Vibration Characteristics of Monolayer Graphene Resonator

T. Hatakeyama,[1] R. Kometani,[1] M. Nagase,[2] S. Warisawa,[1] S. Ishihara[1]

[1]*The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-8656, Japan*

[2]*NTT Basic Research Laboratories, Atsugi, Kanagawa 243-0198, Japan*

Graphene has a great potential for mechanical applications to nanoelectromechanical systems (NEMS) including ultrahigh frequency resonators because of its stiffness and lightness[1]. In this paper, we fabricated a monolayer graphene resonator and evaluated its vibration characteristics using an atomic force microscope (AFM).

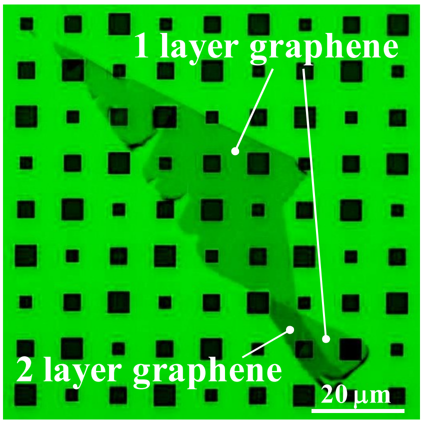
To prepare suspended graphene resonators, square hole array was fabricated on a Si substrate with 280nm SiO_2 using electron beam lithography and reactive ion etching. Width and depth of the etched square holes are 3 – 5 μm and 200 nm. Then Kish graphite was rubbed onto the patterned substrate. Fig. 1(a) shows an optical micrograph of the fabricated 1-layer and 2-layer graphene. The number of graphene layer was confirmed by Raman Spectroscopy measurement as shown in Fig. 1(b).

Vibration of suspended graphene membrane was measured by simultaneous actuation and detection method[2] using AFM. In this method, membrane vibration is actuated by Coulomb force acting between the resonator and Si probe coated with 30 nm Pt (Fig. 2(a)). Concurrently with the actuation, vibration amplitude is measured by the dynamic force mode (DFM) of the AFM as shown in Fig. 2(b). Then by sweeping the actuation frequency, we can get vibration characteristics in the frequency domain. The resonant frequency f_{11}, the quality factor Q, and the resonant amplitude A_{max} can be estimated by fitting the frequency spectrum to a Lorentzian function. All experiments were performed under atmospheric conditions at room temperature.

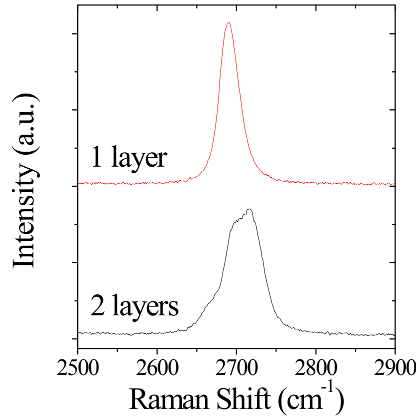
Fig. 3 shows the measured spectrum for the fundamental mode vibration of graphene resonator with a width of 5 μm. As a result, the resonant frequency, the quality factor, and the resonant amplitude were 32.7 MHz, 9.3, and 1.06 nm, respectively. Here, the quality factor was very low. Though there are several factors to affect resonance characteristics, the extremely low quality factor of monolayer graphene is chiefly attributed to energy dissipation by atmospheric molecules. This is because graphene has a highly surface area dominant structure and then its vibration would be highly sensitive to air molecules. It indicates that monolayer graphene is a promising material applied to highly sensitive sensors such as pressure, molecule, and mass sensors. We will discuss how surface conditions of the graphene influence its vibration characteristics.

[1] A. K. Geim, *Science* **324**, 1530 (2009).

[2] K. Tamaru *et al.*, *Japanese Journal of Applied Physics* **48**, 06FG06 (2009).

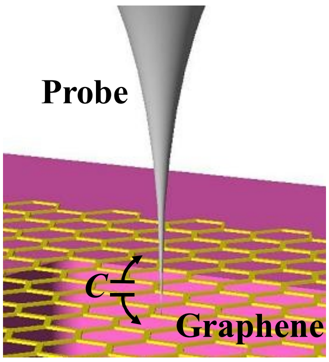


(a)

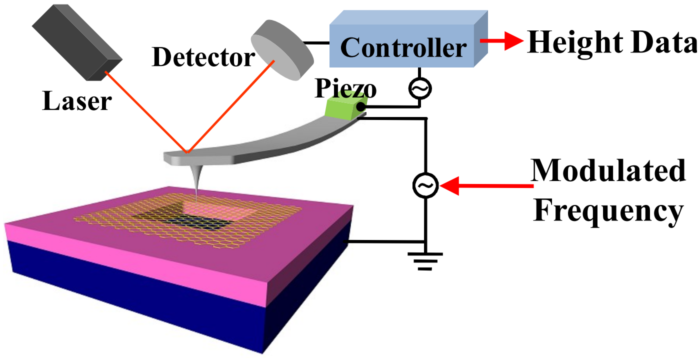


(b)

Figure 1 (a) Optical micrograph of graphene rubbed onto the patterned substrate with 3 - 5 μm holes. (b) Raman spectra of 2D band at 488 nm for 1 layer and 2 layer graphene of Fig. 1(a).



(a)



(b)

Figure 2 (a) Coulomb force between probe and graphene which actuates graphene vibration. (b) Schematic of AFM with simultaneous vibration actuation and detection method[2].

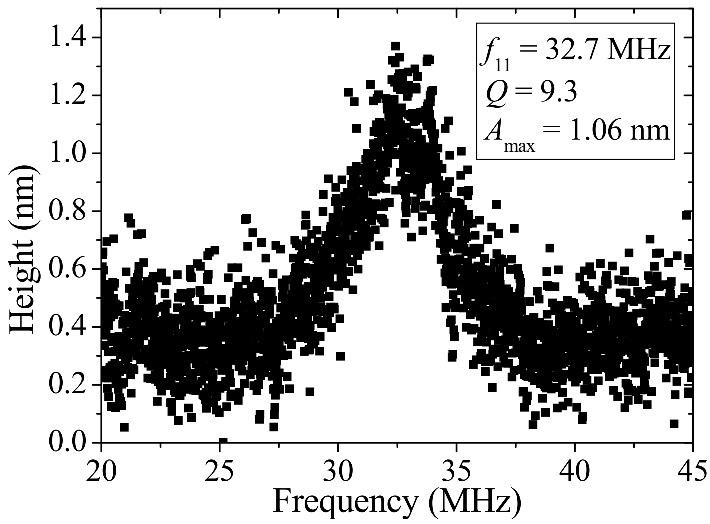


Figure 3 Frequency spectrum of monolayer graphene resonator which was 5 μm wide. Applied voltage was 4.0 V.