MA 55.69 – DPG Frühjahrstagung (Dresden, 2014)

Thin Films of M-Type Magnetoelectric Hexaferrites

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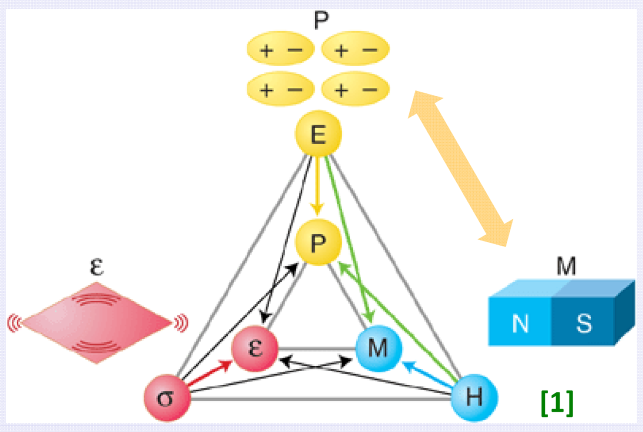
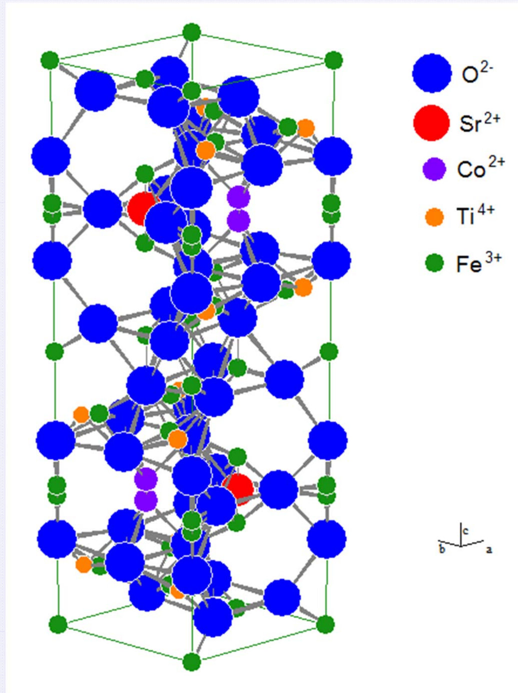
Magnetoelectric hexaferrites

Magnetoelectrics

Intrinsic Magnetoelectrics (ME):
Intrinsic coupling between
direct ME effect: electric polarization and magnetic field
converse ME effect: magnetization and electric field



$SrCo_2Ti_2Fe_8O_{19}$ (SCTFO)

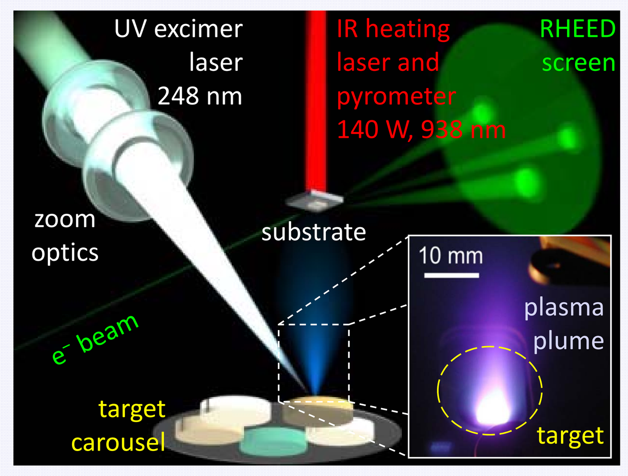


- M-Type hexaferrite
- Hexagonal symmetry with lattice constants $a = b = 5.881$ Å, $c = 23.102$ Å [2]
- Ferrimagnetic [3]
- Magnetic easy axis in c-direction [3]
- Magnetically induced ferroelectric [4]
- Candidate for magnetoelectric effect at room temperature [4]

Electronic configuration:

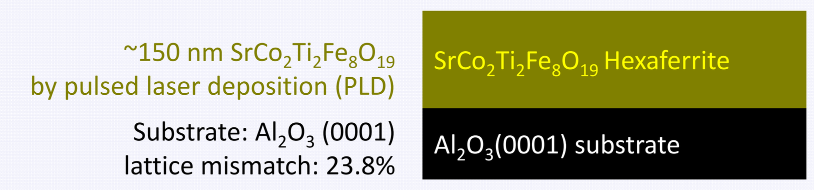
Fe^{3+}: [Ar] $3d^5$:	S = 5/2
Co^{2+}: [Ar] $3d^7$:	S = 3/2 or S = 1/2
Ti^{4+}: [Ar]:	S = 0
Sr^{2+}: [Kr]:	S = 0

Laser-MBE of $SrCo_2Ti_2Fe_8O_{19}$ thin films



PLD parameters

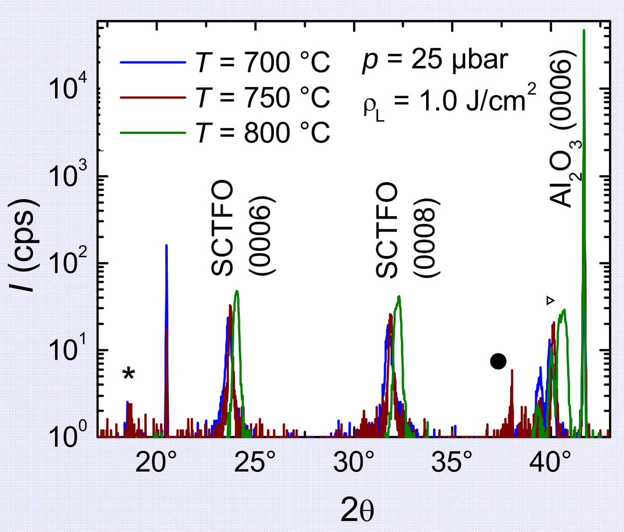
- substrate: Al_2O_3 (Sapphire), hexagonal $a = b = 4.75$ Å, $c = 12.98$ Å
- target: $SrCo_2Ti_2Fe_8O_{19}$
- fluence: 1...2 J/cm²
- rep. rate: 5 Hz
- temperature: 700...800 °C
- atmosphere: 1...50 µbar O_2
- thickness: ~ 150 nm

