LIGHTWEIGHT STRUCTURE INTEGRATION OF SENSOR SYSTEMS

The Future of Intelligent Structural Components

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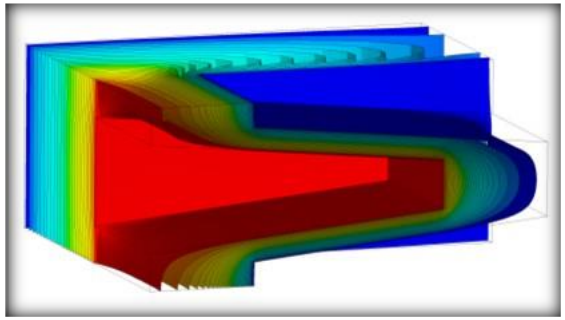
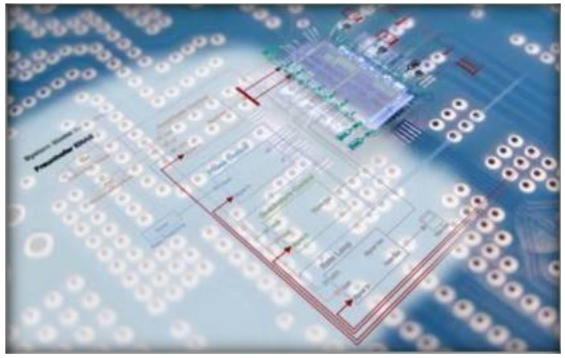
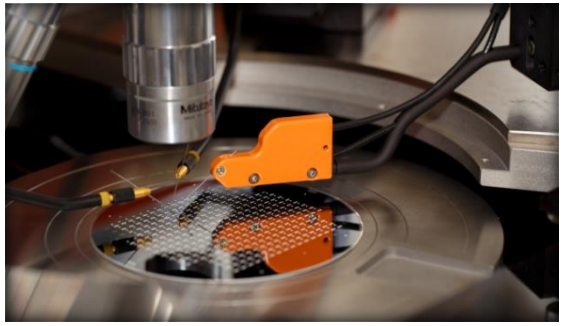
Outline







1 Introduction

2 Integration of Smart Systems Electronics

3 Integration of Smart Sensors

4 Conclusion & Outlook

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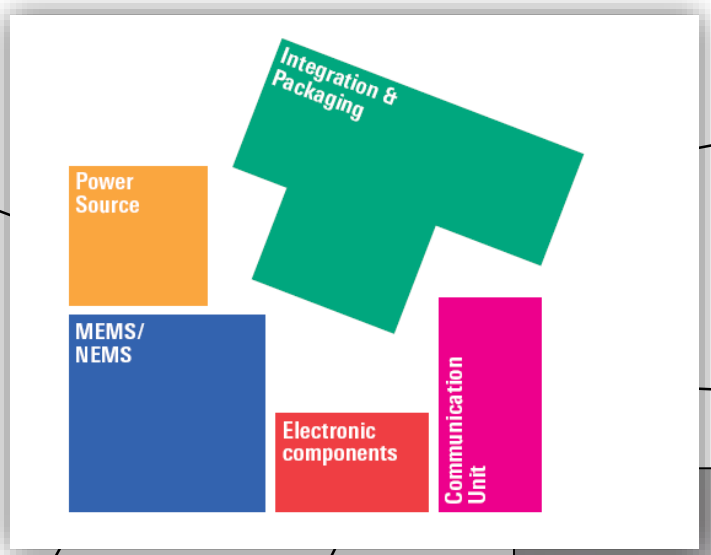
Introduction

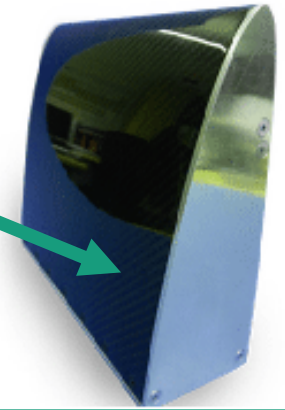
Smart Systems Integration

- Energy Saving Technologies
- Energy Management
- Energy Harvesting



- **Integration Technologies**

- Printed Antennas
- Transceiver
- Meta Materials



- **Piezoelectric Transducers**
- Capacitive Transducers
- Electromagnetic Transducers

