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Reactive joining for temperature sensitive strain sensors

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01

Reactive Multilayer Systems (RMS)

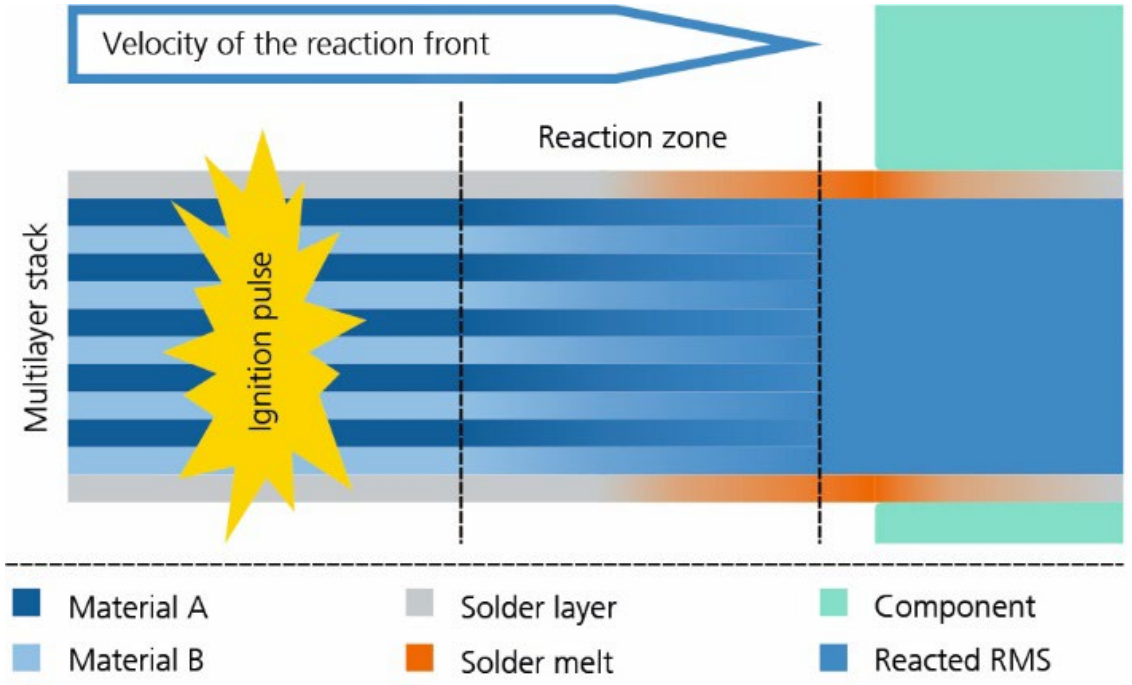
Tailor-Made Joining

Reactive Multilayer Systems

Tailor-Made Joining

Structure and Principle

- Stack of hundreds of alternating periodic layers
- Period thickness between 10 - 150 nm
- Total thickness from a few micrometers to over 100 micrometers
- Ignition of a chemical reaction (exothermic) using for example an electrical spark
- Formation of a self-propagating reaction front
- Heat release in a very short time



