B9

Ferromagnetic oxides for spin dynamics

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Motivation

- growing and characterizing of ferromagnetic oxides for investigation of spin dynamics in ferromagnetic resonance or spin pumping experiments

materials:

- $La_{0.7}Sr_{0.3}MnO$ (LSMO) which is expected to have a high spin polarization of conduction electrons
- $Y_3Fe_5O_{12}$ (YIG) which exhibits ferrimagnetism well above room temperature and exceptionally low damping

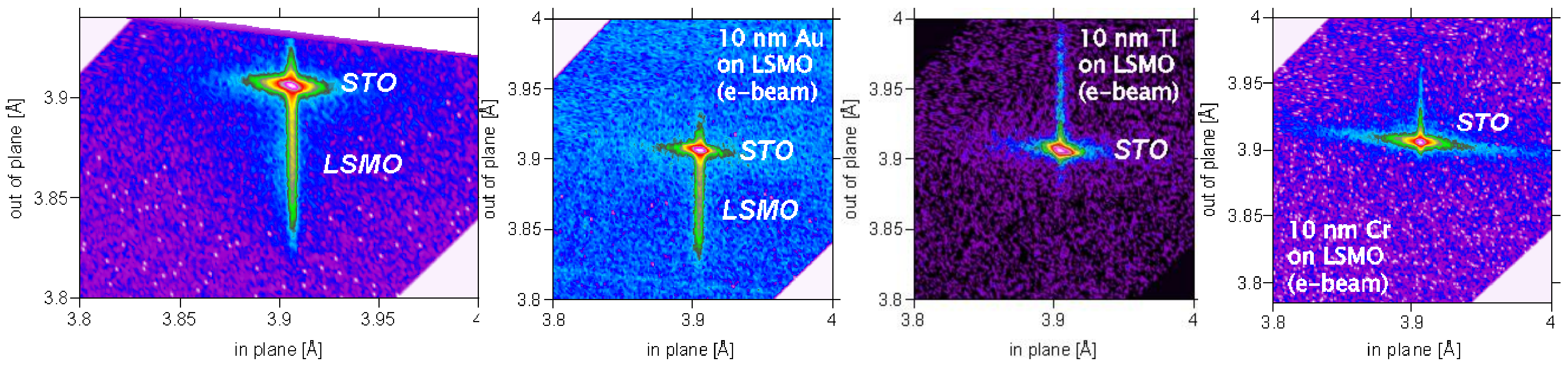
growing:

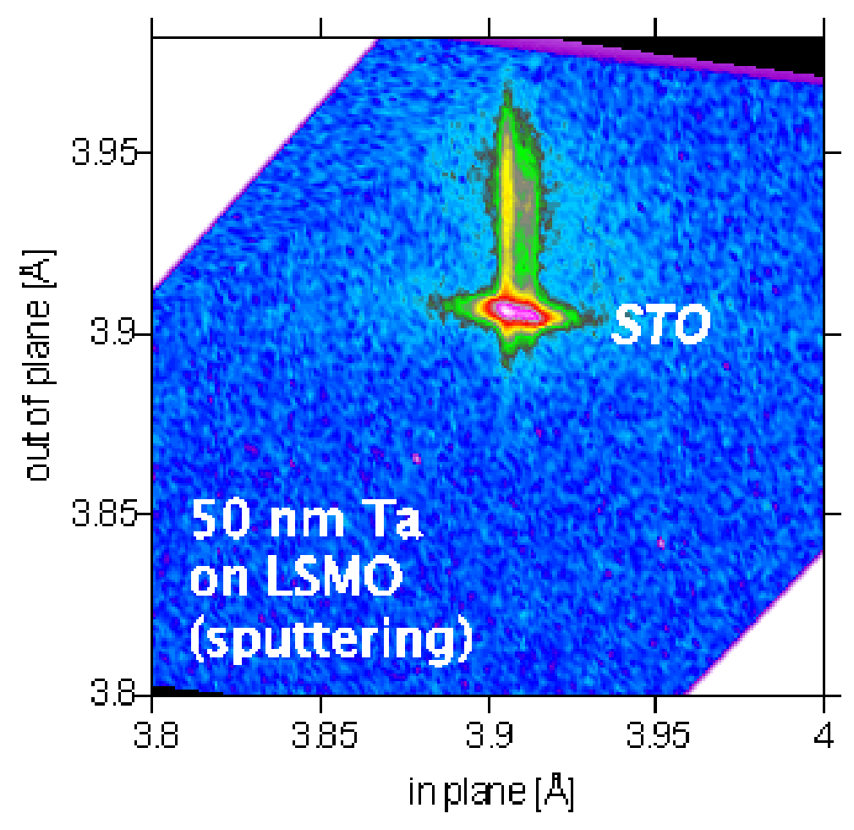
- PLD with RHEED, our best layers are grown with this conditions

	LSMO	YIG
Temperature	700 C	600 C
O_2-Pressure	0.2 mbar	0.025 mbar
Laser fluency	2.5 – 2.7 J/cm²	2.5 – 2.7 J/cm²
Laser repetition rate	5 Hz	5 Hz

- metal layers were deposited with **magnetron sputtering** or **electron beam evaporation** in-situ (without breaking the vacuum) to ensure a perfect interface

