



0.05  $\mu\text{B}/\text{O}$  atom should be induced in the BTO layer. These results show that the spin-polarization of the Fe/BTO and Co/BTO interfaces can be controlled by the FE polarization of the BTO layer.

Magnetoelectric character can also be induced in BTO at room temperature, mediated by a spin-polarized bonding effect on interfacial  $\text{Ti}^{4+}$  ions. The researchers said that their findings may

aid in the development of artificial multiferroic tunnel barriers and novel spintronic memories, as well as new kinds of coupled ferroic order.

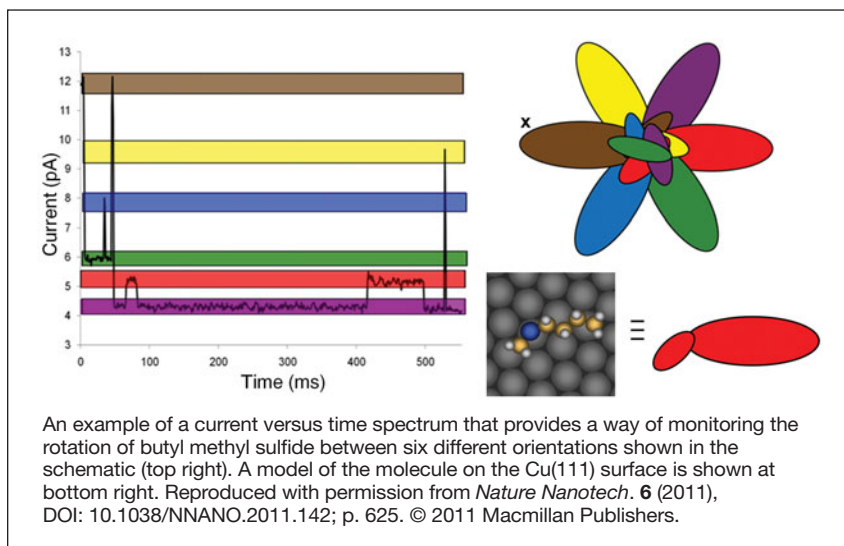
Steven Spurgeon

### Nano Focus

#### Directional molecular motor rotation electrically driven

A research team from Tufts University has demonstrated the first known example of directional molecular rotation driven by electricity. While there are a number of examples of so-called molecular motors driven by light or a chemical reaction, this latest device described in the October issue of *Nature Nanotechnology* (DOI: 10.1038/NNANO.2011.142; p. 625) uses as impetus the electric current supplied by a scanning tunneling microscope (STM).

H. Tierney, C. Sykes, and co-workers



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looked at molecules of butyl methyl sulfide (BuSMe) which, when absorbed on a Cu(111) surface, rotate about the metal-sulfur bond in hops of 60 degrees. The group's previous work on these thioether rotors has shown that the rotation can be driven using a STM tip to electrically excite molecular vibrations which couple to rotational modes. In the current study, placing the tip to one side of the sulfur fulcrum allows the six discrete positions that the molecule adopts on the surface to be distinguishable by different tunneling currents. In this way, the size and direction of each hop taken by the rotating molecule is revealed, along with any directional bias. Without any electrical excitation from the tip, but with thermal energy provided by operating at 8 K, the

molecule rotated in a random fashion as expected. When driven by current from the microscope tip, rotation was considerably slower (around 30 Hz) but showed up to 5% bias toward one direction.

Depending on which of the sulfur lone pairs binds to the metal surface, the bound thioether can exhibit two enantiomeric forms that were found to have an important influence on the STM-driven rotation. The intrinsic chirality which is often present in the STM tip resulted in an enantiomer-specific interaction with the molecule, causing one enantiomer to rotate slowly and with directionality, and allowing the other to rotate randomly and up to three times faster. Some tips appeared to be achiral and failed to cause measurable directional

rotation in either enantiomer.

The directional preference of the rotation ultimately derives from the asymmetry in the potential energies of the six possible surface positions. The slightly greater likelihood of an excited molecule rotating to a lower energy site is enhanced when rotation is slow, and the efficiency of the rotation is in turn highly dependent on the mutual symmetry of tip and molecule. As well as representing an important step toward electrically driven molecular machines, this work serves to highlight the potential importance of chirality in any device that couples molecules to macroscopic electrodes.

**Tobias Lockwood**

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