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NOTES

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Frequency shift on a micromachined resonator excited photothermally in vacuum

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The photothermal activation of a micromachined resonator in vacuum is reported. The resonance frequency shift was obtained at the pressures in the viscosity flow region. This effect will be useful for the development of a miniature vacuum gauge operated optically.

The frictional-type pressure sensor such as quartz oscillator gauge[1] is important for low-pressure vacuum technology. The friction between the resonator and the gas molecules caused the shift of the resonance frequency. Recently, for the development of an all-optical frictional vacuum gauge, the photothermal activation of the resonator has been investigated in the pressure region from 10^{-4} to 760 Torr using a relatively large (~ 1 cm) sample.[2,3] In this note, using a microresonator fabricated by the micromachining technique, the frequency shift of the resonator, excited photothermally, is examined in vacuum. The obtained results will be useful for the development of a miniature vacuum gauge. The technique will be especially useful to measure the pressure in a sealed-off tube and will be valuable for remote measurements of pressure in a very small volume, in hostile environments such as high temperature, corrosive gas, high electromagnetic field.

A SiO_2 about 1-μm thick was formed on a Si substrate by the thermal oxidation. A pattern was transferred to the SiO_2 film by the photolithographic process and the Si substrate was etched anisotropically with KOH solution to make the self-standing SiO_2 microresonator cantilevers 20 μm in width and approximately 150 μm in length. The optical micrograph of the fabricated cantilevers is shown in Fig. 1. The surface of the cantilever was coated with the evaporated aluminum.

The schematic figure of the experimental setup is shown in Fig. 2. Radiation from the laser diode (Sharp LT015MD0, 20 mW, 830 nm) was used to excite the vibration by the photothermal bending effect.[4] The light intensity is chopped by modulating the injection current of the laser diode with an oscillator. The laser power irradi-

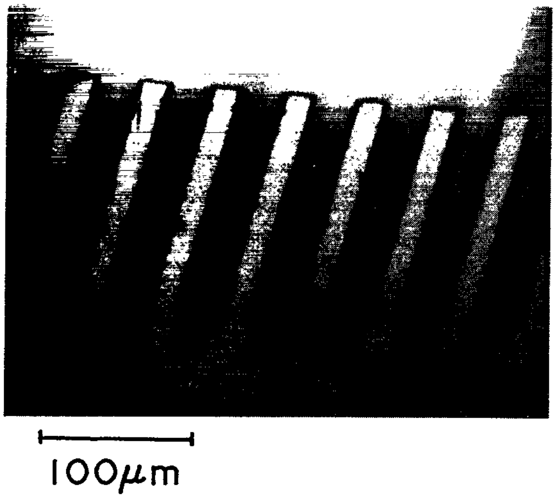

FIG. 1. Optical micrograph of the micromachined cantilevers.

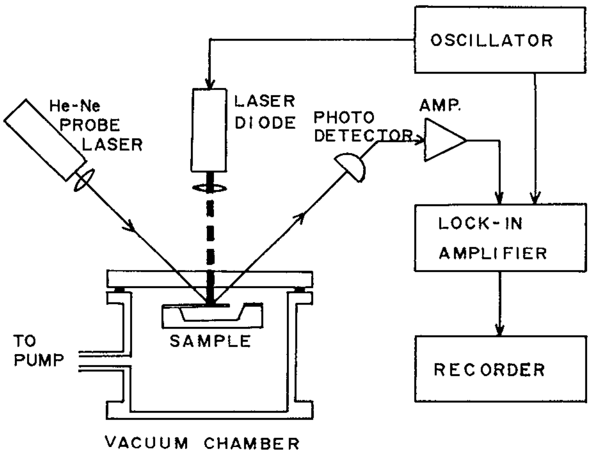

FIG. 2. Schematic diagram of the experimental setup.

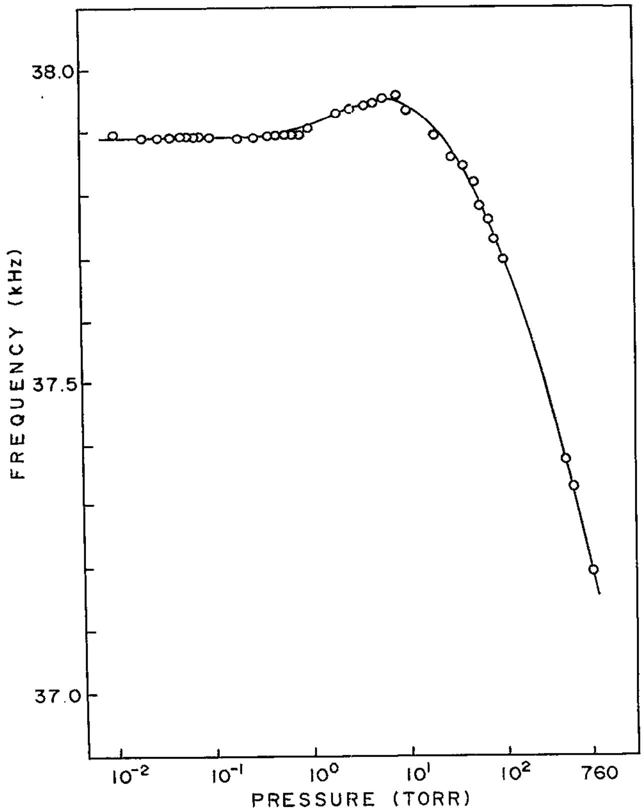

FIG. 3. Resonance frequency as a function of the pressure.

ating a cantilever is 1 mW or less. The vibration of a cantilever is measured by using the deflection of a He-Ne laser beam (0.8 mW) reflected from the cantilever. The signal is measured by a lock-in amplifier (NF-LI575). The pressure is monitored with a Pirani vacuum gauge.

The vibration was excited in the first-order resonance mode of the cantilever. The resonance frequency was determined from the peak amplitude and the phase value of the resonance curve in the pressure region from 10^{-2} to 760 Torr. The Q value of the resonance curve increased with decreasing pressure. The Q value at the pressure of 1 Torr was approximately 50.

Figure 3 show the resonance frequency as a function of the pressure. The resonance frequency increases as the pressure decreases from atmospheric pressure as shown in Fig. 3. According to the theory of the tuning fork quartz resonators,[5] the increase of the resonance frequency can be explained mainly by the acoustic wave emission from the cantilever around the atmospheric pressure. A relatively large frequency shift (2% of the resonance frequency) is obtained in the pressure region between 10 and 760 Torr. On the other hand, the resonance frequency decreases somewhat as the pressure decreases from 5 to 0.1 Torr. This result agrees qualitatively with that obtained by using a relatively large resonator. The frequency shift was attributed to the static thermal stress of the cantilever.[2,3] From Fig. 3 the gauge has greatest sensitivity at pressures greater than 10 Torr.

In conclusion, the resonance vibration of the micromachined resonator was activated photothermally in vacuum and the frequency shift of the resonator was measured from a distance. This noncontact pressure sensing technique may be valuable for remote measurements in a high electromagnetic field or hostile environments.

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