X-Ray measurements I: LSMO with different metal layers

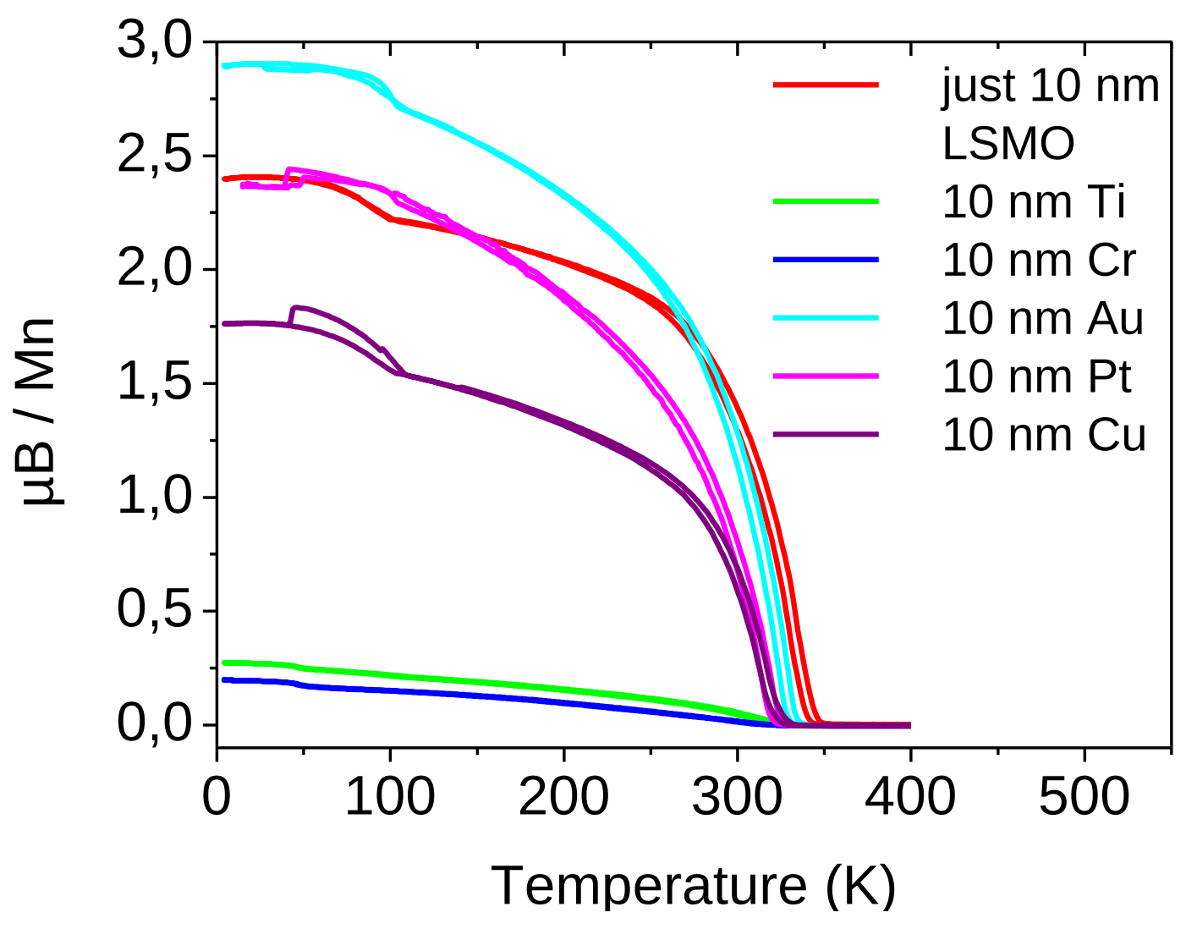




- Reciprocal space maps around the 103 substrate peak for various stacks
- Noble metals like Gold and Platinum have no influence of the LSMO structure
- in samples with different reactive metals like Cr, Ti, and Ta the LSMO layer streak is no longer present

➡ instead of this peak a new peak with lager lattice constant, but still pseudomorphic, is observed

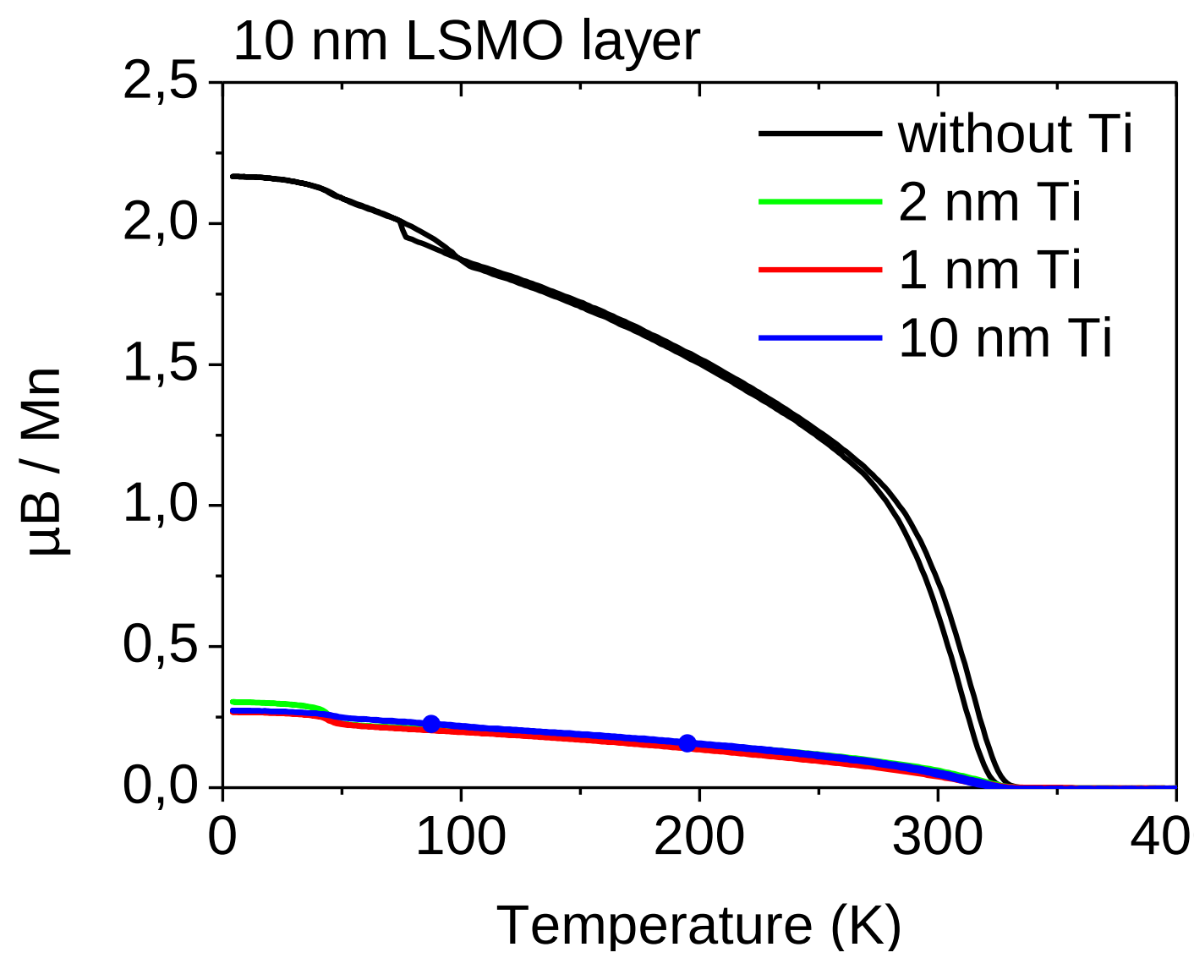
SQUID measurements I: LSMO with different metal layers