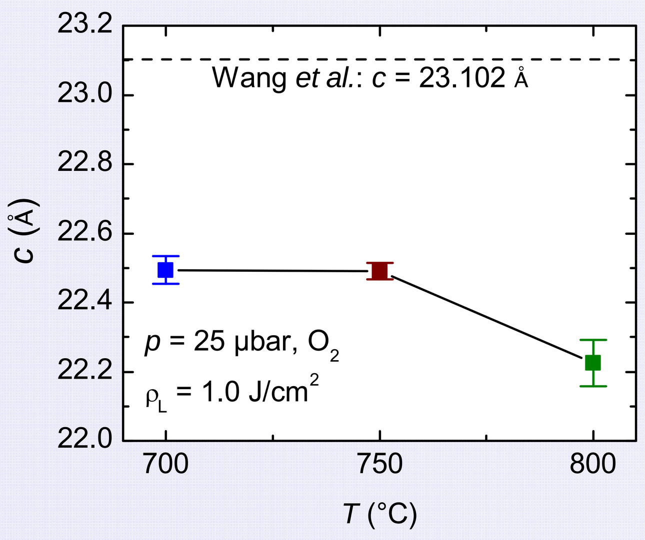


Structural properties

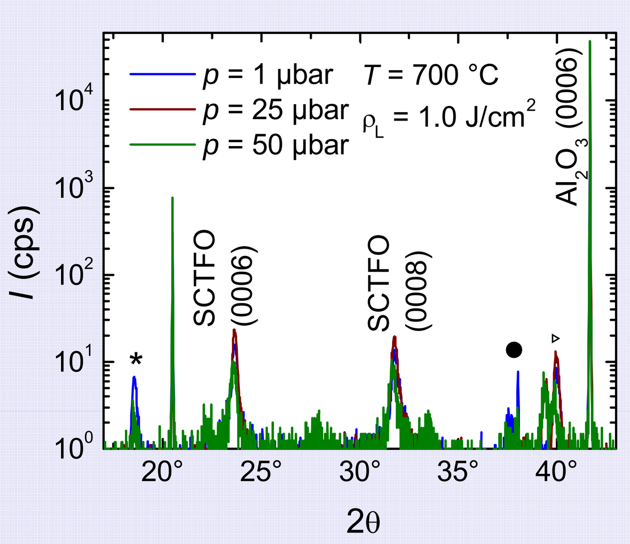
High resolution X-ray diffractometry

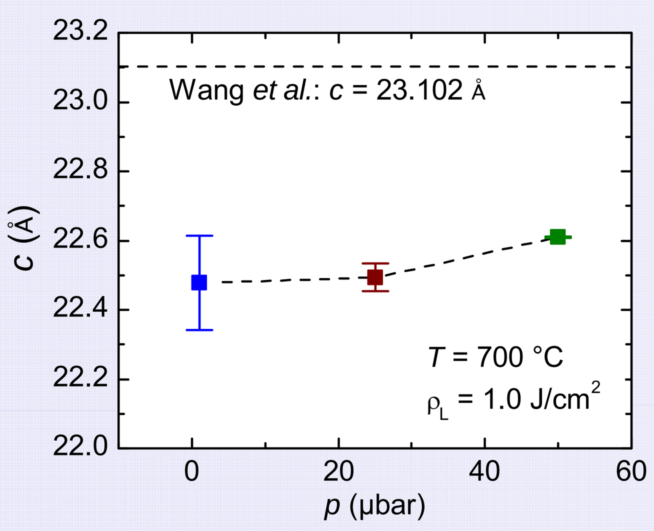
Temperature series



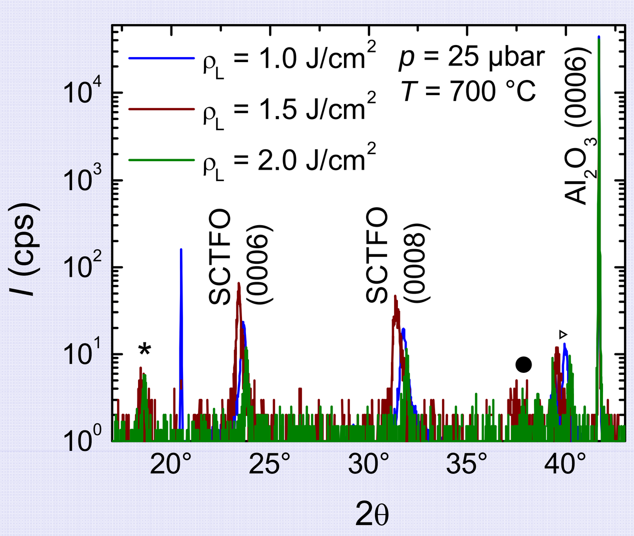


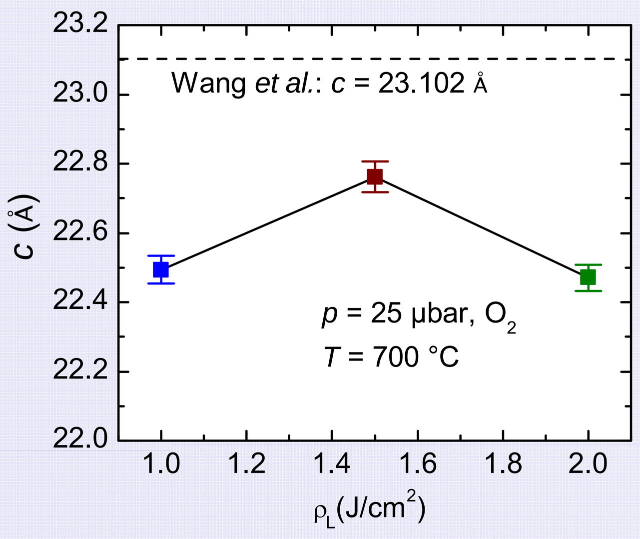
Pressure series





Fluence series





- Reflections from epitaxial SCTFO
- Below 700 °C no crystalline film growth
- Rocking curves around (0006)-peak: FWHM = 0.4...0.6°

