Dynamic Characteristics Control of DLC Nano-Resonator Fabricated by Focused-Ion-Beam Chemical Vapor Deposition

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A nano-scale mechanical resonant structure is a key component to fabricate the high-sensitive sensing devices, because various physical quantities can be detected using changes in the vibration characteristics. To achieve the high-performance nanoresonator as a sensing device, it is required to functionalize nanomechanical resonator and to control its vibration characteristics. Therefore, a vibration characteristics-tunable nanomechanical resonator has been studied in this study.

In this study, the vibration characteristics-tunable resonator made of diamond-like carbon was fabricated by focused-ion-beam chemical vapor deposition using *phenanthrene* ($C_{14}H_{10}$) as a gas source, because DLC deposited by FIB-CVD have the useful material characteristics, such as high Young's modulus, high density and piezo-resistive property[1], to achieve the functional resonant devices. And the DLC mechanical resonator was fabricated on the 2-terminal Ti electrode, as shown in Fig. 1(a). Figure 1(b) shows a scanning electron microscope (SEM) image of a vibration characteristics-tunable DLC resonator. By controlling the applying voltage, the vibration characteristics of DLC resonator can be controlled using the coulomb force induced by the electrostatic attractive force, as shown in Fig. 1(a).

Dynamic characteristics of the DLC resonator were evaluated. In this evaluation, DLC resonator was excited by a piezo-actuator, and resonant characteristics was measured by electron-beam method[2], as shown in Fig. 2. DLC resonator structure bended during fabrication was deformed by applying voltage of 20 V, as shown in Fig. 1(c), though resonant frequency did not change as shown in Fig. 3. After then, vibration frequency increased from 106.7 kHz to 734.3 kHz with an increase in the applied voltage. We found by theoretical fitting that a resonant frequency increased by the changes in the effective spring constant increased by applying voltage. And, DLC resonator had the extremely large tuning ratio of approximately 690 %. We demonstrated that the vibration characteristics of the DLC resonator can be controlled effectively using electrostatic attractive force. Functional dynamic characteristics of the electrically-tunable DLC resonator will be reported in detail.

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[1] R. Kometani, K. Yusa, S. Warisawa, S. Isihihara: J. Vac. Sci. Technol., B **28**, C6F38 (2010).

[2] H. Ashiba, S. Warisawa, S. Ishihara: Jpn. J. Appl. Phys, **48**, 06FG08 (2009).

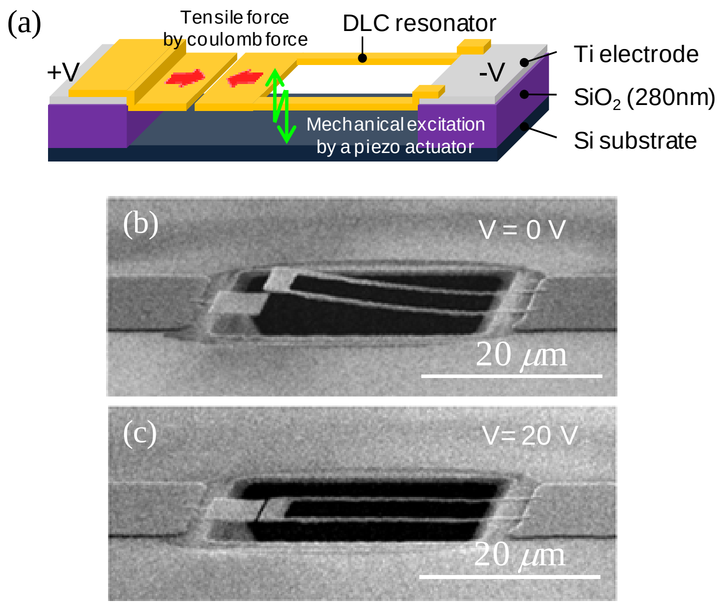

Figure. 1: Vibration characteristics-tunable DLC resonator. (a) a schematic of a vibration characteristics-tunable DLC resonator and a tuning principle, (b) SEM image of a resonator without the applying voltage, (c) SEM image of a DLC resonator with the applying voltage of 20 V.

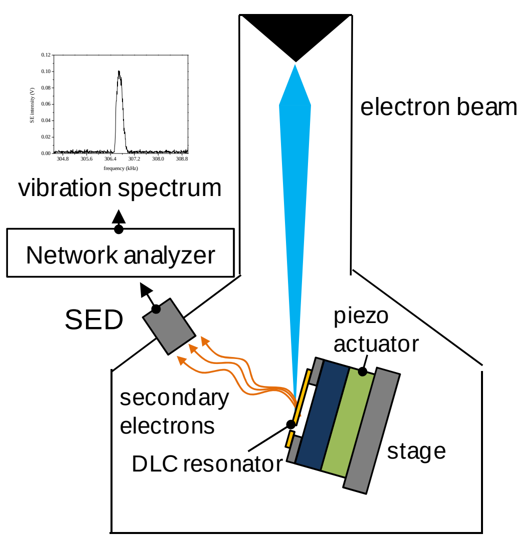

Figure. 2: A schematic of the vibration characteristics evaluation using the electron-beam method. Resonant frequency was measured under the vacuum of 3 X 10^{-3} Pa.

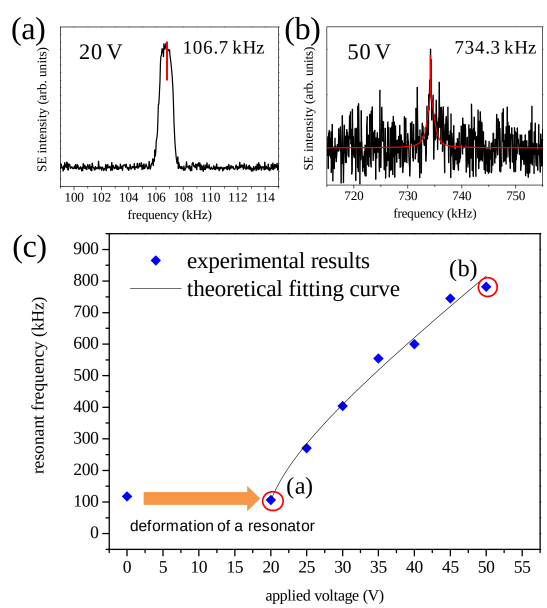

Figure. 3: Vibration spectra of DLC resonator with the applying voltage of (a) 20 V and (b) 50V. (c) the applied voltage dependency of the changes in the resonant frequency of DLC resonator.