Molecular Resolution Investigations in Liquid by Frequency-Modulation Atomic Force Microscopy

Ken Nagashima[1]; Masayuki Abe[1]; Seizo Morita[1]; Noriaki Oyabu[2]; Kei Kobayashi[2]; Hirofumi Yamada[2]; Ryota Murai[1]; Hiroaki Adachi[3]; Kazufumi Takano[4]; Hiroyoshi Matsumura[5]; Satoshi Murakami[6]; Tsuyoshi Inoue[5]; Yusuke Mori[1]; Masahiro Ohta[7]; Ryohei Kokawa[7]

[1] Grad. School of Eng., Osaka Univ.; [2] Electronic Sci. & Eng., Kyoto Univ.; [3] SOSHO Inc.; [4] Adv. Sci. and Biotech., Grad. School of Eng., Osaka Univ.; [5] Appl. Chem., Grad. School of Eng., Osaka Univ.; [6] Grad. School of Biosci. and Biotech., Tokyo Insti. of Tech.; [7] Shimadzu Corporation

http://www.afm.eei.eng.osaka-u.ac.jp/

Atomic Force Microscopy (AFM) has been widely used for investigating a 3-dimensional nano-scale surface topograph. Especially, frequency modulation AFM (FM-AFM) is a powerful method for imaging surfaces on an atomic scale (Morita et al., 2002). However, high-resolution FM-AFM imaging had been limited in vacuum environments. Therefore, studies of solution growth have been carried out by using contact mode AFM.

Recent progress in FM-AFM in liquids has opened a new way to direct visualization (Fukuma et al., 2005a; 2005b). We have developed a high-resolution FM-AFM working in liquids based on a commercially available AFM (Shimadzu: SPM-9600) and already succeeded to obtained atomic or molecular resolution in liquid (Rode et al., 2009).

Recently, we have tried to observe a protein (lysozyme) crystal in liquid. To make high quality protein crystals is very important for determining its molecular structure by X-ray diffraction analysis. We observed (110) face of tetragonal lysozyme crystal in saturated solution. A unit cell (11.2 x 3.8 nm) consists of 4 molecules with different orientations from one another. We observed it with molecular resolution for the first time although contact mode AFM, which is major mode for observing with high resolution, does not have molecular resolution (Li et al., 1999). In addition, we observed admolecule and point defect and we succeed to observe changes of them when the surface was covered with a single unit layer (height = 5.6 nm). In conclusion, FM-AFM is fruitful method for investigating growth mechanism at molecular level.

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