Clarification of atomic bonding stiffness of Ge(001) dimer atoms with FM-AFM

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The individual atomic bonding state on a surface is being reconsidered as an important quantity since it associates to the surface stress/strain and is extremely sensitive on phenomena induced at the surfaces and interfaces. From the force curve measurement by non-contact atomic force microscopy (NC-AFM), the harmonic bonding state of a surface atom can be guessed from the force gradient at the force zero point. However, it seemed experimentally difficult to probe only the intrinsic bonding state on a surface, k_s, because the detected interaction has other contributions from the back bonding state of the tip apex atom, k_t, as well as the interaction between the tip apex atom and the surface atom, k_g.

In order to investigate the intrinsic bonding state at the atomic scale, we measured the force distribution above Ge(001) dimer atoms with frequency modulation AFM. The buckling dimer of Ge(001) is prospected to have different elastic property of between the buckling up and down dimer atoms. Considering that k_t and k_g are invariant, the intrinsic bonding state of the dimer atoms is detectable as a compliance difference between them. All experiments were carried out in a home build atomic force microscopy apparatus using a tungsten coated cantilever as a force sensor under ultra-high vacuum at room temperature [1].

Figures (a) and (b) represent the two dimensional frequency shift map taken above the buckling up and down dimer atoms and the reproduced tip-surface short range force map. Figure (c) is the extracted force curve distributions above the dimer atoms. The harmonic compliance difference of between the buckling up and down dimer atoms is obtainable from the Morse force fitting to the force distribution data. We found that the bonding state between the buckling up dimer atom and the substrate surface is 5.3×10^{-3} m/N stiffer than that for the down dimer atom. This type of elastic property distribution acquisition at the atomic scale has never been reported experimentally.

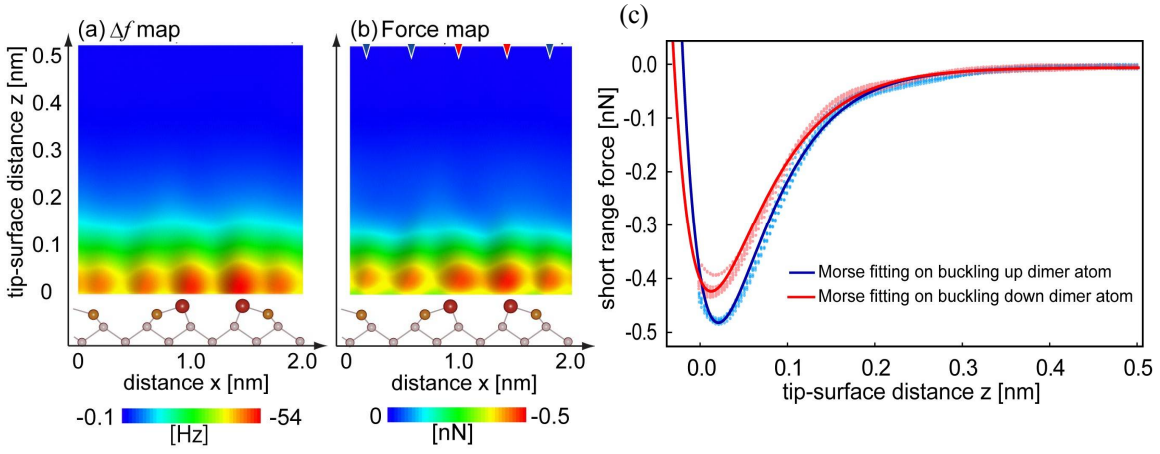

Figure: (a) Two dimensional Δf map on Ge(001) dimer atoms taken above the buckling dimer atoms. (b) The short range force map reproduced from the Δf map data by calculation with the Sader's formula. (c) The Morse fitted short range force curves above the buckling up and down dimer atoms.

Reference

[1] Y. Naitoh, Y. Kinoshita, Y. J. Li, M. Kageshima and Y. Sugawara, *Nanotechnol.* **20**, 264011 (2009).