Ferromagnetism in Ultrathin La_2NiMnO_6 Films

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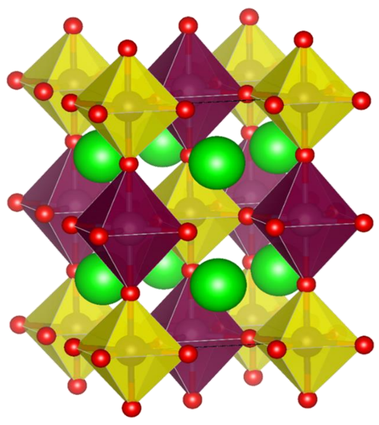
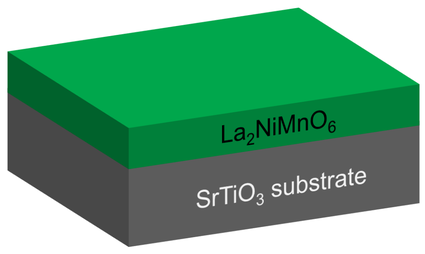
FNSNF Swiss National Science Foundation

Introduction



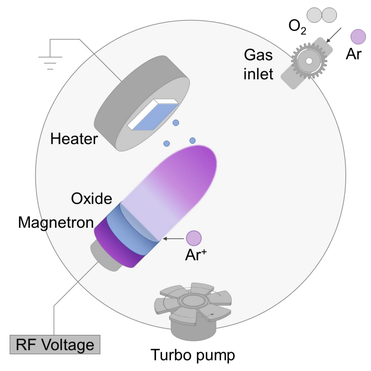
La_2NiMnO_6 (LNMO) double perovskite

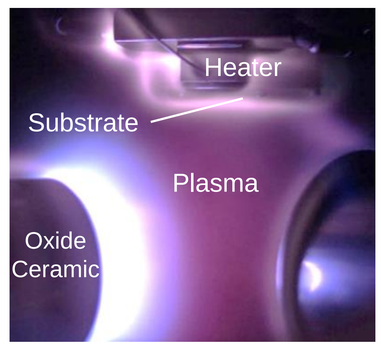
Rock-salt ordering of the NiO_6 and MnO_6 octahedra



- **Insulating ferromagnet** with transition temperature T_C = 280 K [1]
- Magnetism induced by super exchange between the long-range ordered Ni and Mn cations
- Application in electronic devices requires **epitaxial thin films**
- LNMO/RNMO heterostructures are predicted to be **multiferroic** [2]
- *Can the bulk properties be retained in thin films?*