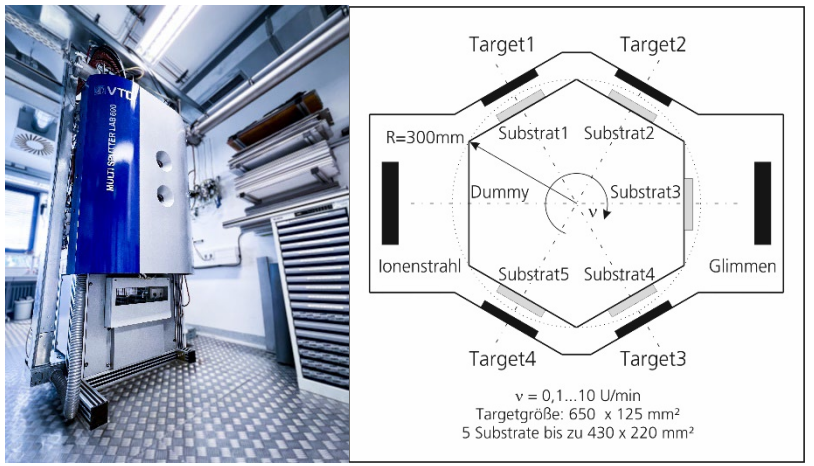
RMS-structure and -principle

Reactive Multilayer Systems

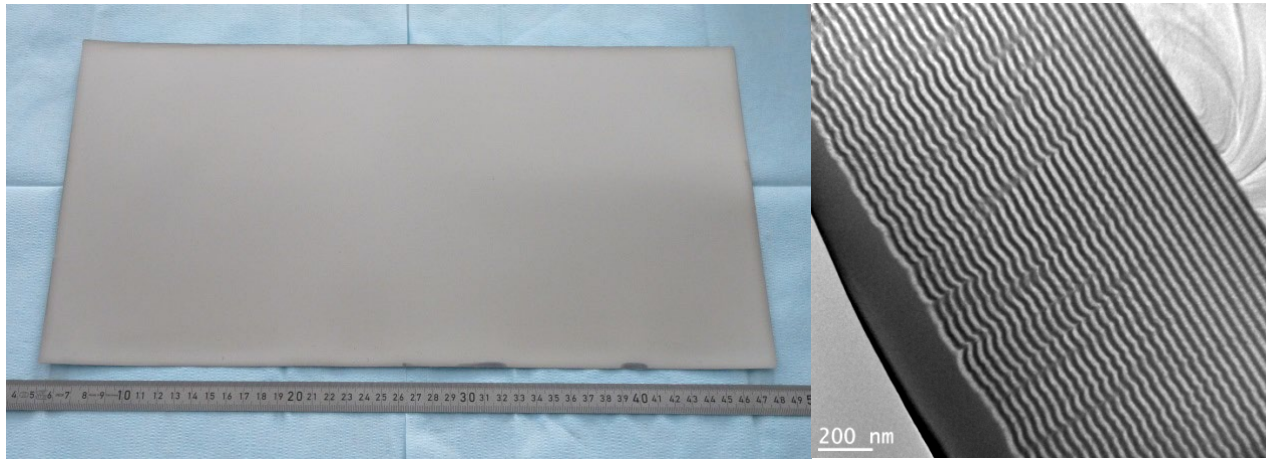
Tailor-Made Joining

Production

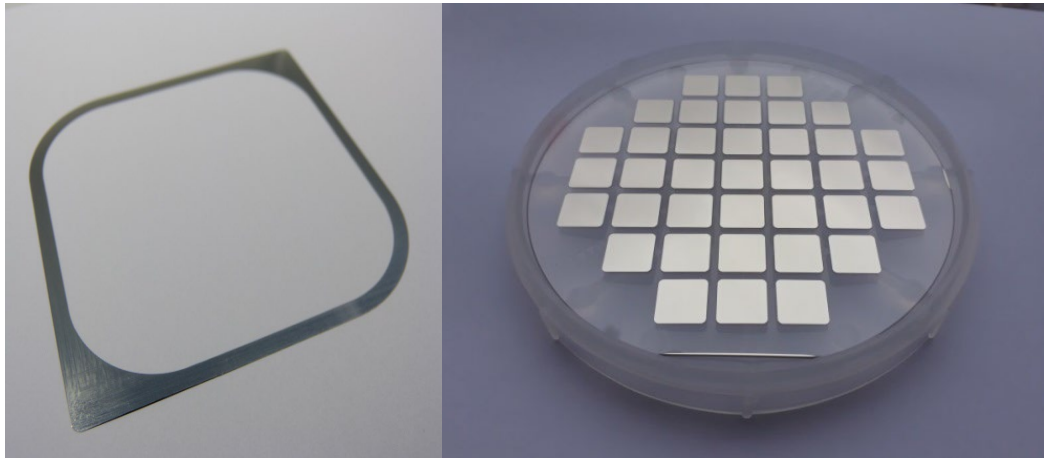
- Process: Magnetron-Sputter-Deposition (MSD)
- Applicable as integrated coating or freestanding foil
- Structuring of the RMS foils using various processes, e.g. punching, cutting, laser processing