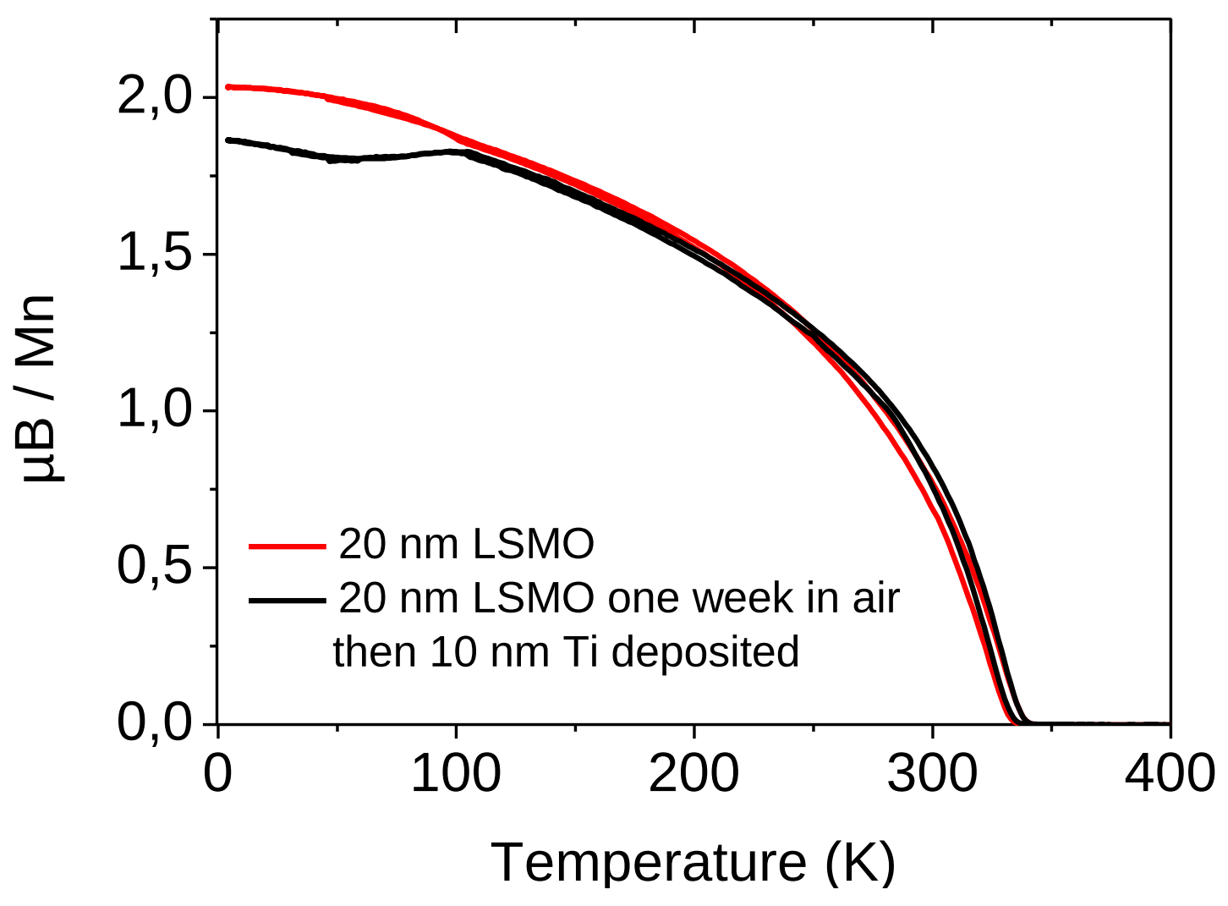


- reactive metals like Ti, Cr and Cu lead to a decrease of the magnetization
- these interface reactions are not observed if the sample is left in air for several days prior to metal evaporation

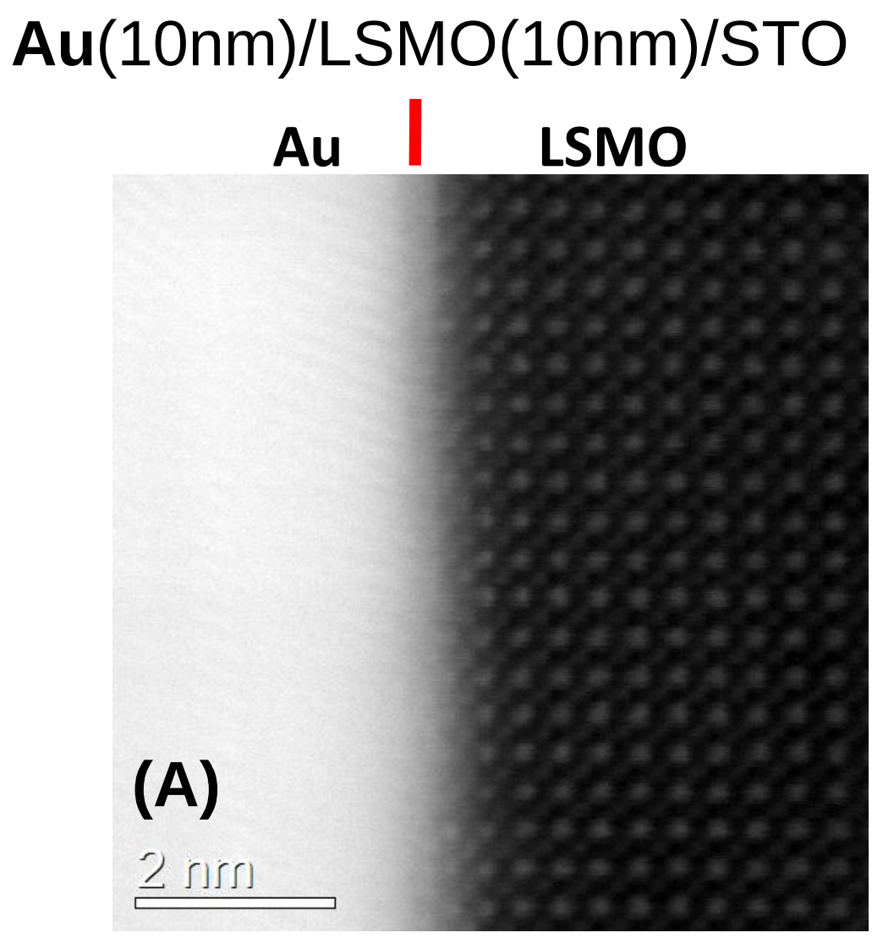
Further measurements have shown:

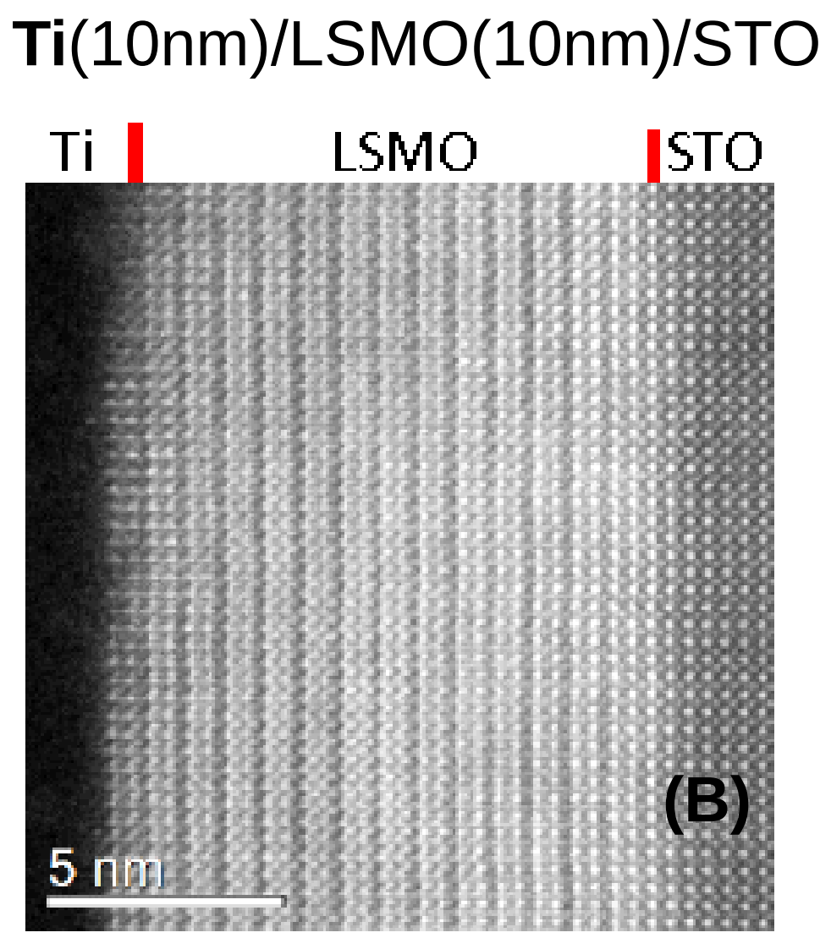
- 1 nm of Titanium is enough to destroy the complete magnetization of a 10 nm LSMO layer
- 4 nm SRO or STO layer can protect the LSMO