- Electronics
- ASICs
- Interposer

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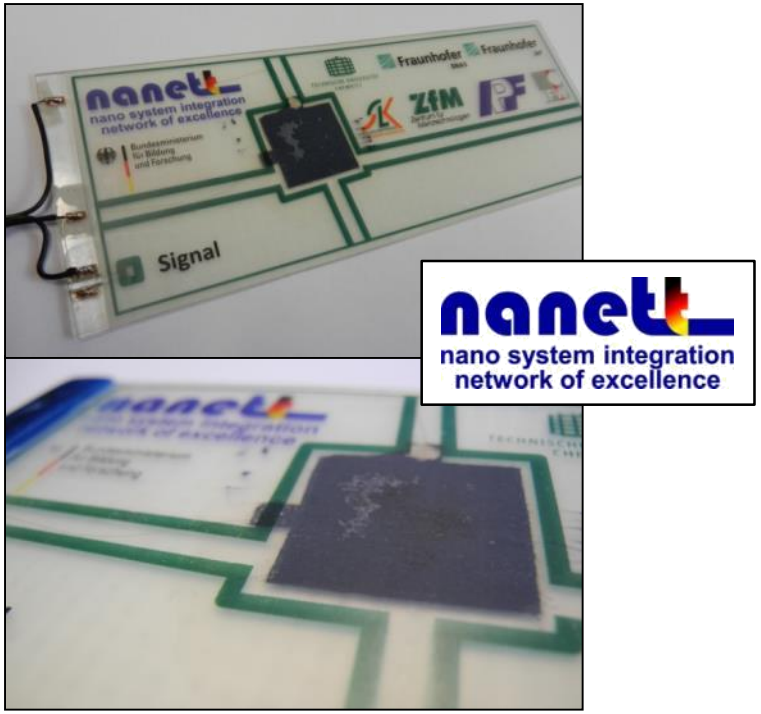
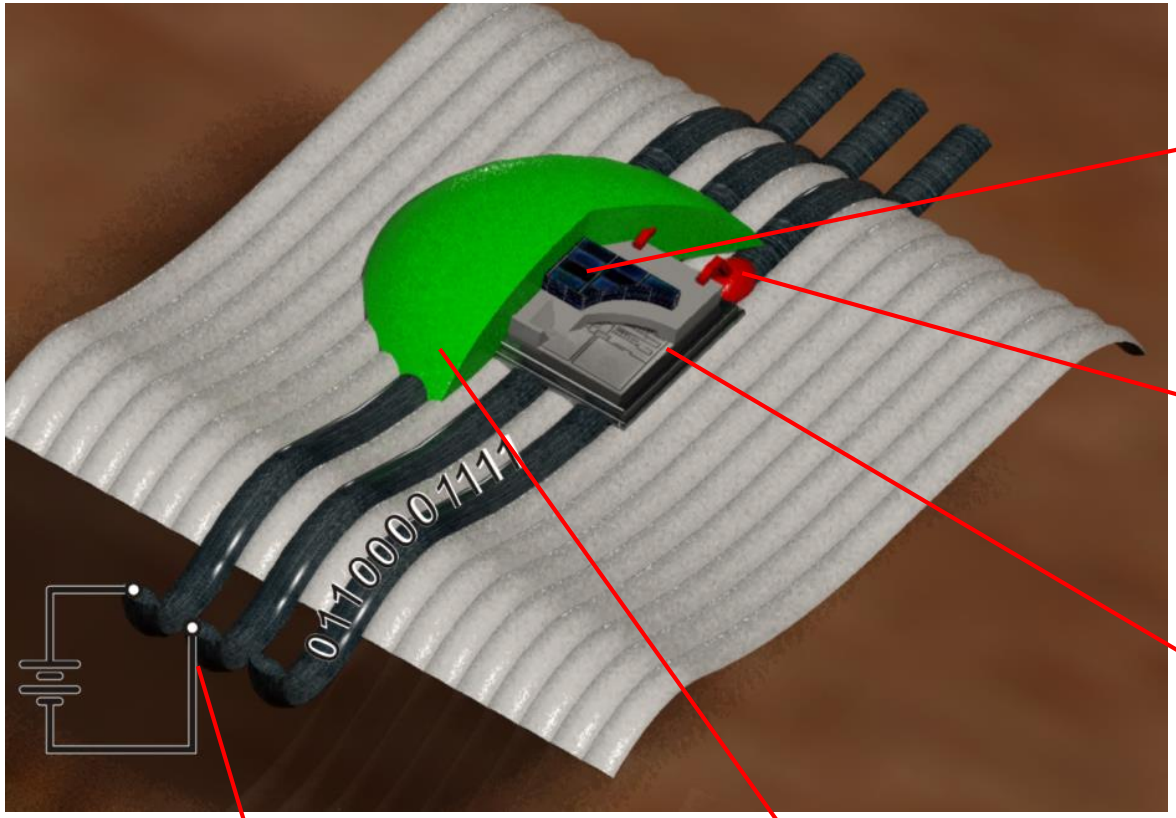
Research Activities in Chemnitz