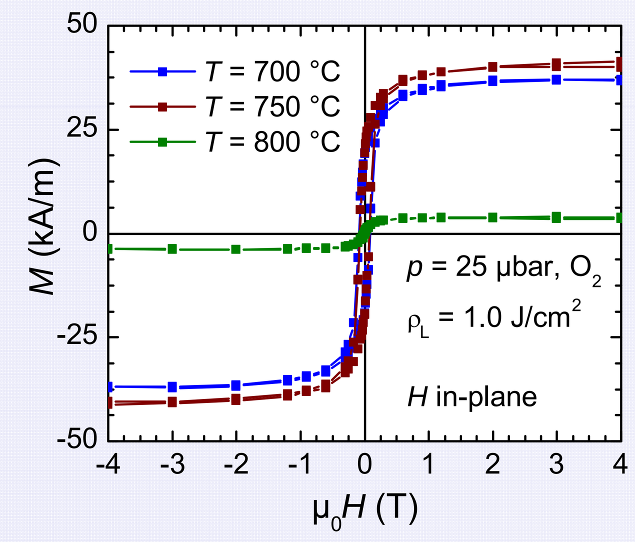
* possible secondary phase
● background
▷ expected 000.10-peak

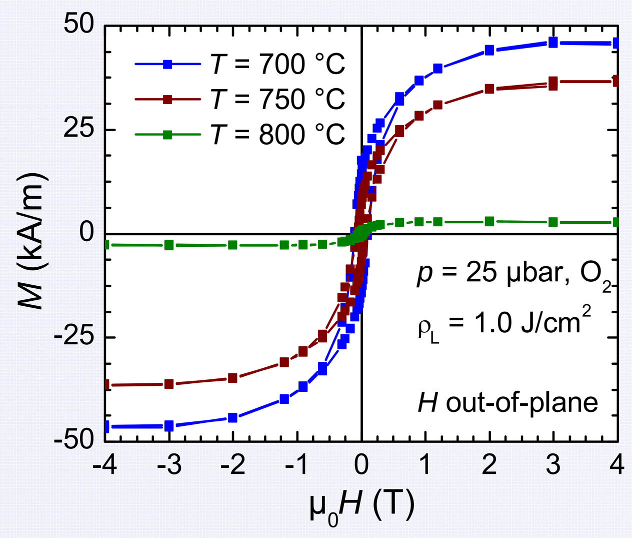
- Measured out-of-plane lattice constant: $c \approx 22.6$ Å slightly smaller than literature value (Wang *et al.*: $a = 23.102$ Å for bulk material)
- possible secondary phase and/or (205)-peak because of crystallites with different orientation