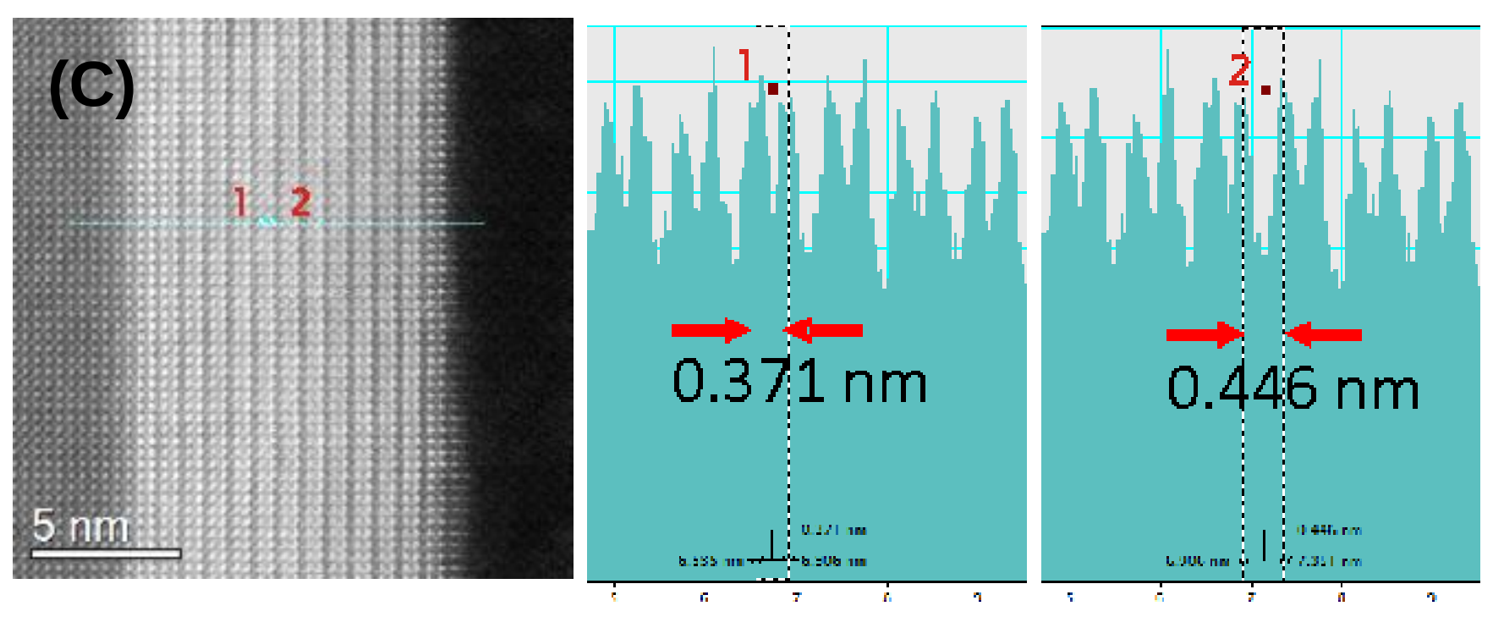


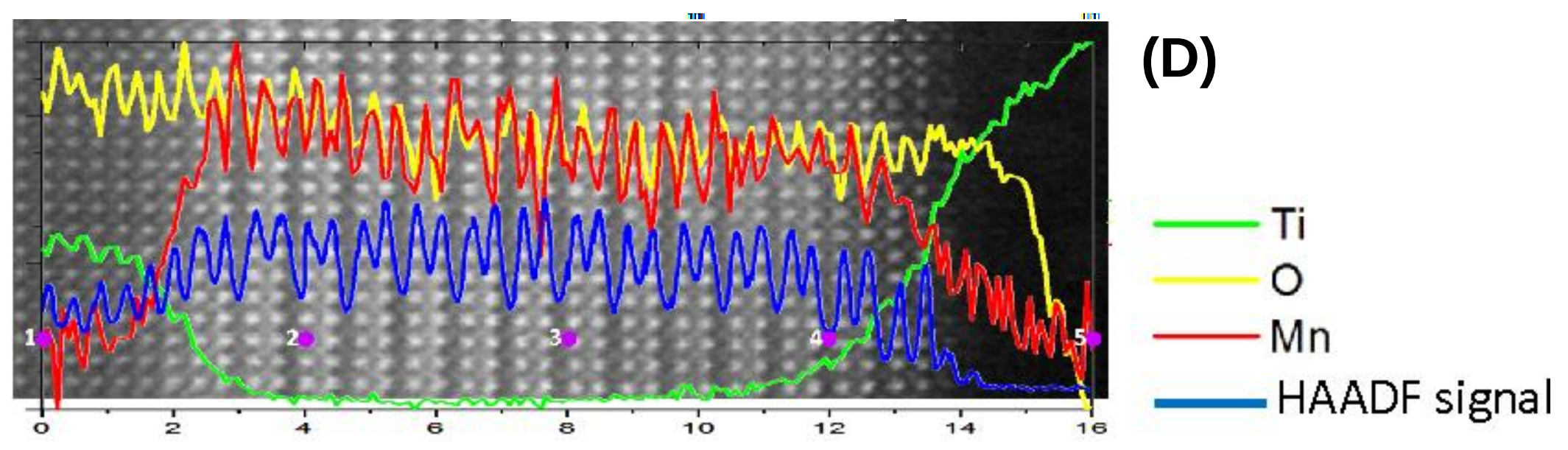


TEM measurements I: LSMO with different metal layers



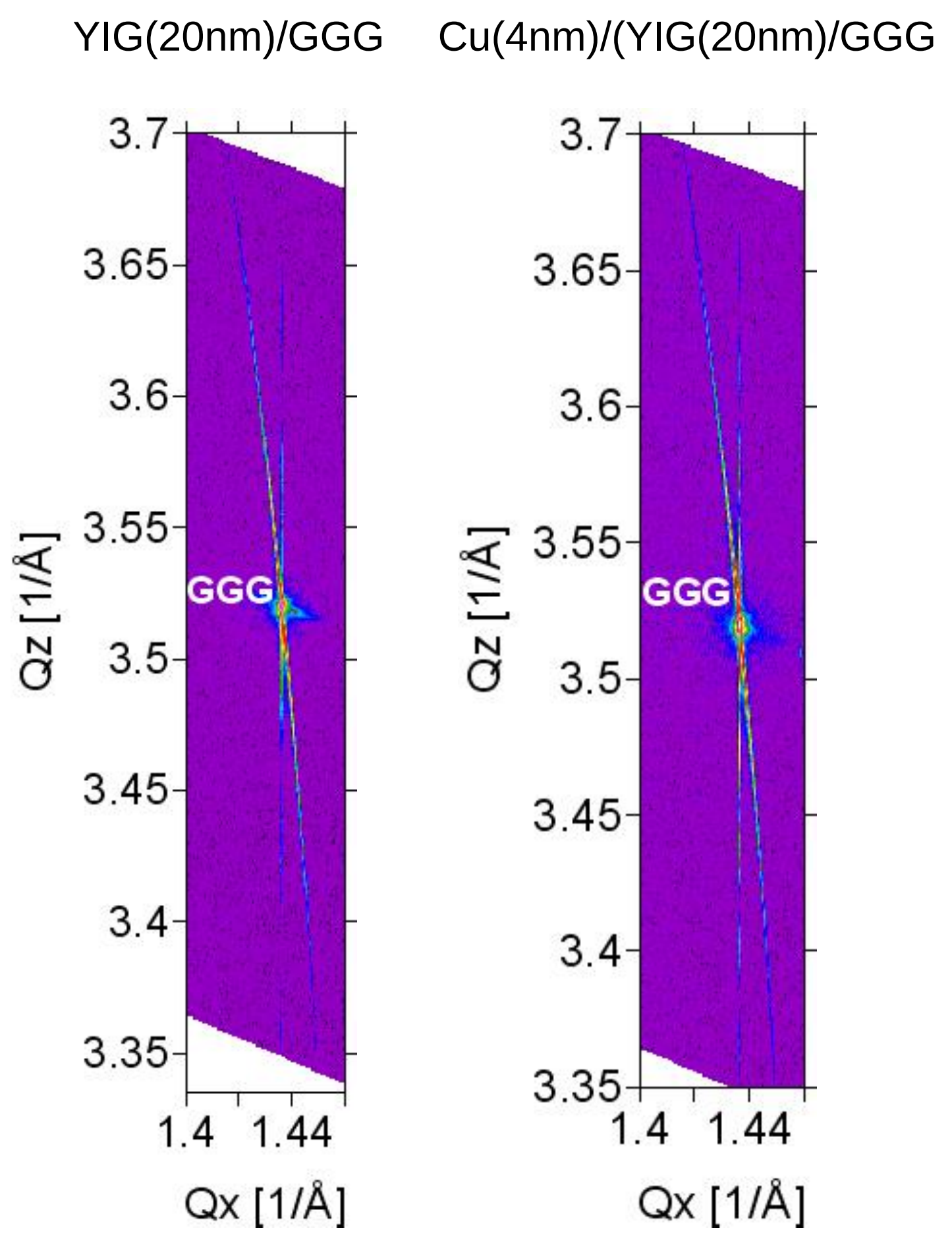


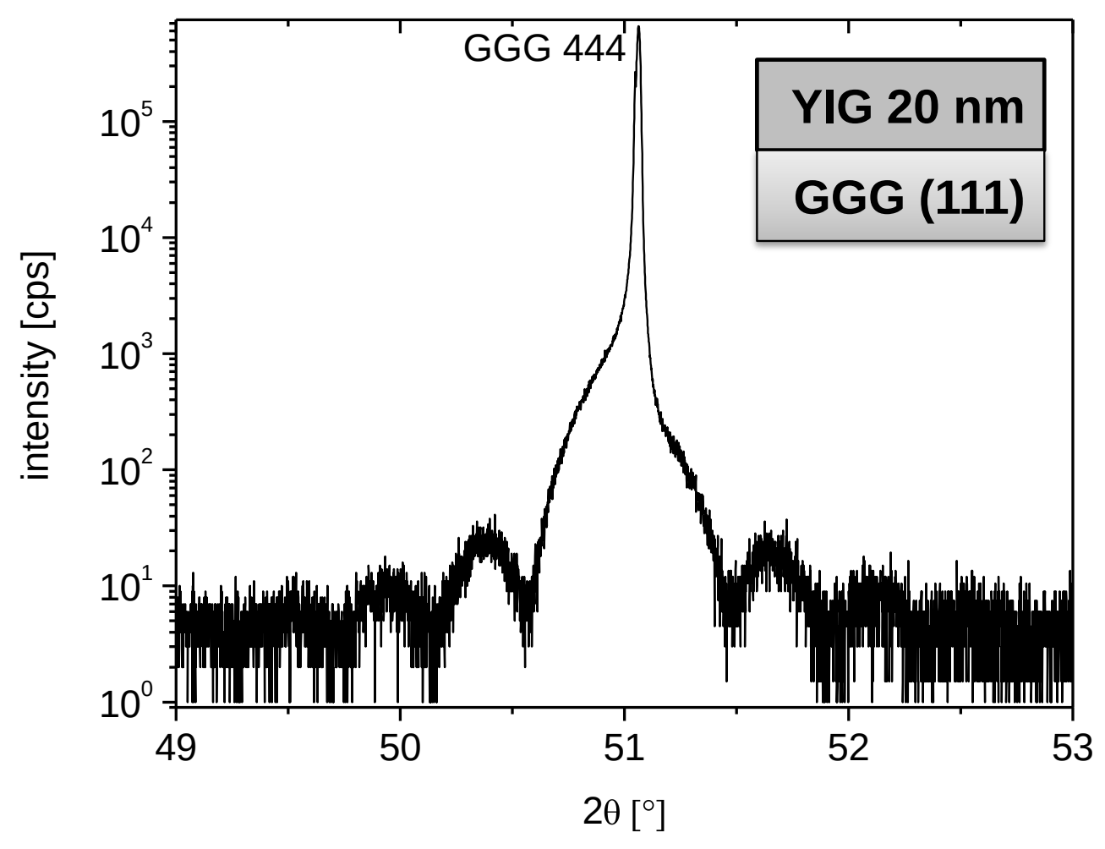


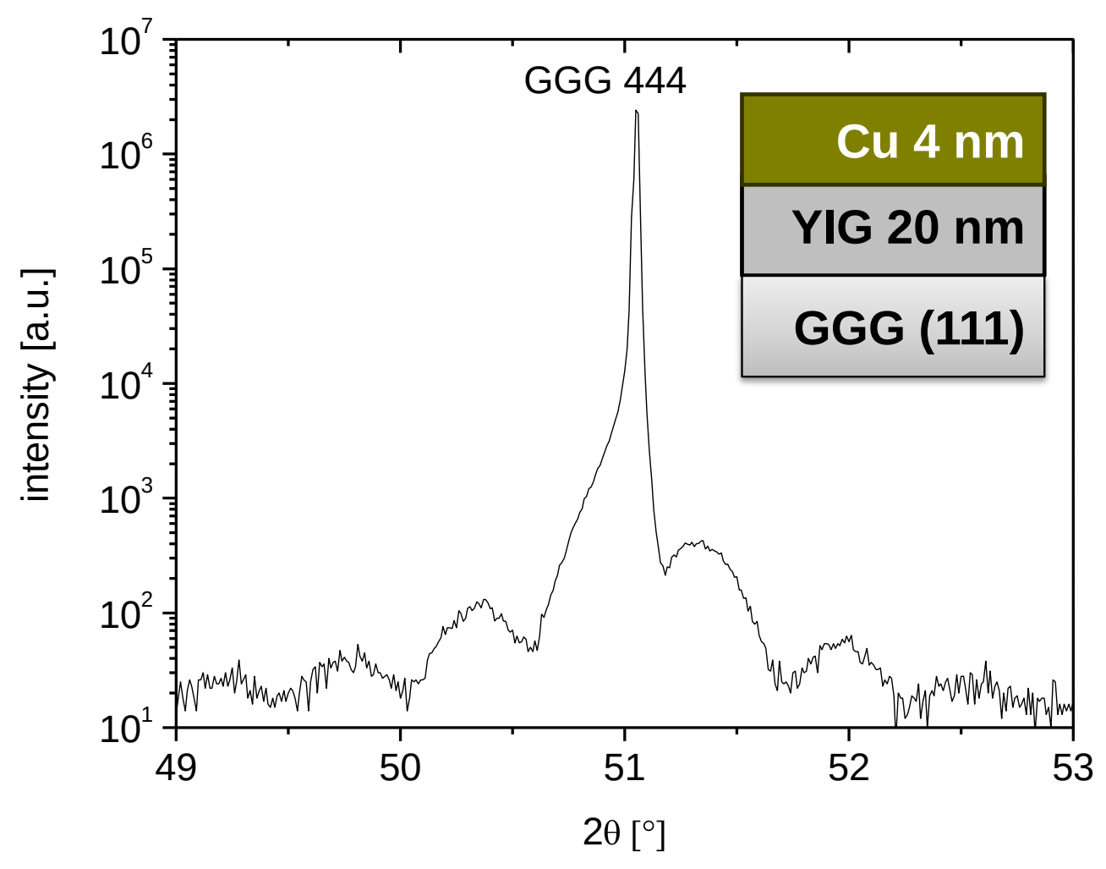


- STEM/HAADF images from a LSMO/Au sample **(A)** show nice periodic crystal structure
- images from a LSMO/Ti sample **(B)** show that the crystal structure of the LSMO film is not as expected
- It appears to have a periodic “cell doubling” along the growth direction, confirmed by line profiles **(C).**
- Effect of oxygen deficiency?
- EELS analysis across LSMO layer shows O is present in the Ti layer **(D)**.