Integration of MEMS / Electronics

Integration of novel sensors



Integration of Smart Systems Electronics



Electronics components & MEMS/NEMS: **Sensor + ASIC**

Integration and Packaging: **Conducting Textiles, Interconnects**

Electronics Components: **Interposer**

Integration and Packaging: **Package / Injection Molding**

Electronics Components & Power Source & Communication Unit: **Evaluation Electronics, Power Supply**

Integration of Smart Systems Electronics

Application fields:

- Structural Health Monitoring (e. g. Strain Sensing, Acoustic Emission)
- Embedded Force-, Pressure- and Acceleration and Shock Tracing
- Haptic and sensory surfaces & embedded illumination

Challenges - Design of lightweight structure integrated/embedded sensors systems:

- High loads during manufacturing:
  - Pressure, Temperature, Chemical interactions
- Mechanical Stress
- Electromagnetic compatibility (EMC)
- Packaging i. e. contacting and assembling
- Reliability
- Compatibility for large scale production

Integration of Smart Systems Electronics

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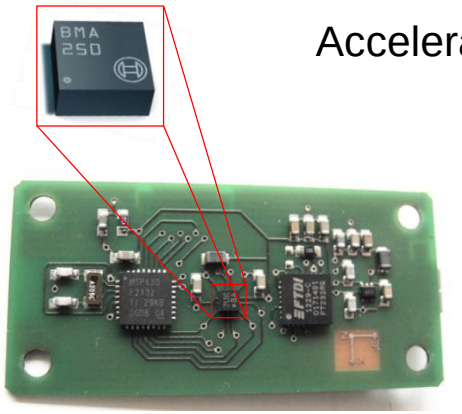
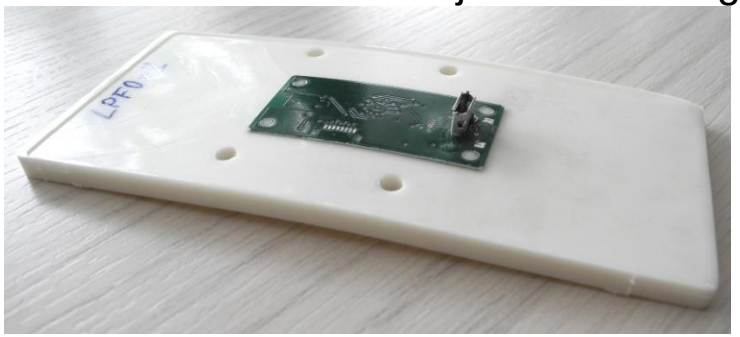
Acceleration Sensor

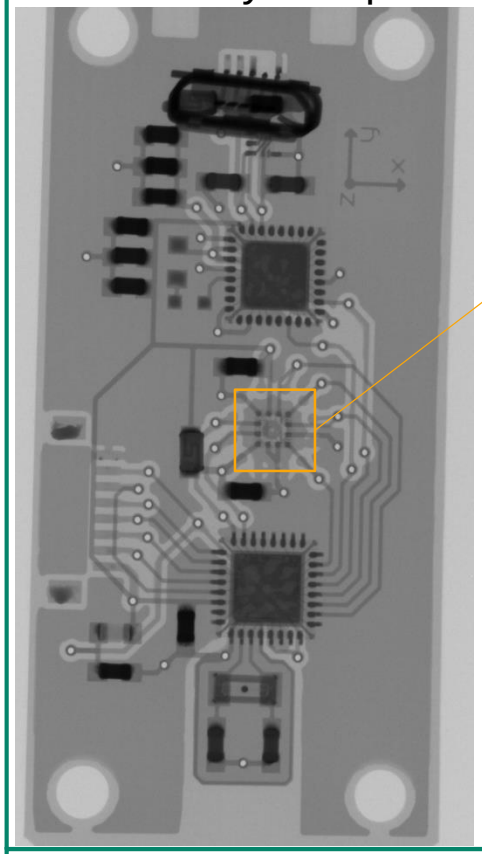


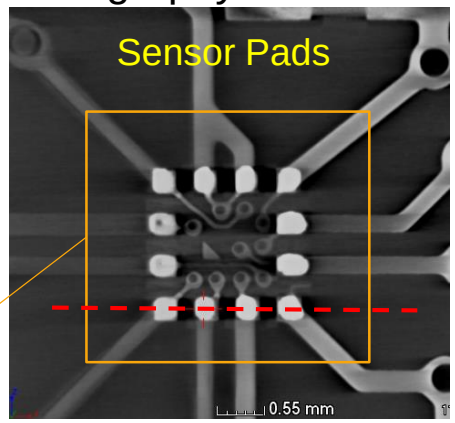
Injection Molding

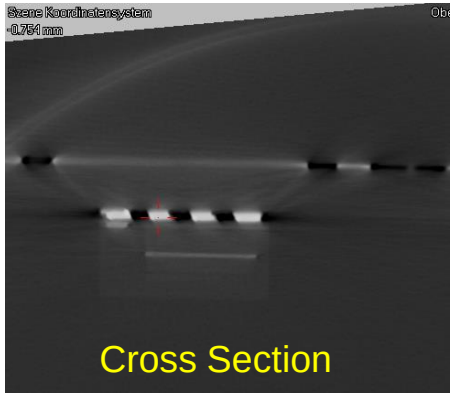


PCB Warping

X-ray Computed Tomography







- No Displacement of Electronic and Sensor Components
- No Defects in Soldered Joints

