance mode are observed in comparison to the first mode. The Q factor is also measured from the experimental phase bahaviour using the following equation:

$$\frac{\partial\phi}{\partial f} = \frac{180^{\circ}\cdot Q\cdot\log e}{f_{res}}$$

where the term on the left is the variation of the phase as a function of the frequency and is obtained adjusting the experimental data to a linear fit near resonance. For the experiment shown in figure 4, the Q values for the first and second harmonic were Q_1=70, and Q_2=100, which is in concordance with previous works [4]. Then, it has been possible to measure the glycerine drop evaporation, as shows figure 4. The addition of mass produces a decrease on the resonance frequency. After the drop is evaporated, the resonance frequency turns to its initial value.

As a conclusion, this works demonstrates that mass measurement sensitivity in the pico-gram range is increased by using microcantilevers operated at the second resonance mode, because second mode shows a higher resonance frequency and a higher Q factor.

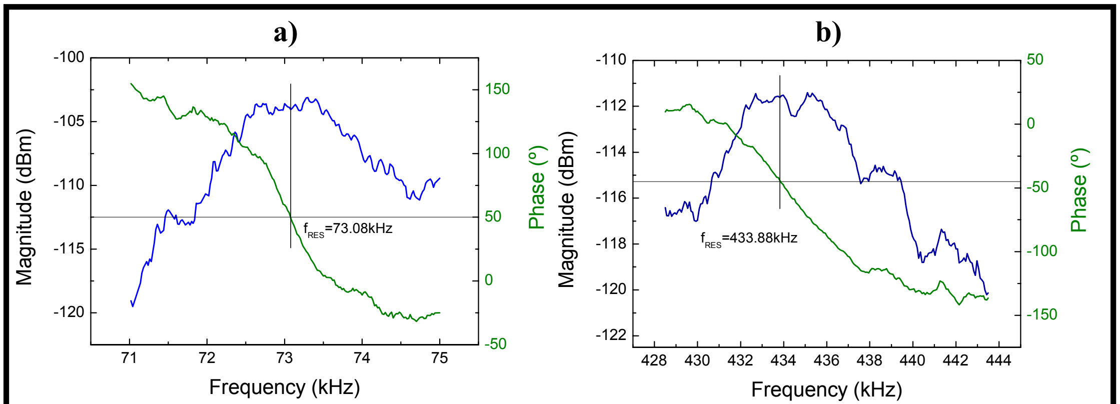

Figure 1: Resonance curves obtained with the laser-photodetector system. a) first harmonic, b) second harmonic.

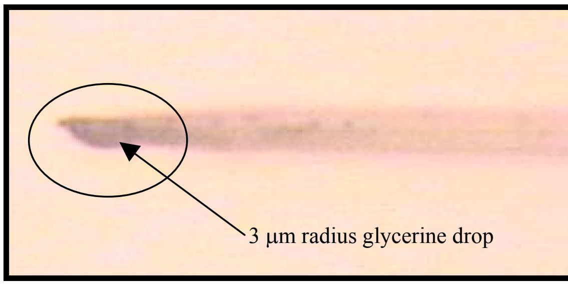

Figure 2:
Photograph showing the free end cantilever-node with the glycerine drop.

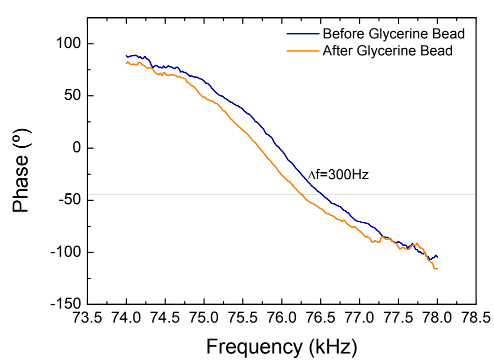

Figure 3:
Phase shift due to the added mass. The measurement corresponds to the first harmonic mode.

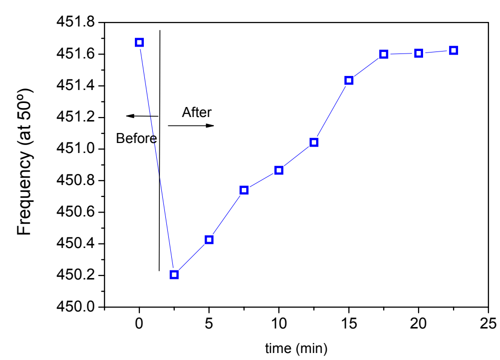

Figure 4:
Glycerine drop evaporation measurement. The figure shows the shift of the frequency of the 2on harmonic.

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