Elasticity measurement of water meniscus using small-amplitude AFM

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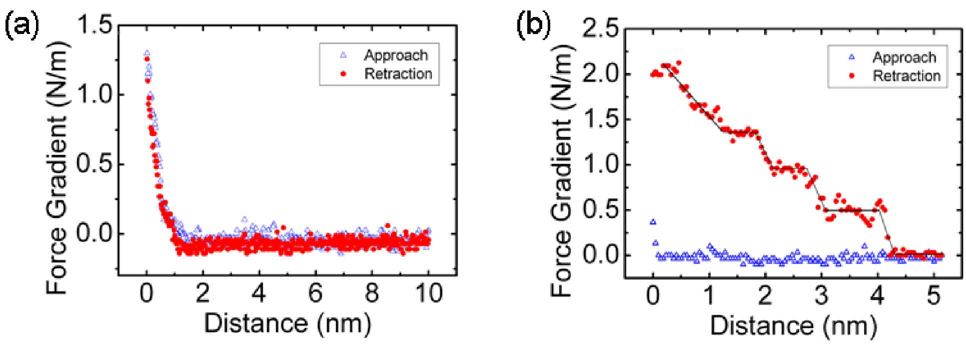
We have employed a high-resolution non-contact atomic force microscope in air and achieved the spontaneous formation of a nanometric liquid column between a hydrophilic substrate surface and a Si cantilever tip. Also, we performed the sensitive measurement of the elastic property (or the force gradient) of the thin water column during its mechanical stretch through force gradient spectroscopy.

A trident-type quartz crystal was employed as a force sensor and a commercial cantilever tip was attached at a prong of the quartz crystal sensor [1]. The resonance frequency of this quartz crystal is approximately 1 MHz. And the experiment was performed in amplitude detection mode using a radio frequency lock-in amplifier (SR844). The oscillation amplitude was about 0.1 nm and the frequency shift was estimated from the measured amplitude reduction based on a pre-measured frequency response spectrum of the tip-attached trident type quartz crystal force sensor. In contrast to a conventional micro-fabricated cantilever-based AFM used either in contact or noncontact operation mode, our AFM tip is stiff enough ($k \sim 10^5$ N/m) to pull the condensed water molecules, as well as sensitive enough to measure the small changes of force gradient (~ 0.1 N/m).

Figure (a) shows the measured force-gradient distance curve at a relative humidity of 2% and no hysteresis related to water meniscus was observed. The silicon cantilever tip and a freshly cleaved mica substrate were used. On the contrary, in figure (b) the force-gradient data was obtained at a relative humidity of 15% and a force-gradient hysteresis related to water meniscus formation was observed. Interestingly, step-wise force gradient change was observed when the hydrophilic tip was retracted after approaching the surface within a pre-defined distance.

The work may give another application of noncontact atomic force microscope and provide a novel experimental tool for studying the kinematics of the condensed or adsorbed liquids on surfaces, which is of fundamental and technological interest in surface science and engineering.



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