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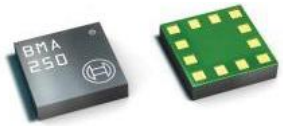
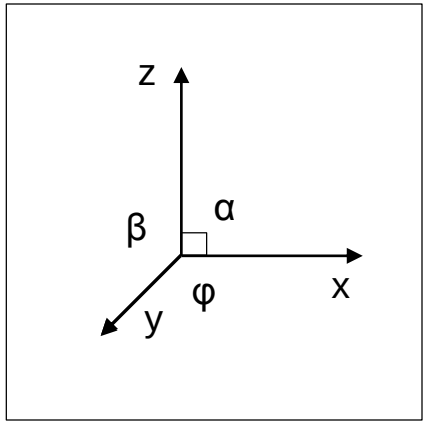
Integration of Smart Systems Electronics

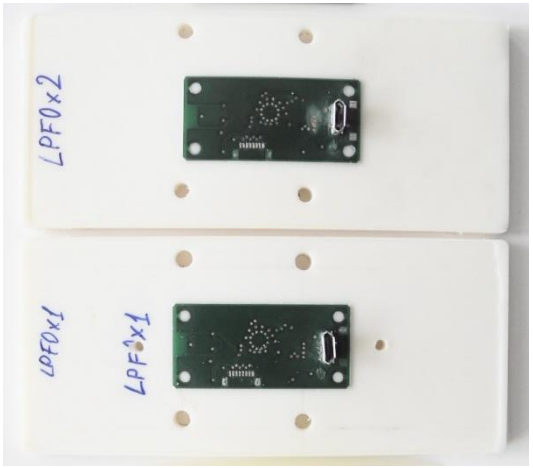
Acceleration Sensor

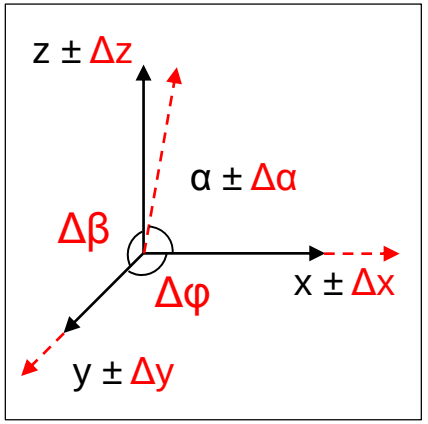




Injection molding

- Min. 500 bar pressure of Microinjection Molding (µIM)-Machine
- Min. 250 °C (Short time), min. 120 °C (Long time)





Thermal and Mechanical Stress →

\+ No change of the sensor axes from orthogonal

$\Delta\alpha \approx 0, \Delta\beta \approx 0, \Delta\varphi \approx 0$

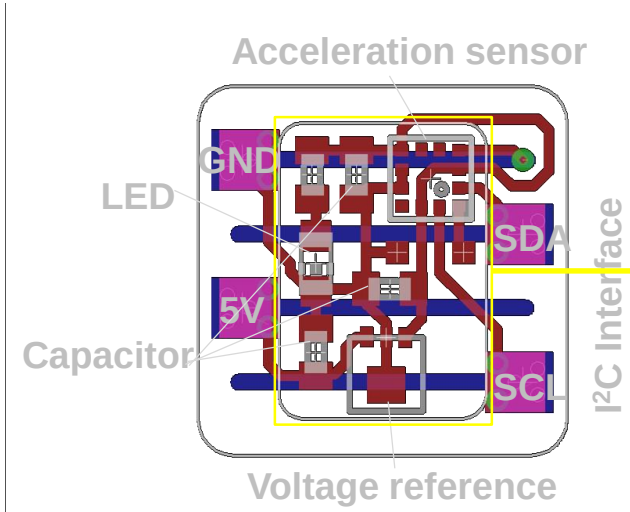
\+ No change of full scale output (sensitivity)

$\Delta z \approx 0, \Delta x \approx 0, \Delta y \approx 0$

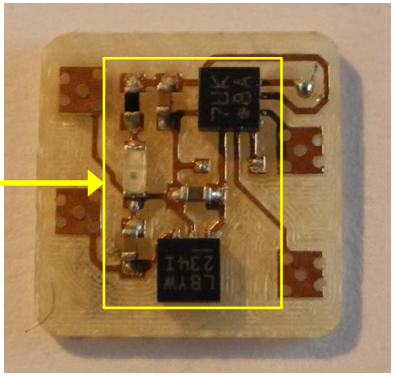
\- Offset shift → Recalibration necessary!