Coating system



Ni/Al-RMS foil and nanostructure



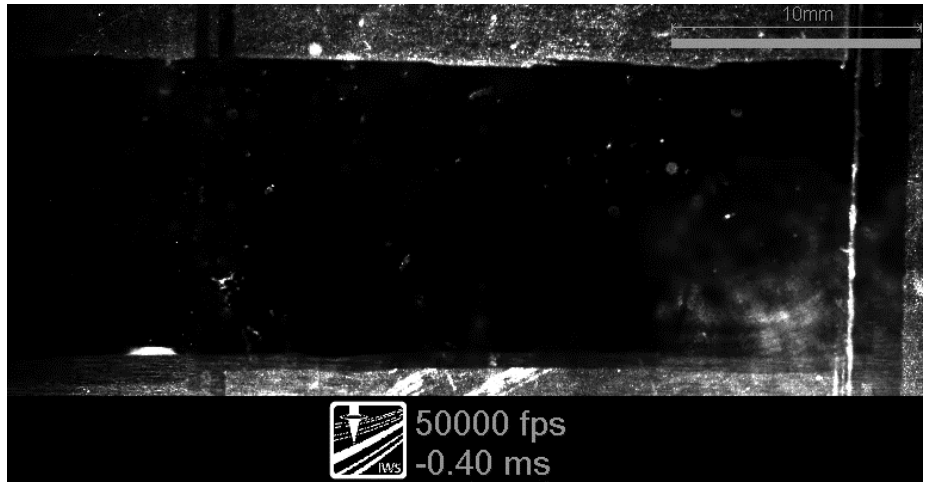
Structured RMS and integrated RMS coating

