High Q factor graphene mechanical resonator fabrication using the clamp-bending method

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Nanomechanical resonator is a key compornent of nanoelectromechanical systems because the nanomechanical resonator enables us to detect various small physical quantities using vibration[1,2]. And, because the lightweight structure is useful in order to achieve the high sensitive devices, the graphene attracts attention as a material of a resonant device. And also, the high quality (Q) factor is required for the high sensitivity. Therefore, Q factor improvement of a graphene mechanical resonator had been researching. Thus far, it was found that the applying of the tensile stress was effective method in order to improve the Q factor[3]. Tensile stress induced the decrease in the thermoelastic damping during vibration. In this study, a more powerful method using a tensile stress was studied for Q factor improvement of the graphene resonator.

Figure 1 shows a fabrication process of a strained-graphene resonator. In this study, the bending of clamps was used in order to apply the tensile stress to the graphene resonator, as shown in Fig. 2(a). The bending of clamps was induced by the thermal shrinkage of hydrogen silsesquioxane (HSQ) resist under the Au/Cr layer. Figure 1(b) shows a scanning electron microscope (SEM) image of the graphene mechanical resonator fabricated in this study. Length and width were 4.7 µm and 200 nm, respectively. And, graphene resonators with bended clamps as shown in Figs 2(c) and 2(d) were obtained by the annealing treatment.

Resonant characteristics were measured under the vacuum of approximately 5 X 10^{-3} Pa by using an optical heterodyne vibrometer (MLD-230V-100, NEOARK Corp.), as shown in Fig. 3(a). Vibration of a graphene resonator was excited by photothermal excitation using semiconductor laser with a wavelength of 408 nm. And, vibration was measured by using He-Ne laser with a wavelength of 632.8 nm. Figure 3(b) shows measurement results of resonant characteristics before and after annealing treatment. As a result, resonant frequencies and Q factors were increased with the increase in the annealing temperature. Maximum Q factor obtained in this experiment was 10411, as shown in Figs. 3(b) and 3(c). Tensile stress was 886.3 MPa. This Q factor at room temperature was quite high as compared with what was reported in previous work. These indicate that the clamp-bending method was useful in order to obtain the strained-graphene resonator with the high Q factor.

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[2] K. L. Ekinci, and M. L. Roukes, Rev. Sci. Instrum. **76**, 061101 (2005).
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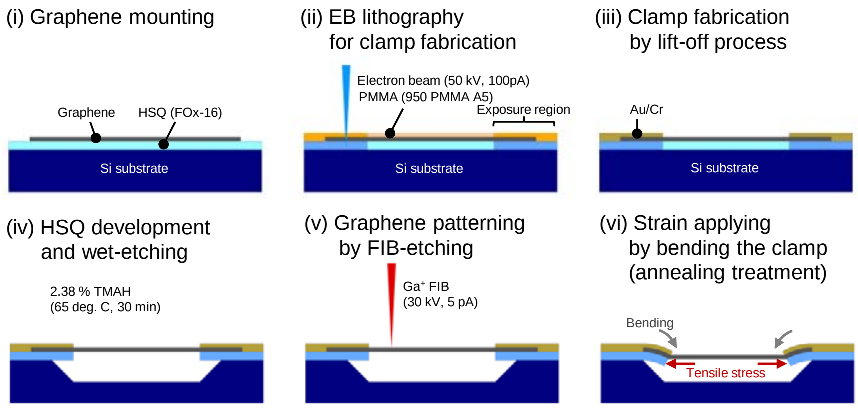

Figure 1: Fabrication process of a graphene resonator strained by the clamp bending induced by the annealing treatment

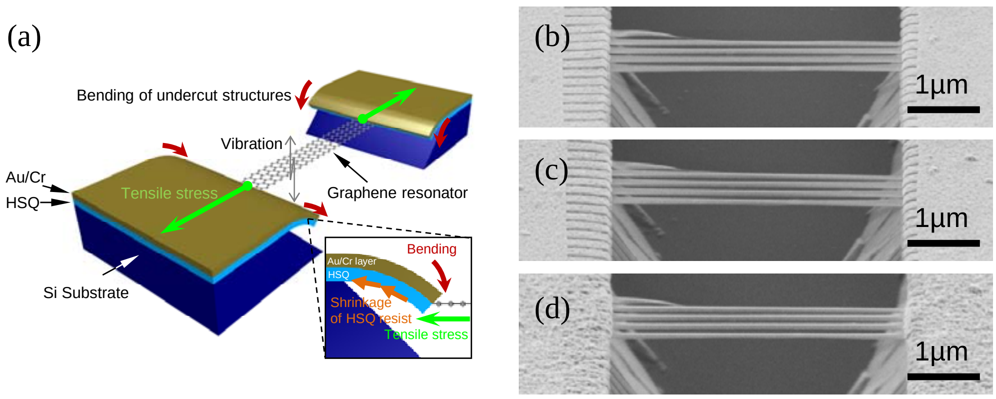

Figure 2: Graphene mechanical resonator strained by the clamp-bending:
(a) A mechanism of the tensile stress applying to a graphene resonator, and SEM images of graphene resonators (b) before and after annealing treatment (c) at 400 deg. C for 3 h and (d) at 800 deg. C for 2 h.

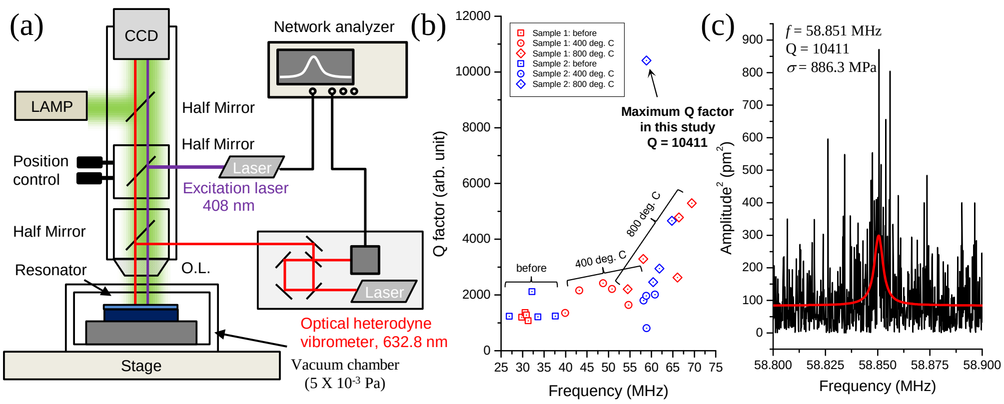

Figure 3: Evaluation of vibration characteristics:
(a) Schematic of the experimental setup, (b) Resonant frequency and Q factor before and after annealing treatment, (c) Vibration spectrum of a strained-graphene resonator with a maximum Q factor