Interposer with MEMS acceleration sensor

Interposer Design



Test Interposer with Electronic Components



Components:

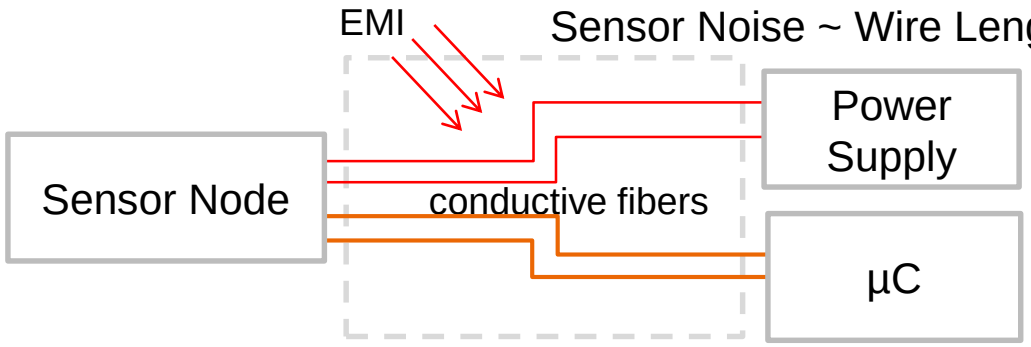
– Digital Acceleration Sensor BMA250

– Voltage Reference LT6660

V_{out} = 3,3V

V_{in} = 4,2V-20V (5V)

Sensor Noise ~ Wire Length ?



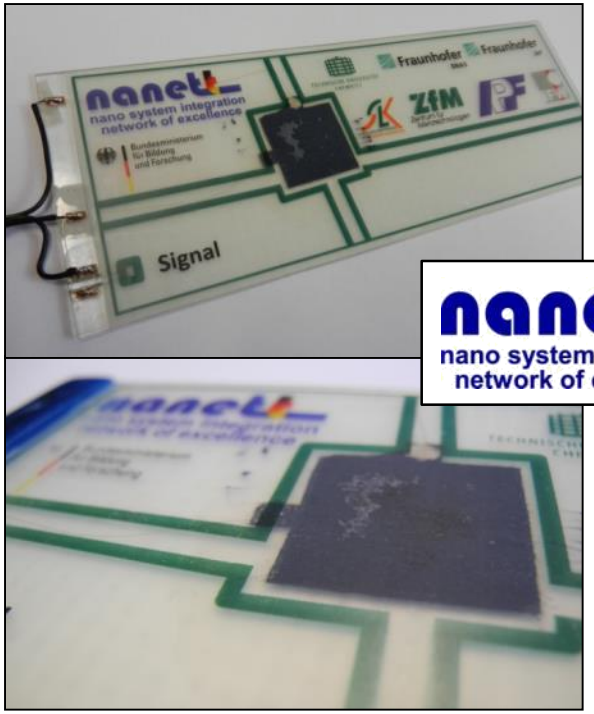
→ Analysis of Influences on Measured Signals by:

- Long Wires (EMI and Wire Resistance)
- Molded Plastics

Research Activities in Chemnitz

Integration of MEMS / Electronics

Integration of novel sensors



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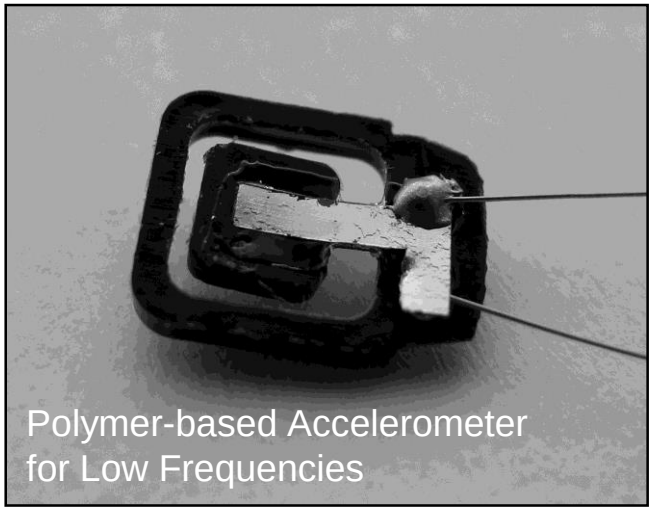
Selected Application Fields

