A9

Surface Acoustic Wave Magnetic Field Sensors

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biomagnetic sensing SFB 1261

Motivation and Objectives

Surface Acoustic Wave (SAW) sensor

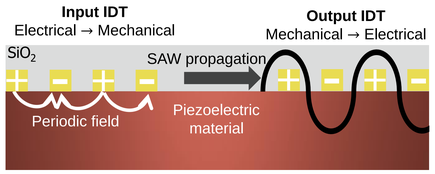
Advantages:

- High bandwidth (MHz)
  → Many application scenarios
  → Miniaturization possible
- High dynamic range (pT - mT)

Objectives:

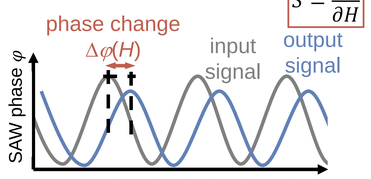
- Fabrication, characterization, modeling
- Investigation of piezoelectric material
- High frequencies
  → Magnetostrictive film developments

SAW generation



Magnetic field detection

$$S = \frac{\partial \varphi}{\partial H}$$



Measurement principle is based on the magneto-elastically induced change of Young's modulus of the magnetostrictive layer (ΔE effect)

Thin-film AlScN SAW sensor (ISIT)

- AlScN on 200 mm Si wafers
- CMP smoothed SiO_2
- Single-layer $(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$
- LOD: 350 pT/Hz$^{1/2}$ at 10 Hz (f_{SAW} = 507 MHz)

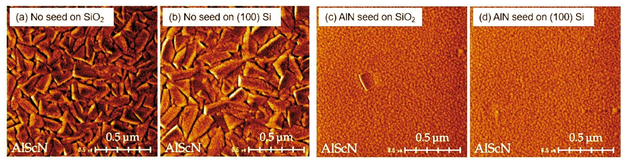
Single crystal SAW sensor (CAU)

- Piezoelectric substrate
- SiO_2 guiding layer (**Love wave**)
- Multi-layer $(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$
- LOD: 28 pT/Hz$^{1/2}$ at 10 Hz (f_{SAW} = 145 MHz)

Results of the Second Funding Period

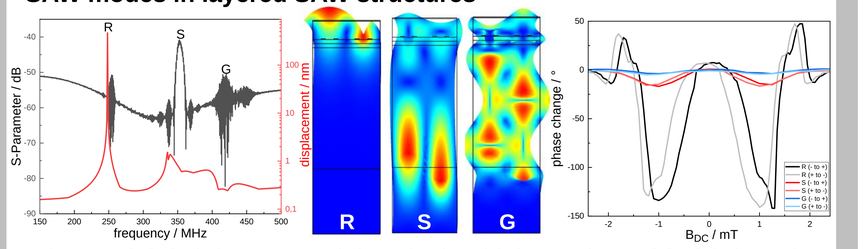
Thin film AlScN SAW sensor (ISIT)

AlScN deposition on Si



AlN seed layer significantly increases the layer growth (*c*-axis quality, piezo-acoustic coupling) [A9-4]

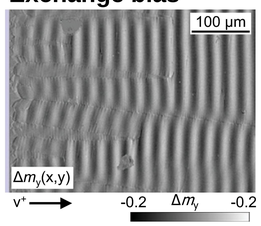
SAW modes in layered SAW structures

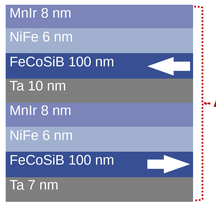


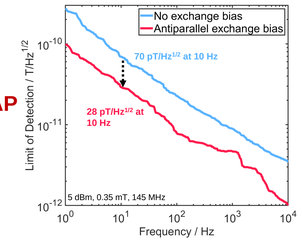
The **Rayleigh** (R), **Sezawa** (S) and other higher order **guided** (G) modes are observed and investigated for magnetic field sensing.

