Challenges and Opportunities of chemical deposited functional complex oxide membranes

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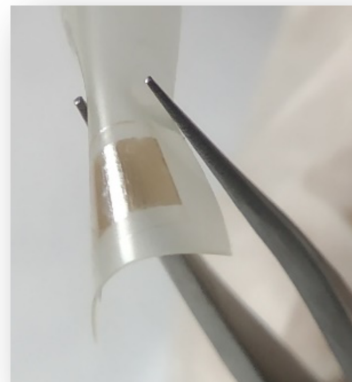

Flexible electronics are gaining more and more importance towards the conception of the Internet of Things (IoT) and integrating all kind of versatile devices in our daily lives. Complex transition-metal oxides are a very promising family of materials that offer a wide range of functionalities, including ferroelectricity, metal-to-insulator transitions, piezoelectricity, colossal magnetoresistance and superconductivity, to name a few. These functionalities are often associated to its crystalline quality and orientation. Therefore, the processing of such materials is constrained on substrates that can stand high temperature treatments and on single crystal substrates when epitaxy is pursued. These constraints are not compatible with flexible electronics, hence approaches to detach these epitaxial oxides from the growth substrate are crucial. The use of a sacrificial layer is an appealing approach for the fabrication and manipulation of freestanding epitaxial complex oxides membranes. This method consists on adding a buffer layer between the substrate and the complex oxide which allows subsequent detachment upon selective etching. Recently, $Sr_3Al_2O_6$ (SAO) has been proved as an attractive candidate to be used as water-soluble sacrificial layer. The deposition techniques to prepare such structures is also a key factor to be considered not only for film quality but also for process scalability. While high vacuum deposition techniques such as molecular beam epitaxy and pulsed laser deposition are well established techniques to produce high quality films, alternate procedures that can deliver low-cost production such as solution processing and atomic layer deposition are gaining interest. [1]

Here we present a robust chemical and low-cost methodology to prepare water-soluble SAO thin films to be used as sacrificial layer [2] however, when it is exposed to air to perform an ex-situ growth of the functional oxides on it, it forms an amorphous capping layer that jeopardizes the transfer of the epitaxy. Using this ex-situ approach, bendable and polycrystalline $CoFe_2O_4$ membranes with robust magnetization at room temperature are obtained [3]. Vacuum annealing and cation substitution in SAO films is a simple combination to modify the SAO softness while reconstructing their surface crystallinity to ultimately obtain epitaxial complex oxide membranes. As a case example, here we will show that the chemical nanoengineering of the sacrificial layer allows to modulate the strain and physical properties of $La_{0.7}Sr_{0.3}MnO_3$ membranes. [4] Therefore, we put forward a procedure to prepare a wide variety of thin film oxide membranes and can allow the fabrication of artificial heterostructures to go beyond the traditional electronic, spintronic and energy storage and conversion devices.

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[1] Mariona Coll and Mari Napari Atomic Layer Deposition of functional multicomponent oxides APL Materials (2019)
[2] Pol Salles, Ivan Caño, Roger Guzman, Camilla Dore, Agustín Mihi, Wu Zhou, and Mariona Coll*, Facile Chemical Route to Prepare Water Soluble Epitaxial $Sr_3Al_2O_6$ Sacrificial Layers for Free-Standing Oxides, Adv. Mater. Interfaces 8, 2001643 (2021)
[3] Pol Salles, Roger Guzmán, David Zanders, Alberto Quintana, Ignasi Fina, Florencio Sánchez, Wu Zhou, Anjana Devi, and Mariona Coll* Bendable Polycrystalline and Magnetic $CoFe_2O_4$ Membranes by Chemical Methods ACS Appl. Mater. Interfaces, 14, 12845−12854 (2022)
[4] Pol Salles, Mariona Coll et al. On the role of the $Sr_{1-x}M_xAl_2O_6$ sacrificial layer composition for improved epitaxial $La_{0.7}Sr_{0.3}MnO_3$ membranes. To be submitted (2022)