X-Ray measurements II: YIG



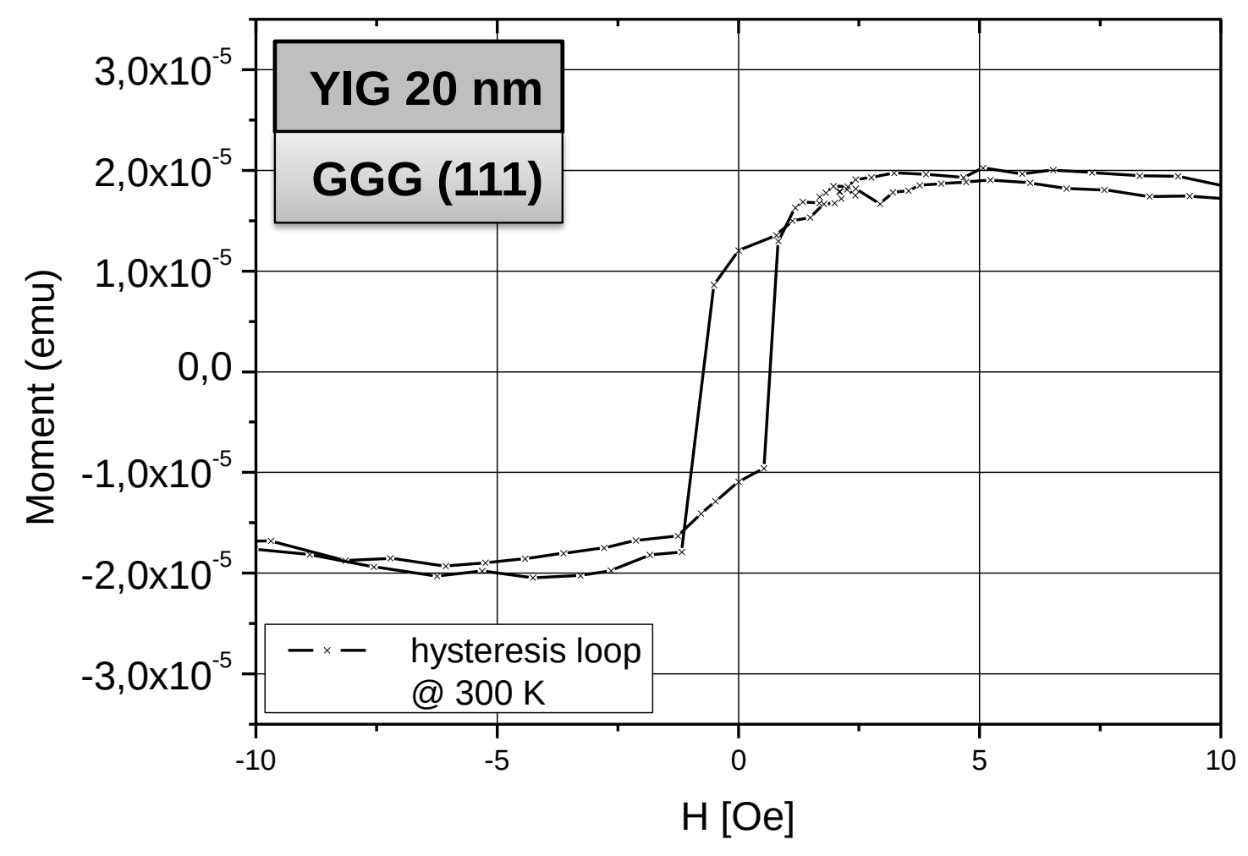




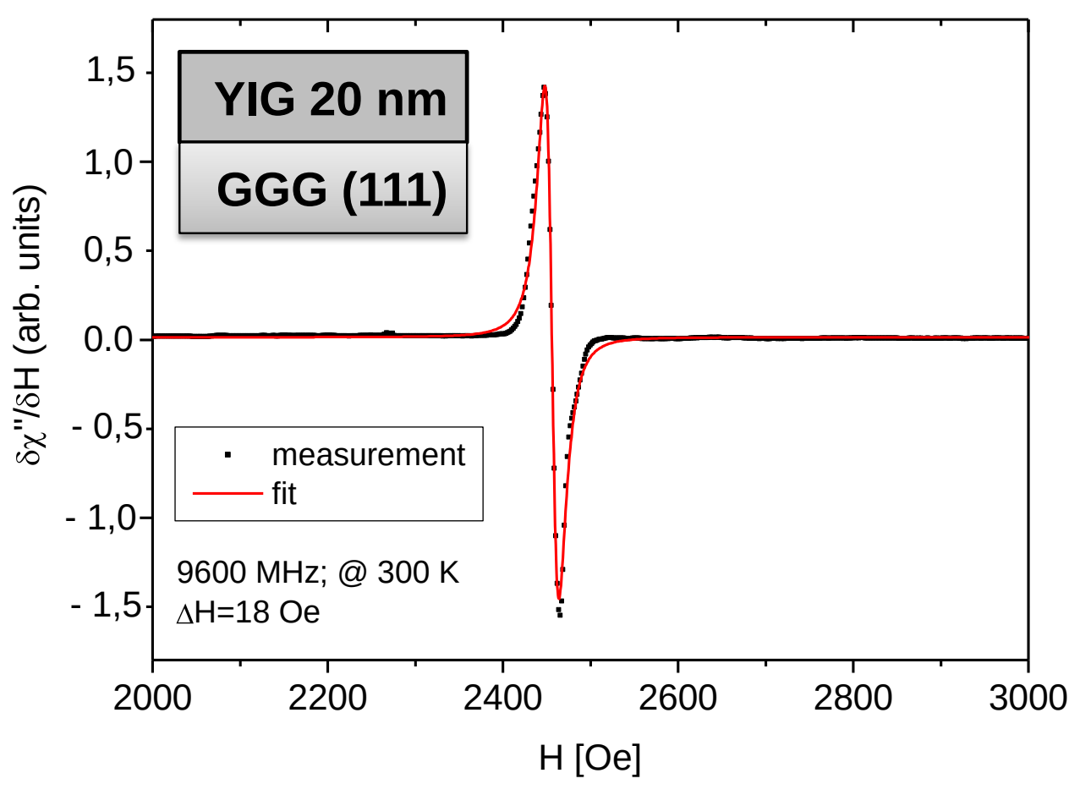
- Reciprocal space maps around the 642 substrate peak
- no difference between layer with Cu and without Cu visible

