Electrical control benefits nuclear spin qubits

Researchers at Karlsruhe Institute of Technology (KIT) and the Centre National de la Recherche Scientifique (CNRS) in Grenoble and Strasbourg have taken an important step toward realizing a quantum computer. Using a spin cascade in a single-molecule magnet, the scientists demonstrated how nuclear spins can be manipulated with electric fields. Such electric field manipulation allows for quick and specific switching of quantum bits. The experimental results were reported in the June 6 issue of *Science* (DOI: 10.1126/science.1249802; p. 1135).

One of the most ambitious goals of nanotechnology is to realize a quantum computer. Such a computer, which is based on the principles of quantum mechanics, is expected to perform tasks much more efficiently than a classic computer. A quantum computer uses so-called quantum bit, or "qubit," as the smallest computation unit. Qubits can rely on nuclear spins. Interlinkage of qubits with each other results in mixed quantum states, which can be used to execute many calculation steps in parallel.

The KIT and CNRS researchers have manipulated a single nuclear spin purely using an electric field. "Use of electric instead of magnetic fields paves the way to addressing quantum states in conventional electronic circuits," said Mario Ruben, head of the Molecular Materials Research Group of KIT's Institute of Nanotechnology (INT). "There, quantum states can be manipulated specifically by so-called displacement currents. Then, they can be directly read out electronically."

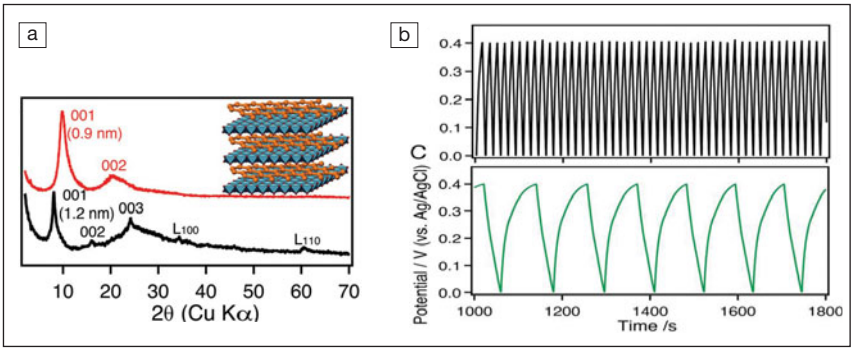
For their experiments, the researchers used a nuclear spin-qubit transistor consisting of a single-molecule magnet connected to three electrodes (source, drain, and gate). The single-molecule magnet was a $TbPc_2$ molecule—a single metal ion of terbium that is enclosed by organic phthalocyanine molecules of carbon, nitrogen, and hydrogen atoms. The gap between the electric field and the spin is bridged by the so-called hyperfine-Stark effect that transforms the electric field into a local magnetic field. This quantum mechanics process can be transferred to all nuclear spin systems and, hence, opens up the possibility of integrating quantum effects in nuclear spins into electronic circuits.

Energy Focus

High conductivity supercapacitors achieved with graphene nanocomposites

According to the US Environmental Protection Agency, 79% of US greenhouse gas emissions in 2010 were due to the burning of fossil fuels. Researchers are actively seeking alternative energy-conversion systems such as supercapacitors that can bridge the gap between conventional capacitors and rechargeable batteries. Supercapacitors can charge and discharge energy quickly, but they cannot store much energy. They also wear out fast with repeated use, as the materials inside them break down with the constant flow of charge in and out. This is a significant drawback when they are used in devices with long lifetimes, such as hybrid cars.

As reported in the April 19 online edition of *Advanced Materials* (DOI: 10.1002/adma.201400054), Renzhi Ma and colleagues from the National Institute for Materials Science in Japan have succeeded in preparing superlattice nanocomposites for use in supercapacitors with both high capacity and high power rates. The nanocomposites were prepared by electrostatic hetero-stacking of Co-Al or Co-Ni layered double hydroxide (LDH) nanosheets with graphene oxide nanosheets (i.e., the LDH nanosheets were sandwiched between each other in an alternating sequence on a molecular scale).



(a) X ray diffraction patterns of layered double hydroxide (LDH) nanosheets and rGO (red trace) nanosheets. Indices 001 are basal series of superlattice lamellar composites whereas L 100 and L 110 are in-plane diffraction peaks from LDH nanosheets. (Inset) Schematic illustration of sandwiched LDH nanosheets and graphene. (b) Comparison of typical charge-discharge CD curves; (top) rGO nanosheets and (bottom) nanocomposites of Co-Ni LDH and rGO nanosheet. Reproduced with permission from *Adv. Mater.* (2014) DOI: 10.1002/adma.201400054. © 2014 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.

X-ray diffraction measurements (see Figure) show that the heteroassembly of LDH nanosheets with GO nanosheets generally produce a basal spacing of ca. 1.2 nm (black trace). Furthermore, the gallery spacing of the lamellar composites could be tuned by modifying the surface charge, and thus the thickness of the GO nanosheets. This is evident in the heteroassembly of LDH with reduced GO (rGO) nanosheets. As demonstrated by the red trace in the figure, a basal spacing of 0.9 nm was obtained, which is consistent with the thickness sum of the LDH nanosheets (0.48 nm) and rGO (0.4 nm). This makes it is easy to modify the interlayer environment and contents of the heteroassembled composites

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