Induced Flaws in Quantum Materials Could Enhance Superconducting Properties

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In a surprising discovery, an international team of researchers, led by scientists in the University of Minnesota Center for Quantum Materials, found that deformations in quantum materials that cause imperfections in the crystal structure can actually improve the material's superconducting and electrical properties.

The groundbreaking findings could provide new insight for developing the next generation of quantum-based computing and electronic devices. The research just appeared in Nature Materials, a peer-reviewed scientific journal published by Nature Publishing Group.

"Quantum materials have unusual magnetic and electrical properties that, if understood and controlled, could revolutionize virtually every aspect of society and enable highly energy-efficient electrical systems and faster, more accurate electronic devices," said study co-author Martin Greven, a Distinguished McKnight Professor in the University of Minnesota's School of Physics and Astronomy and the Director of the Center for Quantum Materials. "The ability to tune and modify the properties of quantum materials is pivotal to advances in both fundamental research and modern technology."

Elastic deformation of materials occurs when the material is subjected to stress but returns to its original shape once the stress is removed. In contrast, plastic deformation is the non-reversible change of a material's shape in response to an applied stress—or, more simply, the act of squeezing or stretching it until it loses its shape. Plastic deformation has been used by blacksmiths and engineers for thousands of years. An example of a material with a large plastic deformation range is wet chewing gum, which can be stretched to dozens of times its original length.

While elastic deformation has been extensively used to study and manipulate quantum materials, the effects of plastic deformation have not yet been explored. In fact, conventional wisdom would lead scientists to believe that "squeezing" or "stretching" quantum materials may remove their most intriguing properties.

In this pioneering new study, the researchers used plastic deformation to create extended periodic defect structures in a prominent quantum material known as strontium titanate ($SrTiO_3$). The defect structures induced changes in the electrical properties and boosted superconductivity.

“We were quite surprised with the results” Greven said. “We went into this thinking that our techniques would really mess up the material. We would have never guessed that these imperfections would actually improve the materials’ superconducting properties, which means that, at low enough temperatures, it could carry electricity without any energy waste.”

Greven said this study demonstrates the great promise of plastic deformation as a tool to manipulate and create new quantum materials. It can lead to novel electronic properties, including materials with high potential for applications in technology, he said.

Greven also said the new study highlights the power of state-of-the-art neutron and x-ray scattering probes in deciphering the complex structures of quantum materials and of a scientific approach that combines experiment and theory.

“Scientists can now use these techniques and tools to study thousands of other materials,” Greven said. “I expect that we will discover all kinds of new phenomena along the way.”

Read the original article on University of Minnesota.