Single crystal SAW sensor (CAU)

Exchange bias





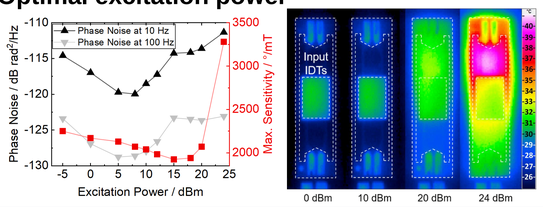


Domain walls
→ Wavefront dephasing
→ Major noise source

Antiparallel exchange bias → one domain

2.5x LoD improvement [A9-3, A9-7]

Optimal excitation power



Sensitivity and phase noise depend on excitation power

Lowest LoD at 5 dBm [A9-7]

Work Plan for Third Funding Period

Research methods: Clean room fabrication

1000 qm ISIT cleanroom

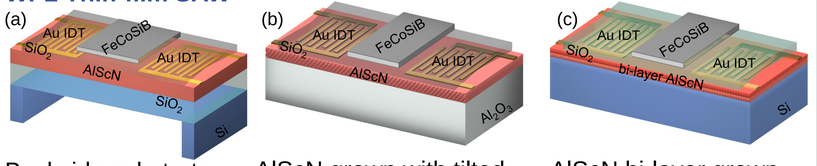
300 qm CAU cleanroom

- SAW fabrication
- Functional characterization
- Structural characterization

WP1 Magnetic multilayer stacks

- Enhance exchange bias stacks for thin film SAW
- Anisotropy alignment for bias-free operation

WP2 Thin-film SAW



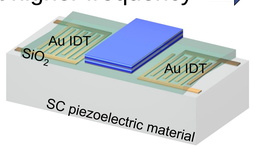
Backside substrate etch

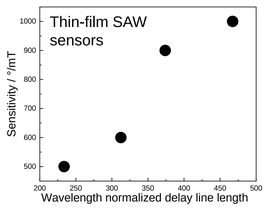
AlScN grown with tilted c-axis on sapphire

AlScN bi-layer grown on a Si substrate

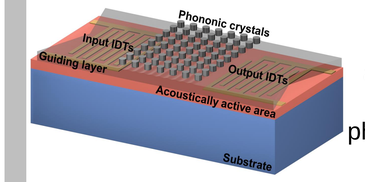
WP3 Single crystal SAW

- Research on optimal SAW carrier frequency
- Sensitivity improves at higher frequency
- Noise increases near ferromagnetic resonance?

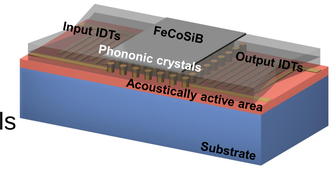




WP4 Phononic crystals



Different approaches to fabricate phononic crystals

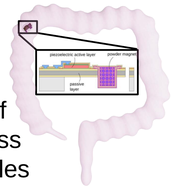


Improving sensitivity by creating resonant modes aligned with SAW modes resulting in enhanced interaction [A9-10]

WP5 Integration in biomedical application

- Providing sensors and measurement expertise
- SAW perfect fit due the broadband capabilities

B13(N): Localization of current wireless motility capsules



ISIT CAU Both

		2024		2025				2026				2027				2028	
		3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2
WP1 – Magnetic multilayer stacks	Exchange bias																
	Zero bias																
WP2 – Thin-film SAW	Acoustic layer																
	Substrate variations																
	Application magnetic stacks																
WP3 – Single crystal SAW	Frequency investigation																
	Design variation																
	Application magnetic stacks																
WP4 – Phononic crystals (PnC)																	
WP5 – Integration in biomedical application																	

Collaborations

A1: Application of advanced magnetic multilayers to SAW sensors
A6: Chemical and structural analysis of AlScN, synchrotron measurements
A8: Modeling of SAW sensor parameters and designs and phononic crystal
A10: Numerical studies on noise and phononic crystals
B1: Analog electronics, noise floor characterization, LOD measurements
B12(N), **B13(N)**: Providing SAW sensors and measurement knowledge
Z1: Support in SAW sensor fabrication
Z2: Support with sensor characterization

Participation in focus groups

F1: Magnetic Layers
F3: Comparison of Sensor Concepts
F4: Magnetoelectric Sensors

Funds Requested

2 Doctoral researchers, consumables: 66 k€

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