Analytical TEM study of thin PLD-grown $LuFeO_3$ layers on Pt/sapphire substrates

X. Jin[1], B. Nergis[2], A. Rodrigues[2], S. Bauer[2], L. Horák[3], T. Baumbach[2], V. Holý[3,4], R. Schneider[1]

[1] Laboratory for Electron Microscopy, Karlsruhe Institute of Technology (KIT), Engesserstr. 7, D-76131 Karlsruhe, Germany; [2] Institute for Photon Science and Synchrotron Radiation, KIT, Hermann-von-Helmholtz-Platz 1, D-76344 Eggenstein-Leopoldshafen, Germany; [3] Department of Solid State Physics, Charles University, Ke Karlovu 5, 121 16 Prague, Czech Republic; [4] Faculty of Science, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic

Karlsruher Institut für Technologie

Laboratory for Electron Microscopy

Introduction

- Hexagonal ferrites *h*-$RFeO_3$ (R = Y, Dy-Lu), promising candidates for many future applications in information processing and storage [1],
- Epitaxial *h*-$LuFeO_3$ (*h*-LFO) thin films were deposited on different substrates, e.g., Al_2O_3 (0001),
- Pt interlayer between *h*-LFO and Al_2O_3 (0001) to reduce lattice mismatch and to act as a bottom electrode,
- **Goal:** Study the thickness effect of the Pt interlayer on the crystalline quality of the *h*-LFO layer.

LFO thin-film deposition

- Pulsed-laser deposition (PLD) of:
  - *h*-LFO (10nm)/Al_2O_3 (0001),
  - *h*-LFO (10nm)/Pt (20 nm)/Al_2O_3 (0001),
  - *h*-LFO (10nm)/Pt (40 nm)/Al_2O_3 (0001).

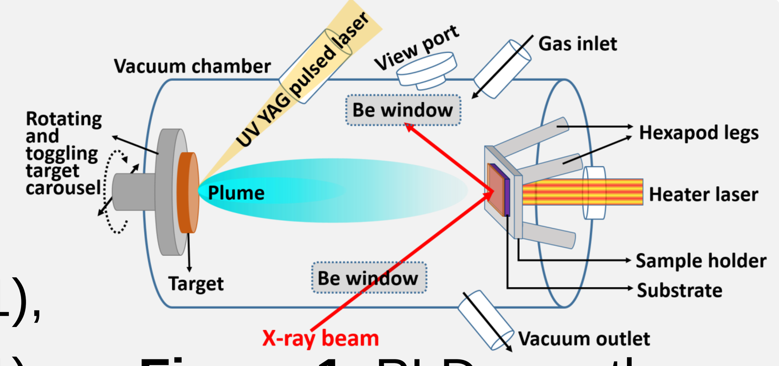

Figure 1. PLD growth

Characterization by electron microscopy

- Topography of the *h*-LFO thin films by secondary-electron (SE) imaging in scanning electron microscopy (SEM), and preparation of cross-sectional TEM lamellae by focused ion beam (FIB) milling, using a Thermo Fisher Dual-beam Helios G4 FX microscope,
- Combined high-angle annular dark-field (HAADF) imaging in scanning transmission electron microscopy (STEM) and energy-dispersive X-ray spectroscopy (EDXS) analyses of the *h*-LFO/(Pt)/Al_2O_3 interfacial regions at 200 kV with a FEI Tecnai Osiris microscope equipped with a SuperX detector,
- High-resolution transmission electron microscopy (HRTEM) imaging of interfacial regions between *h*-LFO and underlying Al_2O_3 substrate or Pt layer.