- Structural Health Monitoring (e. g. Strain Sensing, Acoustic Emission)
- Structure Integrated Acoustics and Ultrasonics
- Embedded Force-, Pressure- and Acceleration and Shock Tracing



Polymer-based Accelerometer for Low Frequencies

Demonstration of the System Integration Capabilities @ ENAS

Exemplary Transducers @ ENAS

- Polymer-based Test-Accelerometer for Low Frequencies
- Integrated Large-Scale Impact and Force Sensors
- Embedded Full Polymer Touch Sensor

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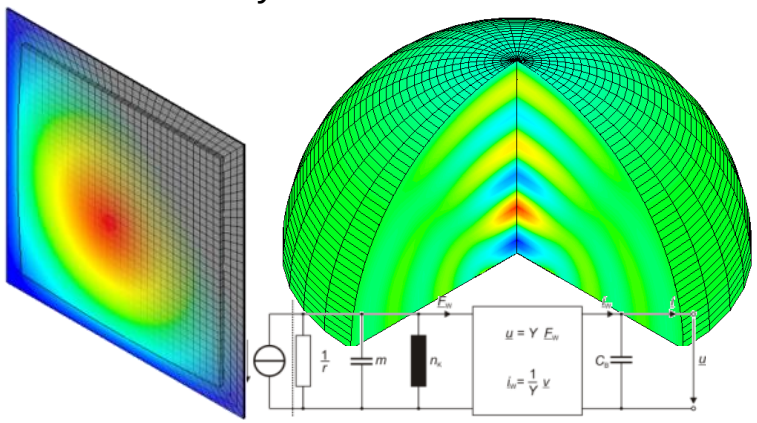
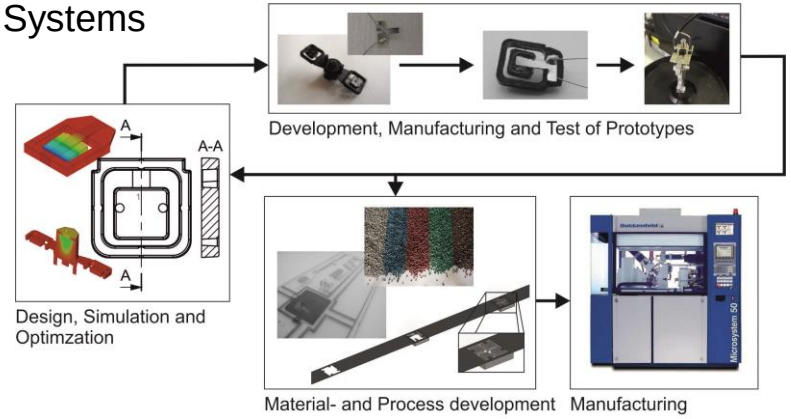
Accessory Developments @ ENAS

- Combined Simulation (Finite- and Lumped Element Modeling) of Piezoelectric Components and Systems
- Multiphysics Simulation of Piezoelectric Transducers (Thermo-Electro-Mechano-Acoustic)

Combined Simulation of Piezoelectric and Electro-Acoustic Systems



Development of Polymer-based Piezoelectric Systems



ENAS Technology

- Design, Simulation and Characterization @ Fraunhofer ENAS
- Process Development and Manufacturing @ TU Chemnitz, SLK and Fraunhofer IAP

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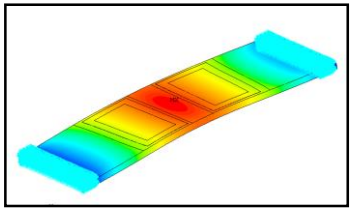
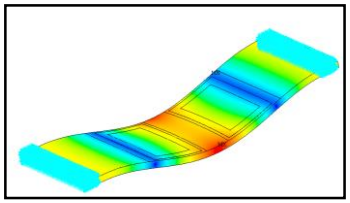
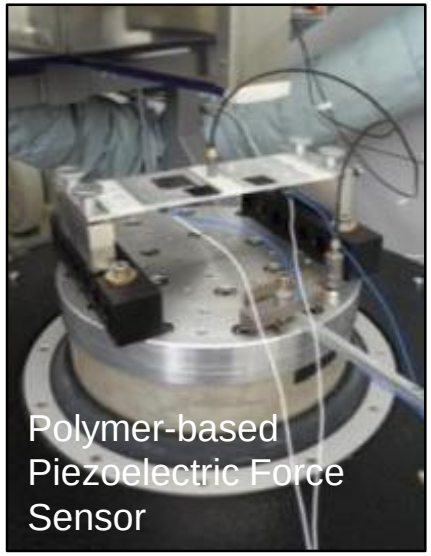
Fraunhofer ENAS Competence

