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Superlattice design realizes elusive multiferroic properties

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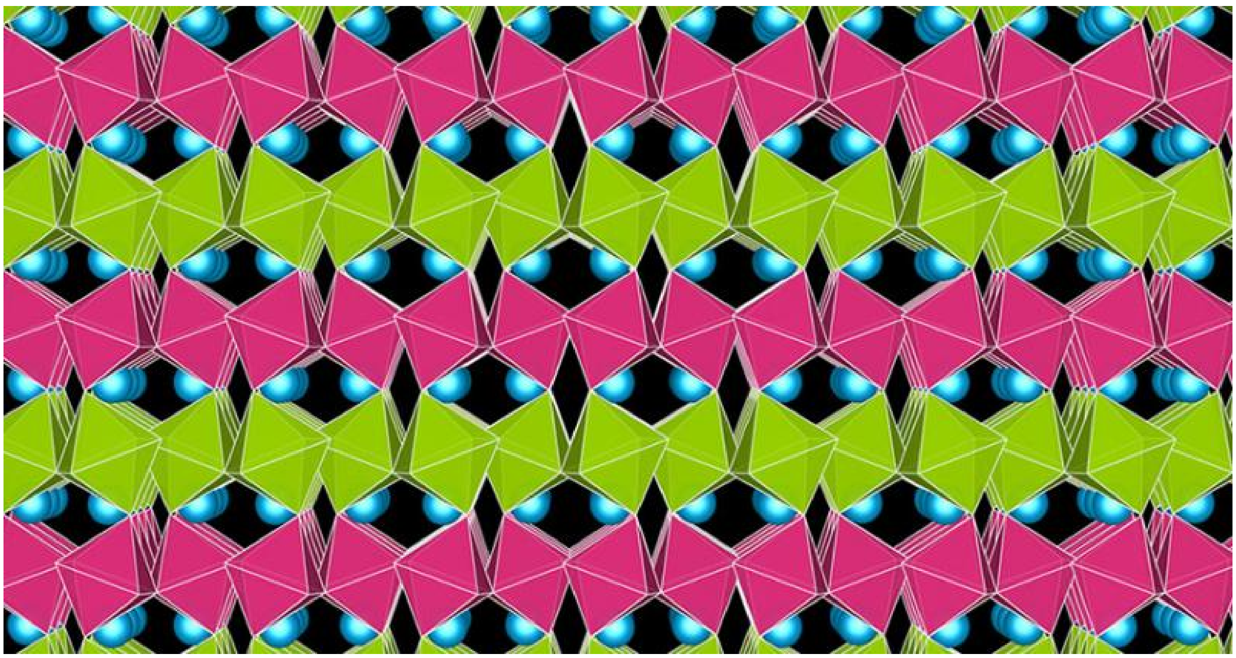

Superlattice structure of lithium osmate and lithium niobate

From the spinning disc of a computer's hard drive to the varying current in a transformer, many technological devices work by merging electricity and magnetism. But the search to find a single material that combines both electric polarizations and magnetizations remains challenging.

This elusive class of materials is called multiferroics, which combine two or more primary ferroic properties. Northwestern University's James Rondinelli and his research team are interested in combining ferromagnetism and ferroelectricity, which rarely coexist in one material at room temperature.

"Researchers have spent the past decade or more trying to find materials that exhibit these properties," said Rondinelli, assistant professor of materials science and engineering at Northwestern's McCormick School of Engineering. "If such materials can be found, they are both interesting from a fundamental perspective and yet even more attractive for technological applications."

In order for ferroelectricity to exist, the material must be insulating. For this reason, nearly every approach to date has focused on searching for multiferroics in insulating magnetic oxides. Rondinelli's team started with a different approach. They instead used quantum mechanical calculations to study a metallic oxide, lithium osmate, with a structural disposition to ferroelectricity and sandwiched it between an insulating material, lithium niobate.

While lithium osmate is a non-magnetic and non-insulating metal, lithium niobate is insulating and ferroelectric but also non-magnetic. By alternating the two materials, Rondinelli created a superlattice that—at the quantum scale—became insulating, ferromagnetic, and ferroelectric at room temperature.

"The polar metal became insulating through an electronic phase transition," Rondinelli explained. "Owing to the physics of the enhanced electron-electron interactions in the superlattice, the electronic transition induces an ordered magnetic state."

Supported by the Army Research Office and the US Department of

Defense, the research appears in the August 21 issue of *Physical Review Letters*. Danilo Puggioni, a postdoctoral fellow in Rondinelli's lab, is the paper's first author, who is joined by collaborators at the International School for Advanced Studies in Trieste, Italy.

This new design strategy for realizing multiferroics could open up new possibilities for electronics, including logic processing and new types of memory storage. Multiferroic materials also hold potential for low-power electronics as they offer the possibility to control magnetic polarizations with an electric field, which consumes much less energy.

"Our work has turned the paradigm upside down," Rondinelli said. "We show that you can start with metallic oxides to make multiferroics."

More information: Design of a Mott Multiferroic from a Nonmagnetic Polar Metal, dx.doi.org/10.1103/PhysRevLett.115.087202

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