OXIDE INTERFACE PHYSICS GROUP

❑ Heterostructures of double and single perovskites

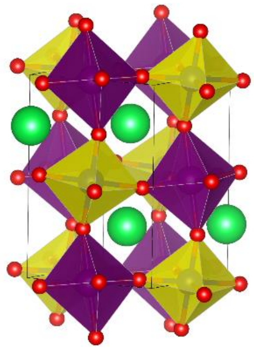

Fig. 1

Double perovskites such as La_2NiMnO_6 (LNMO) are an interesting class of compounds where two different transition metal cations order in a 3D chess-board-like structure (see Fig.1). In LNMO, one electron is transferred from Mn to Ni, and the resulting superexchange interaction between Mn^{4+} and Ni^{2+} leads to an insulating ferromagnetic system with T_C~280K, thus appealing for applications.

To incorporate LNMO films in realistic spintronic devices, it is important to retain such magnetic properties down to low thickness (few unit cells). We recently verified that our LNMO films are indeed ferromagnetic down to 1nm, though they exhibit both reduced magnetization and Curie temperature compared to thicker films (Fig. 2). We associate this behavior to the presence of Mn^{3+} at the interface with the $SrTiO_3$ substrate.

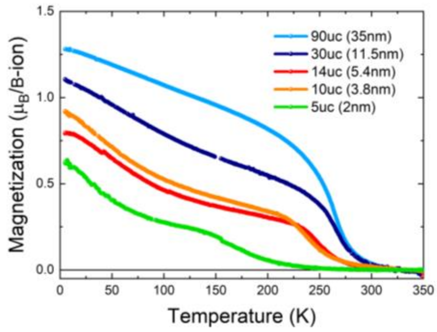

Fig. 2

The aim of the project is to grow ultrathin epitaxial LNMO films “sandwiched” between different perovskite layers (i.e. $LaNiO_3$ and/or $LaAlO_3$) in order to improve the magnetic performance of these very thin films. We will use RF off-axis magnetron sputtering as growth method, and characterize the structure of the films by atomic force microscopy (AFM) and x-ray diffraction (XRD). The magnetic properties of these heterostructures will be investigated using SQUID-magnetometry. There might be a chance to join an experiment at the Swiss Light Source (SLS) to characterize the films’ electronic properties using X-ray absorption spectroscopy.

❑ Growing superlattices of double perovskites that are predicted to become multiferroic

The search for multiferroic materials combining electric and magnetic behaviors in a single phase has attracted a lot of attention from the perspective of designing low energy consuming new devices. However, a material system that exhibit simultaneous sizeable ferroelectric and ferromagnetic ordering around room temperature has never been observed so far.

A recent theoretical prediction (Zhao *et al.*, *Nat. Commun.* 5, 1 (2014)) suggests that superlattices (alternate layers) of the double perovskites La_2NiMnO_6 (LNMO) and R_2NiMnO_6 (RNMO, *R* being rare-earth ion different from La) might be near room temperature multiferroic materials (Fig. 3).

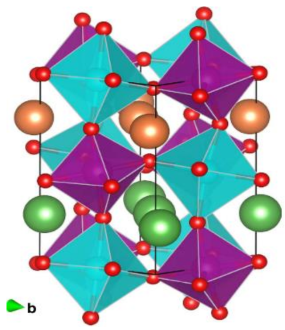

Fig. 3

In our lab we have already developed a vast experience in the growth of LNMO films (see previous project) and the aim now will be to optimize the growth conditions of Nd_2NiMnO_6 (NNMO) films and investigate their magnetic properties as function of strain and thickness. This is the first step towards incorporating both LNMO and NNMO in a superlattice structure. The films will be grown by off-axis magnetron sputtering and their structural quality will be characterized using atomic force microscopy (AFM) and x-ray diffraction (XRD). Magnetism will be studied using SQUID-magnetometry.

