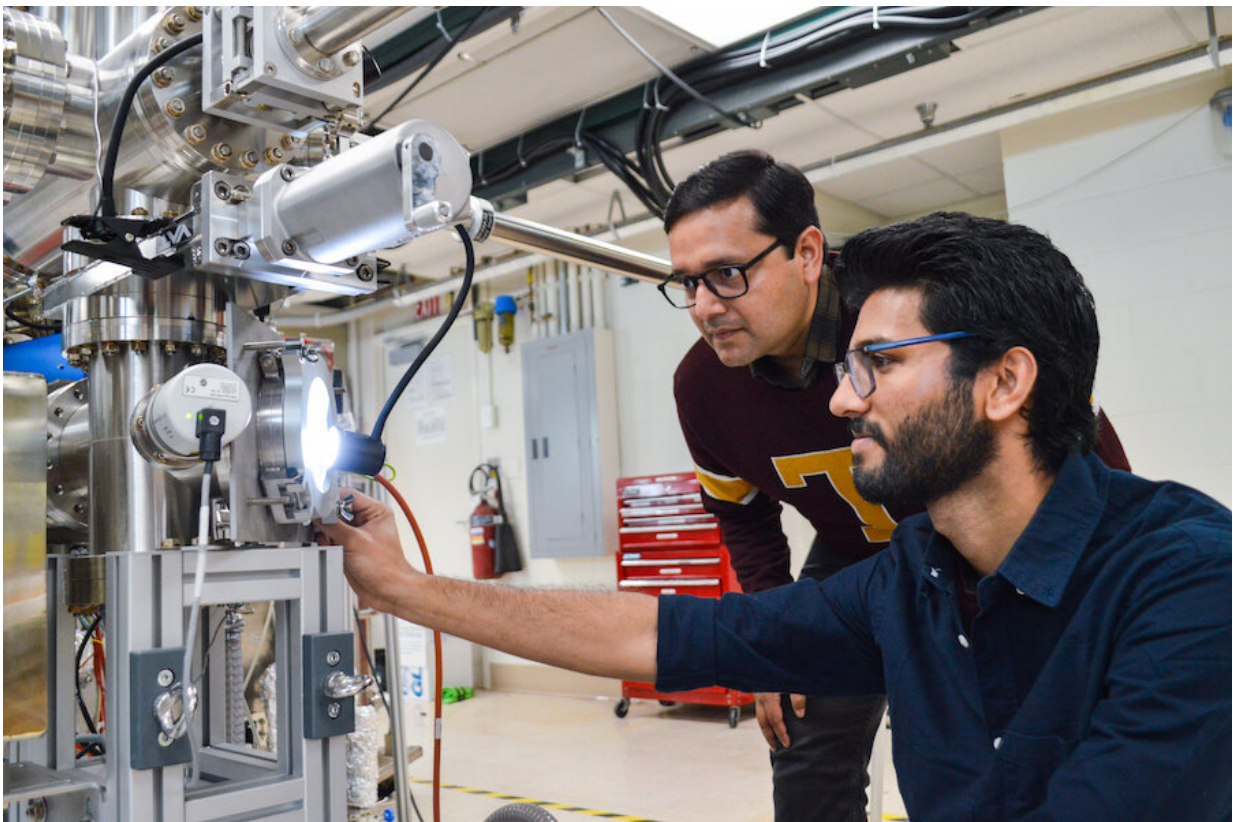


Stretching metals at the atomic level allows researchers to create important materials for quantum applications

May 22 2023



University of Minnesota chemical engineering and materials science researchers have developed a breakthrough method for creating high-quality metal oxide films that are important for next generation applications like quantum computing and microelectronics. Credit: Olivia Hultgren, University of Minnesota

A University of Minnesota Twin Cities-led team has developed a first-of-its-kind, breakthrough method that makes it easier to create high-quality metal oxide thin films out of "stubborn" metals that have historically been difficult to synthesize in an atomically precise manner. This research paves the way for scientists to develop better materials for various next-generation applications including quantum computing, microelectronics, sensors, and energy catalysis.

The researchers' paper is published in *Nature Nanotechnology*.

"This is truly remarkable discovery, as it unveils an unparalleled and simple way for navigating material synthesis at the atomic scale by harnessing the power of epitaxial strain," said Bharat Jalan, senior author on the paper and a professor and Shell Chair in the University of Minnesota Department of Chemical Engineering and Materials Science.

"This breakthrough represents a significant advancement with far-reaching implications in a broad range of fields. Not only does it provide a means to achieve atomically-precise synthesis of quantum materials, but it also holds immense potential for controlling oxidation-reduction pathways in various applications, including catalysis and chemical reactions occurring in batteries or fuel cells."

"Stubborn" metals oxides, such as those based on ruthenium or iridium, play a crucial role in numerous applications in quantum information sciences and electronics. However, converting them into [thin films](#) has been a challenge for researchers due to the inherent difficulties in oxidizing metals using high-vacuum processes.

The fabrication of these materials has perplexed materials scientists for decades. While some researchers have successfully achieved oxidation, the methods used thus far have been costly, unsafe, or have resulted in poor material quality.

The University of Minnesota researchers' solution? Give it a stretch.

While attempting to synthesize metal oxides using conventional molecular beam epitaxy, a low-energy technique that generates single layers of material in an ultra-high vacuum chamber, the researchers stumbled upon a groundbreaking revelation. They found that incorporating a concept called "epitaxial strain"—effectively stretching the metals at the [atomic level](#)—significantly simplifies the oxidation process of these stubborn metals.

"This enables the creation of technologically important [metal oxides](#) out of stubborn metals in ultra-high vacuum atmospheres, which has been a longstanding problem," said Sreejith Nair, first author of the paper and a University of Minnesota chemical engineering Ph.D. student. "The current synthesis approaches have limits, and we need to find new ways to push those limits further so that we can make better quality materials. Our new method of stretching the material at the [atomic scale](#) is one way to improve the performance of the current technology."

Although the University of Minnesota team used iridium and ruthenium as examples in this paper, their method has the potential to generate atomically-precise oxides of any hard-to-oxidize metal. With this groundbreaking discovery, the researchers aim to empower scientists worldwide to synthesize these novel materials.

The researchers worked closely with collaborators at Auburn University, the University of Delaware, Brookhaven National Laboratory, Argonne National Laboratory, and fellow University of Minnesota Department of Chemical Engineering and Materials Science Professor Andre Mkhoyan's lab to verify their method.

"When we looked at these metal oxide films very closely using very powerful electron microscopes, we captured the arrangements of the

atoms and determined their types," Mkhoyan explained. "Sure enough, they were nicely and periodically arranged as they should be in these crystalline films."

More information: Sreejith Nair, Engineering metal oxidation using epitaxial strain, *Nature Nanotechnology* (2023). [DOI: 10.1038/s41565-023-01397-0](https://doi.org/10.1038/s41565-023-01397-0).
www.nature.com/articles/s41565-023-01397-0

Provided by University of Minnesota

Citation: Stretching metals at the atomic level allows researchers to create important materials for quantum applications (2023, May 22) retrieved 21 May 2024 from <https://phys.org/news/2023-05-metals-atomic-important-materials-quantum.html>

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