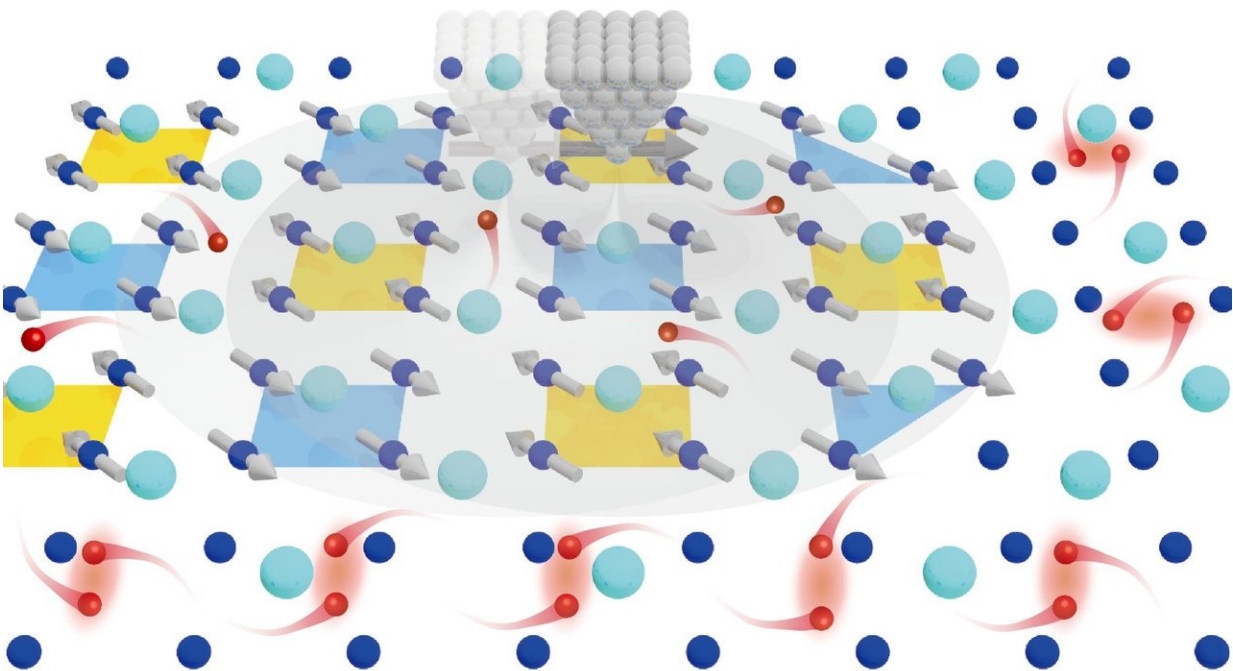


Scientists control superconductivity using spin currents

December 19 2017, by Laura Mgrdichian



The spin-polarized chromium (Cr) tip being scanned over the superconducting area of C_2 magnetism, represented in the background (the right and bottom areas of the image) with electron pairs shown as coupled red spheres. Just beneath the tip, the spin-polarized current locally induces C_4 antiferromagnetic order (illustrated with yellow and blue plaquettes), which remains stable as shown recorded in the trace of the tip on the left. On the other hand, the C_4 order can be erased when the area is heat-treated beyond a specific higher temperature. Since the spin fluctuations for this C_4 order cannot support electron pairing in the typical FeAs band structure, the superconductivity is suppressed, as illustrated with the broken electron pairs in the plaquette region. Credit: Jinhwan Lee

A group of researchers from institutions in Korea and the United States has determined how to employ a type of electron microscopy to cause regions within an iron-based superconductor to flip between superconducting and non-superconducting states. This study, published in the December 1 edition of *Physical Review Letters*, is the first of its kind, and it opens a door to a new way of manipulating and learning about superconductors.

The [iron-based superconductors](#), one of which was studied in this work, are one of several classes of these fascinating materials, which have the ability to conduct electricity with virtually zero resistance below a certain temperature. Scientists are still working out the complex atomic-level details that underlie these materials' electronic and magnetic behaviors. The iron-based materials, in particular, are known to display intriguing phenomena related to co-existing superconducting and magnetic states.

Here, researchers studied a compound composed of strontium (Sr), vanadium (V), oxygen (O), iron (Fe), and arsenic (As), with a structure consisting of alternating FeAs and Sr_2VO_3 layers. They probed its magnetic and electronic properties with a spin-polarized scanning tunneling microscope (SPSTM), a device that passes an atomically sharp metal tip – just a few atoms wide – over the surface of a sample. The tip and the sample do not touch but are brought in quantum-scale proximity to each other so that a bias voltage applied between them causes a current to flow between the tip and the sample. In this case, the current is spin-polarized, meaning its electrons tend to have the same spin – the tiny magnetic field carried by an electron that points either "up" or "down," like a bar magnet.

Typically, this material's FeAs layer is strongly superconducting and

prefers a certain [magnetic order](#), dubbed C_2 order, that refers to how the magnetic fields of its atoms (which are due, in turn, to electron spins) are arranged. Results of the SPSTM scan show that the injected spin-polarized current, when sufficiently high, induces a different magnetic order, C_4 order, in the FeAs layer. In that same local area, superconductivity somehow magically disappears.

"To our knowledge, our study is the first report of a direct real-space observation of this type of control by a local probe, as well as the first atomic-scale demonstration of the correlation between magnetism and superconductivity," said the paper's corresponding author, Jinhwan Lee, a physicist at the Korea Advanced Institute of Science and Technology, to *Phys.org*.

Lee and his group introduced new ways to perform SPSTM using an antiferromagnetic chromium (Cr) tip. An antiferromagnet is a material in which the magnetic fields of its atoms are ordered in an alternating up-down pattern such that it has a minimal stray [magnetic field](#) that can inadvertently kill local superconductivity (which can happen with ferromagnetic tips, such as Fe tips, that other SPSTM researchers use). They compared these Cr tip scans with those taken with an unpolarized tungsten (W) tip. At low bias voltages, the surface scans were qualitatively identical. But as the voltage was increased using the Cr tip, the surface started to change, revealing the C_4 magnetic symmetry. The C_4 order held even when the voltage was lowered again, although was erased when thermally annealed (heat-treated) beyond a specific temperature above which any magnetic order in the FeAs layer disappears.

To study the connection between the C_4 magnetic order and the suppression of superconductivity, Lee and his group performed high-resolution SPSTM scans of the C_4 state with Cr tips and compared them with simulations. The results led them to suggest one possible

explanation: that the low-energy spin fluctuations in the C_4 state cannot mediate pairing between electrons. This is critical because this pairing of electrons, defying their natural urge to repel each other, leads to superconductivity.

Spin-fluctuation-based pairing is one theory of electron pairing in iron-based superconductors; another set of theories assume that fluctuations in the electron orbitals are the key. Lee and his group believe that their results seem to support the former, at least in this superconductor.

"Our findings may be extended to future studies where magnetism and superconductivity are manipulated using spin-polarized and unpolarized currents, leading to novel antiferromagnetic memory devices and transistors controlling superconductivity," said Lee.

More information: J Lee et al, Switching Magnetism and Superconductivity with Spin-Polarized Current in Iron-Based Superconductor, *Physical Review Letters* (2017). [DOI: 10.1103/PhysRevLett.119.227001](https://doi.org/10.1103/PhysRevLett.119.227001)

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