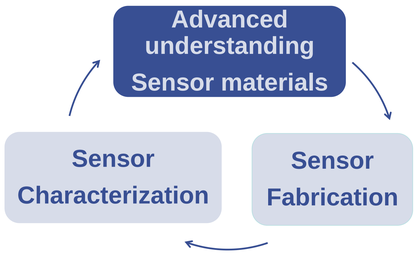
# A6

# Microstructure and Structural Change of Magnetoelectric Sensors

Niklas Wolff, Nicolas Hayen, Otto Lippmann, Philipp Jordt, Bridget Murphy (PI), Lorenz Kienle (PI)

biomagnetic sensing SFB 1261

## Motivation and Objectives



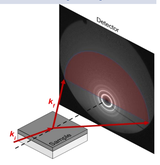

**From Materials to ME Sensors**

- Amorphous structure of **magnetostrictive layers**
  ↔ thermal treatment
  ↔ changes at the nanoscale
  ↔ link to functional properties
- Complex structural behavior of **piezoelectrics** (in operando) in SAW sensors

## Results of the Second Funding Period

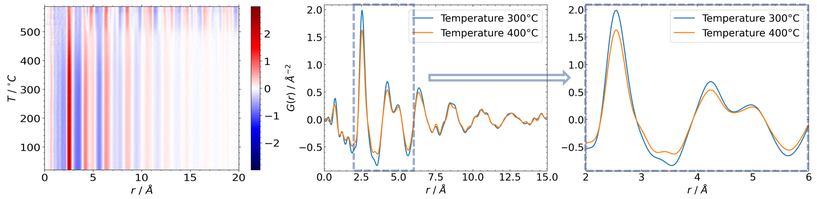
### Time-resolved *in situ* X-ray total scattering on FeCoSiB films (A1)

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



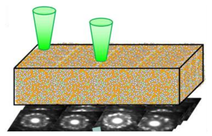

Scattering geometry

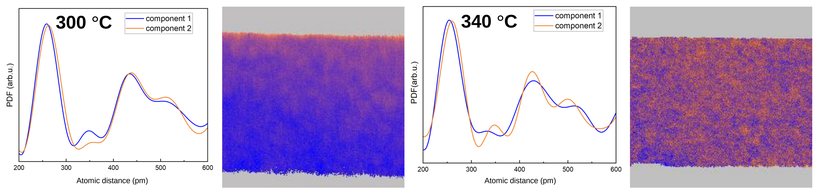
**PDF 50 nm FeCoSiB**




### Structural changes in FeCoSiB before crystallization (A1)

- **4D-STEM** Analysis of Radial Distribution Function in amorphous magnetostrictive layer
- Machine learning approach[1]: Identification and localization of component with increased density



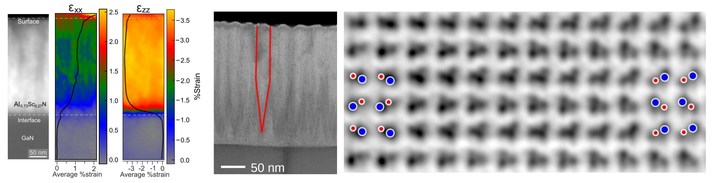



[1] S. Kang, V. Wollersen, C. Minnert, K. Durst, H.-S. Kim, C. Kübel, X. Mu, Acta Materialia 2024, 263, 119495.

### Analyses of strain, atomic structure and polar domains in AlScN

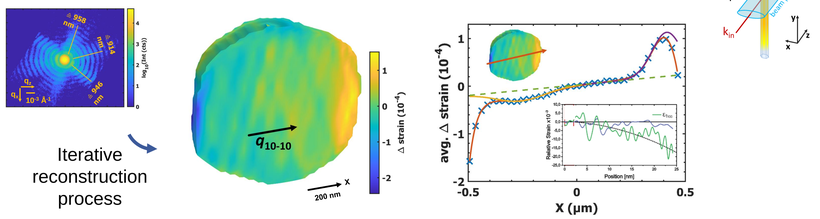
(A7/A9)

- Quantification of interfacial strain by 4D-STEM
- ABF-STEM investigation of polar domain patterns and boundaries




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

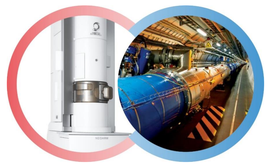
- Strain imaging of Au coated ZnO rod →Schottky contact
- Distinct strain at interface and in volume




