Molecular magnets stand in line（图）

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Researchers in Europe have succeeded in creating molecular magnets capable of adopting a preferred orientation on a gold surface. The result is an important advance for the burgeoning field of spintronics – in which electronic devices exploit the spin of an electron as well as its charge. Such devices are of great interest because they could be smaller and more energy efficient than conventional electronic circuits.

Single-molecule magnets are paramagnetic materials that can switch their magnetization between two states, from "spin up" to "spin down", for example. At low temperatures, the magnetic state of the molecule persists even in the absence of a magnetic field. This memory effect could be exploited to make high-density information storage devices for computing applications.

Last year Roberta Sessoli of the University of Florence and colleagues in Modena and Paris showed that clusters of four iron atoms (Fe_4) incorporated into the structure of a complex molecule could retain their magnetic memory when chemically attached to a gold surface. Now, the same team has gone a step further in its work by chemically tailoring these Fe_4 molecules to orient themselves in a preferred way on the gold. The magnetism of the molecules was studied using synchrotron light.

Resonant quantum tunnelling

The new result allowed the researchers to observe resonant quantum tunnelling of the magnetization in single-molecule magnets on a surface for the first time. Quantum tunnelling, a process whereby quantum particles can penetrate energy barriers normally insurmountable to classical objects, is a rather fragile phenomenon. It can easily be destroyed by external effects – for example, through the connections needed to connect the magnets electronically within practical devices.

"The fact that we observed quantum tunnelling in molecular magnets tethered to a gold surface demonstrates that molecule–surface interactions are not detrimental to such a delicate aspect of magnetism," says Sessoli.

The researchers joined the four coplanar iron ions by adding two new connecting molecules, or "ligands", derived from a trialcohol that has just the right geometry to bind the ions at opposite ends of the iron plane. Such an arrangement means that the iron molecule is highly stable.

"The trialcohol has an aliphatic chain terminated with a sulphur-containing group, which represents a key ingredient in our approach," explained Sessoli. "In fact, we exploited the pronounced affinity of sulphur atoms towards gold to chemically anchor the molecular magnets on the gold surface."

Better memory effect

The team then found that the way the molecular magnets orient themselves onto the gold surface could be controlled by changing the length and flexibility of the alkyl chain. For instance, when the chain length is reduced from nine to five carbon atoms, molecules are forced to bind to the surface via a single "alligator clip" and thus adopt a preferential alignment as opposed to a random one. When the molecules are aligned, they show wider magnetic hysteresis loops and a better memory effect, with clear quantum tunnelling signatures.

"Our work proves that a multidisciplinary approach, combining synthetic chemistry, experimental physics and theoretical modelling, is needed to advance nanoscience," added Sessoli. "Although applications for this technology won't be seen in the near future because of the low working temperatures of single-molecule magnets, this kind of fundamental investigation paves the way for future spin-based technologies."

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