Development of On-Chip Micro Vacuum System with Gas-Liquid Phase Transition

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Development of compact and high-sensitive detection methods for miniaturized analytical systems (so called microTAS or lab-on-a-chip) are required to realize next generation's diagnosis systems such as point of care testing, and on sight monitoring. While mass spectrometry (MS) seems one of the promising techniques due to its outstanding sensitivity, however there are a few reports on the miniaturization of MS[1-2]. These studies demonstrate the miniaturization of ion filter[1], ionizer[2], and detector[2], however an on-chip vacuum from atmospheric pressure has not been realized. In this paper, we report an on-chip vacuum technique by using gas-liquid phase transition with on-chip pressure measurement. In order to measure differential pressure between pressure in the cavity and atmospheric pressure, we carried out a simple method using on-chip detecting by diaphragm deflection. Figure 1 shows a schematic of the experimental setup. The chip was fabricated by bonding quartz diaphragm and plain quartz substrate with CYTOP[3]. The results of the pressure measurement were shown in Fig. 2. The result indicates excellent linearity between the differential pressure and the diaphragm displacement, thereby the measurable range estimates from atmospheric pressure to10^3Pa. In this work, decompression due to the phase transition with temperature control was adopted because it was realized by low temperature difference around the transition temperature. Moreover, it can operate at atmospheric pressure without complicated structures and moving parts. Liquid ethanol was filled in the cavity and heated to evaporate, and then inlet was hermetically sealed and cooled to liquefy. The phase transition due to temperature alteration was facilitated to use ethanol because its boiling temperature is relatively near room temperature. The results of decompression and temperature in the chip were shown in Fig. 3. The phase transition was so effective relative to decompression with temperature decrease, because another experiment filled dry air showed that the pressure in the cavity was 0.98atm after cooling 3.5min. Reductions of dead volume and temperature control area were accomplished by means of the pressure measurement based on an optical system. The measurements showed that the maximum decompression in the cavity is 0.50atm with low temperature difference (50℃). Efficient decompression was realized compared to the micro Knudsen pump[4] which needed high temperature difference (1100℃) for high vacuum.

[1] S. Wright *et al*., *J. MEMS*, **19**, 325 (2010).
[2] H. J. Yoon *et al*., *J. MEMS*, **17**, 1542 (2007).
[3] H. Lu *et al*., *Lab Chip*, **1**, 22 (2001).
[4] S. McNamara *et al*., *J. MEMS*, **14**, 741 (2005).

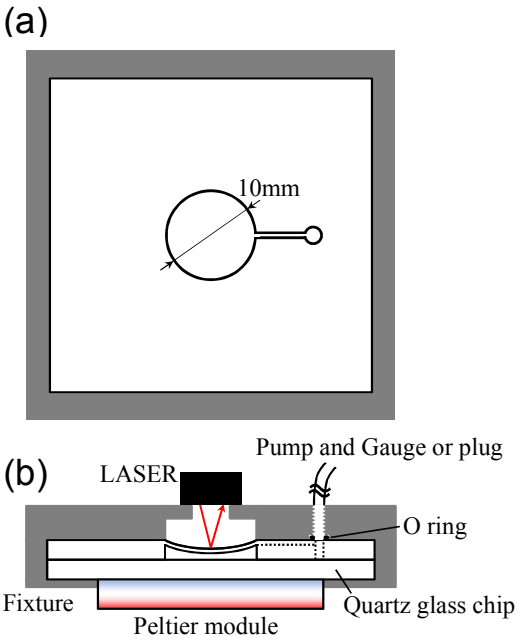

Figure 1: Schematic view of the experimental setup. (a)top view. (b)side view. Diameter and depth of the quartz glass diaphragm are 10mm and 250μm, respectively. Fabricated chip was bonded by using CYTOP between etched quartz glass substrate(35 × 35 × 0.5mm) by buffered hydrofluoric acid and plane quartz glass substrate.

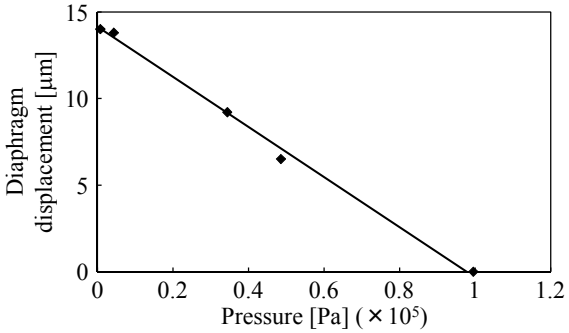

Figure2: Dependence of the diaphragm displacement on the reference pressure. Deflection was measured by using laser displacement meter at the center of the diaphragm bending maximum displacement.

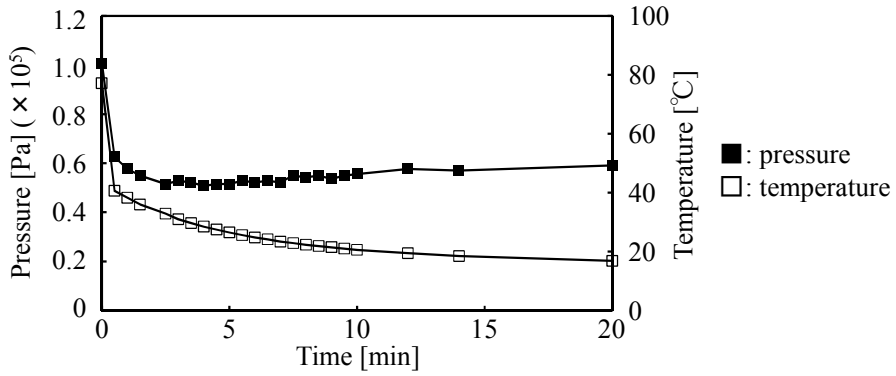

Figure3: Measured pressure and temperature of the phase transition pump. Whole chip was heated up to 80℃ with a Peltier module after filling with ethanol into the cavity. Then, the chip was immediately cooled to room temperature.