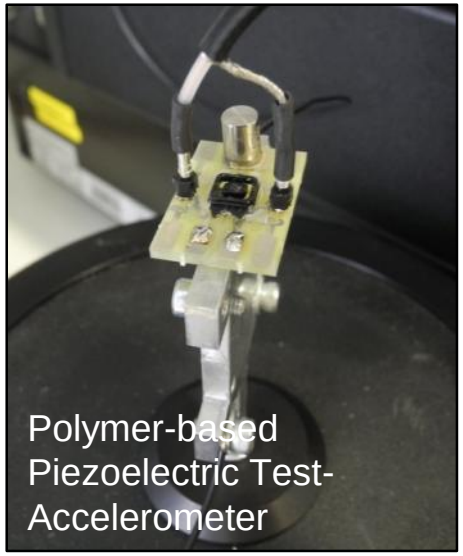
- Evaluation and Characterization of Polymer Based Sensors, Actuators and Systems
- System Design and Combined Simulation Under Consideration of Technological Restrictions and Material Dependent Properties
- Multiphysics Analysis in the Field of Piezoelectrics for Electro-Mechanical and Electro-Acoustic Applications





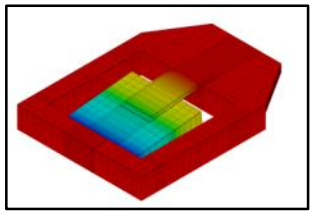


Polymer-based Piezoelectric Force Sensor



Polymer-based Piezoelectric Test-Accelerometer

Simulation and Test of Lightweight Structure Integrated Piezopolymer Transducers



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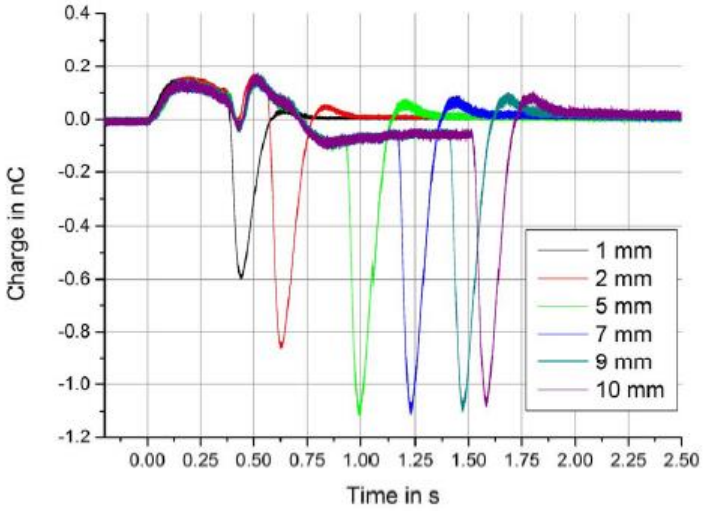
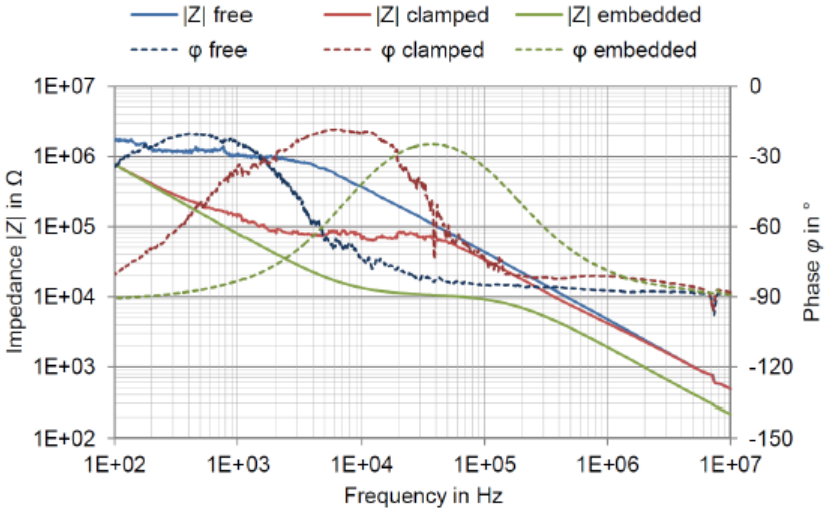
Selected Results

- Embedding of Transducers Into Lightweight Structures
- Application from Micro to Macro Scale for Structural for Health Monitoring (Acoustic emission, Impedance, …)
- Flexible and Robust Transducers with Unique Properties
- Measurement of 3-Point-Bending and Impact





Schulze, R.; Streit, P.; Fischer T.; Tsapkolenko, A.; Heinrich, M.; Sborikas, M.; Kroll, L.; Gessner, T.; Wegener, M.: *Fiber-reinforced Composite Structures with Embedded Piezoelectric Sensors*. In: Proceedings IEEE Sensors 2014, in press, 2014.

