Controlling the magnetic properties of individual iron atoms

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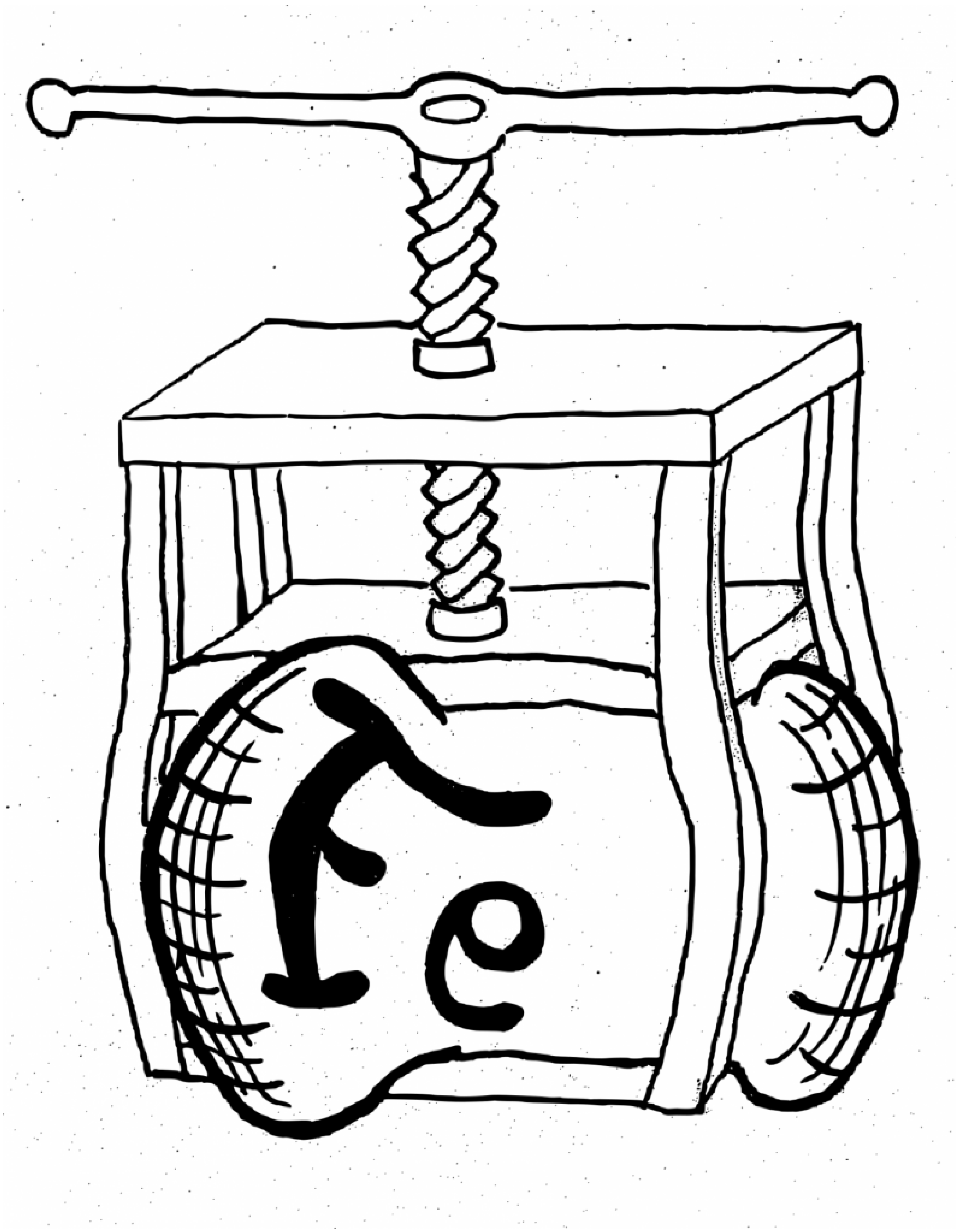

Credit: Source: FUW, A. Bogucki

The Fe2+ atom embedded in a semiconductor exhibits a single non-degenerate ground state of zero magnetic moment. A team of scientists from the University of Warsaw has just shown that by using a sufficiently large strain, it is possible to tailor the energy spectrum of the iron atom to obtain a doubly degenerate (magnetic) ground state. Such a state can be utilized for storage and processing of quantum information. This discovery has been just published in prestigious research journal of *Nature Communications*.

As the water freezes in a bottle, the molecules move farther apart from each other, which results in a strain that may eventually shatter the glass. Similarly, different crystals that are fused together might be stressed as if they would be compressed or stretched by a pressure many times larger than the pressure at the bottom of ocean. The macroscopic bulk crystals cannot withstand such high stresses, which cause dislocations or even may break the crystals apart. However, nanocrystals are able to sustain such built-in stress, which substantially modifies the physical properties of the atoms embedded inside these nanocrystals. This phenomenon has been already employed, for example, to optimize transistor operating speed by integrating nanostructures of different interatomic distances.

Tomasz Smolenski and co-workers from the faculty of physics, University of Warsaw, have examined how the properties of the iron atoms are affected by the high strain produced by semiconductor nanostructures. Although the iron is usually associated with magnetism, it has been known already since the 1960s that the iron atom of 2+ charge state becomes non-magnetic after incorporation into a typical semiconductor. The d-shell electrons of the iron atom have only one lowest-energy configuration, in which the total magnetic moment of the iron vanishes, even upon the application of a small external magnetic field. It turned out, however, that under the influence of a sufficiently large strain, the energy spectrum of the iron electronic states is qualitatively different and comprises two lowest-energy spin states. As a consequence, the non-zero magnetic moment of the iron atom placed in a strained environment can be easily induced by a tiny magnetic field. This discovery has been just published in prestigious research journal of *Nature Communications*.

Using molecular beam epitaxy, Tomasz Smolenski and co-workers fabricated zinc selenide crystals integrated with cadmium selenide nanocrystals of larger lattice constant. This led to the growth of highly strained cadmium selenide quantum dots embedded in a zinc selenide barrier. Additionally, an appropriately adjusted amount of the iron atoms was added during the formation of the quantum dots, so that some contained exactly one iron atom. The presence of such an atom, owing to its magnetic properties, modified the character of the light emission from such quantum dots.

Therefore, by means of the photoluminescence studies of a single quantum dot containing an individual iron atom, it was possible to determine both the electronic configuration and the magnetic properties of the iron atom. Furthermore, it was also found that the magnetic moment of this atom can be induced by light. Consequently, the new system—a quantum dot with a single iron atom—has become an excellent candidate for applications involving storage and manipulation of the quantum information both in the field of spintronics and solotronics, optoelectronics based on solitary dopants.

More information: T. Smoleński et al. Magnetic ground state of an individual Fe2+ ion in strained semiconductor nanostructure, *Nature Communications* (2016). DOI: 10.1038/ncomms10484

Provided by University of Warsaw