ダイヤモンド MEMS 共振器の電気的読み出し

Electrical readout of diamond MEMS resonators

物質・材料研究機構, ◦廖　梅勇、呉海華、桑 立雯、 井村将隆、小泉　聡、小出康夫

National Institute for Materials Science, ◦Meiyong Liao, Haihua Wu, Liwen Sang, Masataka Imura, Satoshi Koizumi, Yasuo Koide

E-mail: meiyong.liao@nims.go.jp

Diamond owns the outstanding properties such as the highest Young's modulus, mechanical hardness, thermal conductivity, and chemical resistance for microelectromechanical or nanoelectromechanical systems (MEMS/NEMS) applications with markedly improved performance and reliability. Silicon-based MEMS has witnessed the broad applications such as pressure/tactile sensors, accelerometers, and gyroscope, to name a few, in our daily life ranging from health management, automobile, to communication. The progress in silicon MEMS is no doubt attributed to the compatibility of silicon MEMS with CMOS process, in which the electrical readout of the MEMS resonators is the key step. Despite the attractive properties of diamond for MEMS/NEMS, there is an intrinsic drawback of diamond for MEMS, lacking of shallow dopants for sufficient electrical conductivity. Therefore, the electrical readout of diamond MEMS/NEMS resonators cannot be as usual as conventional semiconductors.

As a general route, the practical applications of diamond MEMS rely on both the fabrication of diamond MEMS resonators and electrical readout from the resonators. In the first case, we developed the batch fabrication of single crystal diamond (SCD) MEMS/NEMS resonators on diamond by using the ion-beam induced phase transition method (IPT) in diamond.[1,2] We realized that the Q-factor of the IPT SCD resonator was strongly degraded by the ion-implantation induced damaged layer.[3] Therefore, we improved the Q-factor by growing a thick SCD layer and etching the defective layer to reduce the energy loss by the damaged layer at the bottom of the resonator.[4] Ultimately, we achieved the SCD resonators on diamond with ultrahigh Q-factors over one million.[5]

In this work, we aim to achieve on-chip electrical readout of SCD resonators by using nano-thick metal electrodes with imposing little energy dissipation. Intrinsic SCD cantilevers fabricated via the IPT method were adopted to demonstrate the on-chip readout. Source-drain (S-D) electrodes were deposited on the cantilevers for electrical readout of the resonance and the cantilevers were actuated by the piezo-ceramics disk placed at the bottom of the diamond substrate. A heterodyne frequency down-conversion method was utilized to characterize the resonance frequency of the SCD cantilevers. Figure 1 shows an example of the electrical readout from a SCD cantilever with MHz resonance frequency. The readout amplitude can be tailored by the actuation rf amplitude. It was also revealed that both the resonance frequency and amplitude can be tuned by the S-D rf amplitude. This work provides a step for integrated diamond MEMS sensors.

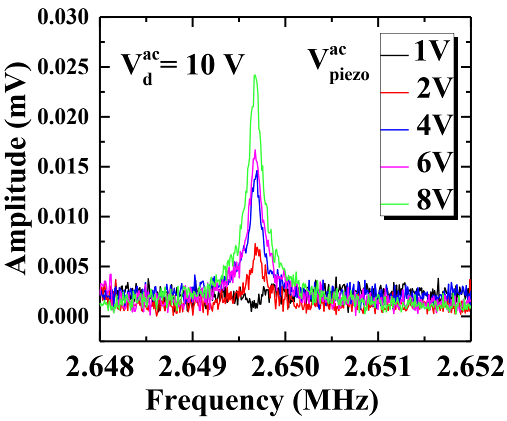

Fig. 1 Electrical readout of the resonance of the SCD cantilever with different rf amplitudes applied to the S-D electrodes (V_d^{ac}) and piezo-ceramics disk (V_p^{ac}).

References

1. M. Liao, S. Hishita, E. Watanabe, S. Koizumi, Y. Koide, Adv. Mat. 22, 5393 (2010).
2. M. Liao, C. Li, S. Hishita, Y. Koide, J. Micromech. Microeng. 20, 085002 (2010).
3. M. Liao, M. Toda, L. Sang, S. Hishita, S. Tanaka, Y. Koide, Appl. Phys. Lett. 105, 251904 (2014).
4. M. Liao, T. Masaya, L. Sang, T. Teraji, M. Imura., Y. Koide, Jpn. J. Appl. Phys. 56, 024101 (2017).
5. H. Wu, T. Teraji, M. Imura, Y. You, Y. Koide, M. Toda, M. Liao, Phys. Rev. Mater. 2,090601(R)(2018)