

## Atomic-resolution Noncontact Atomic Force Microscopy in Ambient Conditions

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We report on atomic resolution noncontact atomic force microscopy operated in ambient conditions. We have used a trident-shape quartz crystal resonator oscillating at 1 MHz with a high spring constant of  $4 \times 10^5$  N/m. There are several advantages in employing the quartz tuning fork over the use of the cantilever: The tuning fork has (i) a high Q-value ( $10^3 \sim 10^5$ ), (ii) small oscillation amplitude (0.01 ~ 0.1 nm), and (iii) low dissipative power ( $\sim 1$  nW).

As a force sensor, a micro-fabricated Si cantilever tip with a 10 nm radius was glued, with its long flexible arm lever detached, to the center prong of the trident tuning fork (Fig. 1). The length of the protruded cantilever tip is about 15  $\mu\text{m}$ . The dithering amplitude of the probe is measured as a function of the distance  $D$  between the tip and the substrate, as shown in Fig. 1.

Figures 2 and 3 present the atomic resolution images of the cleaved clean mica and the HOPG sample, respectively, obtained in ambient condition. The AFM images reflect the sample topography that can be obtained in noncontact tapping mode. Therefore, our force sensor incorporating an extremely high stiffness may be of much important for noncontact operation of the genuine atomic resolution AFM even in ambient conditions.

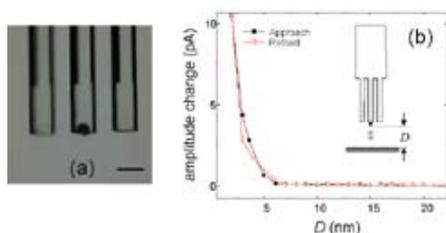


Fig. 1 (a) The trident quartz tuning fork (scale bar is 100  $\mu\text{m}$ ). The 10 nm Si tip is attached to the center prong.

(b) Approach-retraction curve in dry conditions.

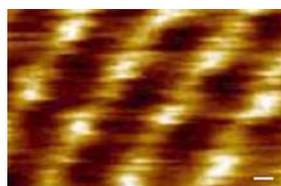


Fig. 2 The atomic resolution AFM image of the cleaved clean mica (scanning area of  $1.5 \times 1 \text{ nm}^2$  obtained during 10 s scan). The scale bar is 1  $\text{\AA}$ .

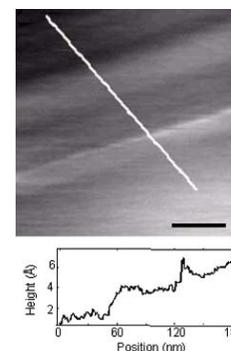


Fig. 3 AFM image of a cleaved HOPG sample, showing 3 to 4  $\text{\AA}$  atomic step (scale bar is 50 nm).

### References

- [1] Y. Seo, H. Choe, and W. Jhe, *Appl. Rev. Lett.* **83**, 1860 (2003).