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❑ Exploring superconductivity in Nickelate-based heterostructures

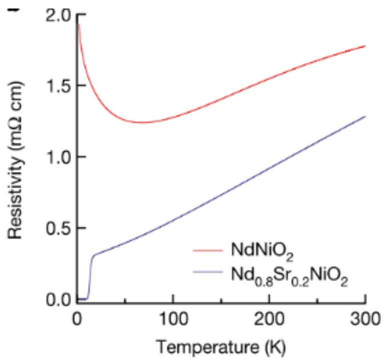

Fig. 4

In the last 30 years, many experimentalists have attempted engineering superconductivity in nickelates analogously to what is found in cuprates. It has been only few months ago when superconductivity has been reported in the layered structure $Nd_{0.8}Sr_{0.2}NiO_2$ (see Fig. 4 from Li *et al.*, *Nature* 572, 624 (2019)). To improve our understanding of the electron pairing process that generate the superconducting behavior in layered oxides, it is of fundamental importance to replicate this experimental result.

In this project, we plan to grow $NdNiO_3$ and $Nd_{0.8}Sr_{0.2}NiO_3$ thin films in the perovskite phase using radio frequency magnetron sputtering. The quality of the films will be investigated using atomic force microscopy (AFM) and x-ray diffraction (XRD). The films are expected to be conductive. Their transport properties will be investigated using a physical property measurement system (PPMS) that can go down to 4.2 K.

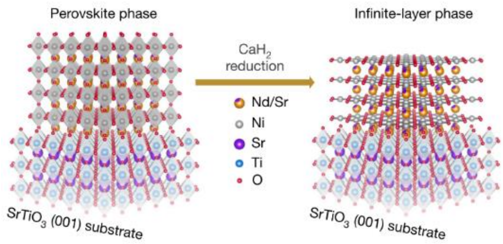

Fig. 5

After having assured that high quality of the nickelate perovskites, in collaboration with the Chemistry department, we will perform a topotactic oxygen reduction to generate the infinite-layer phase (see Fig. 5). We already verified that this process works for the topochemical reduction of the perovskite $LaNiO_3$ to the infinite-layer $LaNiO_2$. We will then finally verify the superconducting properties of our films using the PPMS system.

❑ Following in real time the oxide growth kinetics using *in-situ* polarized optics

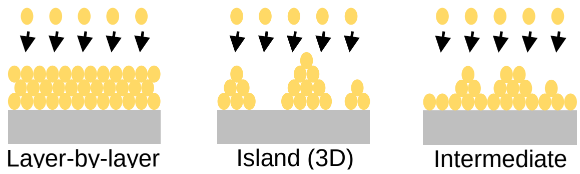

Fig. 7

Traditionally, thin-film thermodynamic growth is described by three possible schemes: layer-by-layer (Frank-van der Merwe), island growth (Volmer-Weber) and an intermediate regime where layer-by-layer is followed by island growth (Stranski-Krastanov) (Fig. 6). The leading technique for real-time diagnostic of layer growth is reflection high-energy electron diffraction (RHEED). However, this technique is hampered in conventional sputtering growth due to intrinsic physical limitations.

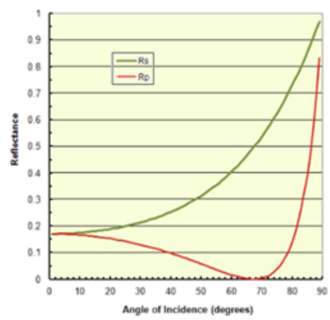

Fig. 6

Here, we propose a cost-efficient alternative to replace the electron beam with laser light and to monitor the oxide growth while impinging the light at the Brewster angle. This is a particular angle where the p-polarized light is compeletely not reflected (see red line in Fig. 7). Therefore, we can relate a change of the p-polarized light to the growth of the thin film and then follow the thermodynamics of the growth in real time! For this project all the relevant optics are already avaialble.

❑ **Additionally…** If you are more into programming, we need to improve our software that monitors the growth process. The software is written in LabVIEW and it works using block diagrams. No coding experience is required because development of the software is not made via coding.

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