

## Scanning Surface Potential Microscopy of Light-Induced Electric Potential from Photosystem I and Photosystem I Reconstituted Proteoliposomes

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Although both processes of vision and photosynthesis are initiated by absorption of visible light, they are chemically and energetically different. In vision, light triggers a thermodynamically downhill reaction that is preloaded by dark metabolism. Photon absorption by rhodopsin activates a G-protein cascade leading to cyclic guanosine monophosphate (cGMP) hydrolysis, which in turn closes cation-specific channels to generate a nerve signal. In photosynthesis, on the other hand, absorption of photons by the special reaction center chlorophylls in Photosystems I and II (PSI, PSII) triggers charge separations across the photosynthetic membrane. This charge separation generates a voltage that is the source of Gibbs energy for the thermodynamically uphill reactions of green plant photosynthesis: oxidation of water to molecular oxygen and reduction of atmospheric carbon dioxide to sugars. We have presented a hybrid system, a new reaction that demonstrates photoactivation of mammalian cells with a plant photosynthetic light sensory system [1]. In this scheme, mammalian cells that possess no photoactivity are changed into photosensitive cells after the treatment with the PSI reaction centers, which were delivered by PSI proteoliposomes.

By using the scanning surface probe microscopy (SSPM) as a diagnostic tool, we report here the measurements of the surface potential of hydrogenated soy phosphatidylcholine/cholesterol proteoliposomes with reconstituted, functional photosystem I reaction centers. The PSI-proteoliposomes were imaged with the combined techniques of tapping-mode atomic force microscopy (AFM) and SSPM, illustrated in Fig. 1 and Fig.2. The apparent range of liposome diameters was 70–100 nm. The AFM-SSPM technique uses a slender cantilever probe with a slightly blunt apex. It provides accurate voltage measurements but exaggerates lateral dimensions. The theory for this technique has been developed by Jacobs *et al.* [2]. Lee *et al.* [3-4] provide additional information on the techniques used for working with single PSI reaction centers. The one-to-one correspondence between the AFM and SSPM liposome images is evident in Fig. 1 and Fig.2. The images were obtained under illumination with a diode laser at 670 nm, near the absorption maximum of chlorophyll (671 nm) in PSI-proteoliposomes. The AFM image of Fig. 1 illustrates the gross geometric structure of the PSI-proteoliposome, whereas the electrostatic SSPM image [Fig. 2] reveals a finer grained pebble-like structure in the surface potential map, suggesting a close packing of the PSI reaction centers in the liposome membrane. The surface potential of the proteoliposomes was found to be in the range of 10-70 mV with particle-like structures on each liposome's surface which is ~1 mV.