Reactive Multilayer Systems

Tailor-Made Joining

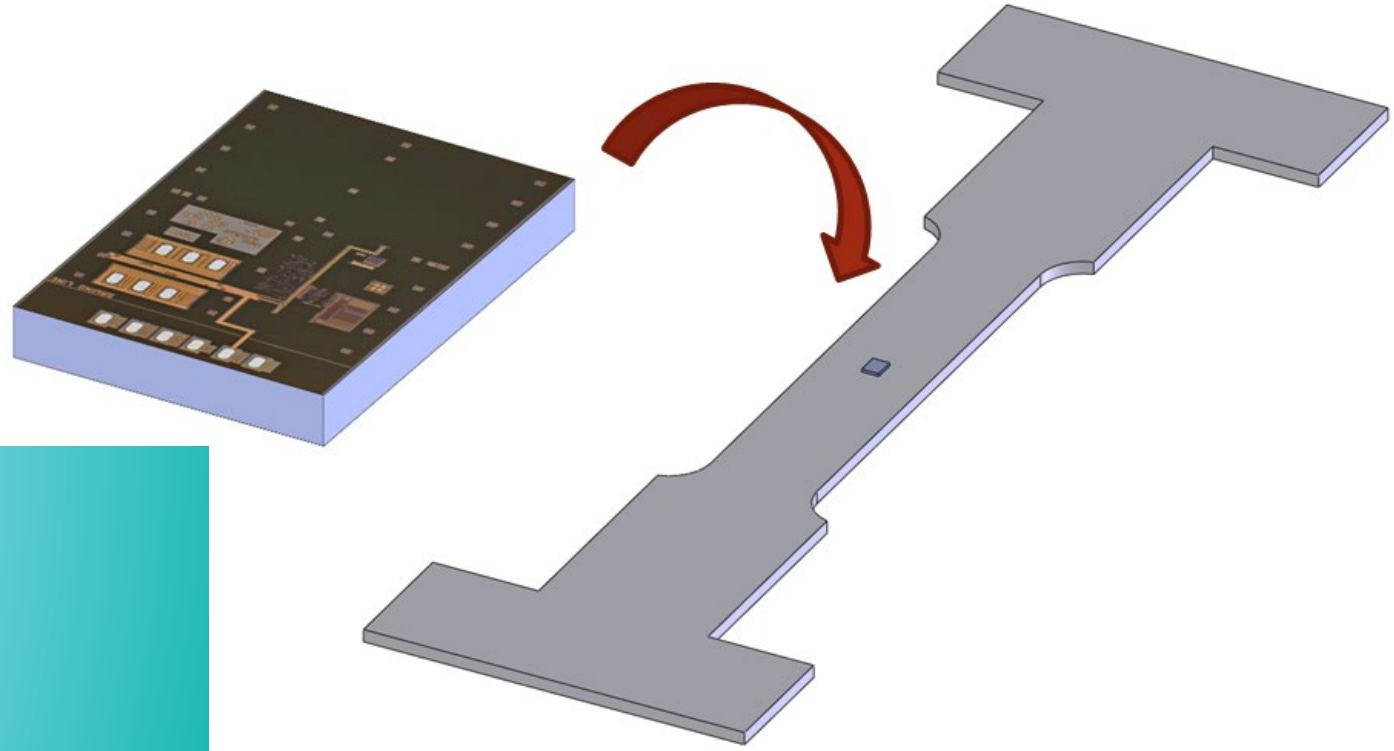
Advantages

- Precisely defined internal heat source
- Localized heat up to 1000 °C for very short time (few milliseconds)
- Fast processing (< 1 second)
- Low thermal and residual stress
- Joining of similar and different materials
  - Indifferent to CTE mismatch
- Low permeability bondings
- High thermal and electrical conductivity
- Reaction does not need oxygen