Growth

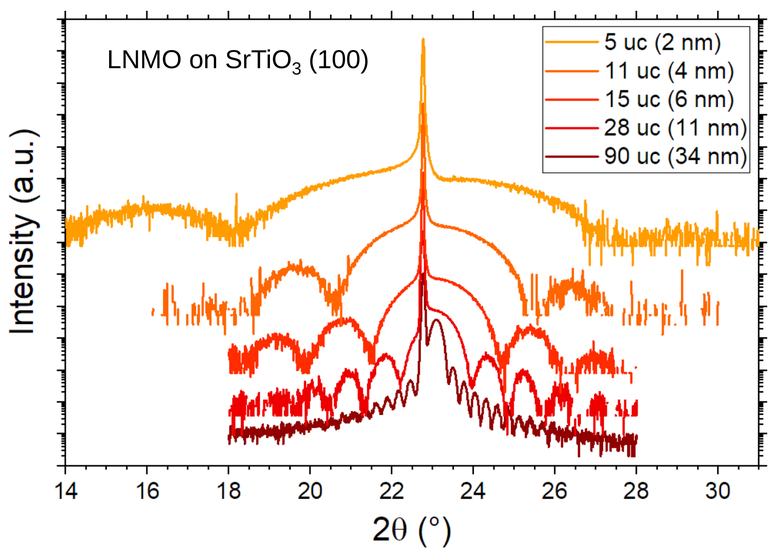




- Thin films are grown by **RF magnetron sputtering**

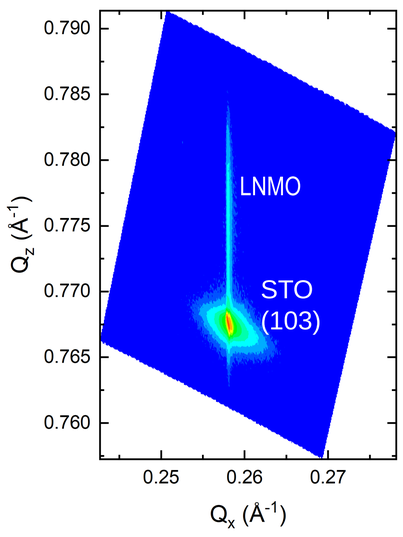
Structural Properties

X-ray diffraction



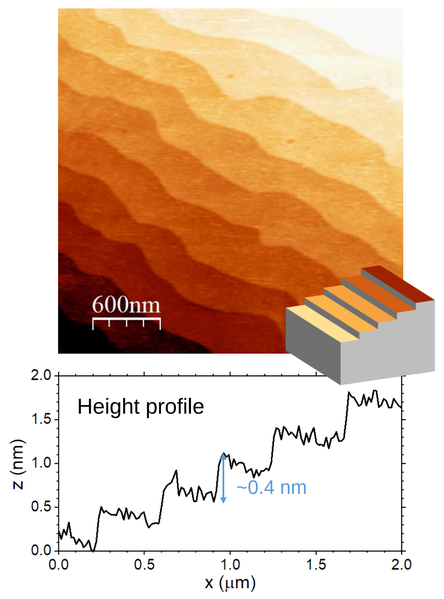
- LNMO thin films grown on $SrTiO_3$ show **high crystalline quality** (Laue fringes)

Reciprocal space mapping



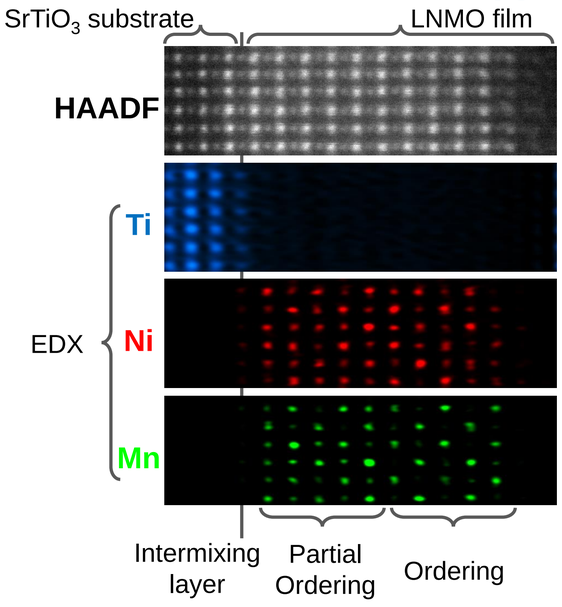
- Films are completely strained to the substrate

Atomic force microscopy



- Atomic steps indicate **excellent surface quality**

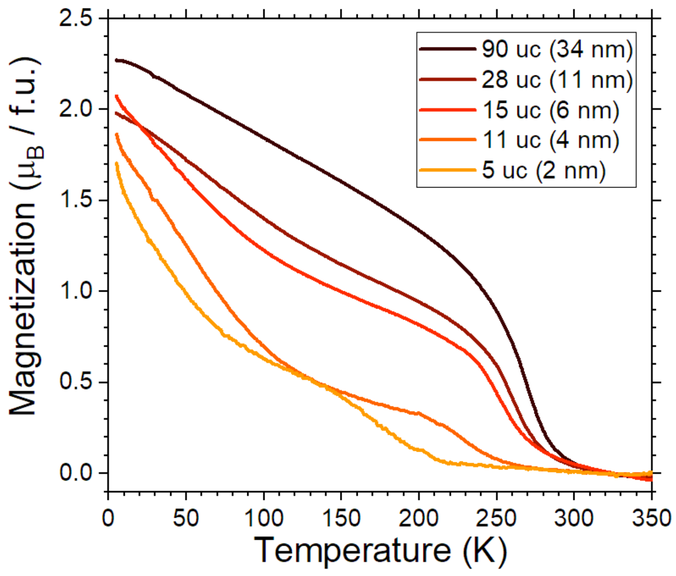
Scanning transmission electron microscopy



