SITE-SPECIFIC FORCE SPECTROSCOPY AT ROOM TEMPERATURE USING ATOM TRACKING TECHNIQUE

Masayuki Abe,Yoshiaki Sugimoto, Kazutoshi Mizuta, Kenichi Morita, Óscar Custance and Seizo Morita
Graduate School of Engineering, Osaka University,
2-1, Yamada-Oka, Suita, Osaka 565-0871, Japan
masa@ele.eng.osaka-u.ac.jp

Noncontact atomic force microscopy (NC-AFM) [1] is a technique that can image atoms on metal, semiconductor, and insulator surfaces. In imaging single atoms, force spectroscopic measurements play an important role for digging out the nature of the atomic interaction force between the tip apex and the surface. Quantitative force as a function of tip-sample distance can be extracted from frequency shift versus distance (Δf-z) curves [2]. One can also expect site-specific information using the force spectroscopy when probing single atoms. At low temperature environment, quantitative site-specific forces that were extracted from frequency shift have revealed surface chemical and electrostatic interactions. At room temperature, however, due to thermal drift, site-specific force spectroscopy has not been demonstrated.

In this contribution, we propose a novel method in which quantitative site-specific force spectroscopy can be done at room temperature. The atom tracking technique [3] that has been mainly used in for studying diffusion process in combination with scanning tunneling microscopy (STM) was modified for compensating the thermal drift in force spectroscopic measurements based on NC-AFM.

In Fig. 1, we have performed the atom tracking using the NC-AFM on the Si(111)-(7x7) surface at room temperature. After obtaining an NC-AFM topographic image of the Si(111)-(7x7) surface (Fig. 1(a)), we positioned the tip on the corner adatom indicated by the arrow, and started the atom tracking. During the tracking, two feedbacks compensated the thermal drift updating signals for the lateral orthogonal directions of the piezoelectric scanner (Fig. 1 (c)). Sixty-one minutes after the atom tracking was started, we opened the atom tracking feedback loops, and obtained the NC-AFM topographic image again (Fig. 1 (b)). An adsorbate with a circle is seen at the same position in both AFM topographic images, before and after the tracking. The distance compensated during the tracking was 130Å (2.3Å/min of drift rate in this experiment) (Fig. 1 (c)). The spatial resolution of the positioning control was within 0.2Å peak-to-peak as shown in the inset of Fig. 1 (c). Its reproducibility is comparable to the tracking experiments using STM. We measured a number of Δf-z curves on a corner adatom of the Si(111)-(7x7). Each of them was measured on the top of the corner adatom just after the feedback loops of the atom tracking were opened. All of the Δf-z curves overlapped perfectly. This means that measurements of the site-specific Δf-z curves can be done even at room temperature using the atom tracking. By averaging fifty Δf-z curves obtained using the atom tracking, we were able to reduce the noise level of the curve as shown in Fig. 2 (grey solid line). Comparing with the non-averaged Δf-z curve (black solid line), noise level is improved by more than 10 times (see inset in Fig. 2). Since AFM tip can be fixed on top of the probed atom using the atom tracking, this technique can be used for the atom manipulation at room temperature in which precise positioning of the AFM tip is needed [4].

References:

[1] S. Morita et. al. (eds), "Noncontact Atomic Force Microscopy" (Springer-Verlag, Berlin, 2002).
[2] F. J. Giessibl, Phys. Rev. B, **56** (1997) 16010.
[3] D. W. Pohl et.al., Rev. Sci. Instrum., **59** (1988) 840.
[4] Y. Sugimoto et.al., Nature Mat., **4** (2005) 156.