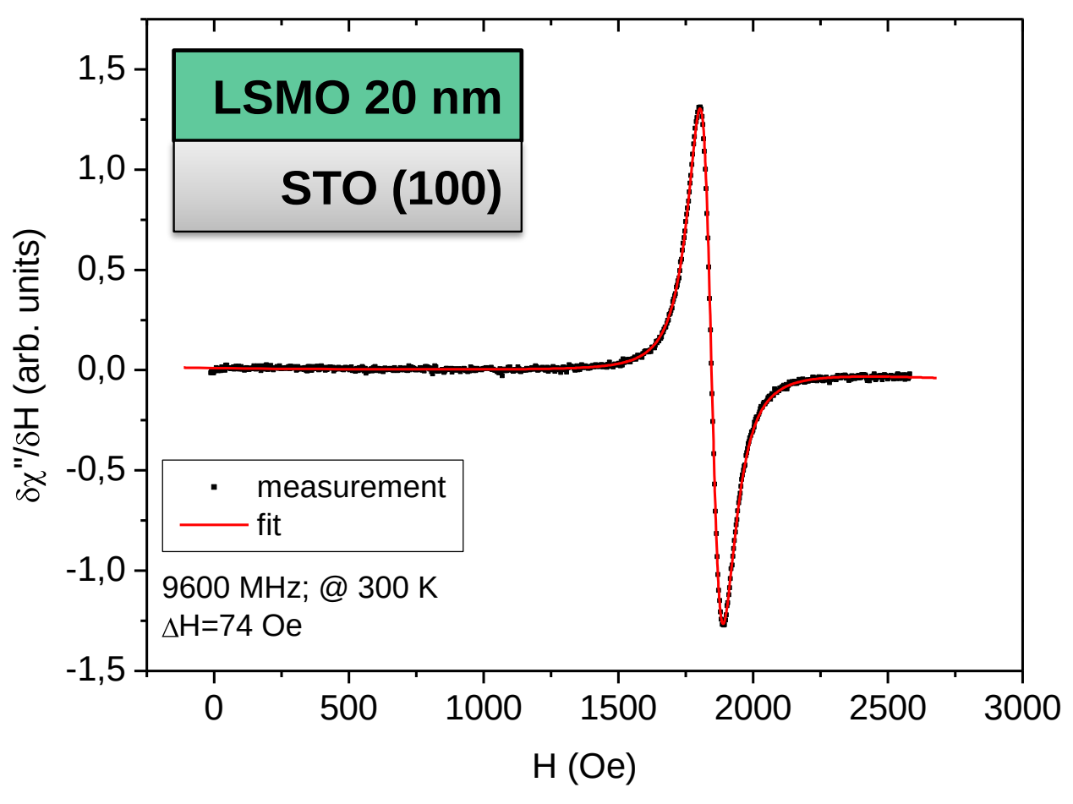
- θ/2θ scan around the 444 substrate reflex
- lattice mismatch between GGG and YIG ~ 0.08% → YIG peak at the same position like the GGG peak

