

# Negative electronic compressibility: More is less in novel material

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Add water to a half-filled cup and the water level rises. This everyday experience reflects a positive material property of the water-cup system. But what if adding more water lowers the water level by deforming the cup? This would mean a negative compressibility.

Now, a quantum version of this phenomenon, called negative electronic compressibility (NEC), has been discovered, a team of researchers led by physicists at Boston College reports today in the online edition of the journal *Nature Materials*.

Physicists have long theorized that NEC— an electron system lowering its highest energy level and effectively shrinking its overall size when electrons are added—could in principle be found in quantum materials with non-rigid band structures. Nevertheless, rare experimental realizations of NEC have been limited to the two-dimensional boundaries between certain materials, but never in any three-dimensional (3D) material.

The first experimental evidence of 3D NEC was discovered using the unique material iridium oxide, which belongs to a class of "correlated" materials in which electrons move in an orchestrated fashion. Here, the addition of an electron to the system has a significant impact on the motion of the other electrons, and changes the overall band structure of the material - like the deformed water cup - a prerequisite for NEC.

The researchers experimented with iridium oxide samples synthesized by

Boston College (BC) graduate student Tom Hogan, working in the lab of former BC and current University of California, Santa Barbara, Assistant Professor Stephen Wilson.

The observation was made by adding electrons to this material and then studying its band structure with a high precision, advanced spectroscopy technique. The study was performed mainly at the SLAC National Accelerator Laboratory and Lawrence Berkeley National Laboratory in California, and was led by postdoctoral researcher Junfeng He and graduate student Thomas Mion, researchers in the lab of BC Assistant Professor of Physics Rui-Hua He, a lead author of the paper.

By comparing with another correlated material, one that exhibits high-temperature superconductivity but not NEC, coauthors at Northeastern University, including graduate student Hasnain Hafiz and Professors Arun Bansil and Robert Markiewicz, believe they've obtained clues as to what makes the iridium oxide unique in terms of the long-sought occurrence of 3D NEC.

"This is a collective achievement that could not have been made without such a close collaboration of leading experts, within and outside BC," said Michael J. Naughton, chairman of BC Department of Physics and a coauthor on the paper.

"Our finding might open the door to uncharted territory in the area of negative [compressibility](#), which potentially features a whole variety of bulk correlated metals," said He.

Co-author and BC Professor Krzysztof Kempa added that the 3D NEC materials may enable new research into terahertz optics and unique applications in areas such as metamaterials, pushing beyond the scope of two-dimensional systems that display NEC.

This discovery serves as a stepping-stone for the team's ongoing effort to theoretically understand 3D NEC in quantum materials, and to experimentally probe 3D NEC in different ways.

**More information:** Spectroscopic evidence for negative electronic compressibility in a quasi-three-dimensional spin–orbit correlated metal, [DOI: 10.1038/nmat4273](https://doi.org/10.1038/nmat4273)

Provided by Boston College

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