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Drum type h-BN nano-electro-mechanical resonator driven by dielectric effect

A hexagonal boron nitride (h-BN) is transparent in the visible light range. Thus, the nano-electro-mechanical resonator (NEMR) consisting of h-BN is considered to be capable of highly accurate force measurement such as light pressure acting on nanomaterials without unexpected photoinduced effect. In addition, h-BN is an emergent material for single photon emitters [1] that are ultrabright and stable under ambient conditions. Very recently, theoretical prediction regarding quantum effects in a mechanically modulated single photon emitter composed of h-BN NEMR has been reported.[2] To realize these optomechanical applications, the oscillation should be precisely tuned by electrical method in addition to the optical method. In this study, we demonstrate the electrical actuation of a drum type h-BN NEMR. To compose the h-BN NEMR, a multilayered h-BN flake, which was prepared by mechanical exfoliation of bulk h-BN, was transferred using gel transfer method onto a predefined pair of electrodes as shown in Fig. 1a. To form the drum-type h-BN NEMR (6 μm in diameter) suspended by metal electrodes, the SiO_2 layer underneath the drum was etched using buffered HF.[3] The frequency resonance of the h-BN NEMR was measured by optical detection method, where a laser with a wavelength of 520 nm was irradiated to the center of the h-BN drum as the probe. To oscillate the drum type h-BN NEMR shown in Fig. 1b, the AC + DC voltage was applied between the n^+Si substrate and the Au electrode. As shown in Fig. 2a, the h-BN NEMR was successfully oscillated by electrical method based on the dielectric effect, where the resonance frequency and Q factor were 26.48 MHz and 115, respectively. Figure 2b shows the DC voltage dependence of the oscillation amplitude at the resonance under various AC bias conditions. The oscillation amplitude increases linearly with increasing the AC or DC voltages. This behavior can be explained by the model based on the electrical actuation based on the dielectric effect.

References

[1] T. T. Tran, K. Bray, M. J. Ford, M. Toth, and I. Aharonovich, Nat. Nanotechnol., 11 (2015) 37.
[2] M. Abdi and M. B. Plenio, Phys. Rev. Lett., 122 (2019) 023602.
[3] T. Inoue, Y. Anno, Y. Imakita, K. Takei, T. Arie, and S. Akita, ACS Omega, 2 (2017) 5792.

Figures

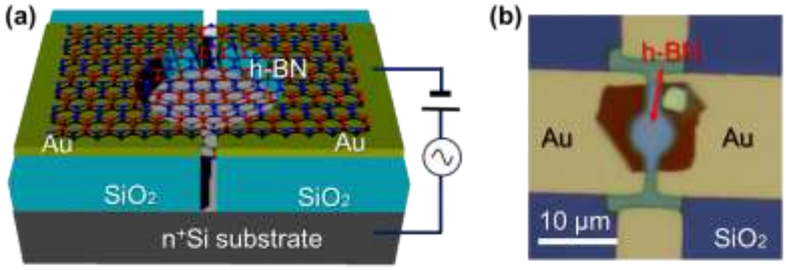

Figure 1: (a) Schematic illustration of the drum type h-BN NEMR. (b) Optical microscope image of the drum type h-BN NEMR.

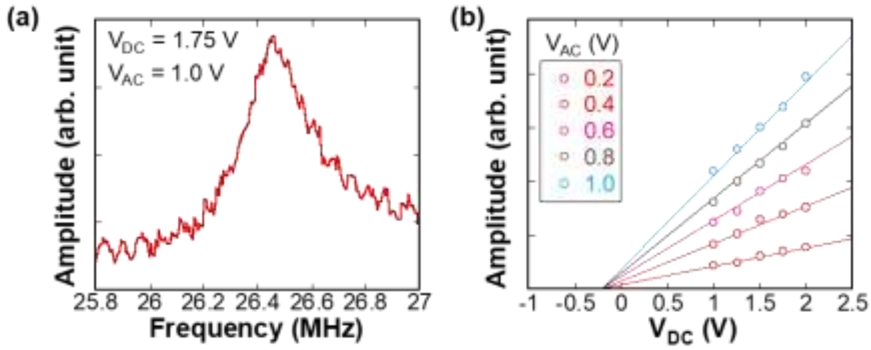

Figure 2: (a) Example of frequency response curve of drum type h-BN NEMR. (b) V_{DC} dependences of oscillation amplitude with various V_{AC}.