A6

Microstructure and Structural Change of Magnetoelectric Sensors

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biomagnetic sensing SFB 1261

Motivation and Objectives

Novel *in situ* and *in operando* experiments

Magnetic material

- Interrelation of preparation, structure and magnetic property
- Amorphous structure of magnetostrictive layers ↔ functional properties
- Fluctuations of amorphous structure ↔ temperature, location in multilayers

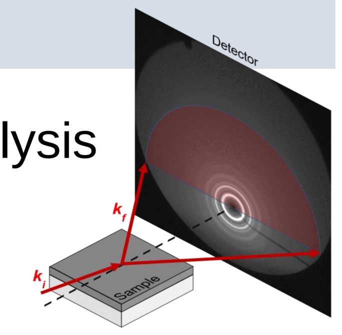
Piezoelectric material

- Complex structural behavior of piezoelectics in SAW sensors and its impact on device function
- Impact of ferroelectric switching on SAW function

Results of the Second Funding Period

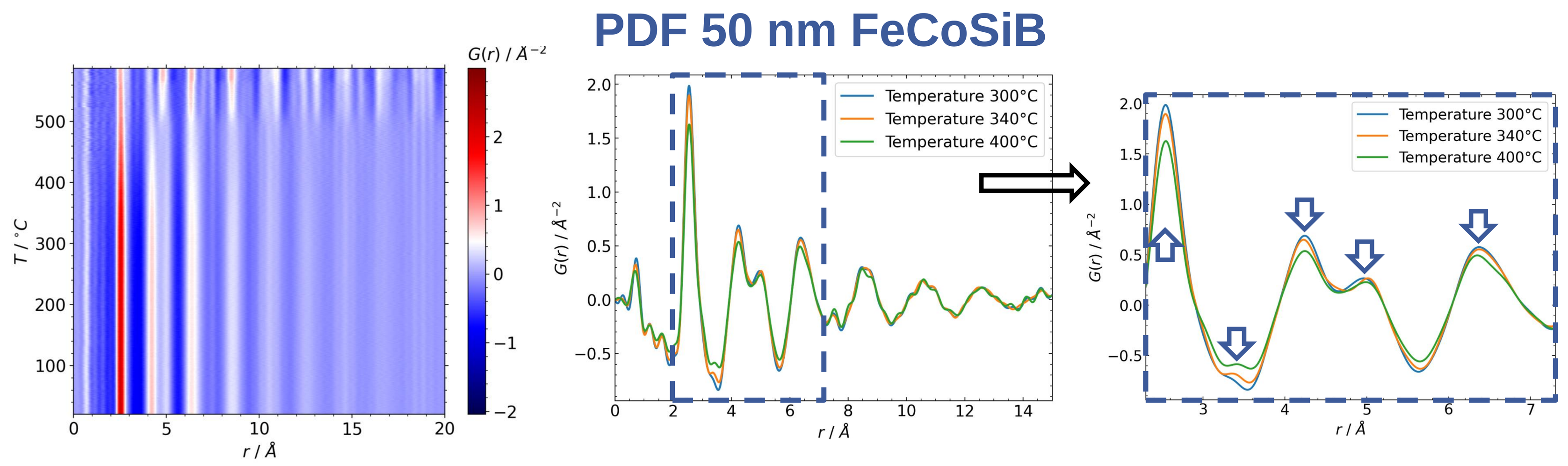
Time-resolved *in situ* X-ray total scattering on 50 nm thin FeCoSiB films (A1)

- Time/temperature resolved Reduced Pair Distribution analysis
- Initial onset of structural changes around 330°C
- Two crystallization transitions: Gradual first transition with α-Fe formation, second transition Fe_2B at 560°C