Figures:

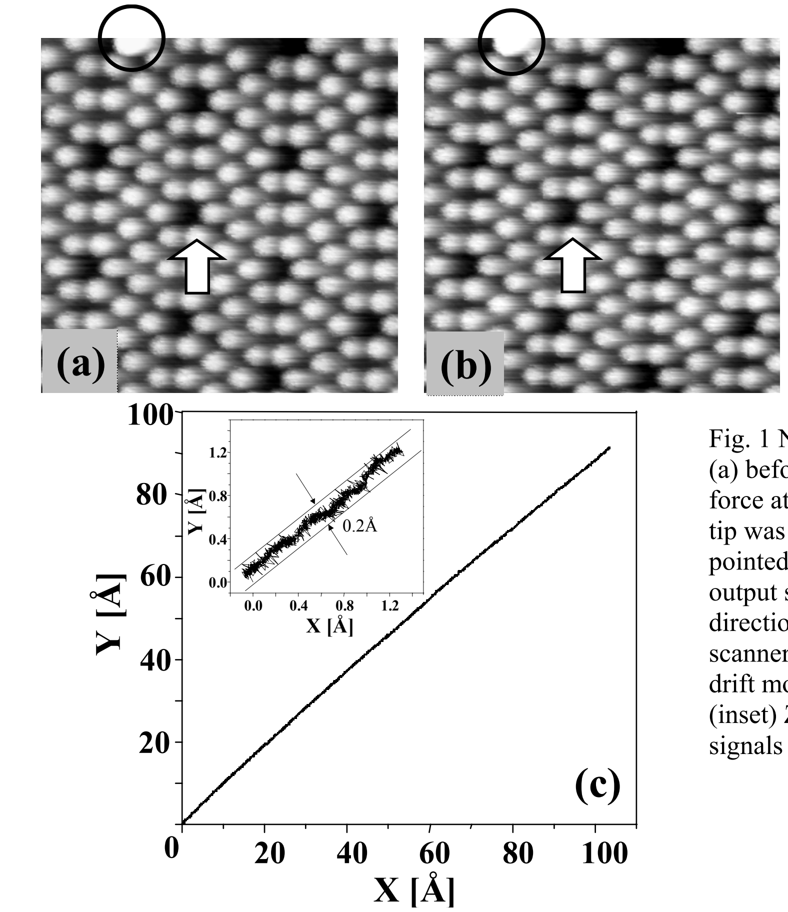

Fig. 1 NC-AFM topographic images of (a) before and (b) after 61 minutes of force atom tracking, respectively. AFM tip was fixed on the corner adatom pointed by the arrow. (c) Feedback output signals in the orthogonal directions (X and Y) of the piezoelectric scanner for compensating the thermal drift movement in the lateral direction. (inset) Zoom of the feedback output signals in X and Y directions.

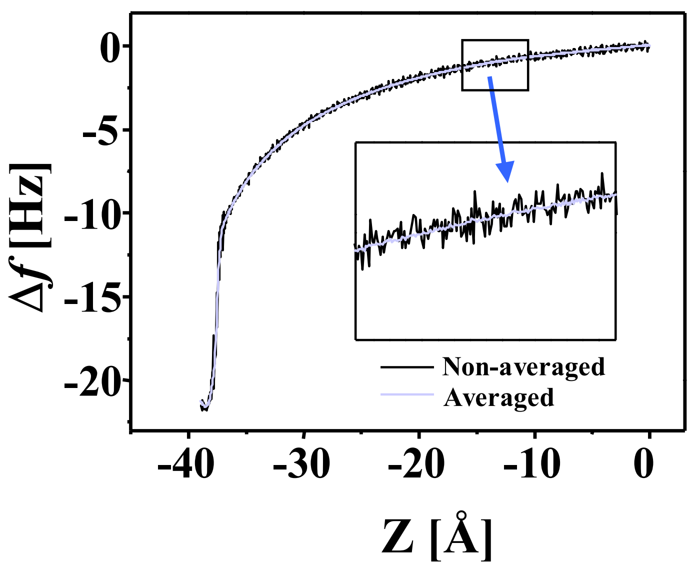

Fig.2 Averaged (grey solid line) and non-averaged (black solid line) Δf-z curves.