Researchers develop novel 'super-tetragonal' sacrificial layer for freestanding oxide membranes

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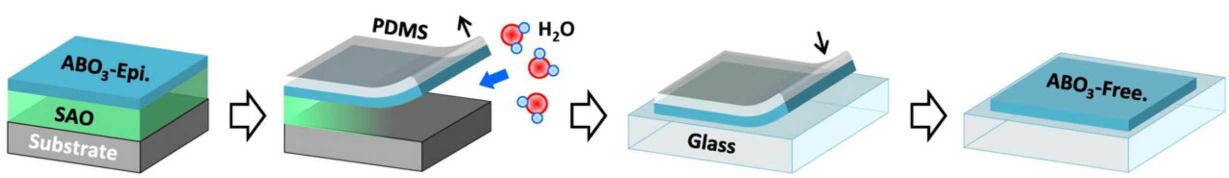

Schematic illustration of water-assisted exfoliation of freestanding oxide membranes from SAO_C and SAO_T sacrificial layers. Credit: Prof. Wu Wenbing's team

Researchers have developed a new water-soluble sacrificial layer, "super-tectragonal" $Sr_4Al_2O_7$ (SAO_T), with broad tunability in lattice constants, which can be used to prepare high-quality freestanding oxide membrane. Their work is published in *Science*.

A freestanding oxide membrane is a type of low-dimensional quantum material that maintains single-crystal properties even after removing the substrate, possessing both the coupled properties of multi-degree-of-freedom in correlated electron systems and the structural flexibility of two-dimensional materials. Its unique properties like superelasticity offer the potential to induce novel quantum-derived phenomena and develop ultrathin flexible electronic devices.

However, the misfit strain relaxation between the water-soluble sacrificial layer and the oxide membrane triggers the formation of high-density cracks during the water-assisted exfoliation of the freestanding oxide membrane, compromising the crystallinity and integrity of the current freestanding oxide membrane. How to suppress the crack formation and obtain large-area, highly crystalline freestanding oxide membranes remains a challenge.

To address the problem, the team delved into the pulsed laser deposition growth window of Sr-Al-O (SAO) based water-soluble sacrificial layer and discovered a previously unknown $Sr_4Al_2O_7$ film, which exhibits extraordinary properties.

The biaxial-strained $Sr_4Al_2O_7$ film has a tetragonal structural symmetry, enabling coherent growth of high-quality ABO_3/SAO_T epitaxial heterostructures, which suppresses the crack formation during water-assisted release and thus enhancing the crystallinity and integrity of freestanding oxide membrane.

The team also verified the exfoliation effect of perovskite oxide films with a broad lattice constant range (3.85 to 4.04 Å) and revealed that the crack-free areas of the freestanding oxide membrane released from the $Sr_4Al_2O_7$ sacrificial layer can span up to a few millimeters in scale, which is 1–3 orders of magnitude larger than previous freestanding oxide membrane. In addition, the crystallinity and functionalities of the team's freestanding oxide membrane are comparable to the epitaxial membranes grown on single crystalline substrates.

Furthermore, the team discovered that the unique structure of $Sr_4Al_2O_7$ results in high water solubility, significantly reducing the time of water-assisted releasing processes and enhancing the efficiency of freestanding oxide membrane.

This discovery is a breakthrough in improving the integrity and crystallinity of freestanding oxide membranes, which can enhance their application potential in low-dimensional flexible electronic devices. Reviewers highly commend this work, saying that "(this work) has the potential to have a broad impact on oxide electronics from multiple perspectives."

The research team was led by Prof. Wu Wenbing and Prof. Wang Linfei from the University of Science and Technology of China, in collaboration with Prof. Si Liang' s team from Northwest University.

More information: Jinfeng Zhang et al, Super-tetragonal $Sr_4Al_2O_7$ as a sacrificial layer for high-integrity freestanding oxide membranes, *Science* (2024). DOI: 10.1126/science.adi6620

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