High speed recording of RMS reaction

Hybrid joining of CFK with aluminium



02

Sensor Joining with RMS

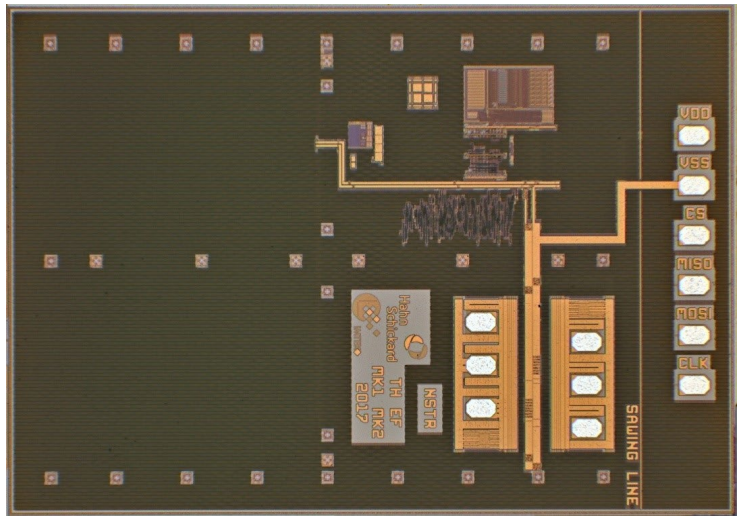
Concept and Approach

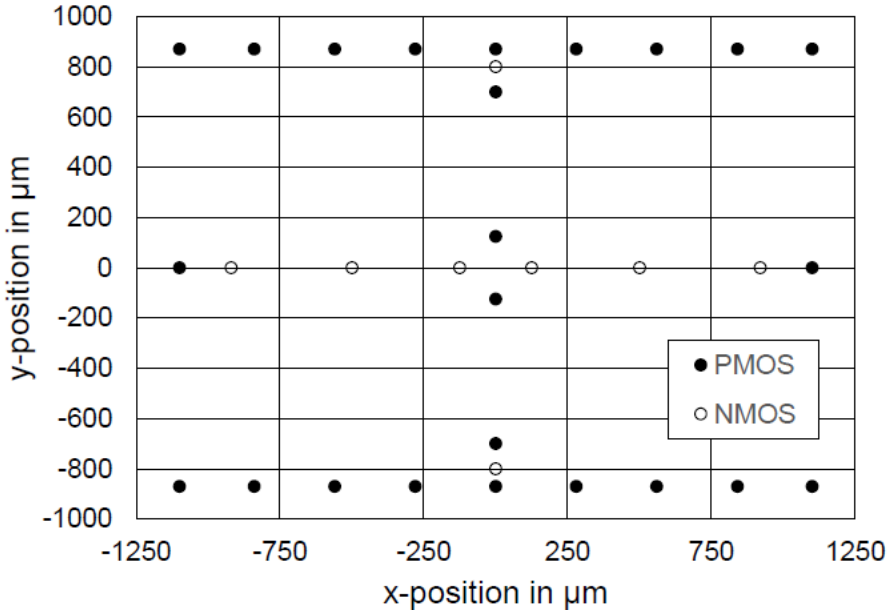
Sensor joining with RMS

Concept and approach

Sensor

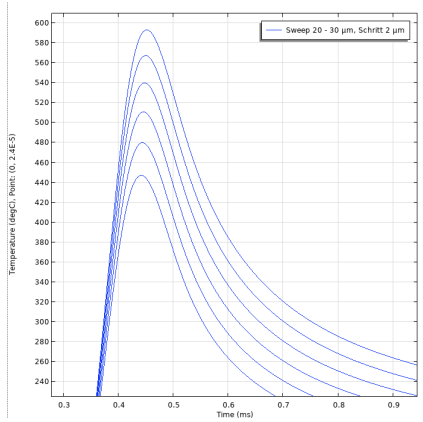
- Si-based sensor chip: 2.0 x 2.85 x 0.3 mm³
- 32 integrated sensor elements
- Application: condition monitoring of devices