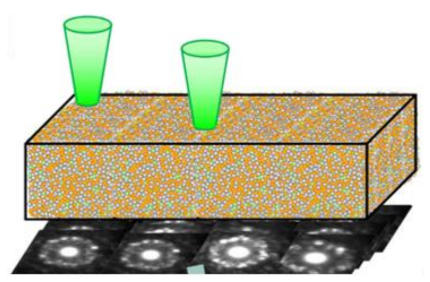
Scattering geometry

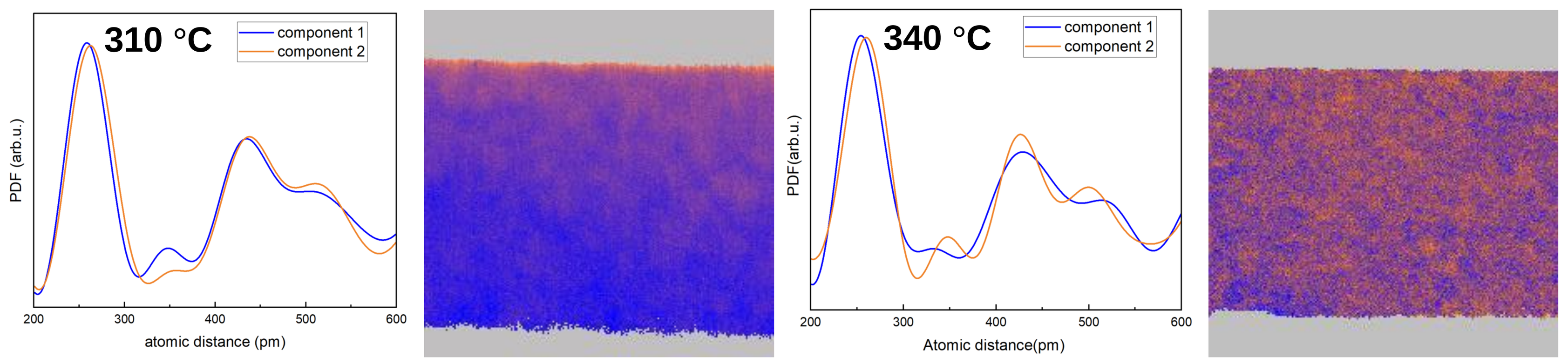
PDF 50 nm FeCoSiB



Structural changes in 200 nm FeCoSiB before crystallization (A1)

- **4D-STEM** Analysis of Radial Distribution Function in amorphous magnetostrictive layer
- Machine learning approach[1] used to evidence distribution of critical changes in near-range order

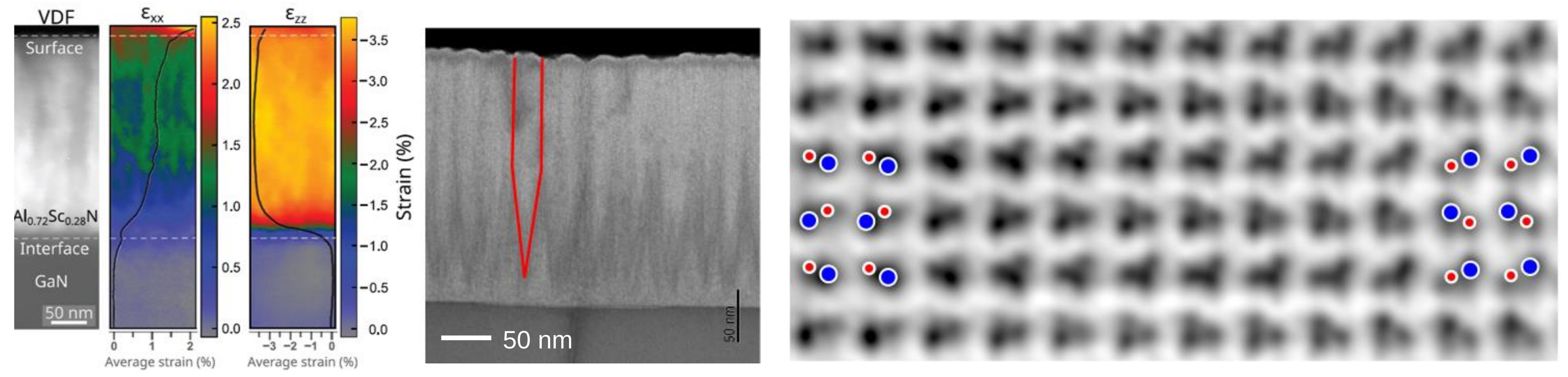




[1] S. Kang, V. Wollersen, C. Minnert, K. Durst, H.-S. Kim, C. Kübel, X. Mu, Acta Materialia 2024, 263, 119495.

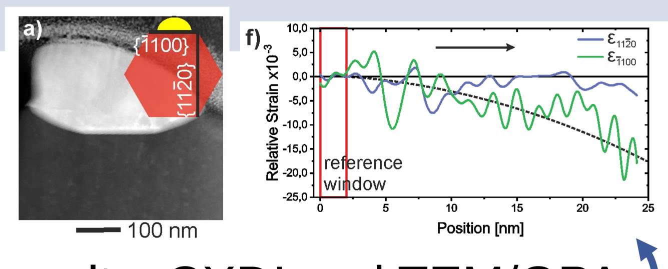
Analyses of strain, atomic structure and polar domains in AlScN

- Quantification of interfacial strain by 4D-STEM (A7/A9)
- ABF-STEM investigation of polar domain patterns and boundaries