SE-imaging results

LFO on Al_2O_3 | LFO on 20 nm Pt | LFO on 40 nm Pt

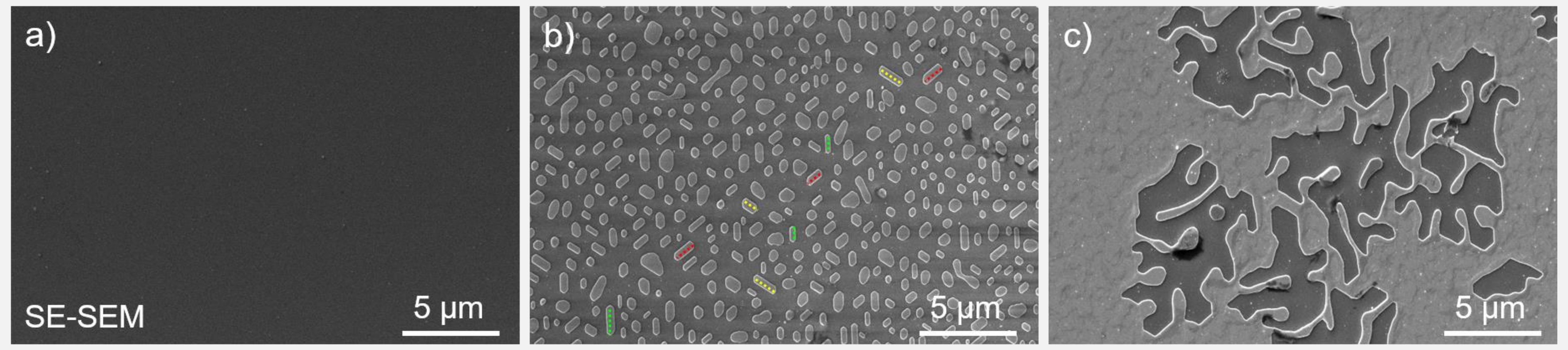

Figure 2. Top-view SE-SEM images of the sample surfaces: a) LFO/Al_2O_3, b) LFO/Pt (20 nm)/Al_2O_3, and c) LFO/Pt (40 nm)/Al_2O_3.

- LFO/Al_2O_3: extremely smooth surface,
- LFO/Pt (20 nm)/Al_2O_3: islands with an orientation alignment (120˚),
- LFO/Pt (40 nm)/Al_2O_3: most of the surface covered by LFO.

STEM/EDXS results

LFO on Al_2O_3 | LFO on 20 nm Pt | LFO on 40 nm Pt

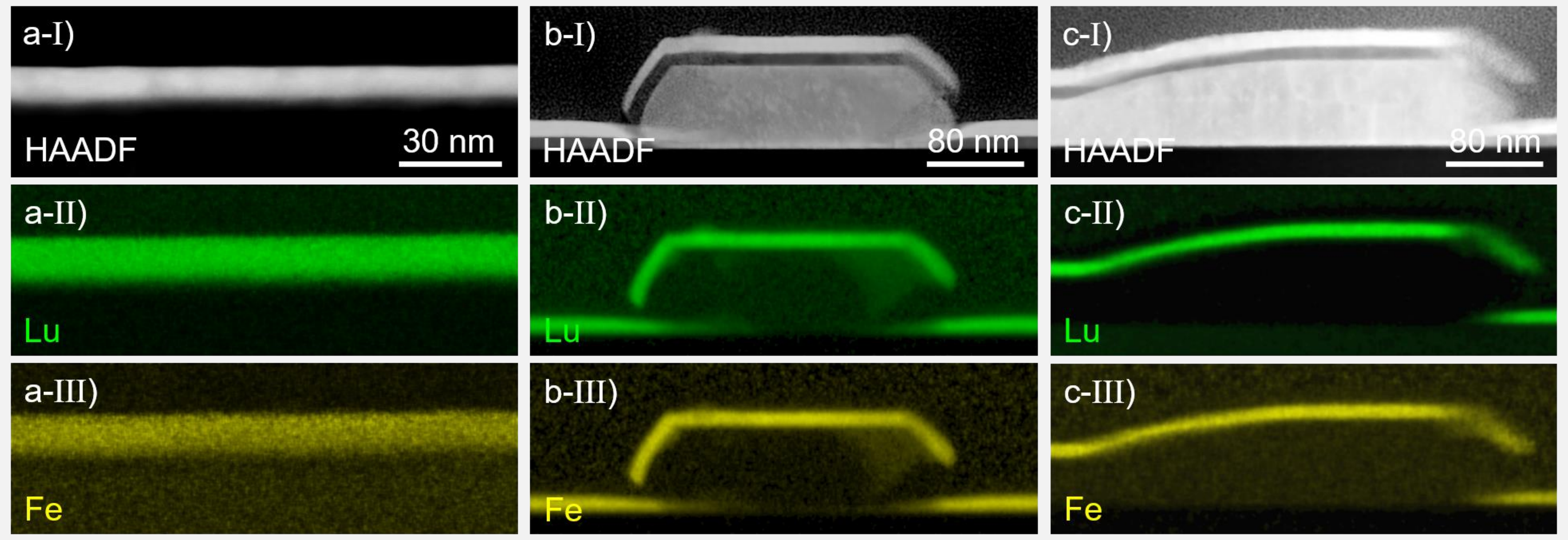

Figure 3. Cross-sectional STEM-HAADF images and X-ray maps of the distribution of the elements Lu and Fe for a) LFO/Al_2O_3, b) LFO/Pt (20 nm) /Al_2O_3, and c) LFO/Pt (40 nm)/Al_2O_3.