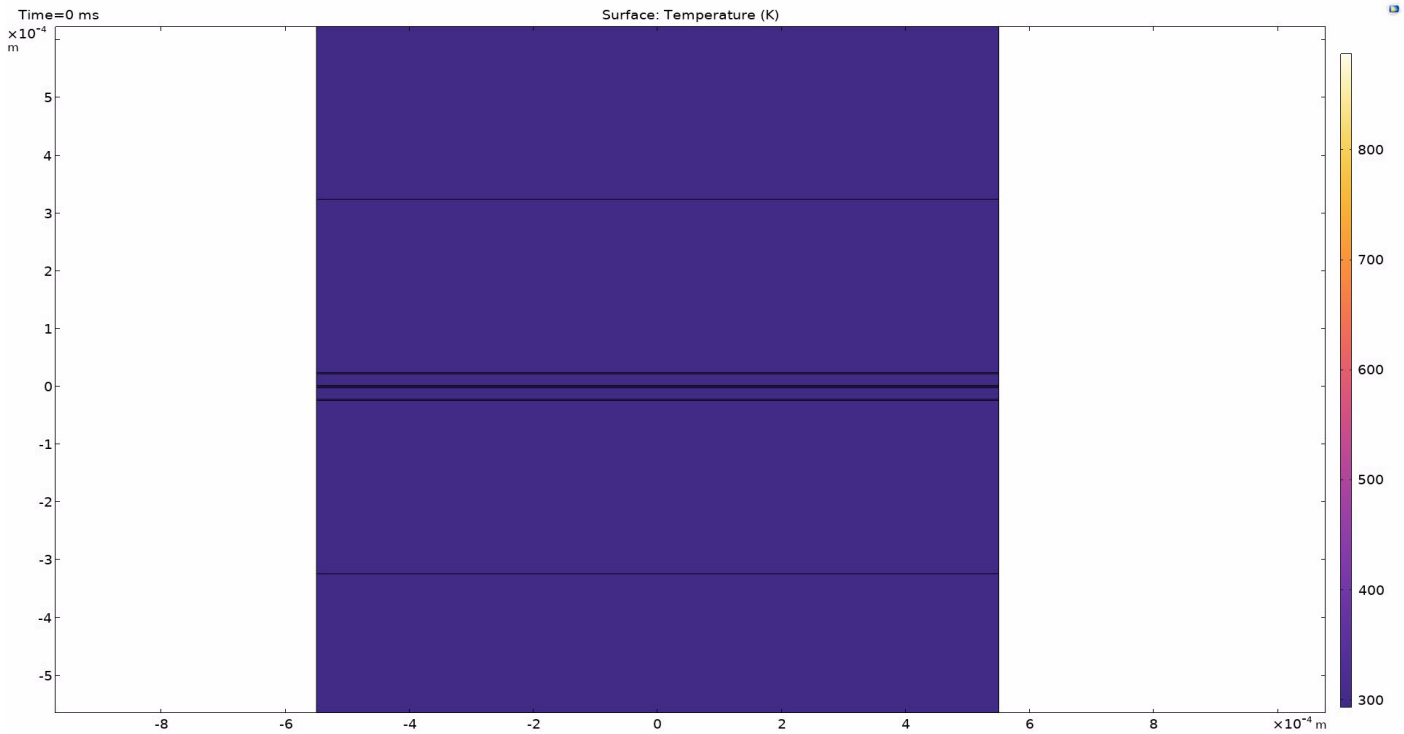
Sensor joining with RMS

Concept and approach



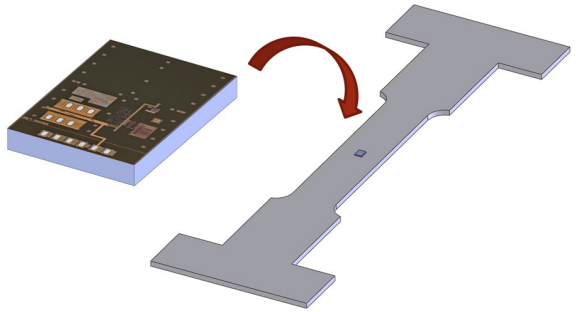
Simulation

- Fast 2D simulation model of RMS joining process
- Statements about:
  - maximum temperatures
  - Temperature distribution
  - Heat-affected zone
  - Effects at the component edge
- Result: RMS design (thickness, structure, …)
- Example: Silicon-Silicon connection



Sensor joining with RMS

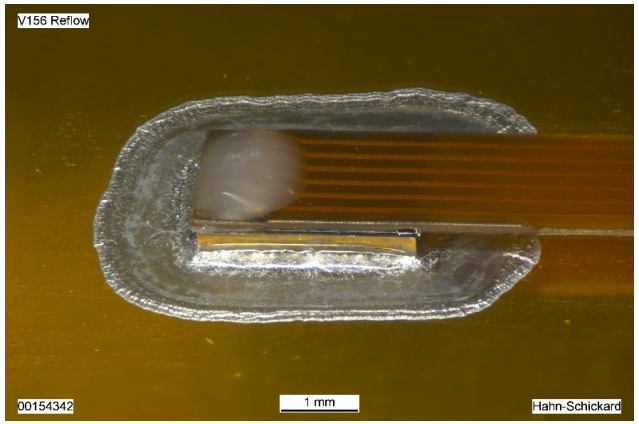
Concept and approach



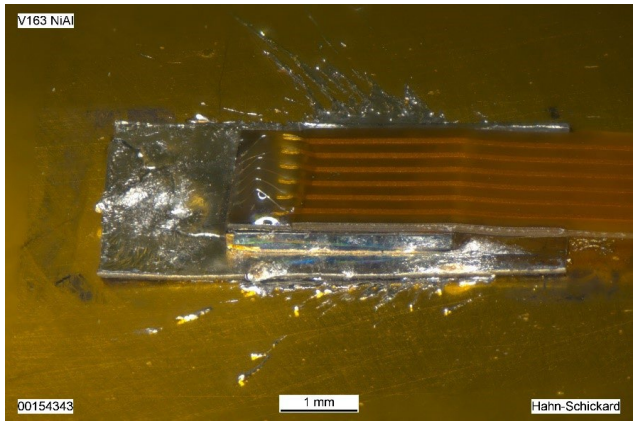
Joining on tensile samples

- Tensile samples
  - 1.4301 stainless steel
  - 12.5 x 1.5 mm²
- Chip on flexible PCB
- 3 joining variants:

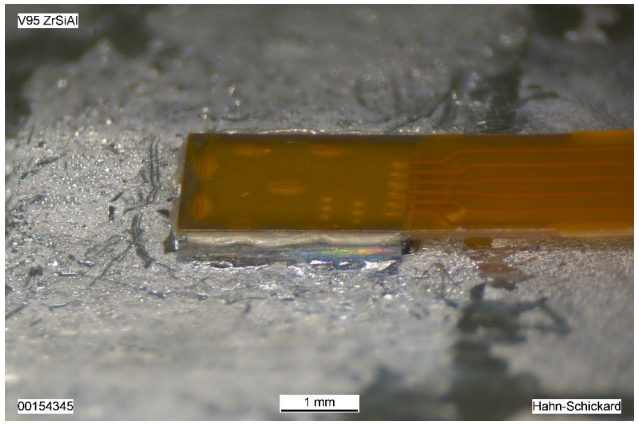
reflow-soldering
solder paste
SAC305 soft solder



