Quality factor improvement of graphene resonator by SU-8 shrinkage-induced strain

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Nanomechanical resonators have been expected as extremely sensitive sensing devices because various small physical quantities can be detected using changes in the mechanical resonance properties. Graphene is an extremely thin graphite layer, which has outstanding electrical and mechanical properties. Graphene is an ideal material for nanomechanical resonators because of its overwhelming strength, stiffness and thinness. Unfortunately, with the decrease of resonator's dimensions, its quality factor generally decreases owing to surface effect.[1] The quality factor improvement is essential for the realization of high sensitivity sensing devices. In this study, we fabricated graphene mechanical resonators using mechanical exfoliation and focused-ion-beam (FIB) technique. Moreover, we improved the quality factor of graphene mechanical resonators by SU-8 shrinkage-induced tensile strain.

Figure 1 shows fabrication process of graphene resonators. In this study, SU-8 (SU-8 3005 Nippon Kayaku Co., Ltd) was used as the negative resist to fabricate bases of resonators. SU-8 resist on Si substrate with 280 nm SiO_2 (Fig. 1-(a)) was exposed by electron-beam (EB) in advance (Fig. 1-(b)), and few-layer graphene sheets were mechanically exfoliated onto this resist (Fig. 1-(c)). After development (Fig. 1-(d)), graphene was clamped with Diamond-like Carbon (DLC) which was deposited using focused-ion-beam chemical vapor deposition (FIB-CVD) (Fig. 1-(e)). Finally, free-standing graphene was trimmed by FIB-etching (Fig. 1-(f)). Figure 2 shows one of the free-standing graphenes fabricated in this process. We demonstrated that FIB etching was effective in trimming free-standing graphene sheets.

Thereafter, SU-8 resist has a characteristic of shrinkage by annealing. We used this characteristic to apply tensile strain in graphene resonator. Annealing was performed several times at 200°C ~ 600°C. We evaluated vibration properties of graphene resonator before and after the annealing with optical heterodyne interferotype vibrometer under medium vacuum ($\sim 10^{-1}$ Pa). In this experiment, the quality factor improved about 7 times higher for the best sample by applying tensile strain, as shown in Fig. 3. This result showed that quality factor could be improved by applying tensile strain to the resonator. We will report the detailed result of graphene resonator fabrication and the influence of applying tensile strain to vibration properties.

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[1] Ekinci, K. L.; Roukes, M. L. Rev. Sci. Instrum. 2005, 76 (6), No.061101.

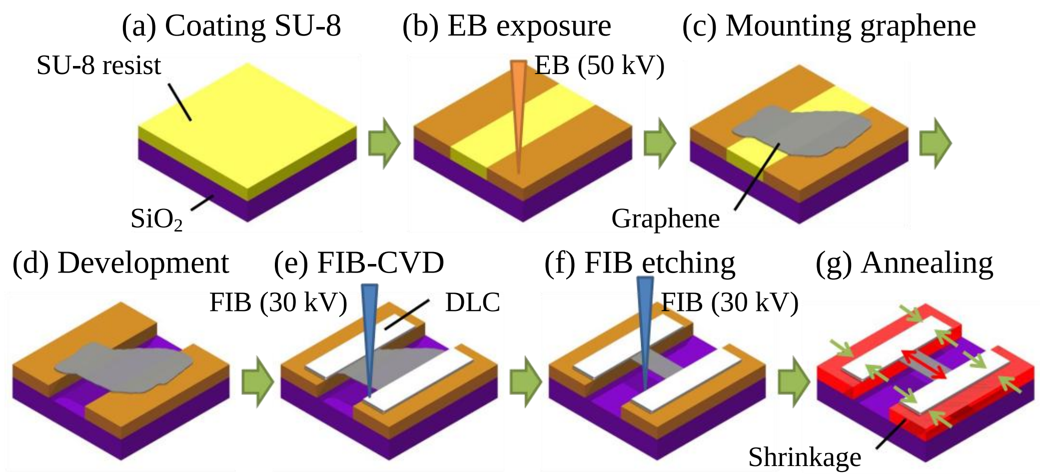

Figure 1: Fabrication process of a strain-induced graphene mechanical resonator by using mechanical exfoliation, focused-ion-beam (FIB) etching and annealing.

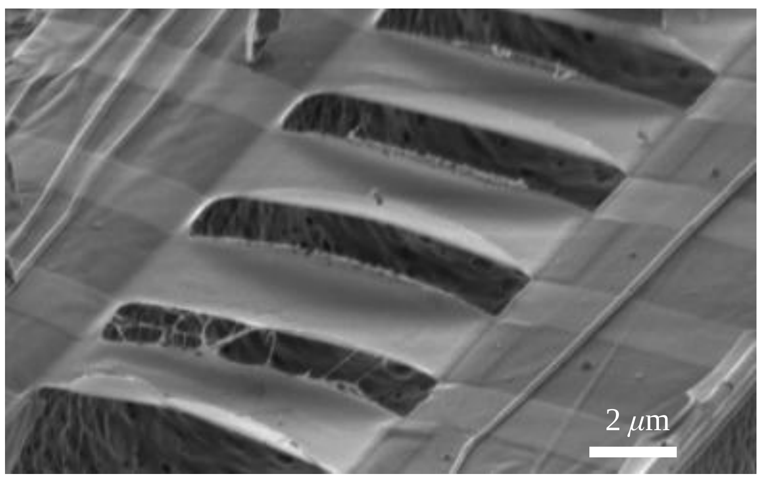

Figure 2: Scanning electron microscope image of graphene mechanical resonators fabricated by mechanical exfoliation and FIB etching.

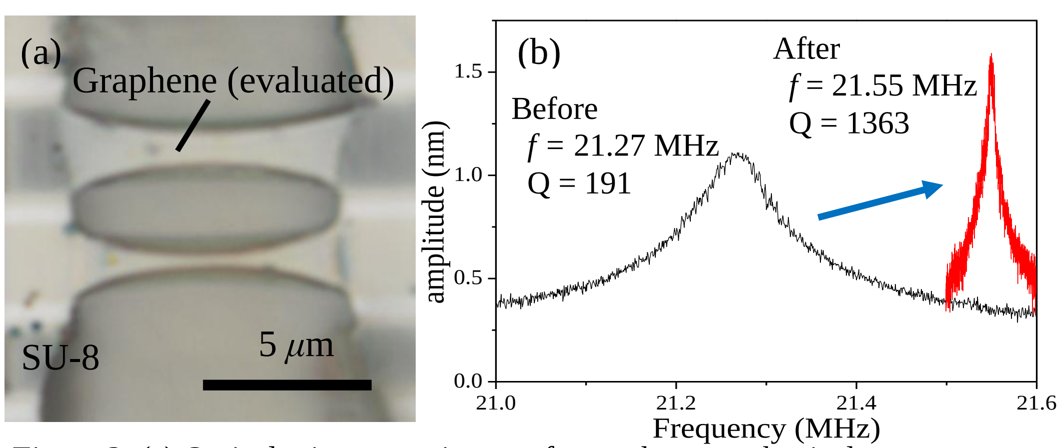

Figure 3: (a) Optical microscope image of a graphene mechanical resonator before annealing. (b) Vibration spectra of a graphene mechanical resonator fabricated by mechanical exfoliation and FIB etching before and after annealing.