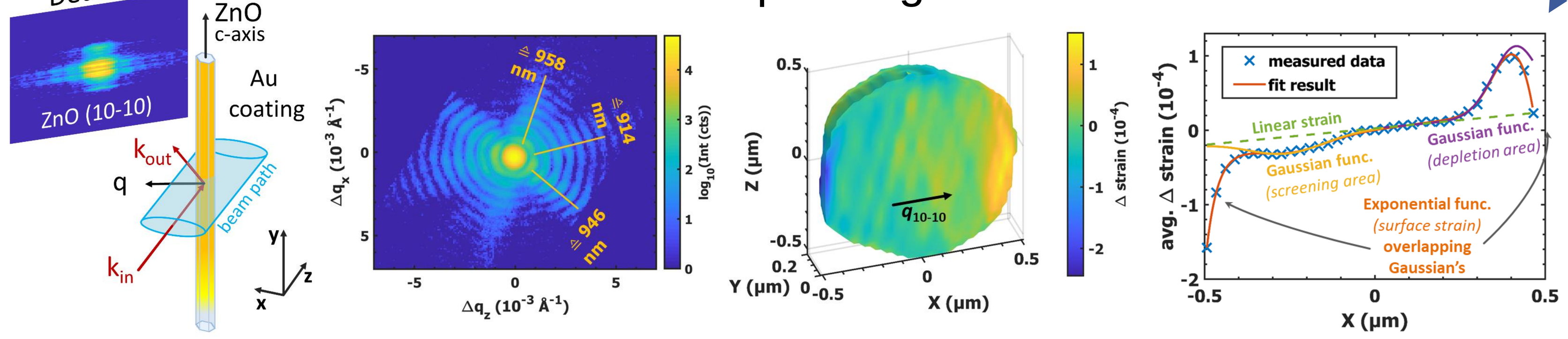


Coherent X-ray diffraction imaging (CXDI) of strain at interfaces of piezoelectric composites (A5E)

- Strain imaging of Au coated ZnO rod →Schottky contact
- Distinct strain at interface and volume

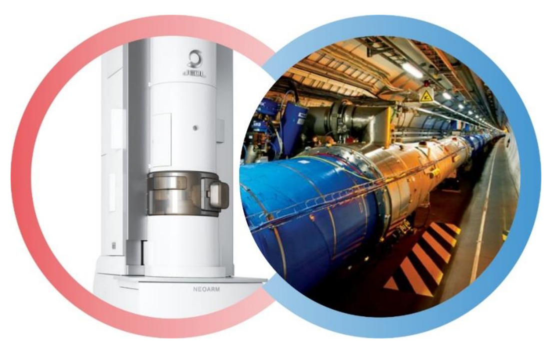


Corresponding results: CXDI and TEM/GPA



Work Plan for Third Funding Period

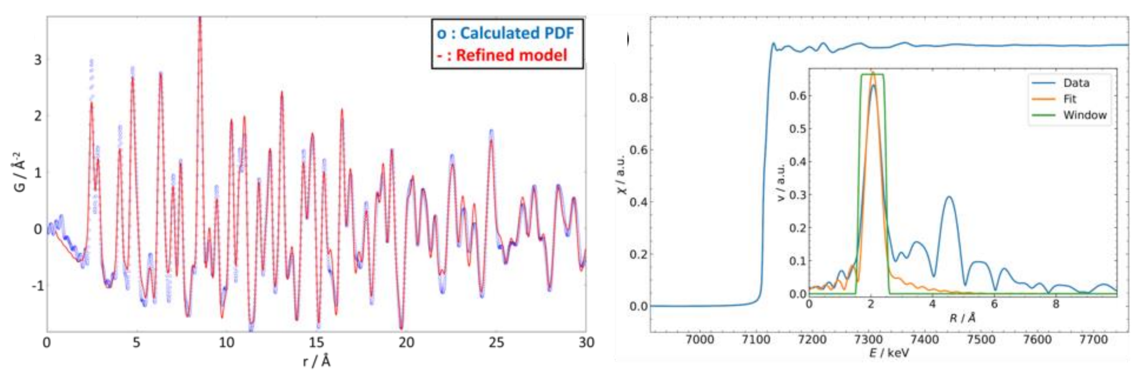
Research methods — *In situ* and *in operando* techniques



Amorphous material
4D STEM & Synchrotron-PDF

Crystalline material
HR(S)TEM & nano-XRD, GID

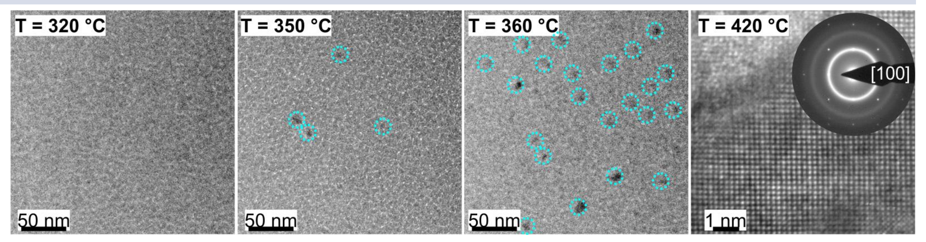
WP1 *Ex Situ* Real Structure Investigations of Exchange Biased (Amorphous) Magnetostrictive (Multi)Layers (A1)



