Surface potential and capacitance image of molecules on insulating substrates

T. Matsumoto[1,2], F. Yamada[1], and T. Kawai[1,2]
[1]ISIR, Osaka University, Ibaraki, Osaka 567-0047, Japan
[2]CREST, JST, Kawaguchi, Saitama 332-0012, Japan
matsumoto@sanken.osaka-u.ac.jp

A lot of research groups are challenging to fabricate molecular devices by using self-assembly of molecules. For this purpose, the knowledge of local surface potential in nanoscale is essential to understand and control the driving force of the self-assembly. However, it is very difficult to measure the local electric properties of the molecular system for molecular devices because the molecular devices are created on an insulating substrate.

Recently we found that potential images of surface molecules on insulating substrates can be obtained by non-contact AFM in high-resolution. This finding is beyond the understanding based on Kelvin force microscopy because the surface potential of insulating substrate is indefinable. Our experiments are also distinguished from scanning capacitance microscopy because the charge of surface molecules is almost negligible in compared with that of bulk substrate.

We report here high-resolution surface potential and capacitance images of DNAs, proteins, synthetic molecules, and gold nanoparticles on an insulating substrate. The experiments based on NC-AFM realize high-sensitive detection of local electrostatic forces preventing charge injection caused by tip-sample contact.

Figure 1 shows (a) topography and (b) potential image of DNA network on a mica substrate. In Fig. 1(b), DNA network is observed as bright contrast indicating that DNA is negatively charged as compared with the substrate surface. The potential measurement resolves thin features less than 10 nm as indicated by arrows. Furthermore, gold nanoparticles of 5 nm are clearly observed by potential measurement (not shown).

To discuss about the contrast mechanism of the surface potential imaging on insulating substrate, we calculate electric filed just below the tip apex using finite element method. The calculation results in Figure 2 reveals that the electric field just below the tip apex is enough strong to detect the local charge on surface adsorbate even if the substrate is insulator.

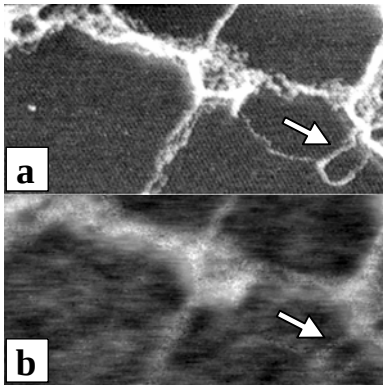

Fig. 1. (a) topography (b) potential image of DNA on mica substrate. Scan size: 0.5 μm×1.0 μm

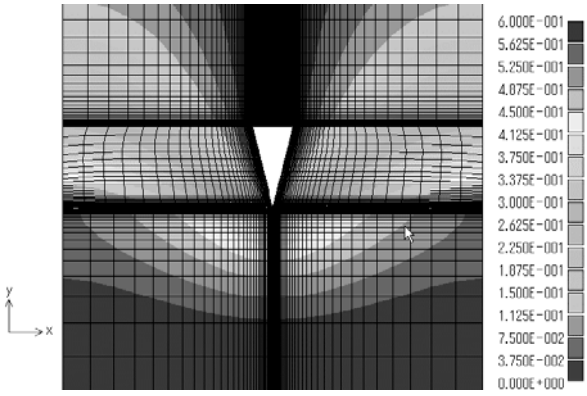

Fig. 2 . Electric filed just below the tip apex calculated by finite element method.