Disclosing surface adsorptions of oxygen- and hydrogen-terminated diamond *via* MEMS

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1. Introduction

Diamonds with different surface terminals exhibit completely different physical and chemical properties on the surface, which is attributed to the distinct adsorption characteristics [1]. Nevertheless, the surface information of the oxygen (O)- and hydrogen (H)-terminated diamond surface has been still mysterious due to the lack of in-situ characterization equipment and high-sensitive diamond resonators. Single-crystal diamond (SCD) presents as a promising candidate for ultrasensitive microelectromechanical systems (MEMS) mass sensors by virtue of its outstanding mechanical characteristic, high thermal conductivity, and the circumvent of other phases and grain boundaries [2]. In this work, we fabricated SCD resonators and clarified the desorption characteristics of O-terminated and H-terminated diamond by *in situ* heating the cantilevers and measuring the resonance frequencies of cantilevers.

2. Experimental

The SCD cantilever resonators were fabricated by using the smart-cut method which includes ion implantation, diamond epilayer growth, lithography, metal deposition, etching, and releasing [2]. Atomic force microscopy (AFM) and Raman spectrometer with a 532 nm laser were used to investigate the surface morphology and the crystal quality of the epitaxial SCD, respectively. The typical resonance frequency spectra of cantilevers were measured and read out by a laser Doppler vibrometer (LDV, LV-1710) combined with a lock-in amplifier system in a high vacuum (~10^{-4} Pa) chamber with a heater.

3. Results and discussion

The Raman peak position of SCD cantilever shown in Figure 1(a) is around 1332.75 cm^{-1}, the 2D Raman mapping of the FWHM is around 1.40~1.76 cm^{-1} and evenly distributed (Figure 1(b-c)). The overall surface morphology is smooth and the root mean square (RMS) roughness is around 0.29 nm, as shown in Figure 1(d). The resonance amplitude of the cantilever increases linearly (Figure 1(e)) with the voltage and the minimum detectable mass is around 6.6×10^{-17} g calculated according to the Allan deviation (Figure 1(f)). The schematic diagrams of surface desorption are shown in Figure 2(a). The surface desorption of O- and H-terminated diamond tends to be saturation at 933 K and 723 K (Figure 2(b-c)), respectively. The H-terminated diamond surface current drops from 7.9×10^{-5} A to 7.3×10^{-11} A due to desorption. And the equivalent thickness of the adsorption layer the O- and H-terminated diamond is ~0.4 nm and ~0.9 nm, respectively.

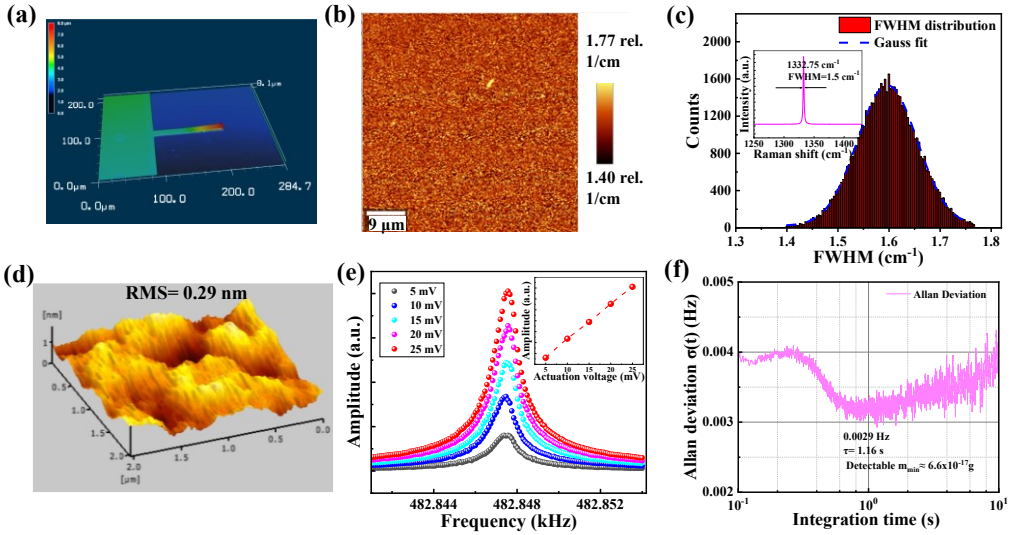

Figure 1. (a)3D optical image, (b-c) Raman measurements, (d) surface morphology, (e) resonance frequency spectra, and Allan deviation of SCD MEMS.

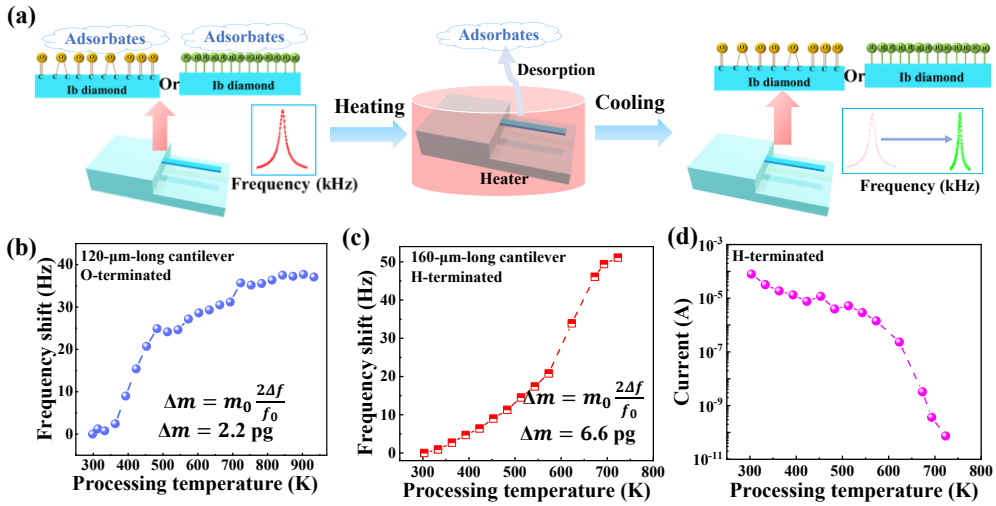

Figure 2. (a) Schematic diagrams of surface desorption. (b-c) Frequency shift of O- and H-terminated diamond MEMS, and (d) Surface conductivity of H-terminated diamond dependence on processing temperatures.

4. Conclusion

In conclusion, single-crystal diamond (SCD) MEMS resonator was proposed to disclose the surface desorption process of adsorbates on O- and H-terminated diamond. The equivalent thickness of the adsorption layer the O- and H-terminated diamond was ~0.4 nm and ~0.9 nm, respectively. This work discloses that MEMS provides a precise insight into the surface nature of the semiconductor.

References

[1] K. Gu et al., Carbon, 2024, 225: 119159; [2] M. Liao et al., Adv. Mater., 2010, 22(47): 5393.