FEMTOGRAM MASS DETECTION USING DYNAMIC MODE OPERATION – BASED MICROCANTILEVER

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Abstract

In this work, we present a detection of femtogram mass (water vapour and gas) using dynamic mode operation-based microcantilever. In the detection of water vapour (humidity), the result shows that the resonance frequency of microcantilever decreases about 10 Hz when the humidity increases from 30% RH to 35% RH. Such resonance frequency shift corresponds to water molecules mass of 59 fg attached on microcantilever surface. For gas detection, gas molecules of about 910 fg is detected by SnO_2 sensitive layer-coated microcantilever. Such results open up the possibility of femtogram mass detection using developed microcantilever system.

Keywords: microcantilever, mass detection, femtogram, resonance frequency shift

1. Introduction

In the last decade, a development of microelectromechanical system (MEMS) has promoted an innovative microcantilever-based sensor. Such sensor has potential to replace many conventional sensors because of a relatively low cost of production, high sensitive, rapid response, and a reduced size of the active area [1]. Basic principle of the microcantilever sensor is a detection of the microcantilever deflection due to the attachment of the objects on the cantilever surface. There are two methods for detecting the microcantilever deflection, i.e., static and dynamic modes. The static mode directly detects the microcantilever deflection, while the dynamic one detects the resonance frequency shift of the microcantilever vibration due to the object detection.

Several groups have reported a possibility of the microcantilever for detecting the objects in picogram level or less, better than that of conventional sensors such as transistor-based sensors and semiconducting film-based sensors. Hosaka group has reported a mass detection in picogram [2] and femtogram [3] levels using a piezoresistive microcantilever. The smallest mass detection in attogram level has been demonstrated by Roukes group [4].

So far, we have studied the picogram mass detection using piezoresistive microcantilever [5-7]. In this work, we present the detection of femtogram mass using dynamic mode operation-based microcantilever. Here, mass detection of water vapour (humidity) and gas molecules will be discussed.

2. Experimental Setup

A measurement setup consists of microcantilever, a function generator, an optical system to detect the cantilever deflection (laser source, lens, and position sensitive detector – PSD), an electronic circuit, and an oscilloscope (Fig. 1). The microcantilever used here is commercial one having a length of 450 μm, a width of 55 μm, a thickness of 4 μm, and a spring constant of 1.6 N/m. Here, the microcantilever deflection is detected by position change of laser light reflection. The focused laser light falls on the cantilever surface and the reflected light is captured by the PSD. The photocurrents in PSD due to light spot are converted into output voltage and amplified by electronic circuit. The amplified output signal is monitored by oscilloscope.

We measure two objects, i.e., humidity change and gas (LPG). For measurement of humidity change, the sensor system is placed inside a dehumidifier box module. To increase the humidity level, the box is opened. For detection of gas, we use sensitive layer (SnO_2) coated microcantilever to measure the resonance frequency shift before and after inserting of the gas into the experimental box.

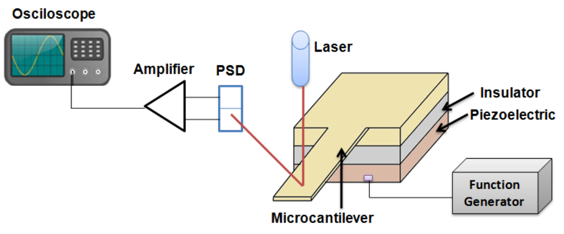

Figure 1. Optical system for measuring microcantilever deflection

3. Results and Discussions

Figure 2 shows the experimental result of resonance frequency as a function of humidity. It can be seen that the resonance frequency decreases with the increasing humidity. The decrease of resonance frequency is caused by the increased amount of water molecules, resulting in an increase of the total mass of the microcantilever. From equation $f = (1/2\pi)\sqrt{k/m}$, the mass of the microcantilever (m) is calculated to be 71.3 pg. When the water molecules attached on the microcantilever surface at humidity level from 30% RH to 35% RH, the resonance frequency shifts (Δf) from 23.99 kHz to 23.98 kHz. Such resonance frequency shift (about 10 Hz) is a function of a mass change (Δm). Using the relationship of $\Delta m = -2(m/f)\Delta f$, we can predict that the water molecules desorbed on the microcantilever surface is about 59 fg. Moreover, it is estimated that the increase in number of water molecules layer from 30% to 35% is 32 layers.

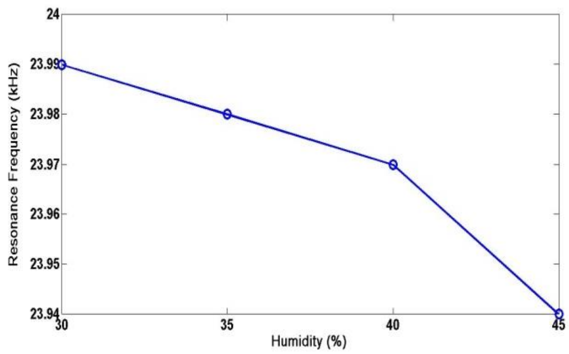

Figure 2. Resonance frequency change for the increased humidity level from 30% to 45%

Figure 3 shows the measured resonance frequency as a function of the time taken before and after introduction of gas. The resonance frequency sensitively decreases from initial frequency of 20.802 kHz to 20.642 kHz when the gas is flowed. From the value of resonance frequency shift, the mass of propane/butane molecules attached on microcantilever surface is predicted to be about 910 fg. It is noted that the resonance frequency does not return to initial value when the gas flow is stopped. Probably, this is caused by remain of propane/butane molecules on microcantilever surface even the gas is not discharged. The detail of this result is under study.

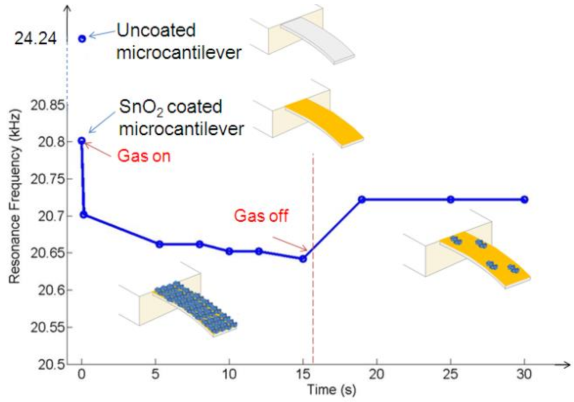

Figure 3. Decrease of resonance frequency due to gas response

4. Conclusion

We have investigated the femtogram mass detection using the dynamic mode microcantilever for objects of water vapour and gas molecules. In measurement of water vapour, the mass on the microcantilever surface is detected to be about 59 fg, while in gas measurement, the mass of gas molecules on microcantilever surface is predicted to be about 910 fg. The results showed that the developed microcantilever system is good enough to detect the mass in femtogram level.

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