Effect of Energy Dissipation in Higher-Order Resonance on SCD MEMS Cantilevers Toward High *f*·*Q*

National Institute for Materials Science [1], China University of Geosciences (Beijing) [2]

◦(D) Guo Chen [1,2], Zilong Zhang [1], Keyun Gu [1], Satoshi Koizumi [1], Zhaohui Huang [2], and Meiyong Liao [1]

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

Single-crystal diamond (SCD) has been regarded as one of the most promising materials for microelectromechanical system (MEMS) sensors, because of its superior mechanical and thermal properties. [1-3] The quality (Q) factor, which is the inverse of the dissipation (Q^{-1}), along with the resonance frequency (f_0), are the two most fundamental and important characteristics for SCD MEMS resonators. [4] High frequency and low dissipation are generally desirable, which make better device response, sensitivity, efficiency and less susceptibility to mechanical noise. [2,4] Typically, higher-order resonances have much higher f·Q than first-order mode with less energy loss both from the intrinsic and extrinsic sources. [5,6] However, this effect on SCD MEMS has not been clarified clearly yet.

In this work, we investigate the higher-order resonance of SCD MEMS cantilevers with high f·Q value. The resonance frequency and Q factors were measured and analyzed at the first three order vibration modes. Fig.1. (a) shows a typical resonance frequency spectrum of a 140 μm-long SCD cantilever at the 3rd order vibration. Under the 1st order vibration and 2nd order vibration mode, the dependence of the resonance frequency on the SCD cantilever length are depicted in Fig.1. (b, c, d, e). It is clear that for both of the fundamental mode and the higher-order mode, the resonance frequency and the SCD length follow the inverse power law relationship strictly. As shown in Fig.1. (f), it was found that the value of f·Q of the SCD cantilevers significantly increases with the higher-order resonance. Due to little change of the Q factors that are limited by the ion-implantation induced defects, the f·Q is greatly improved by the higher-order resonance modes.

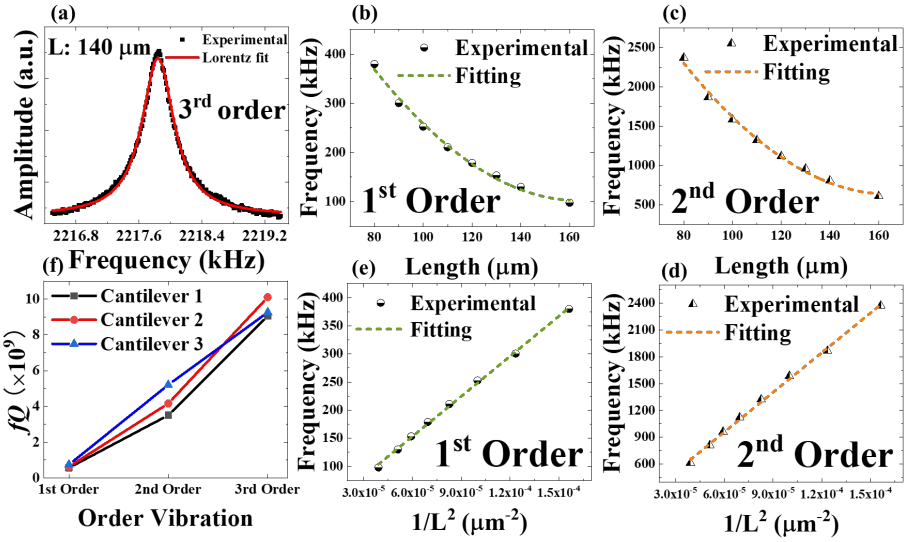


Fig. 1. A typical resonance spectrum of the cantilever under the 3rd order vibration (a). Dependence of the measured resonance frequency on cantilever length at the 1st order vibration (b) and 2nd order vibration (c). The bottom (d, e) shows the linear fitting of the measured resonance frequency with $1/L^2$ under the two order vibrations. (f) The improvement of f·Q under high-order resonance of the cantilevers.

References

1. M. Liao, M. Toda, L. Sang, *Appl. Phys. Lett.* 105(25), 251904 (2014).
2. H. Sun, L. Sang, H. Wu, Z. Zhang, M. Liao, *Phys. Rev. Lett*. 125(20), 206802 (2020).
3. H. Wu, L. Sang, M. Liao, *Phys. Rev. Mater*. 2(9) 090601 (2018).
4. A. Gaidarzhy, M. Imboden, P. Mohanty, *Appl. Phys. Lett.* 91(20), 203503 (2007).
5. M. Imboden, P. Mohanty, *Phys. Rep.* 534(3), 89-146 (2014).
6. X. M. Henry Huang, C. A. Zorman, M. Mehregany, *Nature.* 421(6922), 496 (2003).

© 2023年 応用物理学会