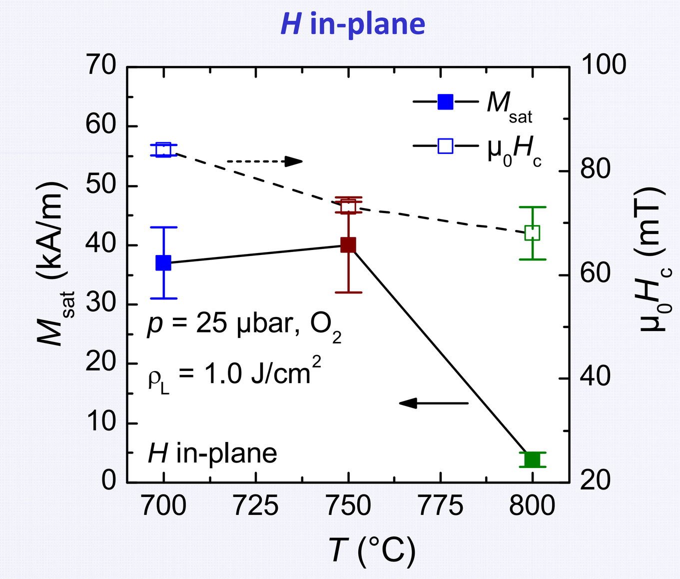
Magnetic properties

SQUID magnetometry at 300 K

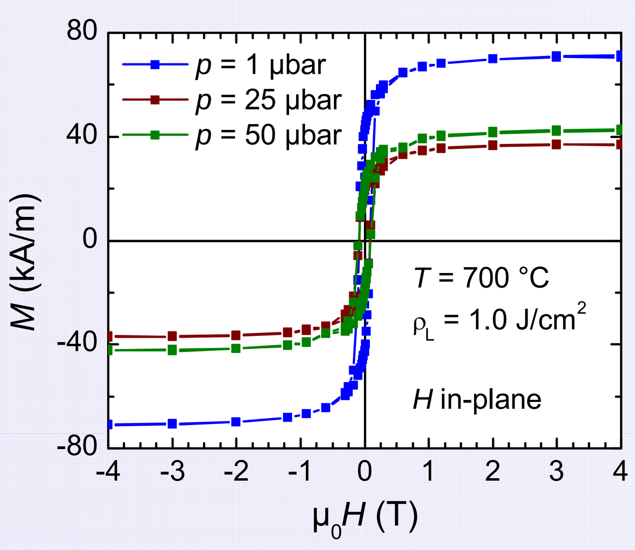
Temperature series

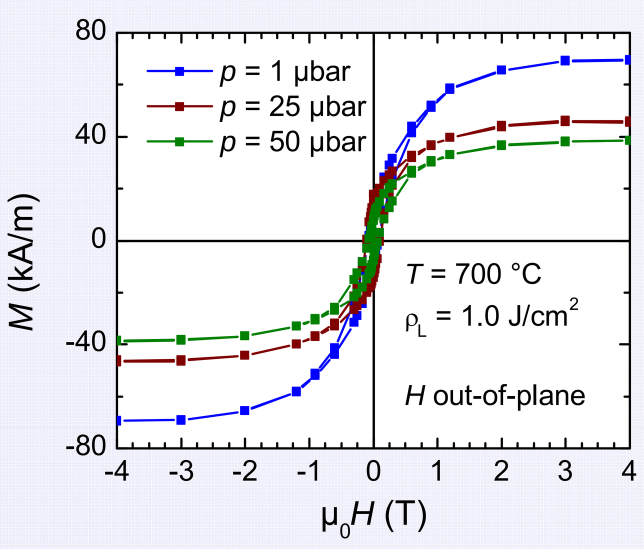


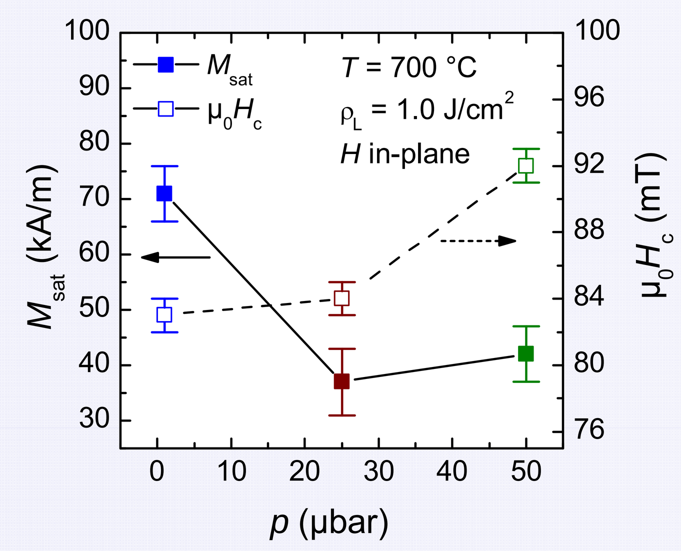




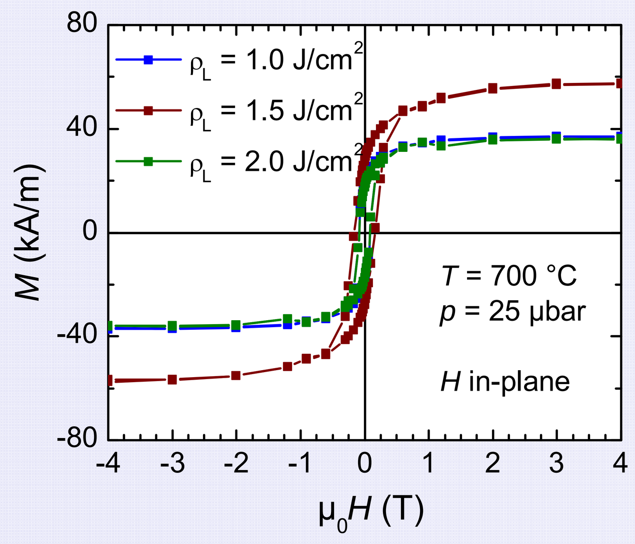
Pressure series

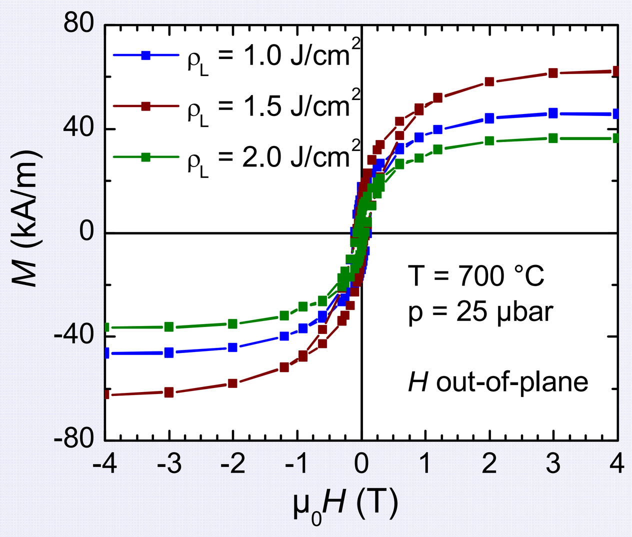


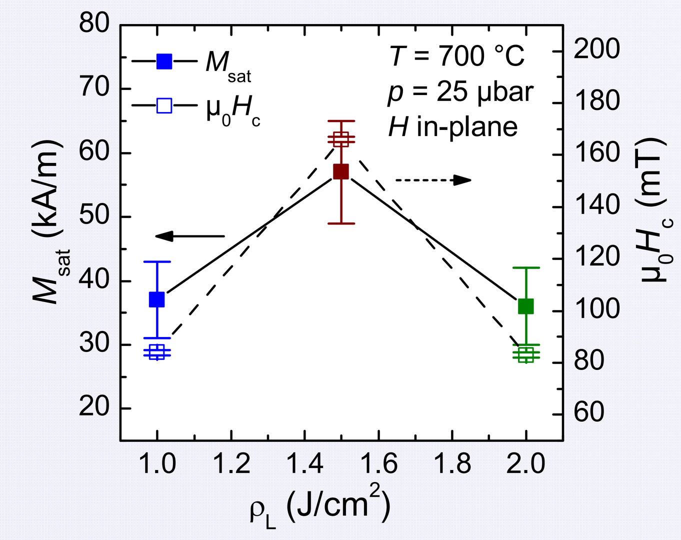




Fluence series

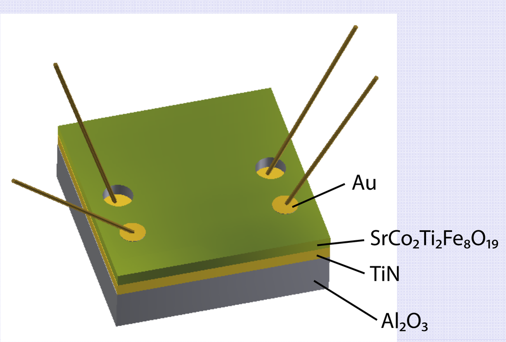




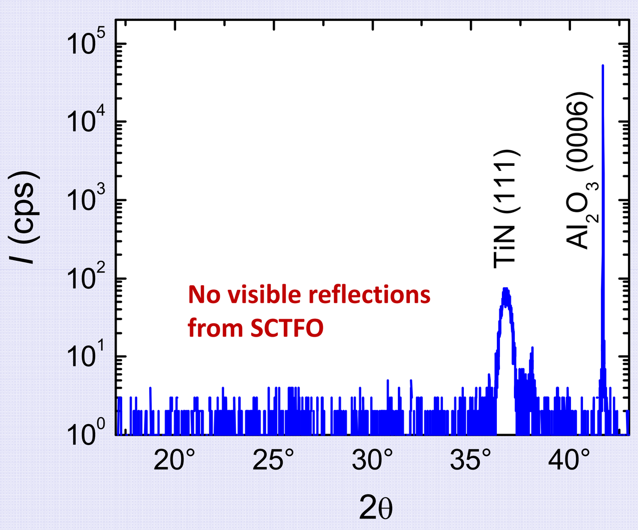


- Ferromagnetic hysteresis for all samples
- Saturation magnetization dependent on deposition parameters
- Saturation magnetization lower than literature value $M_{sat} = 160$ kA/m (bulk) [2]
- Magnetic easy axis in ab-plane, in contrast to literature [4], possibly due to shape anisotropy

