**Scanning interaction spectroscopy with changing bias voltage in noncontact AFM**

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For the last decade noncontact atomic force microscopy (nc-AFM) has successfully been applied to imaging of various surfaces. Nc-AFM has unrivaled features for surface spectroscopy utilizing the force interaction between an nc-AFM tip and a sample. We have investigated bias dependence of nc-AFM images and tunneling current images, which were simultaneously obtained [1,2]. From our results, it was concluded that both a strong force interaction and a large electron tunneling arose from the overlapping of the wave functions between the electronic states of the tip and the sample at the same energy level under a certain bias voltage, as shown in Fig. 1. If a strong attractive force originates from the chemical hybridization of the wave functions of the tip and the sample, it is probable that the electron tunneling through these states is also enhanced with quantum resonance. The degree of overlapping of the wave functions at the same energy level can change with the applied bias voltage, the band bending and the energy level shift induced by changing the atomic structure of the tip apex. In this study we present the spectroscopic curves of the interaction versus the bias voltage between a tip and a sample.

A home-made UHV nc-AFM with a piezoresistive Si cantilever with a [001]-oriented Si tip was used for samples of a Si(111)7x7 and a Ge thin film grown on Si(111)7x7. We have observed the nc-AFM images, the average tunneling current images and the damping energy images, simultaneously with changing bias voltage between the tip and the sample. At hundreds of points on the sample surfaces, we took the spectroscopic curves of the interaction, i.e., the frequency shift $\Delta f$ versus the bias voltage curves at a fixed separation between the tip and the sample. The curves exhibited prominent peaks deviated from parabolic characteristics, indicating the quantum resonating between the tip and the sample at a certain voltage. The features of the spectroscopic curves will be discussed.

[1] T. Arai and M. Tomitori, Appl. Surf. Sci. **157**, 207 (2000).
[2] T. Arai and M. Tomitori, Jpn. J. Appl. Phys. **39**, 3753 (2000).

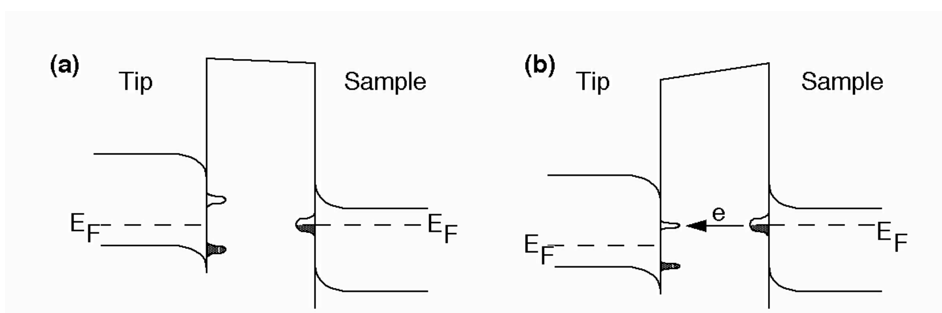


**Fig. 1** Schematic energy diagram of a [001]-oriented Si tip and a Si(111)7x7 surface. **(a)** at a bias voltage of 0V between the tip and the sample. **(b)** by applying a bias voltage the energy level of empty surface states of the tip is lowered to the same level with the half-filled surface states near the Fermi level of the sample. The wave functions of both electronic states at the Fermi level of the sample overlap and resonate, leading to a strong interaction and tunneling.