Identification of subsurface atom species utilizing NC-AFM

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Noncontact atomic force microscope (NC-AFM) can image the atomic features of various surfaces. Recently, we found that it has a capability to identify or recognize atom species on the Ge/Si(111)7x7 surface. In the present experiments, we further investigate the capability to identify the atom species under the surface. Then, for the first time, we found that the NC-AFM can identify the subsurface atom species such as B and Si atoms.

It is well known that B atoms easily diffuse into the Si bulk crystal at high temperature due to its small atomic radius. By using this nature of B atom, the Si(111)$\sqrt{3}\times\sqrt{3}$-B substrate with different atom species under the surface was prepared by B_2O_3 evaporation onto a clean Si(111)7x7 surface at 570°C under $5x10^{-9}$ Torr for 10 minutes and its substrate annealing at 800°C for 10 minutes. The experiment was performed in our NC-AFM apparatus under UHV condition ($3x10^{-11}$Torr). As a force sensor, a conductive Si cantilever with sharpened tip was adapted. The spring constant and mechanical resonance frequency of the cantilever was typically 40 N/m and 160 kHz, respectively. The tip apex was cleaned by Ar^+ ion sputtering in situ and hence has reactive dangling bond.

Figure shows an NC-AFM image of the Si(111)$\sqrt{3}\times\sqrt{3}$-B surface. Two types of bright spots are visible. The brighter spots correspond to the Si-T_4 structure with dangling bond orbit, where both topmost and its subsurface atoms are Si atoms. On the other hand, the darker spots correspond to the B-S_5 structure with empty orbit, where topmost and its subsurface atoms are Si and B atoms, respectively. This image contrast is due to that the force interaction between dangling bond orbit and dangling bond orbit is stronger than that between dangling bond orbit and empty orbit. This experimental result suggests that contrast of the NC-AFM images change depending on the atom species under the surface. Thus, we found that the NC-AFM has a capability to identify or recognize atom species under a sample surface.

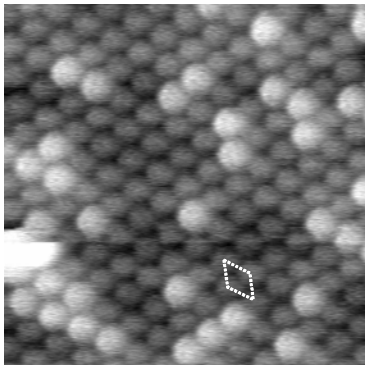

Figure Noncontact AFM image of Si(111)$\sqrt{3}\times\sqrt{3}$-B surface. The brighter and darker spots correspond to Si-T_4 and B-S_5structures, respectively. Scan size is 7.7 nm×7.7 nm.

[1] S. Morita et al., Scanning Probe Microscopy: Characterization, Nanofabrication and Device Application of Functional Materials (Kluwer Academic Publishers, 2005), 173.