- LFO/Pt (20 nm)/Al_2O_3: no Pt in island-free regions; LFO layer interrupted by Pt islands,
- LFO/Pt (40 nm)/Al_2O_3: most Pt islands extend to form a Pt layer.

HRTEM results

LFO on Al_2O_3 | LFO on 20 nm Pt | LFO on 40 nm Pt

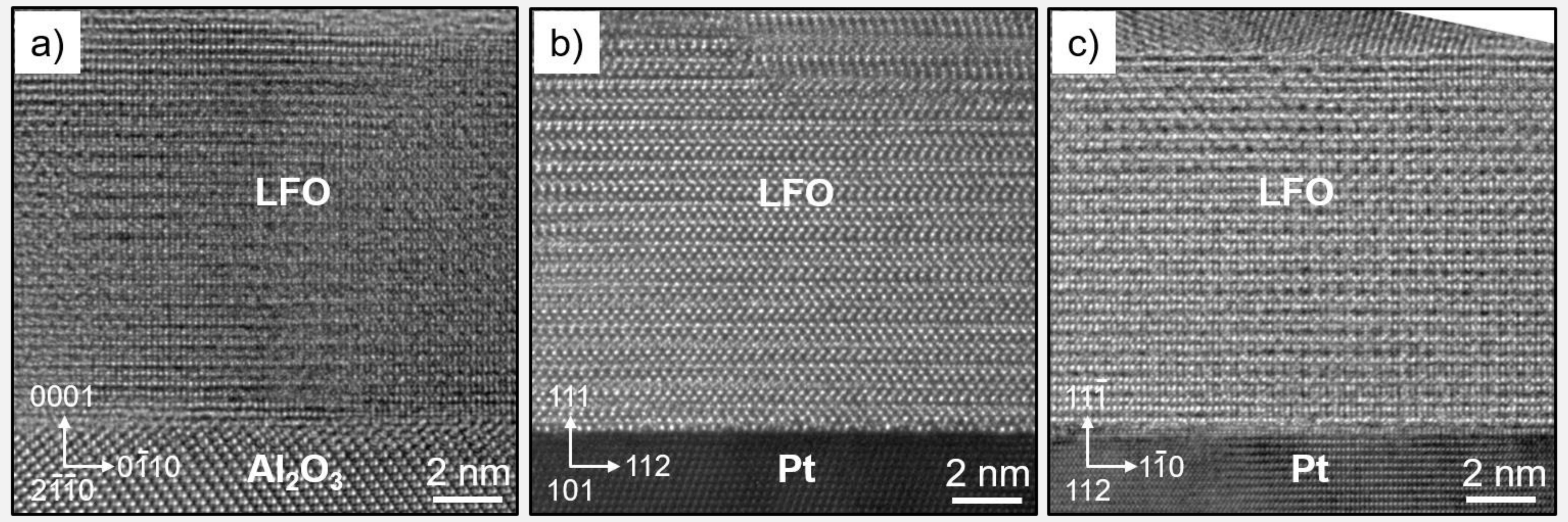

Figure 4. Cross-sectional HRTEM images of interfacial regions of a) LFO/Al_2O_3, b) LFO/Pt (20 nm), and c) LFO/Pt (40 nm).

- Hexagonal structure of LFO proved in all three samples,
- LFO/Al_2O_3: low crystalline quality of LFO layer (29 % lattice mismatch) with many crystal defects,
- LFO/Pt (20/40 nm): better crystallinity (mismatch of 6 %) and epitaxial growth.

Summary

- Crystalline quality of LFO thin films, deposited by PLD on Al_2O_3 (0001) or Pt buffered Al_2O_3 (0001), improves with increasing thickness of the Pt interlayer.

References

[1] H. Schmid, *Ferroelectrics* **162** (1994) 317.

[2] S. Bauer et al., *Materials* **13** (2020) 61.

The support of Czech Science Foundation (project 19-10799J) and German Research Foundation (projects SCHN 669/11 and BA 1642/8-1) is acknowledged.

contact: xiaowei.jin@kit.edu