# Research team saves information on a single molecule

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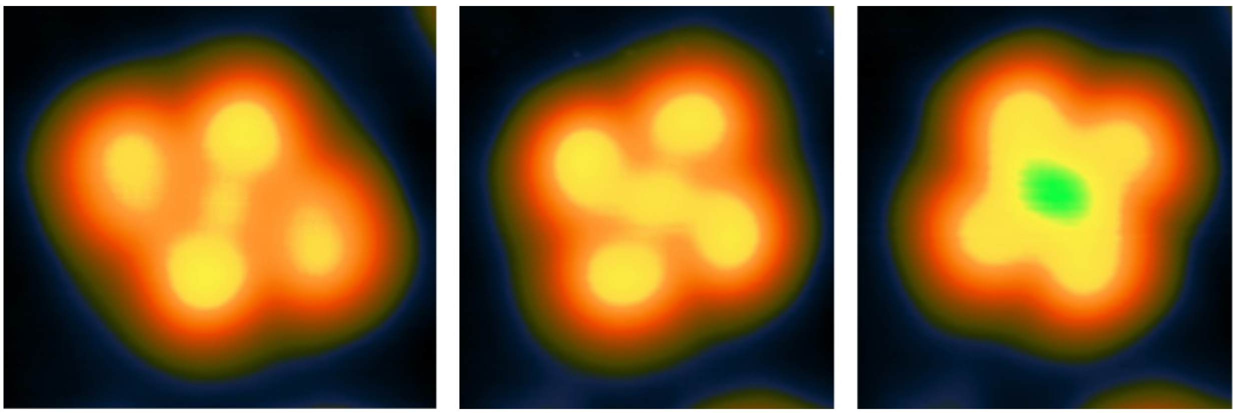


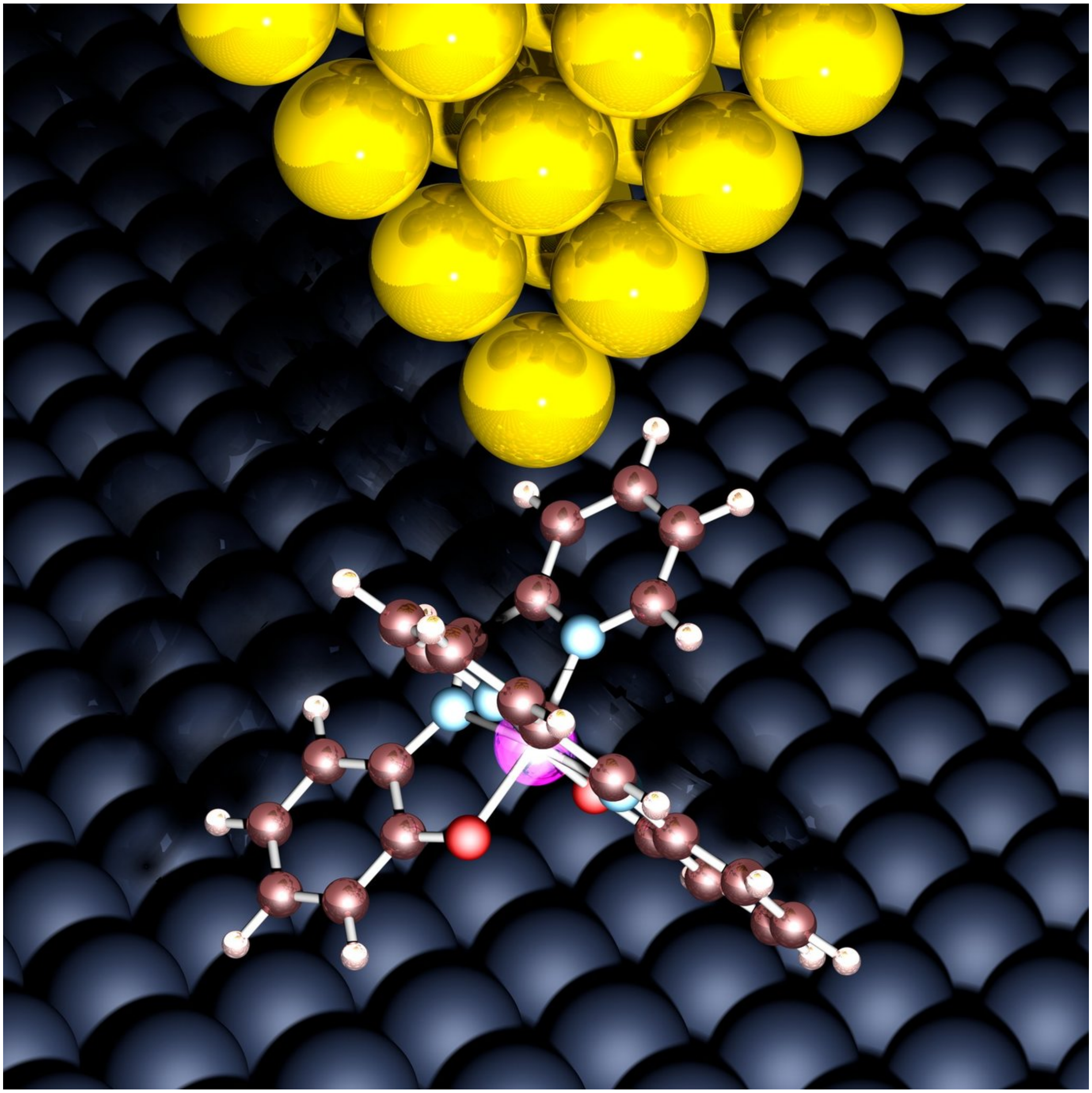
The images from the scanning tunnelling microscope (STM) show the three different states of the molecule, which correspond to a trinary code for encrypting information: in a highly magnetic state (left), in a low magnetic state with atoms that have moved closer together (middle) and in an equally low magnetic state but turned by 45 degrees (right). Credit: Manuel Gruber

