Reversible Switching of Single Dipolar Molecule towards Ultrahigh Density Information Storage

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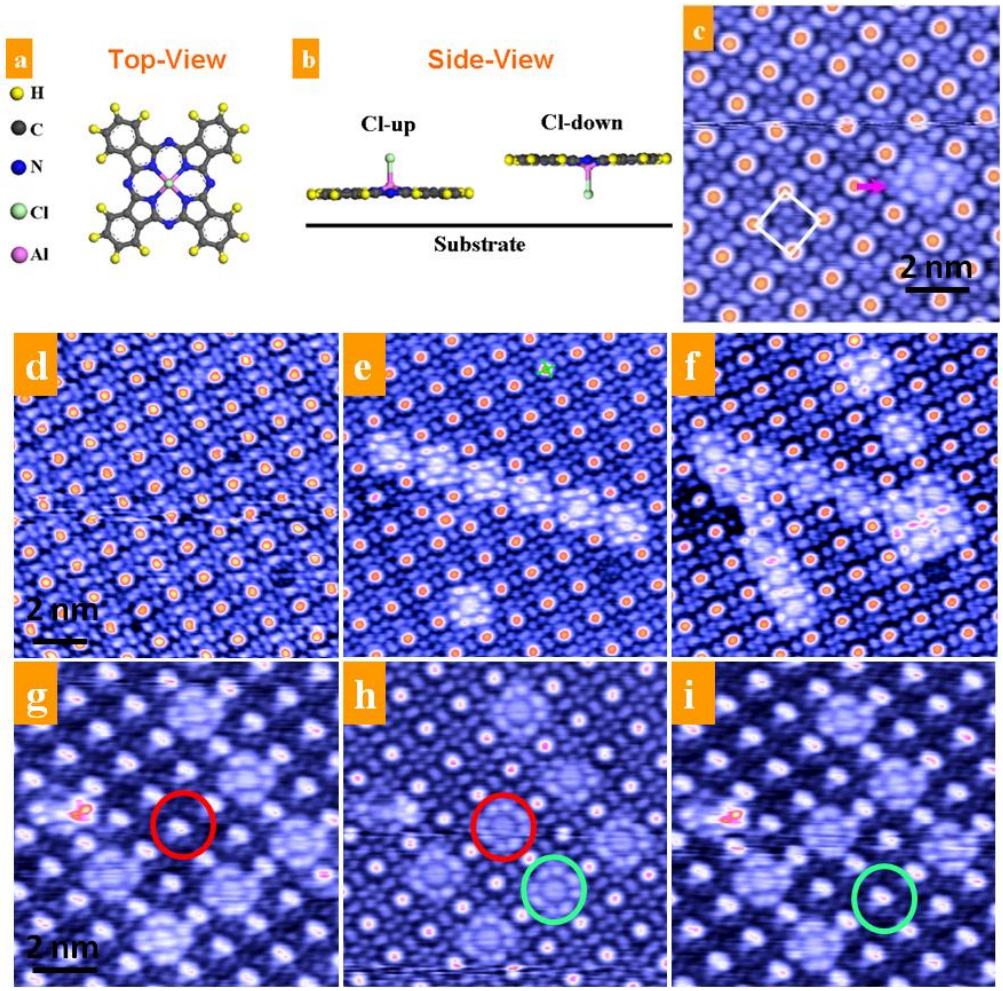

Reversible switching of single dipolar ClAlPc molecule in a closely packed monolayer on graphite, as revealed by atomically resolved in-situ low-temperature scanning tunneling microscopy. d)–f) A letter 'N' was recorded by applying a series of voltage pulses. g)-i) demonstrate the processes of transferring the pattern 'U' to 'H'. Red circles denote the target molecules at where positive voltage pulses of (+4.5 V, 2 ms) were applied, and the green ones at where negative pulse of (-3 V, 2 ms) were applied.

Single-molecule-based functional devices, where individual molecules can be used as high-density data-storage bits, magnets, spintronics, diodes, switches, and so on, have attracted much attention due to the drive towards electronic device miniaturization at the nano-meter scale. To construct such molecular devices, the ability to manipulate a single molecule between bistable states in a repeatable and reversible manner is imperative. Furthermore, it is very import to be able to integrate the molecular components into a complex device with high controbility and sub-molecular precision. For instance, the fabrication of single-molecule-based storage is only possible when we can reversibly manipulate the target molecule in a well-ordered self-assembled molecular array, where the initial states of all the molecules are uniform.

We demonstrate the reversible switching of a non-planar dipolar molecule, chloroaluminum phthalocyanine ClAlPc (ClAlC32H16N8), between bistable conformations in its closed-packed monolayer on graphite.[1-3] As the ClAlPc molecule possesses an out-of-plane chlorine atom (Figure 1), it processes two distinct electric dipole configurations on a surface, namely Cl-up (or state '1') and Cl-down (or state '0'), with the Cl atom pointing towards the vacuum and the substrate respectively. On the graphite surface, the ClAlPc molecules are spontaneously aligned in the Cl-up configuration at the first monolayer to form ordered molecular dipole arrays due to molecule-graphite π-π interactions. The single-molecule switching is controlled by voltage pulses applied through an atomically sharp metal tip in a scanning tunneling microscopy (STM) system. The switching is reversible, repeatable and well localized. The easy reading, writing and erasing of binary information on the ClAlPc molecular array make it a model molecular system for ultra-high density data storage at ~ 40Tb/cm2 (~250Tb/in2).

References:

1. Huang YL, Lu YH, Niu TC, Huang H, Kera S, Ueno N, and Wee ATS, Chen W, ***Small*** (Accepted). DOI: 10.1002/smll.201101967

2. Niu TC, Huang YL, Sun JT, Kera S, Ueno N, Wee ATS, Chen W, ***Appl. Phys. Lett***. **99**, 143114 (2011).

3. Huang YL, Wang R, Niu TC, Kera S, Ueno N, Pflaum J, Wee ATS, Chen W, ***Chemical Communication*** **46,** 9040–9042 (2010).