Physicists show trilayer metal oxide's true stripes

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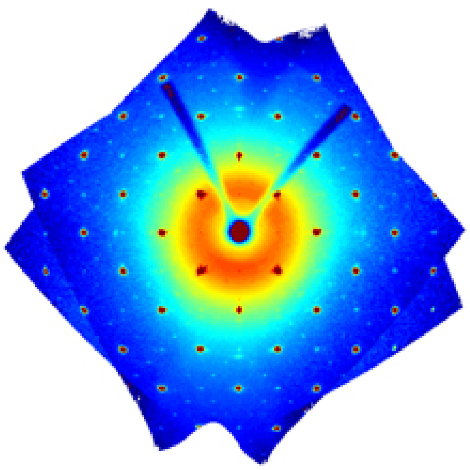

Argonne scientists created a triple-layer metal oxide in a never-before-made single-crystal form. Using powerful X-rays at the Advanced Photon Source, they saw a unique spacing signature (orange spots, above) that signaled the presence of charge striping, a phenomenon previously only observed in single-layer oxides. Credit: Mitchell et al.

The true stripes of triple-layer metal oxides are charge stripes, physicists say.

In a study published today in the *Proceedings of the National Academy of Sciences*, a team of researchers from the U.S. Department of Energy's (DOE's) Argonne National Laboratory describe a process to create a triple-layer metal oxide in a never-before-made single-crystal form; and observed in it an interesting phenomenon called charge striping, which may shed light on the physics behind similar useful electronic properties of metal oxides, such as superconductivity.

In the 1990s, studying the behavior of electrons in layered nickel oxide compounds in order to learn more about their conductive properties, physicists observed "stripes" of charge forming in the layers. Because this occurs near the stage where similar copper-based materials become superconducting—the strange and highly sought-after property where electricity can be carried with zero loss—it's thought the two phenomena may be related.

Since then, scientists had seen charge stripes in several other materials, but only in single-layer sheets of nickel oxides.

That was until Argonne researcher Junjie Zhang grew crystals of a triple-layer lanthanum nickel oxide in Argonne's high-pressure zone furnace, one of just a few of its type in the world, and took them to the Advanced Photon Source, a DOE Office of Science User Facility that generates extremely bright X-rays for scientific research.

The X-rays revealed a distinctive pattern that suggested charge stripes. "What he found when he cooled this material down through its metal-insulator transition temperature, were these extremely weak extra spots that could only be seen at a synchrotron. And what he saw immediately was that they were spaced in thirds. That's exactly what we knew happened in the single-sheet compounds when stripes form," said John Mitchell, associate director of Argonne's Materials Science Division and corresponding author on the paper. "It was a bit of a eureka moment."

More X-ray diffraction and modeling helped the team quantitatively, as well as qualitatively, point to charge striping as the cause.

They noticed something unexpected in the triple-layer structure. The positive charges in each stripe stack on top of one another in the trilayer. Since like charges normally repel one another, the stripes should have staggered from layer to layer; "But they don't," Mitchell said.

Farther apart, however, the stripes in one trilayer block do start to appear staggered from neighboring blocks. "We're left with a situation that is exactly the opposite of what you'd predict based on charge alone," he said. Members of the team have written a companion theory paper to explain the phenomenon based on coupling between the charge stripes and the nickel oxide lattice.

"Finding these stripes is a relief, actually. It tells us there is a simple, unifying picture for this phenomenon – just count the charges and you know what to expect," Mitchell said. "A potentially bigger picture about these particular compounds is that they may offer a different route to explore the physics surrounding cuprates." (Cuprates are the class of materials that contain the famous "high-temperature" superconductors, which can be cooled with liquid nitrogen rather than the scarcer and more expensive liquid helium needed for conventional superconductors.)

The team is planning to further explore the materials and related bilayer materials, which could further help us explain the underlying physics of superconductivity and similar electronic properties.

More information: Junjie Zhang et al. Stacked charge stripes in the quasi-2D trilayer nickelate $La_4Ni_3O_8$, *Proceedings of the National Academy of Sciences* (2016). DOI: 10.1073/pnas.1606637113

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