Over the past few years, the building blocks of storage media have become ever smaller. But further miniaturization of the current technology is hindered by fundamental limits of quantum mechanics. A new approach consists of using so-called spin-crossover molecules as the smallest possible storage unit. Similar to normal hard drives, these special molecules can save information via their magnetic state. To do so, they have to be placed on surfaces without damaging their ability to save the information.

A research team from Kiel University has now not only successfully placed a new class of spin-crossover molecules onto a surface, they have also used interactions which were previously regarded as obstructive to improve the molecule's storage capacity. The storage density of conventional hard drives could therefore theoretically be increased by more than 100-fold, and data carriers could be made significantly smaller. The scientists have published their findings in *Nano Letters*.

The differentiation between two possibilities is the smallest piece of information that a computer can save. bits, as the smallest electronic storage unit, are the basic building blocks for all information stored on hard drives. They are presented as a sequence of zeroes and ones. Over the past few years, storage media have become ever smaller while their capacity to store information has increased. One bit on a hard drive now only requires a space of around 10 by 10 nanometres. This is still too big for miniaturising components, however.

"The technology that is currently being used to store data on hard drives now reaches the fundamental limits of quantum mechanics due to the size of the bit. It cannot get any smaller, from today's perspective," says Torben Jasper-Tönnies, doctoral researcher in Professor Richard Berndt's working group at Kiel University's Institute of Experimental and Applied Physics. He and his colleagues used a single molecule to encode a bit to demonstrate a principle that could enable even smaller hard drives with more storage in the future. "Our molecule is just one square nanometre in size. Even with this alone, a bit could be encoded in an area 100 times smaller than what is currently required," says Dr Manuel Gruber. This would be another step towards shifting the limits of quantum physics in storage technology.



The tip of the STM (yellow) assumes the role of a hard drive's reading and writing head for the molecule attached to the copper nitride surface (black). Credit: Manuel Gruber

The molecule that the research team used can assume two different magnetic states, and when attached to a special surface, it can also change its connection to the surface. It can then be switched between a high and low magnetic state, and turned by 45 degrees. "When transferred onto storage technology, we would be able to depict information on three states—those being 0, 1 and 2," explained Jasper-Tönnies. "As a storage unit, we wouldn't have a bit, we would have a 'trit.' Binary code would become trinary code."

The challenge for the researchers was finding a suitable molecule and a suitable surface, as well as using the correct method to connect the two in a way that would still allow them to work. "Magnetic molecules, so-called spin-crossover molecules, are very sensitive and easily damaged. We needed to find a way to firmly attach the molecule to the surface without affecting its switching ability," explained Gruber.

Their experiments finally paid off: Chemists from Professor Felix Tuczek's working group at the Institute of Inorganic Chemistry synthesized a magnetic molecule of a special class (a so-called Fe(III) spin crossover molecule). Physicists Jasper-Tönnies, Gruber and Sujoy Karan were able to deposit this molecule on a copper nitride surface by means of evaporation. Using electricity, it can be switched between different spin states, and also between two different directions (in the so-called low-spin state). The fine tip of a scanning-tunnelling microscope (STM) acts as a hard drive's reading and writing head in their experiments. It allows the molecule not only to be "written" as a storage medium, but also to be "read" using electricity.

Before these molecules can be used as a data storage on an industrial level, further investigation must be carried out. Indeed, the proof of principle is demonstrated using bulky equipment, and further work is required to integrate such a molecular memory on a small chip.

**More information:** Torben Jasper-Toennies et al, Robust and Selective Switching of an FeIII Spin-Crossover Compound on

Cu2N/Cu(100) with Memristance Behavior, *Nano Letters* (2017). DOI: 10.1021/acs.nanolett.7b02481

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