Optical Response of Micromechanical Infrared Thermal Detector

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In order to achieve highly sensitive IR detection, we have developed a micromechanical IR thermal detector by using nonlinear vibration of a torsional resonator. The torsional resonator is a bimaterial structure which consists of a resonator body and an IR absorber [Fig. 1-(a)]. The IR absorber has a high coefficient of thermal expansion (CTE) rather than that of the resonating body. When IR radiation heats up the resonator, it is bent upward by the difference in thermal expansion between the resonator body and the IR absorber [Fig. 1-(b)]. The bent resonator increases a spring constant of torsion-bars by a hard spring effect, thereby increasing a resonant frequency of the resonator. Therefore, a sensitive IR detection can be achieved by measuring the frequency changes.

According to the previous study [1], the longitudinal profile of the resonator should be flat in initial condition to obtain large bending displacement. The large displacement is needed to achieve high sensitivity of the IR detection. In this study, the resonator was fabricated with a tension-enhanced poly-Si thin film and high CTE metal of Al. The poly-Si film was formed by using a crystallization-induced tensile stress of a hydrogenated amorphous Si (*a*-Si:H) film. To increase the tensile stress further, a metal-induced lateral crystallization using Ni nanoparticles was applied to annealing process of the *a*-Si:H film [2]. Furthermore, a CTE of Al (23.6 ppm/K) is 10 times higher than that of Si (2.6 ppm/K). By using these two methods, the resonator profile was flat in initial condition and achieved a large bending displacement.

To characterize the fabricated device in terms of substrate temperature and optical incidences [visible light (λ = 650 nm) and thermal IR (over λ = 3 μm)], a laser-based measuring system was employed. The resonant frequency shifted to larger value with increasing a laser density and a substrate temperature (Fig. 2). The shift rates were 7330 ppm/W-cm^{-2} and 1000 ppm/K for the laser incidence and the temperature, respectively. The result of the shift rate was higher than that of the previous study (–830 ppm/K) by 20% [1]. The measurement for a thermal IR was carried out by using a soldering heater as an IR source. The source had areas of 5 cm^2 and was placed 15 cm away from the device. A shutter was set between the detector and the IR source to observe the response to IR irradiation. The resonance shifts were 7453 and 608 ppm when the IR source consumes 92.4 and 3.6 W, respectively (Fig. 3).

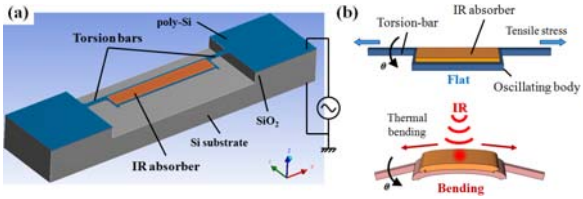

Fig. 1. (a) Schematic diagram of IR thermal detector using a torsional resonator, and (b) its principle of IR detection.

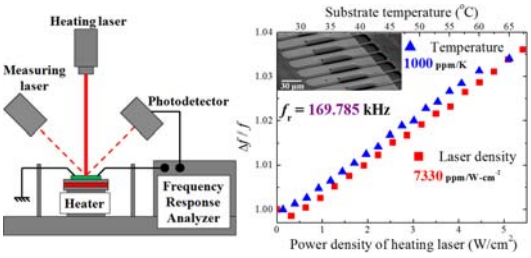

Fig. 2. Shifts of resonant frequency as functions of a substrate temperature and a laser density.

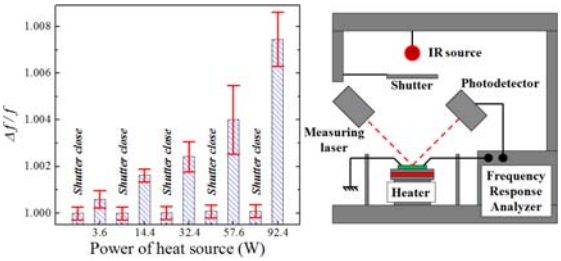

Fig. 3. Shifts of resonant frequency against IR radiation when the shutter is closed or opened.

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