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単結晶ダイヤモンドナノマシン共振特性のサイズ依存性

Size effect on the single crystal diamond NEMS resonators

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Diamond is the ideal material to overcome the drawbacks of silicon for high-performance MEMS/NEMS applications due to its extreme mechanical and electronic properties.　In order to realize the ultimate properties of diamond for MEMS/NEMS, the utilization of high-quality single crystal diamond (SCD) is highly desirable. We have developed the batch fabrication method for all single crystal diamond MEMS/NEMS resonators. Based on the process, NEMS switch able to operate at high temperature was demonstrated. In this work, the geometrical effect on the mechanical resonance of SCD micro- and nano-mechanical resonators is investigated.

The diamond NEMS resonators are fabricated based on the ion-implantation assisted lift-off process. Homoepitaxial diamond layer was grown by microwave plasma chemical vapor deposition (MPCVD). After growth, photo- and e-beam lithography processes were conducted to achieve the designed geometries. The length of the SCD cantilevers/beams was ranged from 40 to 206 μm. The thickness of the SCD cantilevers was from 0.68 to 2.25 μm. The width was from 0.1-8 μm.

The resonant frequency of the SCD beams　was measured by piezoelectric actuation and optical detection in vacuum. The dependence of the measured resonant frequency on the cantilever length follows well with the theoretical predication, as shown in Fig. 1. This suggests the good reproducibility and reliability of the batch fabrication process. The Young's modulus of the cantilevers was typically 1100GPa by numerical fitting using the known thickness of the cantilevers. The quality factor dependence on the cantilever length is shown in Fig. 2. The quality factor decreased with decreasing the cantilever length. Two possible mechanisms are responsible for the energy dispersion: one is the clamping loss, the other is the defects induced by ion implantation.

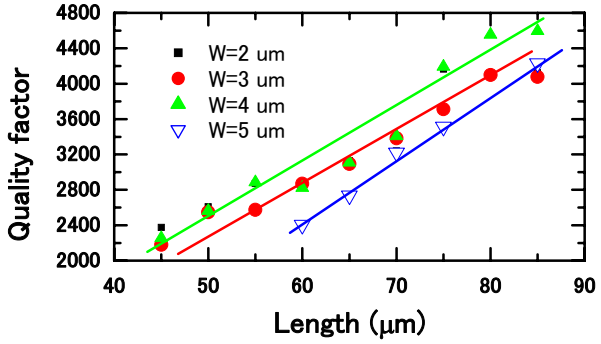

Fig. 1 Size effect on the resonant frequency.

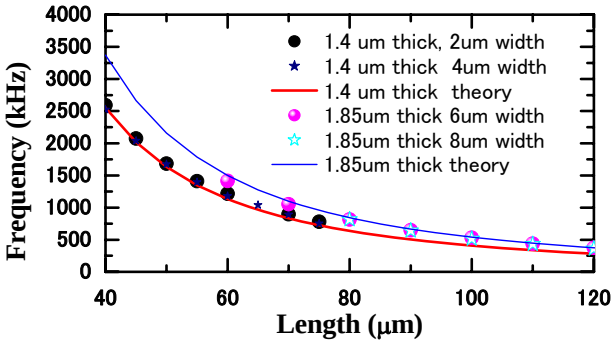

Fig. 2 Size effect on the quality factor.

Single crystal diamond NEMS resonators fabricated by the ion-implantation assisted lift-off process were investigated with regards to the mechanical resonance as an effect on the resonator size. The size effect is consistent with that of predicated by theory. The SCD mechanical resonators showed good reliability. The energy dispersion mechanism seems to be dominated by the defects or the clamping loss.

References

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