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."

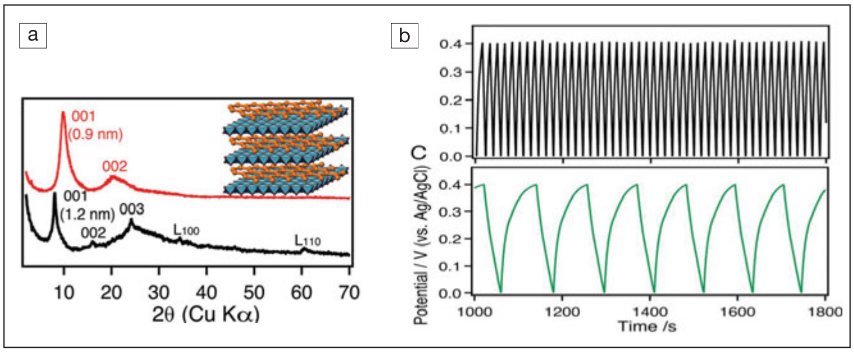
For their experiments, the researchers used a nuclear spin-qubit transistor consisting of a single-molecule magnet connected to three electrodes (source, drain, and gate). The single-molecule magnet was a $TbPc_2$ molecule—a single metal ion of terbium that is enclosed by organic phthalocyanine molecules 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

https://doi.org/10.1557/mrs.2014.144 Published online by Cambridge University Press

by adjusting the charge density of the GO/rGO nanosheets. Thus, structures can be designed that exhibit both high ion diffusion and electron transport efficiency.

Additional work was conducted to explore the possibility of using this nanomaterial to increase the performance of supercapacitors. Graphene electrodes with an electric double layer (EDL) in supercapacitors have shown an increase in capacitance of ca. 100 farads per gram. More interesting, the overall capacitance was significantly enhanced by the hybridization of conductive graphene oxide nanosheets and the LDH nanosheets. This yielded a high capacitance of up to ca. 650 farads per gram, approximately six times that of pure graphene nanosheets. The direct combination of graphene with the insulating LDH nanosheets thus resulted in an improvement in the charge-transfer efficiency. Such a superfast charging and discharging performance potentially enables a huge energy output within a very short subsecond time scale.

According to the researchers, this work would be of benefit to applications in most electronic device and hybrid cars. Additionally, Ma said they expect that this three-dimensional transition metal/graphene hybrid approach to be effective in developing non-noble metal electrocatalysis for applications such as fuel cells.

Jean. L. Njoroge

Feather microstructure leads to reduced friction surfaces

The African darter duck is known to dive up to 35 meters without getting wet due to the microstructures of their feathers. Now, Michael Rubner, Gareth McKinley, and Robert E. Cohen from the Massachusetts Institute of Technology, Andrew Parker at the Natural History Museum, London, and their colleagues have correlated the birds' diving behavior with the microstructures of their wings. Their goal is to apply what they learn to create friction-reducing surfaces on water-going vessels.

By placing drops of different fluids on the birds' wings, the researchers found the "contact angle" to be very high. But those experiments were carried out in the open air. When ducks are immersed in water, the microstructures on their feathers entrain tiny pockets of air, forming an air film called a "plastron" which prevents water from wetting the feathers. Waterways, however, often contain an additional component: oils. Oils are known to wet bird feathers (observed as a low contact angle), which is why oil spills are particularly devastating to bird populations. Thus, before this technology can be successfully applied to ocean-going vessels, it is imperative to develop a mechanism for preventing oil from wetting the surfaces. As reported by the researchers in the July issue of the *Journal of the Royal Society Interface* (DOI: 10.1098/rsif.2014.028), the key is replacement of the preening oils on feathers with a very low-energy fluorinated polymer composite, containing molecules known as fluorodecyl polyhedral oligomeric silsesquioxanes or F-POSS.

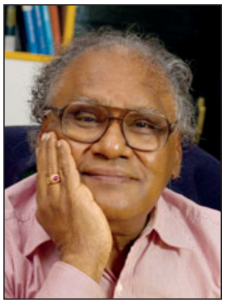
The coated duck wings also allowed the researchers to study the role of just the microstructures in the feathers' wetting behavior, essentially taking the variation of the ducks' preening oil out of the picture. This helped them understand the important contribution of larger scale defect structures that also are always present in feathers. In other words, the natural gaps in the duck feathers' micropattern prevent the duck feathers from staying dry to as great a diving depth as theory would predict. As a result, the plastron layer collapses and the feathers get wet beyond a certain diving depth.

However, the researchers' calculations show that feathers spontaneously dewet when the bird comes back up to the surface. The researchers speculate that there is a chance that the observed "wing spreading" behavior of birds such as cormorants helps them rapidly recover dry feathers after a deep dive. "I don't think you'll see ships that are able to 'stretch out their wings,'" quipped McKinley, emphasizing that this work has augmented the understanding of the defect sensitivity of these superhydrophobic microstructures, a key to designing real surfaces that perform as desired.

Mary Nora Dickson

Materials Researchers

C.N.R. Rao receives Bharat Ratna Award



C.N.R. Rao, the Linus Pauling Research Professor and Honorary President at the Jawaharlal Nehru Centre for Advanced Scientific Research in Bangalore, received India's Bharat Ratna Award. This is India's highest civilian honor given for exceptional service toward advancement of art, literature, and science, and in recognition of public service of the highest order. Rao received the award from President of India Pranab Mukherjee on February 4, 2014, in New-Delhi. Rao's research focused on solid-state and materials chemistry and on structural chemistry. He is the founder and president of the Materials Research Society of India. His service to his profession includes chair of the Science Advisory Council to the Prime Minister, and president of the Indian Academy of Sciences and of the Indian Science Congress.

https://doi.org/10.1557/mrs.2014.144 Published online by Cambridge University Press