reactive joining
60 µm Ni/Al foil
10 µm Sn soft solder



reactive joining
23 µm Zr/Si/Al direct coating
4 µm AlSi12 braze

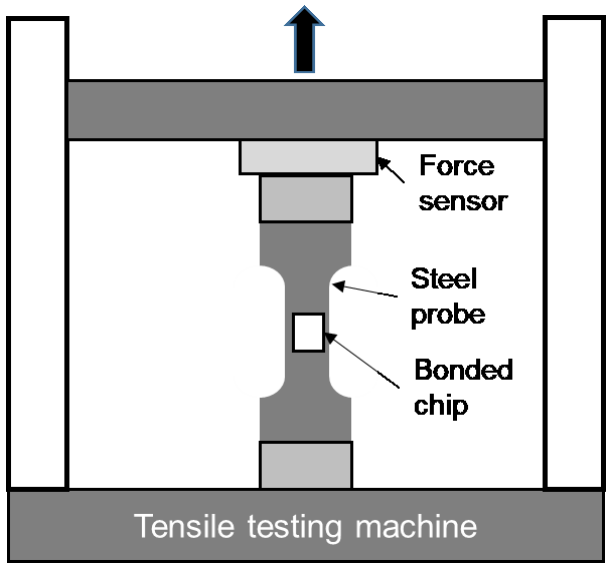


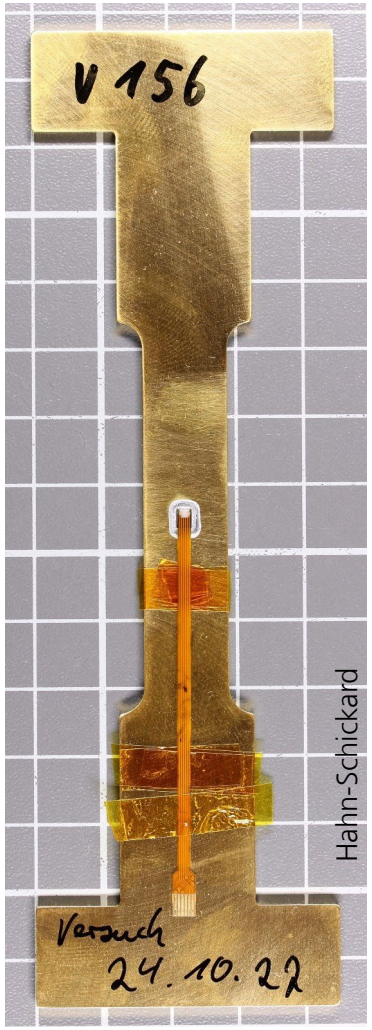
Sensor joining with RMS

Concept and approach

Tensile measurements

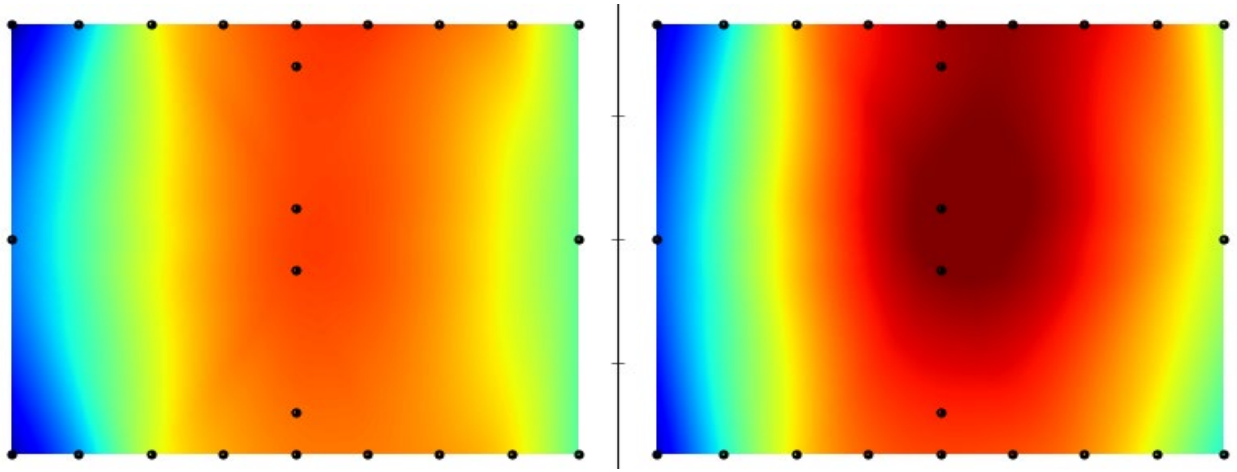
- Tensile forces 0 to 1200 N
  - 0 to 64 MPa in the sample
- Measurement of sensor signals and visualization of the distribution over the chip area