PDF and EXAFS analysis of structural and chemical order in FeCoSiB films

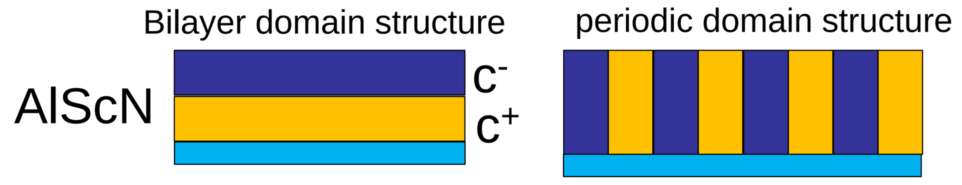
WP2 *In situ* examination of the structural evolution in amorphous magnetic (multi)layers (A1)

Example of *in situ* crystallization on a FeCoSiB layer



WP3 *Ex situ* investigation of AlScN structures for SAW sensors (A9)

- Focus on crystalline texture, interfacial strain, polar domain structures

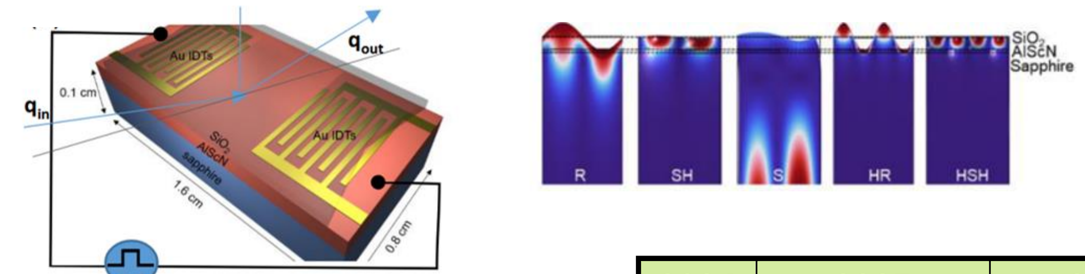


WP4 Imaging of acoustic wave propagation in AlScN SAW sensors

- Focus on pertubations related to defects, strain and texture (A7/A9)

WP5 *In operando* examination of depth-dependent strain in AlScN during excitation of SAW modes (A9)

- Development of *in operando* measurements → time-resolved change



red = Postdoc TEM, blue = PhD XRD	2024		2025				2026				2027				2028	
	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
WP1 – *Ex situ* examination of amorphous magnetostrictive (multi)layers																
WP2 – *In situ* examination of amorphous magnetic (multi)layers																
WP3 – Real structure examination of AlScN thin film SAW sensors																
WP4 – Imaging of surface acoustic wave propagation in AlScN thin film sensors																
WP5 – *In Operando* examination of depth-dependent strain during excitation of SAW																

Collaborations

A1: Investigation of nanoscale structure properties of magnetic multilayer systems
A2: Nanoscale analysis of electret sensor components
A4: Interrelation of (amorphous) structure and process parameters in FeCoSiB deposition
A7/9: Structural characterization of piezoacoustic and magnetostrictive components
A8: Modeling of photonic structures for SAW sensors
A10: Input of morphological parameters for description of suitable submodels
Z1: Advanced characterization of sensor materials to improve fabrication technology
B12(N): TEM analysis of functionalized magnetic nanoparticles

Participation in focus groups
F1: Magnetic Layers
F2: Sensor Modelling
F4: Magnetoelectric Sensors

Funds Requested

1 Postdoctoral researcher (100%), 1 Doctoral researcher (75%), consumables: 64.8 k€

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[A6-2] Mandal P., Giri R.P., **Murphy B.M.**, and Ghosh S.K.: (2021) ACS Applied Materials & Interfaces 13 (48), 57023-57035.

[A6-3] Schönweger, G., Petraru, A., Islam, M. R., Wolff, N., Haas, B., Hammud, A., Koch, C., **Kienle, L.**, Kohlstedt, H., & Fichtner, S.: (2022) Advanced Functional Materials, 32(21), 2109632 (open access).

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[A6-7] Jordt, P., Hrkac, S. B., Gröttrup, J., Davydok, A., Krywka, C., Wolff, N., **Kienle, L.,** Adelung, R., Magnussen, O. M. & **Murphy, B. M.**: (2021) Advanced Engineering Materials, 23(11), 2100201. (open access).

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