Effect of Ultra-High Vacuum Annealing and Hydrogen Plasma Treatment on the Resonance Properties of Single-Crystal Diamond MEMS Cantilevers

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Single-crystal diamond (SCD) presents as an ideal semiconductor material for high-performance and high-reliability nano- or microelectromechanical system (N/MEMS) devices, on account of its outstanding mechanical, physical, chemical and electronic properties.[1,2] To be specific, compared to the other traditional materials, such as Si, SiC, III-nitride and so on, SCD has superior mechanical strength, ultra-wide bandgap, the highest Young's modulus and thermal conductivity, and low coefficient of thermal expansion with excellent chemical inertness.[3] Therefore, the quality (Q) factor and reliability of SCD MEMS could be improved greatly, compared with the state-of-the-art resonators prepared by the other materials.[4]

A smart-cut technology based on the ion-implantation assisted lift-off (IAL) technique method was proposed and demonstrated to fabricate the SCD-on-SCD N/MEMS resonators with ultrahigh Q factors over one million in our previous work.[5] It was shown that the ion-implantation damage induced defects degraded the Q factor of the diamond MEMS resonators.[6] Reducing the defects in the resonators by annealing the as-fabricated SCD MEMS cantilevers in an ultra-high vacuum ambient is one of the strategy to improve the Q factors.[7] Nevertheless, the annealing effect on the SCD MEMS cantilevers is not well understood and has not been systematically investigated yet.

In this work, we investigated the effect of ultra-high vacuum annealing and hydrogen (H_2) plasma treatment on the resonance properties of SCD MEMS cantilevers. The resonance frequency and Q factors were measured and analyzed after annealing from 900 to 1100°C followed by H_2 plasma treatment. Despite the annealing and plasma treatment, the resonance frequency of the SCD cantilevers well follows the inverse power law relationship with the length of different SCD MEMS cantilevers, revealing the excellent reliability of SCD MEMS as shown in Fig.1 (a). It was found that the Q factors were markedly improved from the typical value around 8,000 to over 15,000 after the annealing treatment at 1100°C for 7 hours (Fig.1(b)). And the Q factors also increased after further cleaning by H_2 plasma. The improvement of the Q factors is due to the annihilation of the defects within the SCD cantilevers.

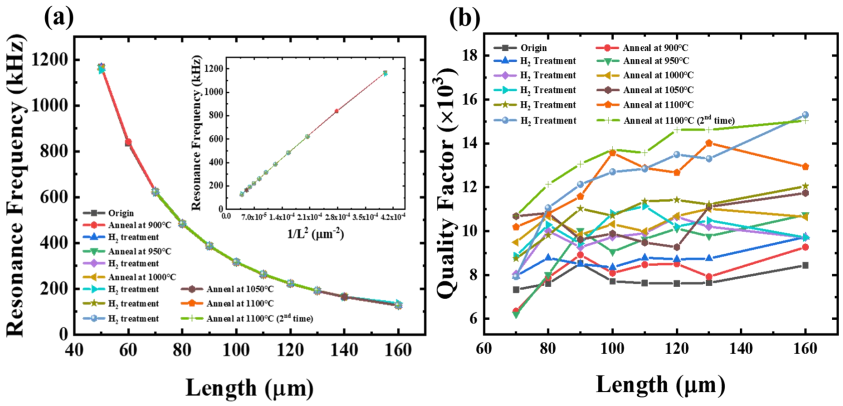


Fig. 1 The resonance frequency (a) and Q factors (b) change with the H_2 plasma treatment and different annealing temperature for the SCD MEMS cantilevers with different length.

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