magnetic measurements: YIG

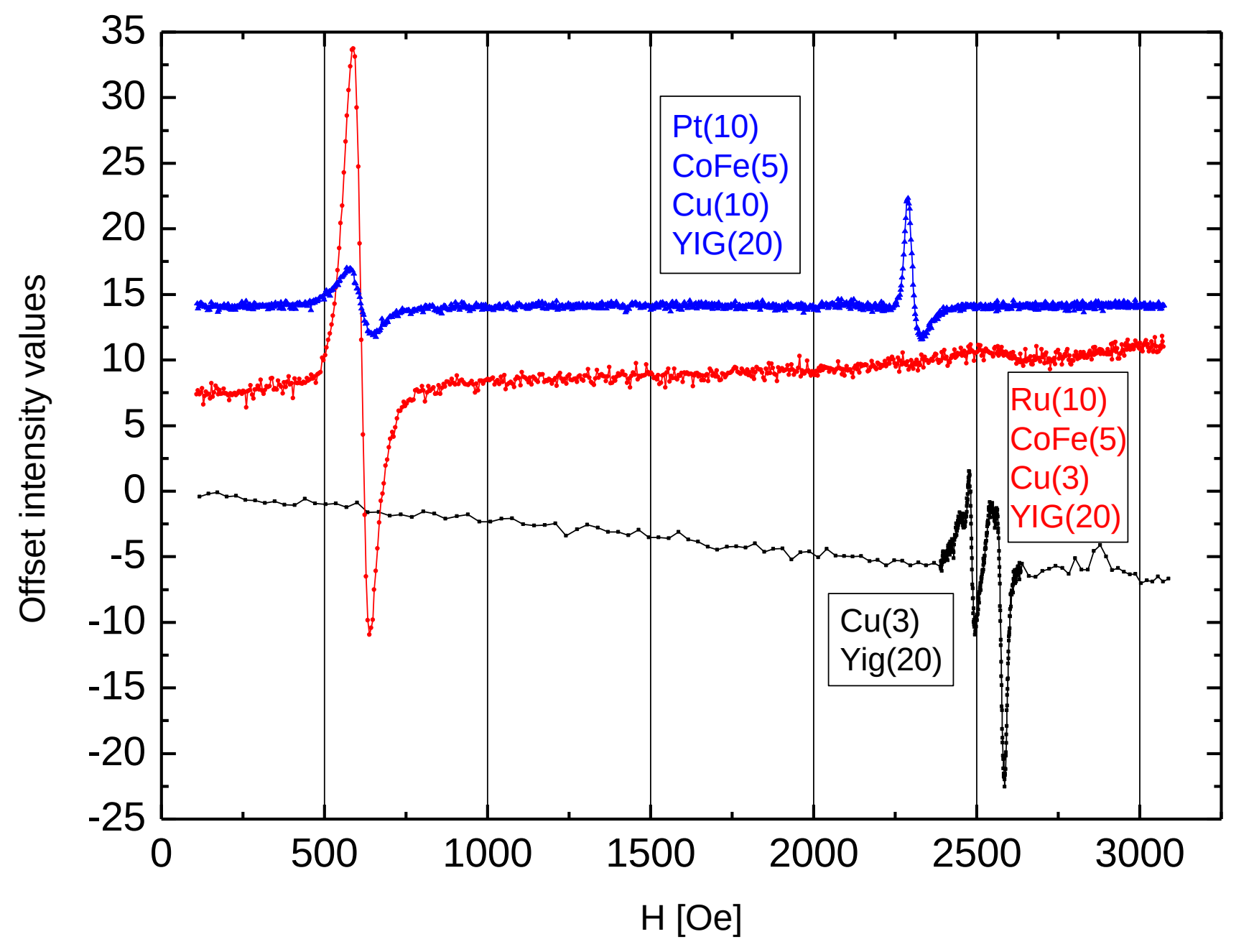


- SQUID measurement at RT shows for 20 nm YIG a coercive field strength of H_c^+ **= 0.6 Oe** and H_c^- **= -0.7 Oe**
- paramagnetic amount from GGG substrate was subtracted from the measurement



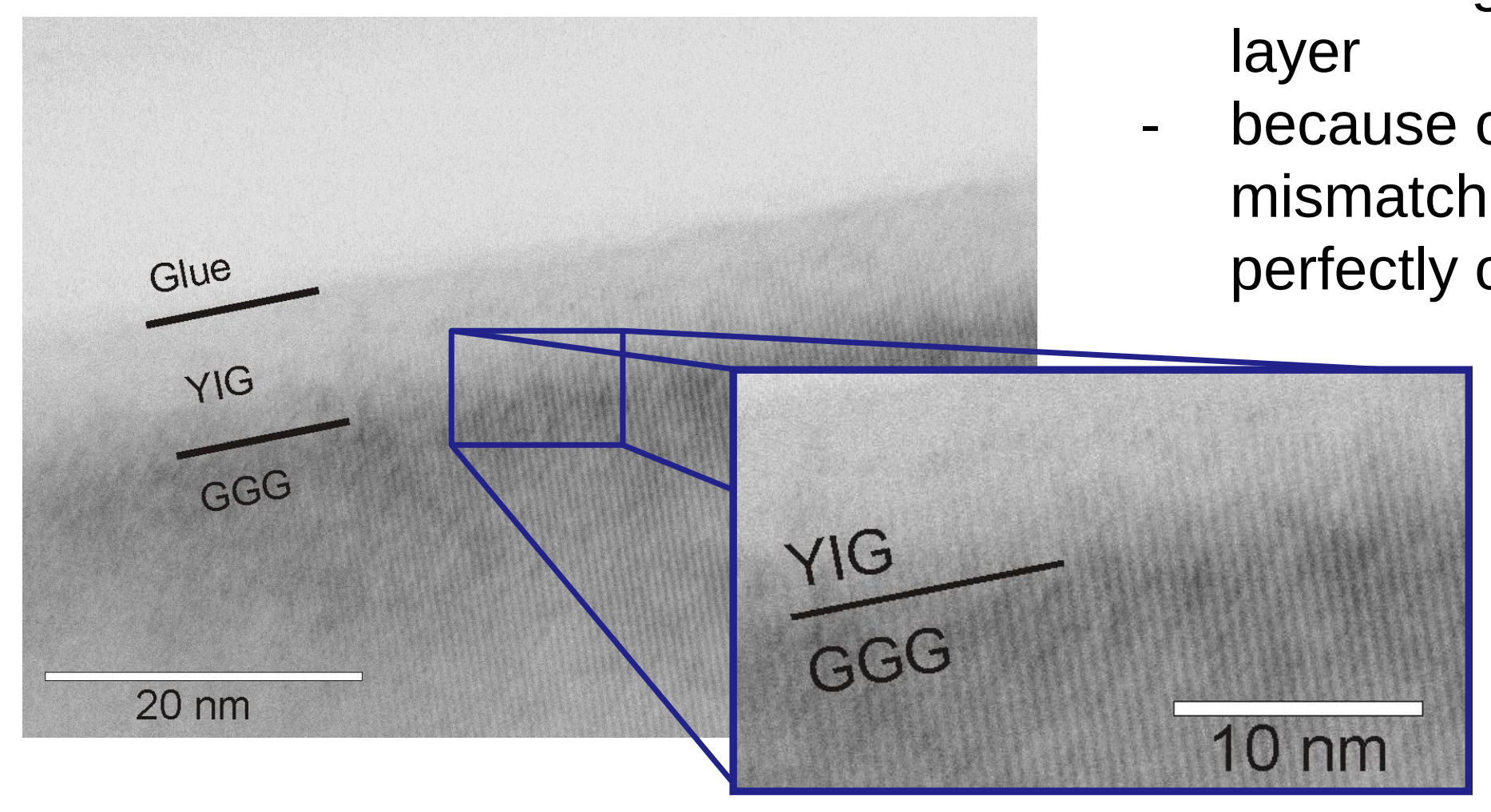


- FMR measurements from single layers at RT show for YIG a line width of **ΔH = 18 Oe,** for LSMO **ΔH = 74 Oe**



- YIG/Cu and YIG/Cu/CoFe multilayers have been investigated by ferromagnetic resonance. For the trilayer a broadening of the line is observed when the thickness of the Cu layer is reduced to 3 nm. A likely explanation is the observation of spin pumping and increased damping by the close proximity of the CoFe.

TEM measurements II: YIG



- TEM image of a 10 nm YIG layer
- because of the small lattice mismatch YIG grows perfectly on the GGG

YIG 10 nm
GGG (111)

Conclusion

- for non-noble metals like Cu, Ta, or Ti a strong interface reaction takes place which destroys the magnetism at the interface, only noble metals like Au or Pt guarantee an undisturbed LSMO layer

➡ **Au** and **Pt** have **strong spin orbit coupling** and **short spin diffusion lengths** this limits the options for hybrid spin transport structures

- for YIG and LSMO single layer materials with state of the art quality could be achieved and oxide/metal hybrid structures have been fabricated

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