High Resolution Imaging of Protein 2D Crystal Using Frequency-Modulation Atomic Force Microscopy (FM-AFM) in Liquid Environment

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Dynamic force microscopy, which utilizes the resonance enhancement of the force sensitivity by oscillating the cantilever around the resonance frequency, is a very powerful operating mode for atomic force microscopy. True atomic or molecular resolution of frequency modulation atomic force microscopy (FM-AFM) has been achieved on various surfaces such as metal, semiconductor, alkali halide and etc, in ultra high vacuum since mechanical Q-factor of the cantilever is very high in such environment. However, in liquid environment, mechanical Q-factor of the cantilever is dropped to about 1 - several 10th due to the viscosity dumping of the liquid, hence atomic resolution imaging is not achieved. Recently, a low noise cantilever deflection sensor has been developed by Yamada et.al. [2]. The low noise nature of the deflection sensor makes it possible to obtain a maximum frequency sensitivity limited by thermal Brownian motion of the cantilever.

In this study, FM-AFM in liquid environment is applied to two kinds of protein 2D crystal sheet whose structure and function are well known, the purple membrane from *Halobacterium Salinarum* and photosynthetic membrane from *Rhodopsudomonas viridis*, to assess the accuracy of high resolution FM-AFM images. From purple membrane imaging, constant height topography exhibited a lateral resolution <1nm. On the purple membrane surfaces, FM-AFM constant frequency shift images were in agreement with published contact mode AFM image or tapping mode AFM images. [3-4] This demonstrates that FM-AFM has the ability to capture high resolution images and has sufficient sensitivity to image soft bio-molecule surfaces without deformation.

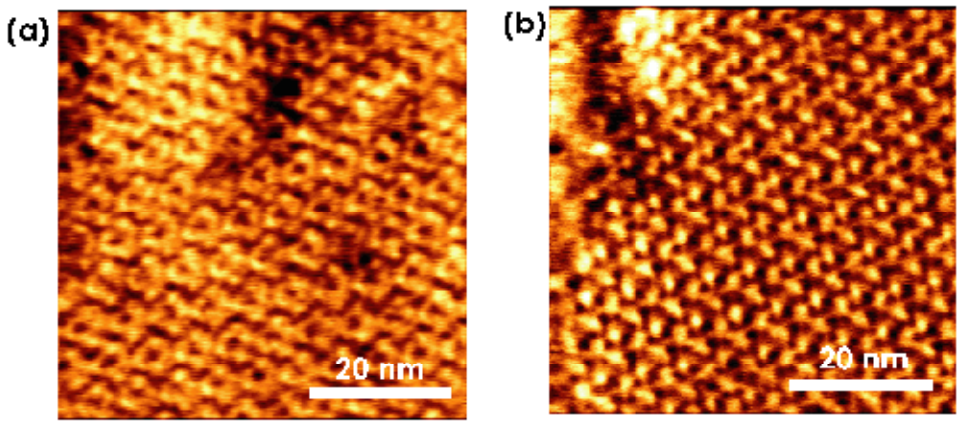

Figure FM-AFM images of purple membrane in 150 mM KCl and 10 mM phosphate buffer solution (image size: 80 x 80 nm). Constant frequency shift image (a) (Δf = +205 Hz, Amplitude = 4.5 nm) and constant height image (b) (Δf = +174 Hz, Amp. = 3.7 nm) of the cytoplasmic purple membrane surface.

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