Fabrication of the optomechanical resonator with U-shaped cavities for the wavelength detection

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High resolution wavelength detector is demanded in the optical communication field in order to stabilize the light source. And, a novel principle was needed to achieve the high accuracy wavelength detection. In this study, the wavelength detection was researched by using a nanomecahanical resonator with a plasmonic nanostructure because the nanomechanical resonator enables us to detect various small physical quantities using vibration[1] and plasmonic nanostructure is also coupled strongly with the light[2].

In this study, the U-shaped cavity was used as a plasmonic structure in order to give the wavelength dependence of heat absorption to a resonator. U-shaped cavity enables us to select the arbitrary detection wavelength range and to control absorption in wide range by its shape and material.[3] Figure 1(a) shows a scanning electron microscope (SEM) image of an optomechanical resonator with Au/diamond-like carbon (DLC) U-shaped cavities. This resonator was fabricated by focused-ion-beam chemical vapor deposition (FIB-CVD), wet-etching and sputtering process, as show in Fig. 2. Length, width and thickness of a mechanical resonaotor were 12 μm, 7 μm and 170 nm respectively. And, width, height and period of Au/DLC bilayer U-shaped cavity on a mechanical resonator were 148 nm, 1180 nm and 880 nm, as shown in Fig. 1(b).

Wavelength detection properties were evaluated using an optical heterodyne vibrometer, as shown in Fig. 3(a). Wavelength-variable laser (wavelength: 1350 nm - 1565 nm) was used as a measurement object. All measurements were performed under a laser with power of 1 mW. Spot diameter and incident angle of a laser was 5 μm and 15 deg., respectively. Initial resonant frequency and Q factor of an optomechanical resonator without laser irradiation was 2.2400 MHz and 160, respectively. Figure 3(b) shows the changes in the vibration properties under irradiations of a laser with the wavelength from 1535 nm to 1565 nm. As a result, resonant frequencies were depended on the wavelength, as shown in Fig. 3(b). We found that the maximum wavelength detection resolution was 2.2 pm by the spectrum analysis. This implies that a resonator has enough performance for wavelength detection in the optical communication. Wavelength detection characteristics will be reported in detail.

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[2] C. Genet and T. W. Ebbesen: Nat. **445**, 39 (2007).
[3] Y-L. Ho, Y. Lee, E. Maeda and J-J. Delaunay: Opt. Express **21**, 1531, (2013).

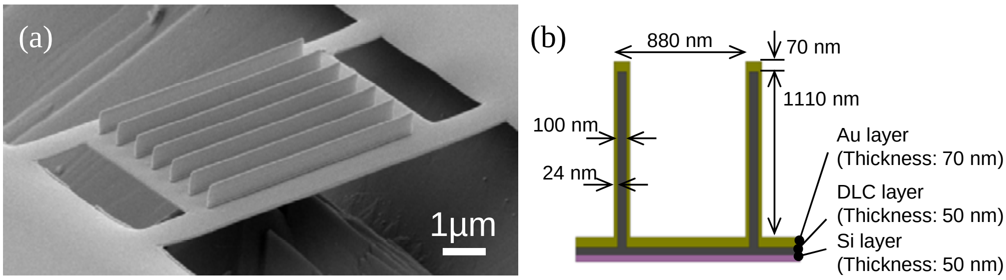

Figure 1: Optomechanical nanoreosnaotor with U-shaped cavities:
(a) SEMimage of an optomechanical resonator with U-shaped cavities, (b) Schematic diagram of a U-shaped cavity on the optomechanical resonator

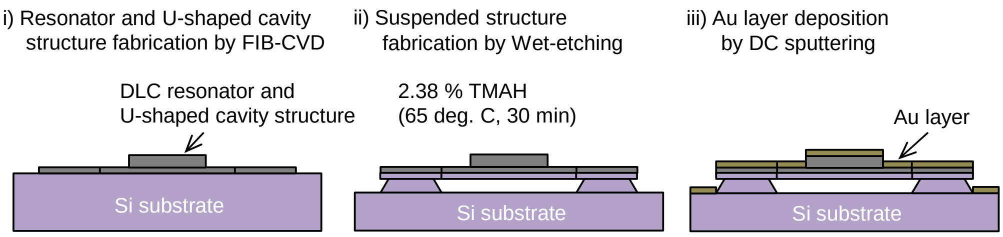

Figure 2: Fabrication process of the optomechanical nanoreosnaotor with U-shaped cavities: FIB-CVD was carried out using 30 kV Ga^+ beam with a beam current of 1.0 pA. Frames of U-shaped cavities were made of DLC becausePhenanthrene ($C_{14}H_{10}$) was used as a gas source for CVD. And, TMAH wet-etching of Si substrate was carried out at 65 deg. C for 30 min. After then, Au layer for a plasmon excitation was deposited by DC sputtering.

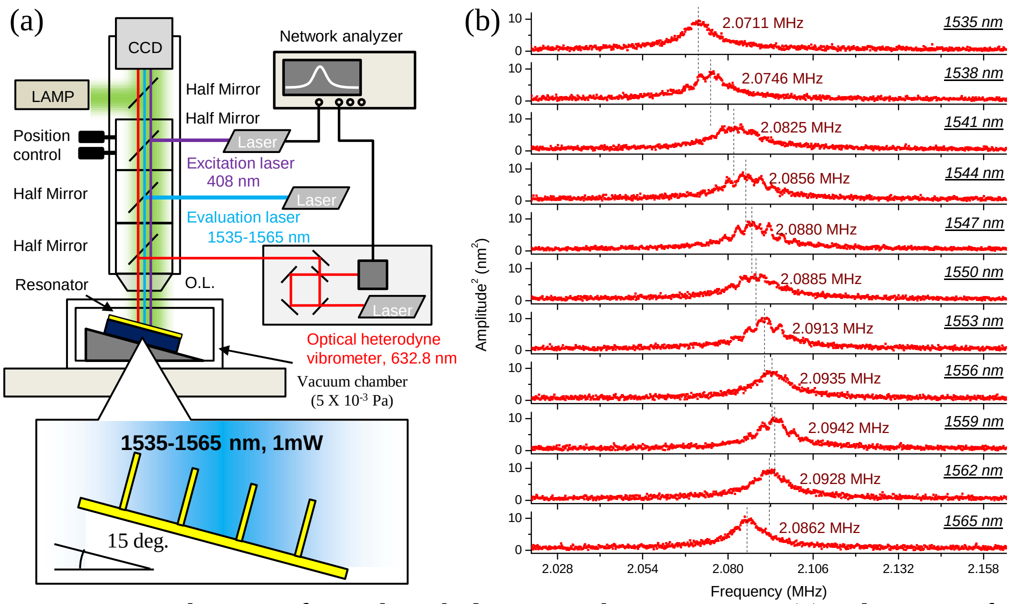

Figure 3: Evaluation of wavelength detection characteristics: (a) Schematic of the experimental setupfor evaluation, Vibration of a mechanical resonator was excited by photothermal excitation using semiconductor laser with a wavelength of 408 nm. And, vibration was measured by using He-Ne laser with a wavelength of 632.8 nm. (b) Wavelength dependency of the resonance