STM Manipulation of Nanoscale Biological Molecules

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Scanning-tunneling-microscope (STM) is an instrument not only used to *see* individual atoms by imaging, but also used to *touch* and *pick-up* the atoms or to *hear* their vibrations by means of manipulation and spectroscopy [1]. In this perspective, the STM can be considered as the *eyes, hands* and *ears* of the scientists connecting our macroscopic world to the exciting atomic and nanoscopic world. Here, we use a variety of STM atom/molecule manipulation procedures to investigate the electronic and structural properties of nanoscale biomolecules such as chlorophyll-a, carotene and amyloid β/A4 precursor protein at an atomic level. As an example of STM manipulation, single molecule switching of chlorophyll-a is presented below.

Chlorophyll-a consists of a porphyrin unit as the 'head' and a carbon chain called 'phytyl' as the 'tail' (Figure 1 & 2). Chlorophyll-a is responsible for the green color in plant leaves and it is also a vital molecule in photosynthesis --one of the most important biological processes that convert sunlight into chemical energy in plants. Chlorophyll-a conforms into various shapes in the light harvesting reaction centers. Even though it is expected to play a central role in photosynthesis, the detailed nature of conformation changes is still an open question. Here, we are not only able to determine different conformations of single chlorophyll-a molecules but also to reversibly and selectively switch four conformations of the molecules on a Au(111) surface using the STM-tip, thereby a "four-step single molecule switching mechanism" is demonstrated for the first time (Figure 1 & 2). This conformational switching is realized by injecting tunneling electrons into the molecule and each switching step involves 60º bending of the chlorophyll-a tail (Fig. 2). Selective switching between two conformations produces a two-step current signal, which functions like a toggle-switch. This work demonstrates that the chlorophyll-a, an important molecule from the evolutionary standpoint, may also serve as a vital resource for the future nanobiotechnology applications. Our experiments also prove that STM manipulation is a novel powerful tool in probing and controlling conformations of nanoscale biomolecules at an atomic limit.

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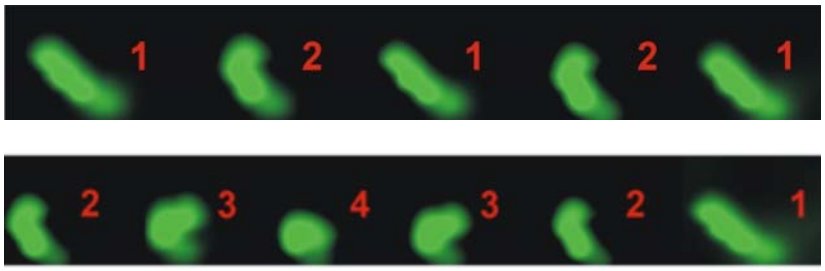

Figure 1. Snap shot images from a STM movie showing a manipulation sequence.

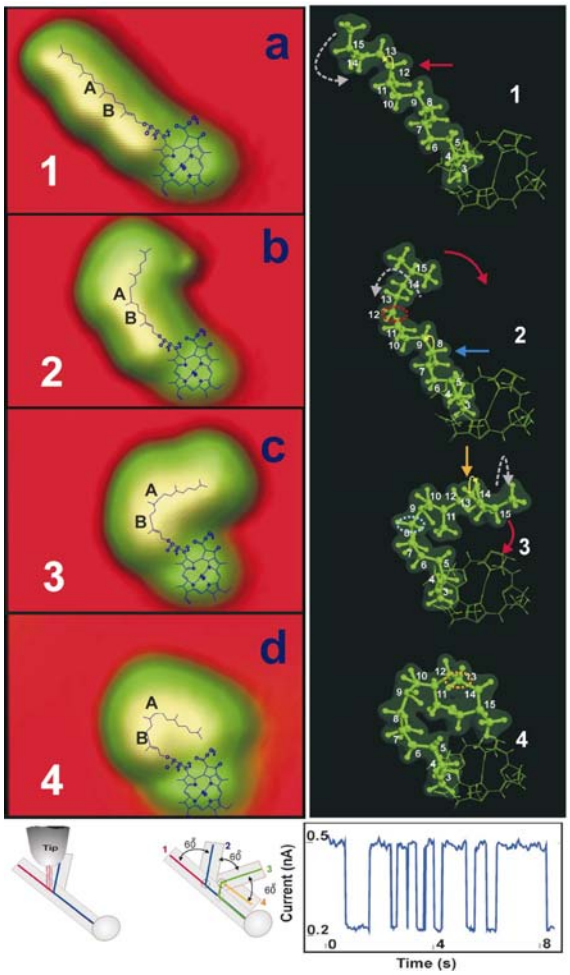

Figure 2. Four-step single molecule switch induced by STM manipulation.

References:

[1] S.-W. Hla, "*STM Single Atom/Molecule Manipulation and Its Application to Nanoscience and Technology* **",** J. Vac. Sci. Technol. B **23** (2005) 1351-1360.
[2] V. Iancu, S.-W. Hla, "Single molecule switch made of chlorophyll-a from spinach", submitted.