- STEM reveals B-site **cation ordering**

Magnetic Properties

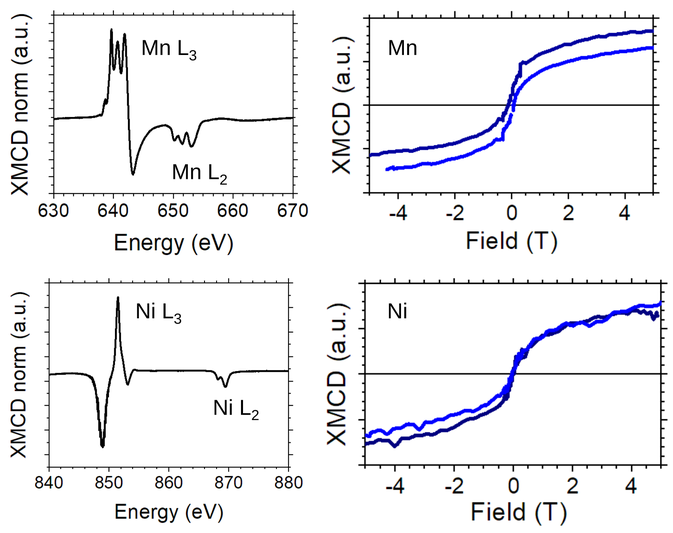
SQUID Magnetometry



- Bulk-like magnetic properties are achieved in films with thickness ≥ 15 uc (~6 nm)
- Reducing the film thickness depresses both T_C and the absolute magnetization

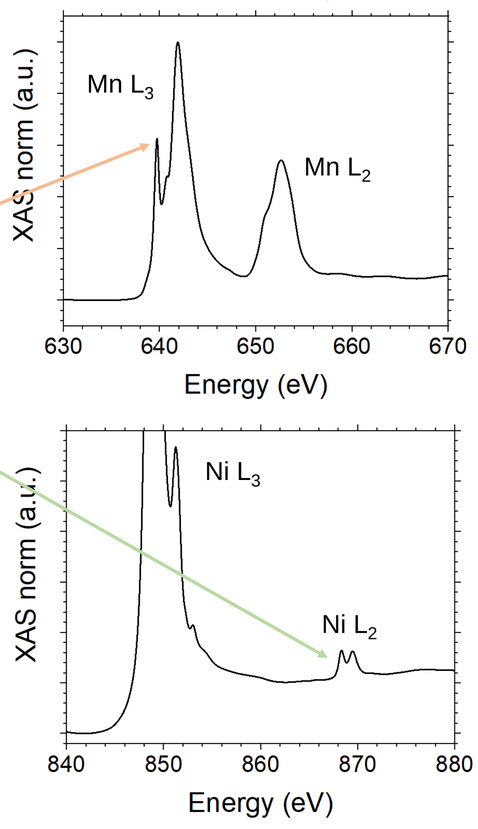
Synchrotron Measurements

X-ray magnetic circular dichroism
3 uc (~1.2 nm) LNMO on $SrTiO_3$ (100) at 20 K



- XMCD confirms **ferromagnetism down to 3 unit cells**
- The sign of the XMCD spectra confirms parallel alignment between the Ni and Mn magnetic moments

X-ray absorption
15 uc (~6 nm) LNMO on $SrTiO_3$ (100) at 20 K



- The pre-peak at the Mn L_3-edge [3] and the multiplet at the Ni L_2-edge [4] indicate **Mn^{4+}/Ni^{2+} valence states**

Conclusions

- Epitaxial La_2NiMnO_6 thin films grown by RF magnetron sputtering show exceptional structural quality
- Cation valence states Mn^{4+}/Ni^{2+} could be shown by XAS and B-site ordering is indicated by STEM image analysis
- Ferromagnetism is conserved down to film thicknesses of only 3 unit cells (~1.2 nm)

References

[1] Rogado et al., *Adv. Mater.* **17**, 2225 (2005)
[2] Zhao et al., *Nat. Commun*. **5**, 1 (2014)
[3] Sánchez et al., *Phys Rev. B* **65**, 144409 (2002)
[4] Piamonteze et al., *Phys Rev B* **92**, 014426 (2015)