Quality Factor Enhancement on Nano Mechanical Resonators Utilizing Stiction phenomena

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Nano mechanical resonators are fascinating structures which have the potential to be used as various novel devices such as ultra-high sensitive sensors. Some researchers have reported the quality factors (Q-factors) of the resonators are increased with applying tensile stress[1]. The tensile stress application requires an additional process such as chemical vapor deposition (CVD) or molecular beam epitaxy (MBE), and thus a more simple method is needed. We employed stiction which often occurs during a wet etching process to apply a tensile stress to resonators. The fabrication process of the *stiction resonator* is shown in Fig. 1. The process utilized focused-ion-beam chemical vapor deposition (FIB-CVD) and wet etching[2]. A double-beam pattern made of diamond-like carbon was deposited on (100) silicon surface using FIB-CVD. The silicon under the beams was removed by tetramethyl-ammonium hydroxide (TMAH) wet etching. After water rinse, the silicon substrate was dried in the air. At that time, the beams were attracted and finally sticked to each other owing to the surface tension of water. A scanning electron microscope (SEM) image of the stiction resonators is shown in Fig. 2(a). Dimensions of each beam of the resonators were 50 μm long, 120 nm wide and 65 nm thick. The resonators with various beam distance were fabricated to obtain various tensile stress state. Figure 2(b) shows the relationship between beam distance d and stiction length l_s of the resonators shown in Fig. 2(a). With decreasing l_s, tensile stress applied to the resonator should be increasing until l_s reaches zero.

Vibration characteristics of the stiction resonators were evaluated utilizing an electron beam[3]. Figure 3(a) shows spectra of the stiction resonators of 50 μm long. The resonant frequency was obviously shifted to higher on the larger beam distance resonator. Going through a calculation procedure, the signal intensities were converted into amplitudes and the quality factor was evaluated from the amplitudes. The resonant frequencies and the Q-factors of the resonators are summarized in Fig. 3(b). With increasing the beam distance, both the resonant frequency and the Q-factor were largely increased. The increment reveals tensile stress has validly affected vibration characteristics. Therefore, utilization of the stiction is proved to be valid on enhancement of the Q-factor of nano mechanical resonators.

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[2] R. Kometani *et al.*, MNE 2010 abstract, P-LITH-31.
[3] H. Ashiba *et al.*, Jpn. J. Appl. Phys. **48**, 06FG08 (2009).

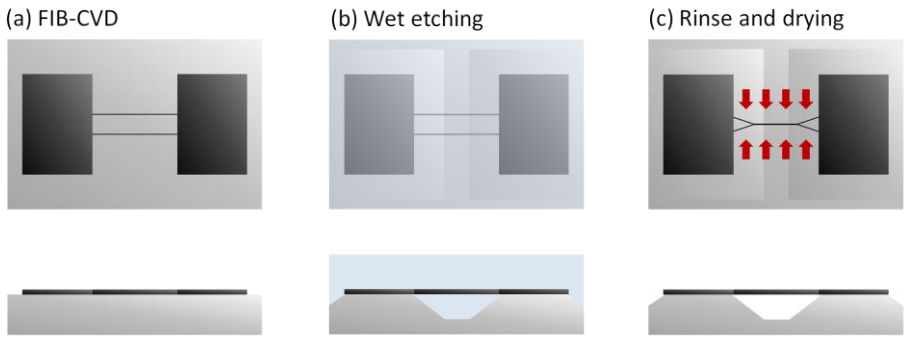

Figure 1: Fabrication Process of the Stiction Resonator: (a) Diamond-like carbon is deposited on (100) silicon surface in the shape of the resonator using FIB-CVD. Two beams are laid parallel to each other. Etching mask pattern covers both ends of the beams. (b) The silicon substrate is etched by TMAH. (c) The substrate is rinsed by pure water and dried in the air. During the drying, the capillary force brings both beams closer. Finally the beams stick to each other.

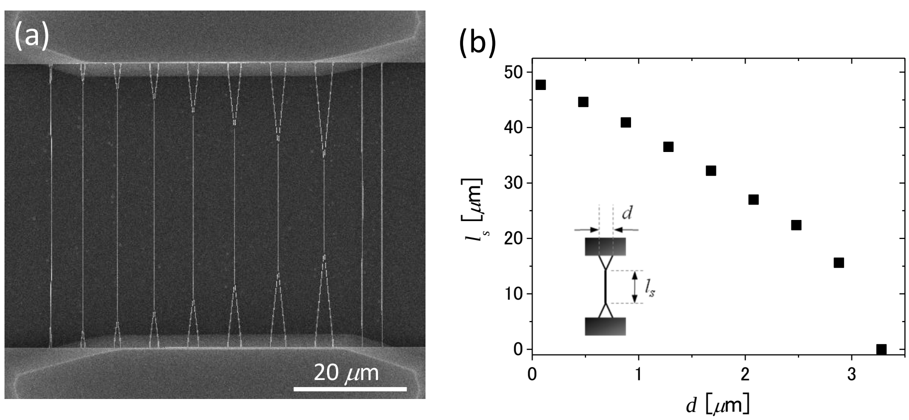

Figure 2: Stiction resonators fabricated in this work: (a) SEM image of stiction resonators. (b) Plot of stiction length l_s vs. beam distance d of the stiction resonators shown in Fig. 2(a).

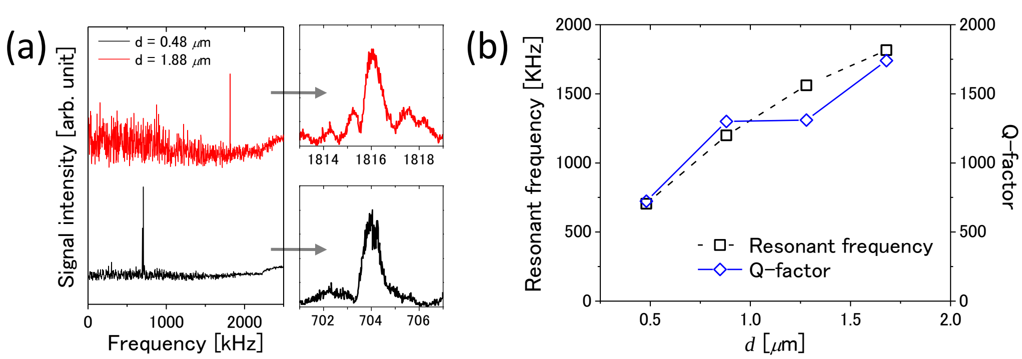

Figure 4: Results of vibration characteristics evaluation of stiction resonators: (a) Spectra of stiction resonators. Beam distance d of the samples shown here is 0.48 μm (black line) and 1.88 μm (red line). (b) Beam distance dependence of the resonant frequencies and the Q-factors. Both resonant frequency and the Q-factor are positively correlated to beam distance.