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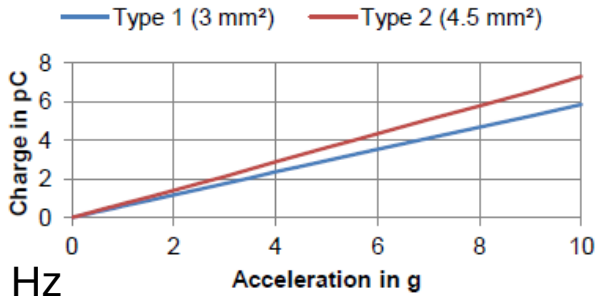
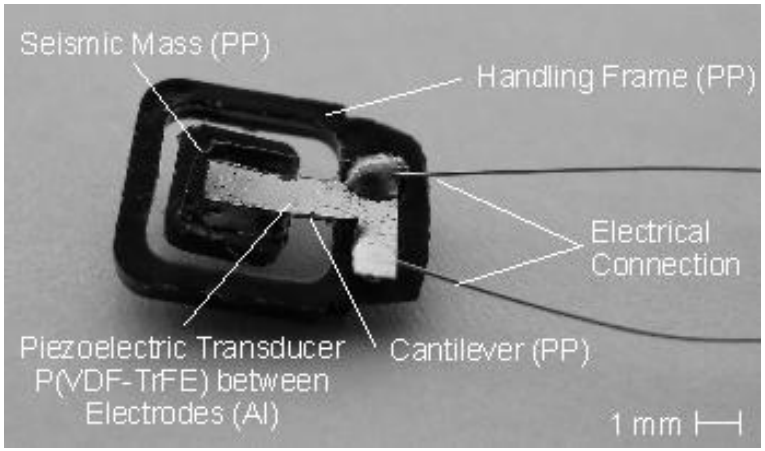
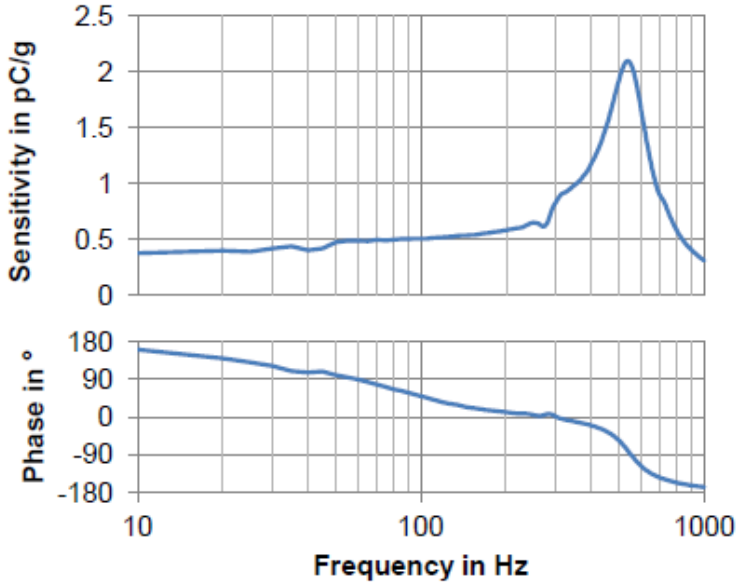
Selected Results

- Measured resonance frequency: 735 Hz
- Sensitivity: 0.69 pC/g
- Linearity (10 %) in the range of 0.1 g up to 10 g: 275 Hz
- 3dB bandwidth: 145 Hz
- Damping ratio: 0.1







Schulze, R.; Heinrich, M.; Nossol, P.; Forke, R.; Sborikas, M.; Tsapkolenko, A.; Billep, D.; Wegener, M.; Kroll, L.; Gessner, T.: *Piezoelectric P(VDF-TrFE) transducers assembled with micro injection molded polymers.* In: Sensors and Actuators A: Physical, 208, pp 159-165, 2014.

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Summary & Conclusion

Summary

- **Integration of Smart Electronics** is possible and lead to **fundamentally new applications**
- **Novel concepts** come along with **novel technological challenges** which also influence the design of integrated smart sensor systems
- A lot of challenges are faced within the MERGE Cluster of Excellence

- Alternatively the **integration of novel sensor materials** might lead to **further new or improved applications**
- The **Smart Systems Integration approach** provides **methods** of the **design** and **characterization** of smart integrated sensors
- A lot of scientific work has been carried out within the network of Excellence nanett

- **The combination of both approaches in the future will enable a design of novel tailored sensor systems**

Thank you for your attention!

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