Visualization of strain distribution in MEMS resonators using stroboscopic differential interference contrast microscopy

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MEMS resonators are promising for sensing applications owing to their intrinsic high sensitivities. In MEMS devices, piezoelectric or piezoresistive transducers are crucial for converting the mechanical vibrations into electrical signals. Since the output signal is in proportional to the surface strain, it is highly desirable to preciously characterize the surface strain distribution in MEMS devices. Currently, numerical methods such as Finite Element Method are commonly used to analyze the strain distribution in MEMS devices. However, owing to the small size of MEMS devices, experimental analysis of strain distribution remains challenging.

In this work, we propose a novel surface strain analysis method for MEMS resonators using stroboscopic differential interference contrast (DIC) microscopy. The stroboscopic DIC microscope visualizes the mechanical vibrations of MEMS devices through the interference of two light beams reflected from the sample surface with a small lateral shift [1]. With the DIC images, we can obtain the differential surface deflection of MEMS resonators caused by the vibration motions. By further differentiating the result, we can obtain the deflection induced strain (ε) distribution of MEMS resonators, by

$$\varepsilon = \frac{t_0}{4} \times \frac{d^2 z}{dx^2} \qquad (1).$$

We have performed the strain measurement for a GaAs doubly clamped MEMS beam resonator with a geometry of $100(L)\times30(W)\times1.2(t)\mu m^3$, as shown in Fig. 1(a). The MEMS resonator is driven in its 1st bending mode, with a resonance frequency of ~695 kHz. The measured surface strain distribution is shown in Fig. 1(b), as seen, surface strain distributes not only on the MEMS beam, but also on the over etching part, indicating that the over etching effectively extends the vibration area, which must be considered in designing the transducers. Fig. 1(c) plots the numerical result of the MEMS beam resonator for the 1st bending mode by using a FEM tool (COMSOL). As seen, the experimental result shows reasonable agreement with the numerical result, demonstrating the effectiveness of the stroboscopic DIC method for analyzing the surface strain distributions of MEMS devices.

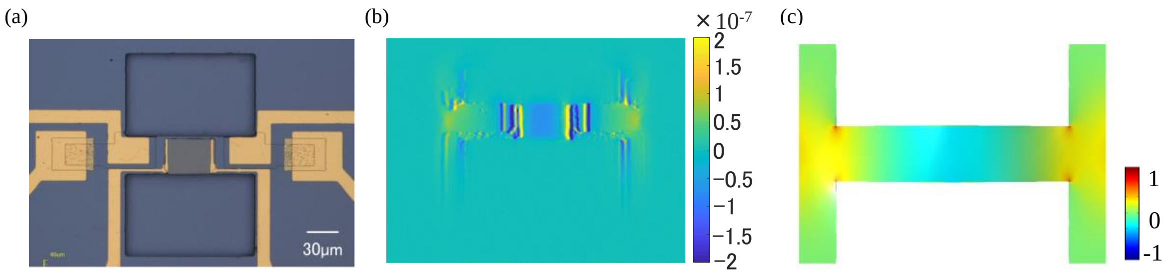

FIG 1. (a) microscope image of a fabricated MEMS beam resonator, which has a geometry of 100×30×1.2 µm³. (b). Calculated strain-displacement (ε). The different direction is along the beam direction. (c). The surface strain distribution of MEMS resonators was obtained through COMSOL Multiphysics simulations.

Reference
[1] Mirai Iimori and Ya Zhang, "Two-dimensional measurement of resonance in MEMS resonators using stroboscopic differential interference contrast microscopy," Opt. Express 30, 26072-26081 (2022)