Local Potential Measurements of Biological Systems on Insulating Substrate by Open-Loop Electric Potential Microscopy in Liquid

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Measurement technique for local potential distribution at solid/liquid interfaces is essential for understanding the mechanisms of biological and electrochemical processes. Kelvin probe force microscopy (KFM) has been used for local potential distribution measurements in air and vacuum. However, KFM cannot be used in liquid due to electrochemical reactions and redistribution of ions and water caused by the application of dc bias voltage between a tip and sample. Recently, we have developed open-loop electric potential microscopy (OL-EPM) [1] that can measure local potential distribution in liquid. In this method, only an ac bias voltage with a high modulation frequency is applied between a tip and sample. Owing to the slow time response of electrochemical reactions and redistribution of ions and water, the application of the ac bias voltage with a high modulation frequency can prevent these problems. Potential values are calculated from the amplitudes of the first and second harmonic cantilever oscillations induced by the ac bias voltage.

In the previous study [1, 2], OL-EPM measurements have been performed on conductive substrates (e.g. graphite). However, AFM imaging on biological systems are mostly performed on an insulating substrate such as mica or glass. Thus, we investigated the possibility of potential measurements on insulating substrates by OL-EPM.

The ac electric field applied to the tip surface is greatly reduced by the existence of insulator between the bottom electrode and the conductive tip. To detect the weak electrostatic force, we have reduced the thickness of the mica substrate to as thin as 5 μm and used relatively soft cantilever ($k \approx 0.1$ N/m). In addition, we have introduced a correction factor for compensating the reduced ac electric field. With these modifications, we have obtained topographic and potential images of DNA adsorbed on a mica substrate (Fig. 1). The potential image shows that the potential of the negatively charged DNA is 210 mV lower than that of the mica substrate decorated with Ni^{2+} ions. The result shows that potential imaging is possible even on an insulating substrate although the spatial resolution is not as high as that obtained on conductive substrate.

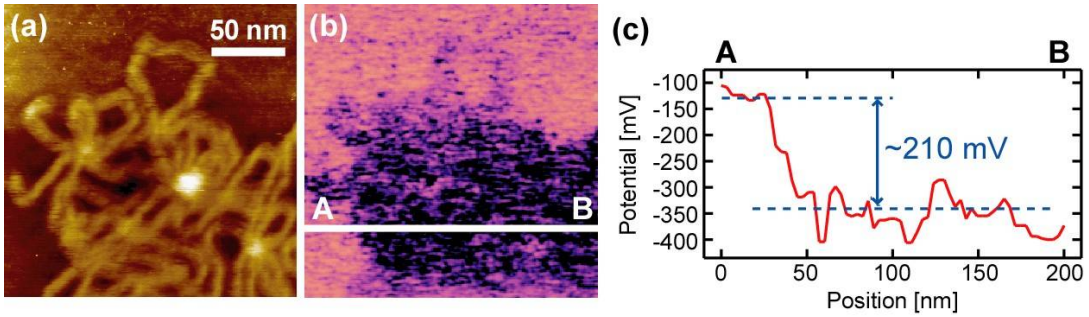

Figure 1. (a) Topographic and (b) potential images of DNA adsorbed on mica taken in 1 mM HEPES/0.1 mM $NiCl_2$. (c) Potential profile measured along Line A-B in (b).

References

[1] N. Kobayashi, H. Asakawa, and T. Fukuma, Rev. Sci. Instrum. **81** (2010) 123705.
[2] N. Kobayashi, H. Asakawa, and T. Fukuma, J. Appl. Phys. **110** (2011) 044315.