Development of a work-detection method for transient phenomena using atomic force microscope

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The atomic force microscope (AFM) manipulates atoms on surfaces by reducing the energy barrier to another adsorption site with a tip proximity [1, 2, 3]. A density-functional-theory calculation implies that the energy barrier remains finite for the atom manipulation at room temperature [3]. This has been considered that thermal fluctuation helps to overcome the residual energy barrier. A direct measurement of the work required for the atom manipulation would give a quantitative evaluation of the thermal fluctuation. In the frequency-modulation atomic force microscope with constant amplitude (FM-AFM), the work done by a cantilever is measured from the change in the cantilever excitation voltage. However, this method cannot be applied to transient phenomena like atom manipulation because the method requires the atom's motion to synchronize with the cantilever's oscillation.

We are developing a work-measurement method for transient phenomena using frequency-modulation atomic force microscope with constant excitation (CE-AFM). In CE-AFM, the time for the amplitude feedback is absent, and therefore, a fast phenomenon, such as atom manipulation, should appear in the amplitude change. To test the method, bias pulses were applied between the tip and the sample to mimic transient phenomena. As Fig. 1 shows, the work done by a bias pulse was successfully detected. With weaker intensities of bias pulse, we evaluated that the resolution of the work detection is around 100 meV. This value is close to the force hysteresis in atom manipulation [4]. Consequently, it is anticipated that the current CE-AFM is sufficiently precise to detect the work for atom manipulation.

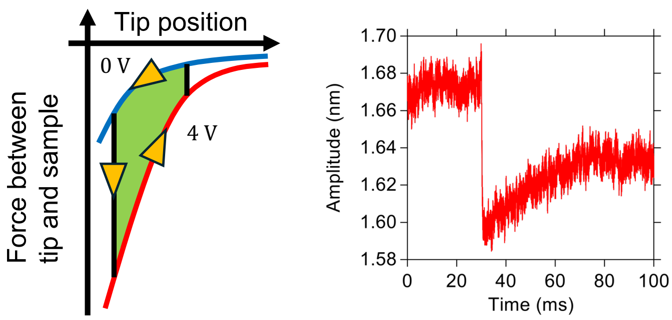

Figure 1. (left) Force hysteresis when a bias pulse is applied. (right) Change in the oscillation amplitude showing the cantilever's energy loss associated with a bias pulse.

References

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