RIKEN Seminar

“Dynamic force spectroscopy: *from one-dimensional to three-dimensional, from large amplitude to ultra-small amplitude, and from one-vector to two-vector force detection*"

Dr. Shigeki Kawai

Department of Physics, University of Basel,
Klingelbergstrasse 82, 4056 Basel Switzerland

Time & Date : July 5, 2011 3:00-4:00 PM

Place : Seminar room, 2nd floor, The Nanoscience Joint Laboratory, RIKEN

Since the first systematic achievement of atomic resolution in 1995[1], frequency modulation dynamic force microscopy (FM-DFM) has become a reliable technique for imaging surfaces with atomic resolution. The shift of resonance frequency of the cantilever, caused by the tip-sample interaction, is used for controlling the tip-sample distance. However, the interpretations of such images are, in principle, complicated because the short- and long-range interactions coexist. Therefore, a site-dependent frequency vs. distance measurement, the so-called dynamic force spectroscopy (DFS), is mandatory to understand the tip-sample interactions. DFS was first demonstrated at drift-free low temperature [2], and recently even at room temperature while compensating the thermal-drift [3]. This drift compensation technique is successfully applied for three-dimensional DFS measurements [4].

In the case that the oscillation amplitude is larger than the width of hysteresis loop, the force extraction via the frequency shift is independent to the magnitude of the oscillation amplitude. [5] However, more correctly, the force should be called “dynamic force” because several metastable force distance curves upon approach and retract exist in one cantilever oscillation cycle, and the probabilities of jumps among the states are, in principle, immeasurable. Therefore, setting an ultra-small amplitude of less than 100 pm, which can be realized by using a tuning fork sensor [6] and a second flexural mode of a Si cantilever [7], is very important. Since the front-most atom in the tip always stays in short-range force regime, a thermal-equilibrium atomic-contact can be established, but infrequent jumps of the tip condition make an imaging condition unstable. [8] In order to overcome this instability, bimodal DFM with first (large amplitude) and second (ultra-small amplitude) flexural resonance modes was demonstrated, and a higher imaging contrast were achieved in the second flexural frequency shift map, compared to that obtained by conventional DFM with a large oscillation amplitude. [9] The highest sensitivity to the short-range interaction can be achieved by the detection of the lateral force with the torsional resonance mode [10] because only the site-dependent force (mainly short-range force) gives rise to the lateral force. [11] This two-vector force detection was incorporated into the three-dimensional force mapping (Figure).

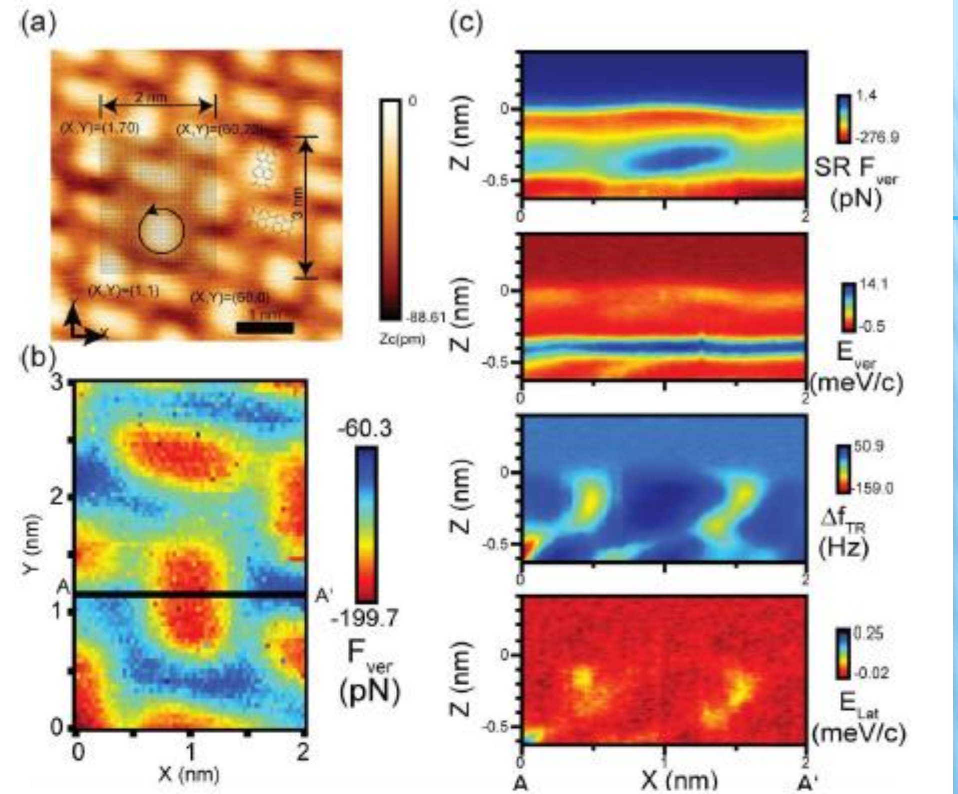

Figure (a) Topograpic image of the PTCDA self-assemby on Cu(111). The inset shows the position of the 3D-DFS measurement. (b) The constant height image of the short-range force, extracted via the measured frequency shift of the second flexural mode. (c) Two dimensional map of the short-range force, vertical energy dissipation, torsional resonance frequency shift, and latera energy dissipation across A-A' in (b).

[1] F. J. Giessibl, Science **267**, 68 (1995).
[2] M. A. Lantz, H. J. Hug, R. Hoffmann, P. J. A. Van Schendel, P. Kappenberger, S. Martin, A. Baratoff, and H. J. Guntherodt, Science **291**, 2580 (2001).
[3] Y. Sugimoto, P. Pou, M. Abe, P. Jelinek, R. Perez, S. Morita, and O. Custance, Nature **446**, 64 (2007).
[4] S. Kawai, Th. Glatzel, S. Koch, A. Baratoff, and E. Meyer, Phys Rev B **83**, 035421 (2011).
[5] S. Kawai, Th. Glatzel, S. Koch, B. Such, A. Baratoff, and E. Meyer, Phys. Rev. B **80**, 085422 (2009).
[6] F. J. Giessibl, Appl. Phys. Lett. **73**, 3956 (1998).
[7] S. Kawai, S. Kitamura, D. Kobayashi, S. Meguro, and H. Kawakatsu Appl. Phys. Lett. **86**, 193107 (2005).
[8] S. Kawai and H. Kawakatsu, Phys. Rev. B **79**, 115440 (2009).
[9] S. Kawai, Th. Glatzel, S. Koch, B. Such, A. Baratoff, and E. Meyer, Phys. Rev. Lett. **103**, 220801 (2009).
[10] S. Kawai, Th. Glatzel, S. Koch, B. Such, A. Baratoff, and E. Meyer, Phys. Rev. B **81**, 085420 (2010).
[11] S. Kawai, N. Sasaki, and H. Kawakatsu, Phys. Rev. B **79**, 195412 (2009).

Contact：Taketoshi Minato（Kim Surface & Interface Science Lab.）Ext. 8713 tminato@riken. jp