Dynamic Characterization Of Protein Electric Properties Associated With Structure Deformation By Conducting Atomic Force Microscopy

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Real-time characterizations of the structure deformation of metalloprotein, azurin, under various anisotropic compressions, were carried out using a conducting atomic force microscope (C-AFM) with a tip modification strategy. Compared to the tip dimensions, only a single or very few, protein molecules were attached to the conducting substrate, enabling to observe molecular-level electric and mechanical properties dynamically using the time-resolved C-AFM technique.

A full story of force-dependence of protein electricity is evidently revealed and theoretically analyzed. In particular, under very slight stress, typically less than 2 nN, the large interfacial conductance caused by the loose physical contact impeded an electron tunneling. The dielectric breakdown was, therefore, took place due to the charge accumulation on the protein molecules. A little higher tip force, 2~5 nN, push protein closer to the conducting substrate, facilitating the electron flow out from the molecular orbitals. The energy-resolved resonant electron tunneling can be observed with about 30% possibility. While a more reliable electric contact was achieved under a force higher than 5 nN, electrons may directly tunnel through the protein molecule.

Dynamic I-V behavior associated with protein deformation was analyzed with the modified Simmons model, giving the electron tunneling barrier height that reflects the protein atomic packing density and barrier length from which one can analyze the protein mechanic properties. The results showed two kinds of structure evolution involved in the protein deformation, which depend on the stress amplitude and the time scale. A protein driven by a small force perturbation deviated slightly from the relative equilibrium point, leading to a fast structure relaxation with time scale less than dozens seconds. Strong anisotropic compression resulted in a much-distorted structure, until decomposition on 1-hour time scale.

References:

[1] J. J. Davis, N. Wang, A. Morgen etc, Faraday Discuss, **131** (2006)167

Figures:

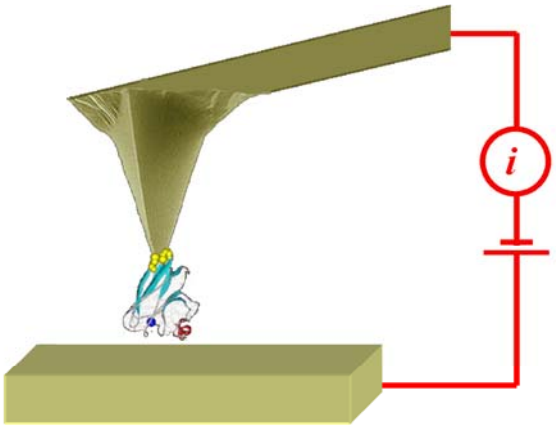

Fig. 1. Schematic representation of the conducting tip-oriented protein– conducting substrate junction, where a chemical bond is formed between tip and protein, whereas a physical contact between protein and conducting substrate.

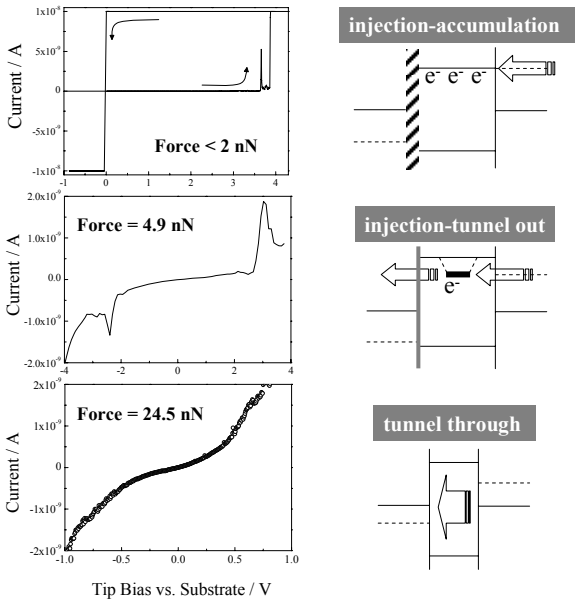

Fig. 2. I-V characteristics together with schematic representation of protein junction under different force loads of a) F < 2 nN; b) F ~ 4.0 nN; c) F = 24.5 nN.