## Work Plan for Third Funding Period

### Research methods

***In situ* and *in operando* techniques**

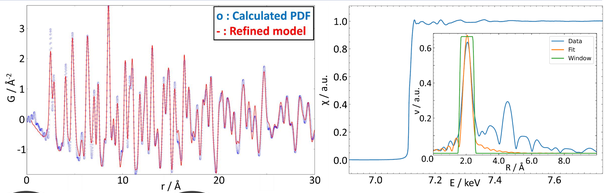


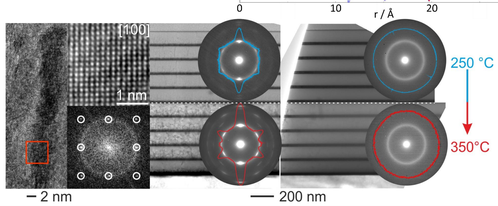
**Amorphous material**
4D STEM & Synchrotron-PDF

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

### WP1/WP2 *Ex situ/In situ* Real Structure Investigations of (Amorphous) (Multi)Layers (A1)

PDF and EXAFS: structural and chemical order in FeCoSiB films




*Interface dependent* crystallization of Ta-Cu-MnIr-FeCoSiB multilayers

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

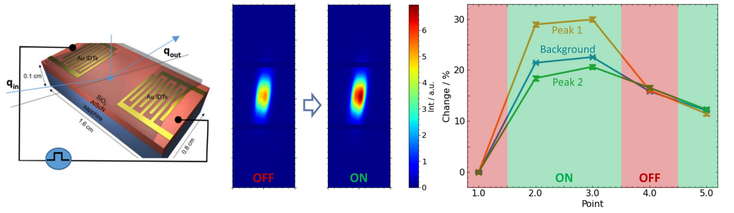
- Focus on crystalline texture, interfacial strain, polar domain structures

### 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




| | Kienle / Murphy | 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 of magnetic multilayer systems**

A2: Nanoscale analysis of electret sensor components

A4: (Amorphous) structure <-> process parameters in FeCoSiB deposition

**A7/9: Structure of piezoacoustic and magnetostrictive components**

A8: Photonic structures for SAW sensors

A10: Input of morphological parameters for 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€

[A6-1] Jordt, P., Wolff, N., Hrkac, S. B., Shree, S., Wang, D., Harder, R. J., Kübel, C., Adelung, R., Shpyrko, O. G., Magnussen, O. M., **Kienle, L., & Murphy, B. M.**: (2021) Advanced Electronic Materials, 7(11), 2100546. (open access). – **A5, A6**

[A6-2] 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). – **A5, A6**

[A6-3] Wolff, N., Jordt, P., Braniste, T., Popa, V., Monaico, E., Ursaki, V., Petraru, A., Adelung, R., **Murphy, B. M.**, **Kienle, L.,** Tiginyanu, I.: (2019) ECS Journal of Solid-State Science Technology, 8(8), 141–146 (open access) – **A5, A6**

[A6-4] Wolff, N., Jordt, P., Jetter, J., Vogt, H., Lotnyk, A., Seemann, K., Ulrich, S., Quandt, E., **Murphy, B. M.** & **Kienle, L.**: (2021) Materials Characterization, 172, 110871. – **A1, A6**

[A6-5] Sartori, A., Giri, R.P., Fujii, H., **Murphy B.M.**, Magnussen O.M.: (2022) Nat Commun 13, 5421 (open access). – **A6**

[A6-6] Mandal P., Giri R.P., **Murphy B.M.**, and Ghosh S.K.: (2021) ACS Applied Materials & Interfaces 13 (48), 57023-57035. – **A6**

[A6-7] 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). – **A6**

[A6-8] Wolff, N., Fichtner, S., Haas, B., Islam, M. R., Niekiel, F., ... & **Kienle, L.**: (2021) Journal of Applied Physics, 129(3). – **A6**

[A6-9] Koops, C. T., Hrkac, S. B., Abes, M., Jordt, P., Stettner, J., Petraru, A., Kohlstedt, H., Hrkac, V., Wolff, N., **Kienle, L.**, ... & **Murphy, B. M.**: (2020). In 4th International Conference on Nanotechnologies and Biomedical Engineering: Proceedings of ICNBME-2019, September 18-21, 2019, Chisinau, Moldova (pp. 187-191). Springer International Publishing. – **A6**

[A6-10] Abes, M., Koops, C.T., Hrkac, S.B., Greve, H., Quandt, E., Collins, S.P., **Murphy, B.M.** and Magnussen, O.M.,: (2013) Applied Physics Letters, 102(1), 011601. – **A6**