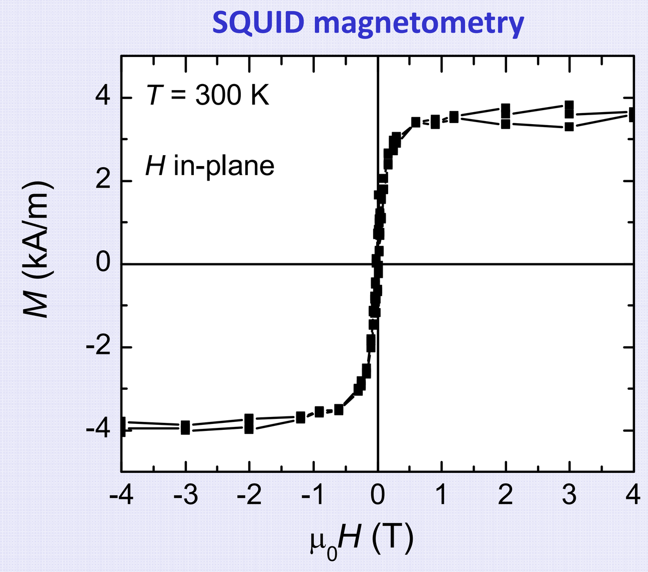
Multilayer sample for magnetoelectric measurements



- $SrCo_2Ti_2Fe_8O_{19}$ thin film on epitaxial TiN layer
- Epitaxial, (111)-orientated TiN layer as bottom electrode
- Polycrystalline Au layer as top electrode via sputtering
- Deposition parameters:
  TiN: $T = 600$ °C, $p = 1$ µbar (Ar), $\rho_L = 2$ J/cm²
  SCTFO: $T = 750$ °C, $p = 25$ µbar (Ar), $\rho_L = 1.5$ J/cm²



- No crystalline layer of $SrCo_2Ti_2Fe_8O_{19}$



- Saturation magnetization significantly lower than without TiN

➢ Growth optimization for TiN-SCTFO bilayers under Ar atmosphere necessary

Summary

Conclusions

- Epitaxial thin film growth of $SrCo_2Ti_2Fe_8O_{19}$
- Growth parameters for optimized structural properties: $T = 750$ °C; $p = 25$ µbar; $\rho_L = 1.5$ J/cm²
- Growth parameters for optimized magnetic properties: $T = 750$ °C; $p = 1$ µbar; $\rho_L = 1.5$ J/cm²
- Secondary phases existent for all samples, independent of deposition parameters
- Saturation magnetization lower than expected (possibly because of stoichiometry)
- $SrCo_2Ti_2Fe_8O_{19}$ shows polycrystalline growth on epitaxial TiN using Ar-atmosphere
- Too small resistance of M-Type hexaferrites for magnetoelectric measurements [4]
- Z-Type Hexaferrites better candidates for magnetoelectrics [4]

[1] N. A. Spaldin and M. Fiebig, Science 309, 391–392 (2005)
[2] L. Wang *et al.*, Sci. Rep. 2, 223 (2012)
[3] U. Özgür *et al.*, J. Mater. Sci.: Mater. Electron. 20, 789–834 (2009)
[4] T. Kimura *et al.*, Ann. Rev. of Cond. Mat. Phys. 3, 39-110 (2012)

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