### References

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- [2] H. O. Jacobs, et al., J. Appl. Phys. 84 (1998).
- [3] I. Lee et al., J. Phys. Chem. B 104 (2000) 2439.
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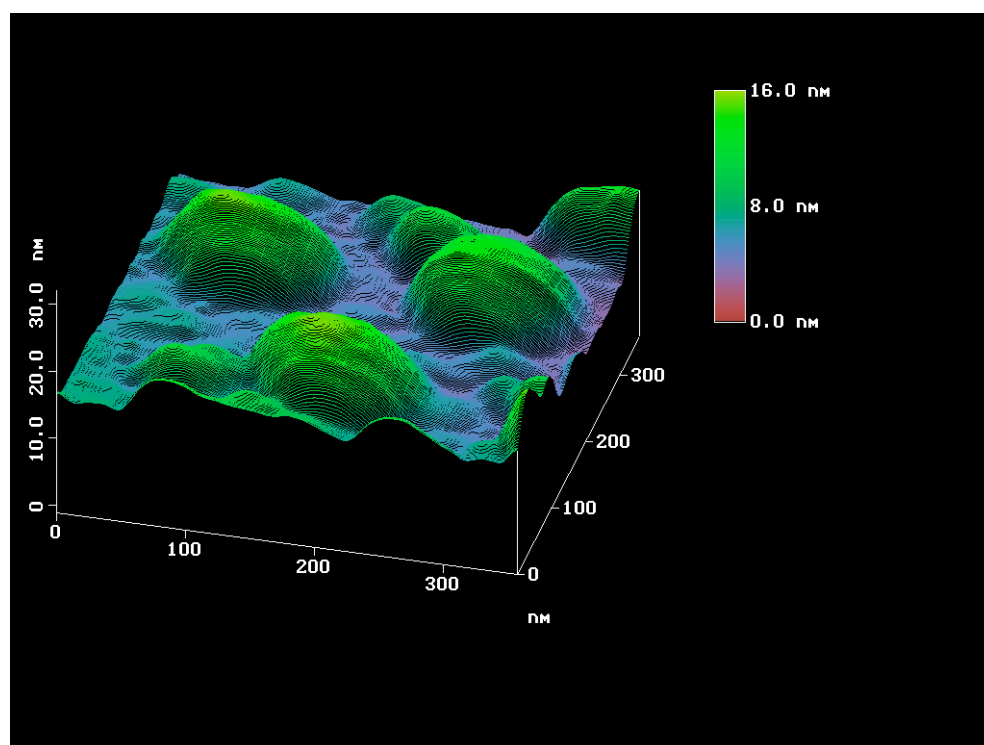


Fig. 1. PSI-proteoliposomes imaged by tapping-mode AFM.

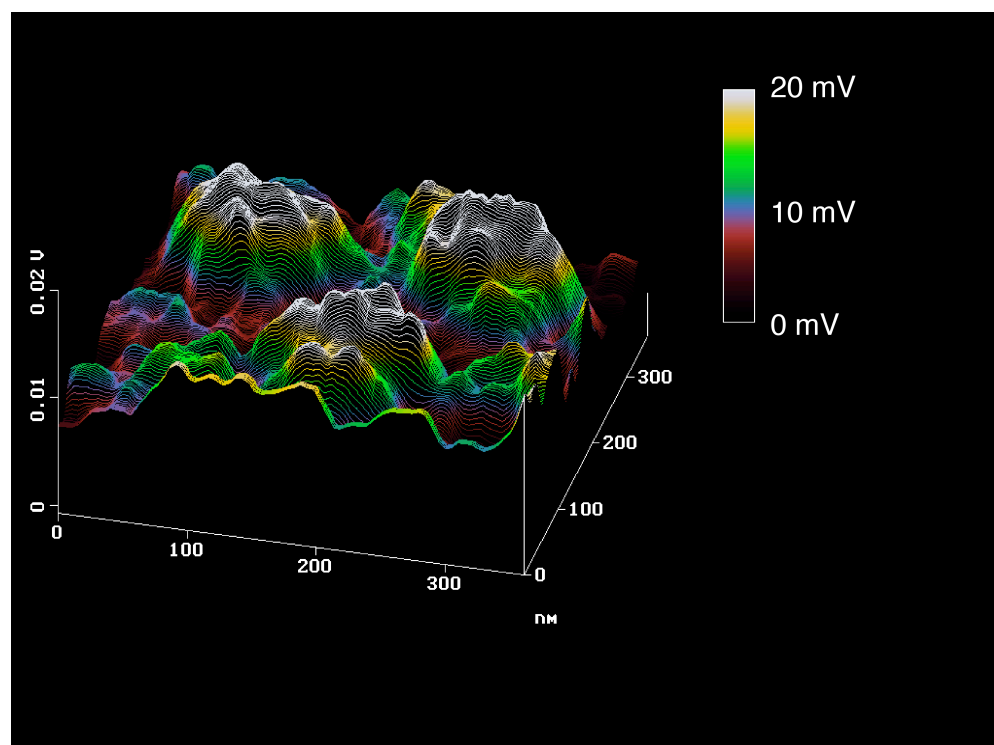


Fig. 2. PSI-proteoliposomes imaged by lift-mode SSPM.