Vacuum-packaged Resonant Thermal Sensor for Biological Cell in liquid

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A vacuum-packaged resonant thermal sensor was fabricated to measure the generated heat from a single brown fat cell in liquid. The measurement principle relies on the resonant frequency variation of the cantilevered Si resonator due to heat flow from the target sample attached to sensing area. The part of the cantilevered thermal sensor (detection area) is thermally insulated from ambient environment by encapsulating in a micro vacuum chamber (Fig. 1). The heat from the attached cell in microchannel is conducted via a Si beam into the resonant sensor placed in the vacuum chamber, as shown in Fig. 2. The resonant frequency will be decreased by the temperature increase due to the heat conduction. The thermal isolation by encapsulating in vacuum can minimize the heat loss from the sensor and increase the sensitivity. We have fabricated and analyzed the performance of the fabricated sensor.

Many researches to clarify the biological thermal phenomenon have been conducted for the monitoring of diseased cells or biochemical reaction in the cell etc. The brown fat cells generate the heat, which have been measured in bulk condition up to now. Though its value was calculated to be approximately 5 nanoWatt per cell, the generated heat from a single cell have not been measured actually in the past.

At first we evaluated the temperature of the cantilever with finite element method when the end of the cantilever in microchannel was heated (Fig.3). The simulated conditions are two cases; in the first case the microchamber was evacuated in vacuum, in the second case the microchamber is filled by water. The temperature of the cantilever in former case was 35.7°C. In second case temperature decreases gradually from the support to the end due to heat loss into the water, and the temperature at the end was 26.4°C (Fig.4). From these results, it was shown that heat loss from the resonant sensor (cantilever) can be decreased by encapsulating in vacuum.

The Si cantilever is sandwiched between patterned two glasses, and at the same time the vacuum chamber and the microchannel are formed as shown in Figs. 5(a) and 5(b). The irradiated laser power dependence on the resonant frequency was measured in vacuum. Making a thin Au film on the laser irradiated part of cantilever, the temperature increase became smaller. Then, we heated the end of cantilever by a laser and measured the temperature at another end. When the temperatures at heated end were 1.3 °C and 5.7°C, those of another end was 0.7°C and 3.3°C, respectively (Fig.6). These results indicate that the heat was conducted to the end from another end, though the some heat escaped through the glass wall supporting the cantilever.

In summary we proposed, fabricated and evaluated the cantilevered thermal sensor encapsulated in vacuum microchamber to measure the generated heat from the sampler in water. The heat conduction of cantilever supported by glass wall was evaluated in vacuum. It is expected that this sensor can apply to high sensitive measurement of the heat from a sample in water.

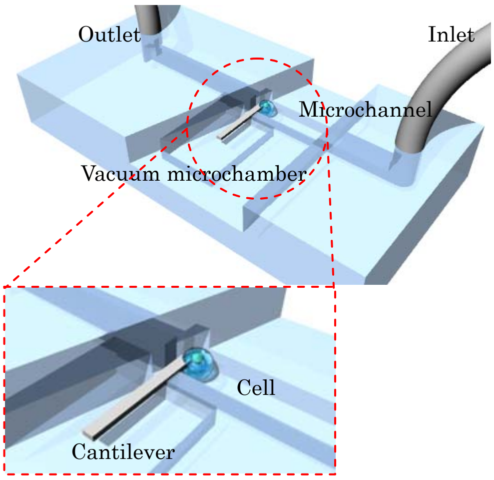

Fig.1. Schematic of the cantilevered thermal sensor based on the Si cantilever with a vacuum microchamber.

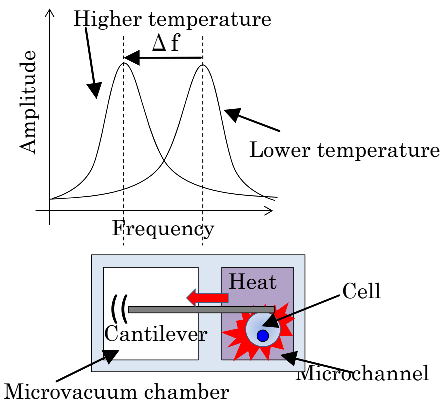

Fig.2 Principle of the cantilevered thermal sensor

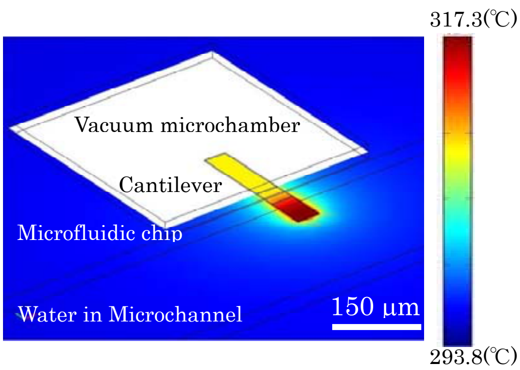

Fig.3 Analyzed temperature of the cantilever when the microspace was evacuated in vacuum. The cantilever space in the microchannel filled with water (red area) was heated.

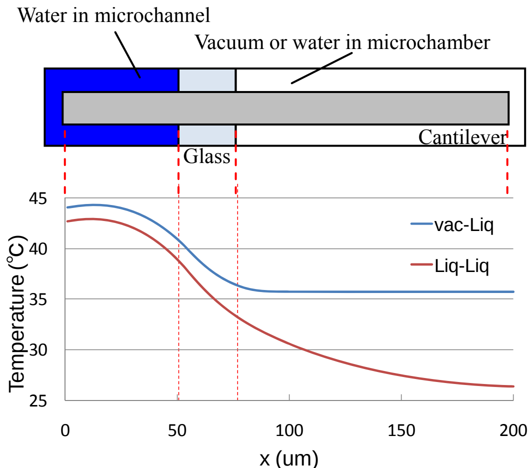

Fig.4 Simulated temperature profile on the cantilever. The blue and red lines show the temperature profiles when microchamber was evacuated in vacuum and filled by water, respectively.

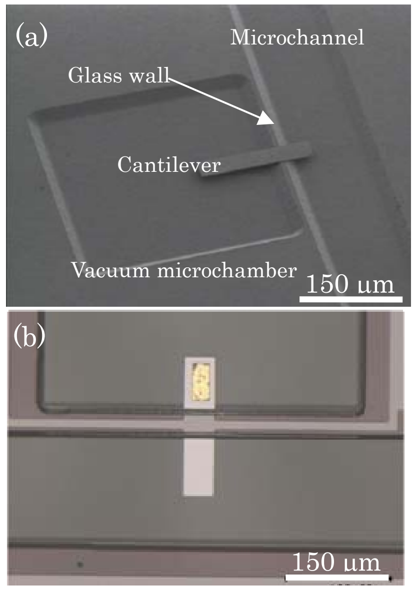

Fig. 5 (a) SEM image of the cantilever. (b) Optical micrograph after packaging.

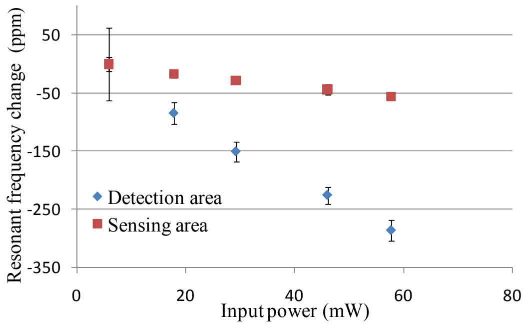

Fig.6. Temperature change of the cantilever as a function of input power.