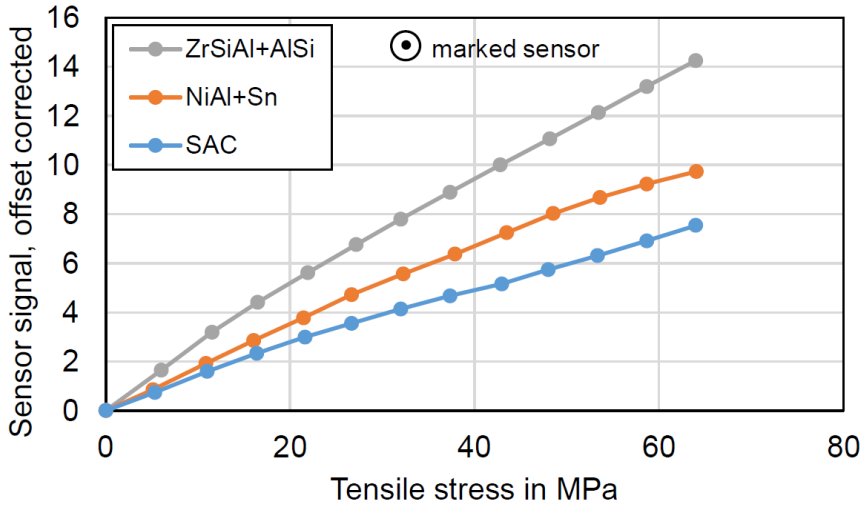
03

Results



Results

- Stress distribution: normal stress at 64 MPa
  - Interpolated from 24 PMOS-sensor signals
- Mechanical bond depending on joining method
- Best mechanical bond with Zr/Si/Al and braze



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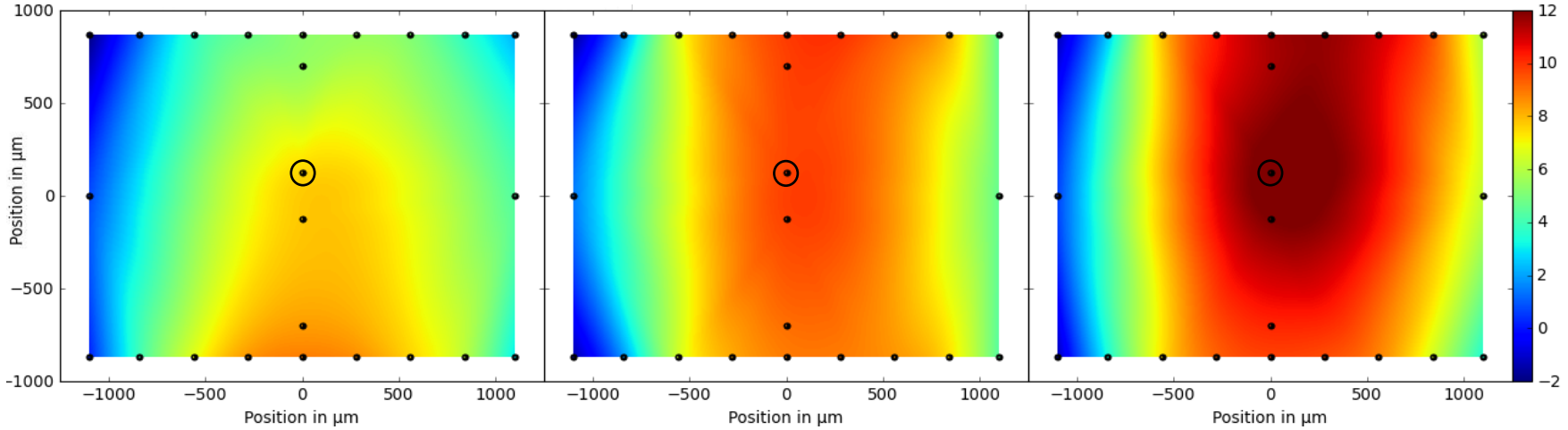

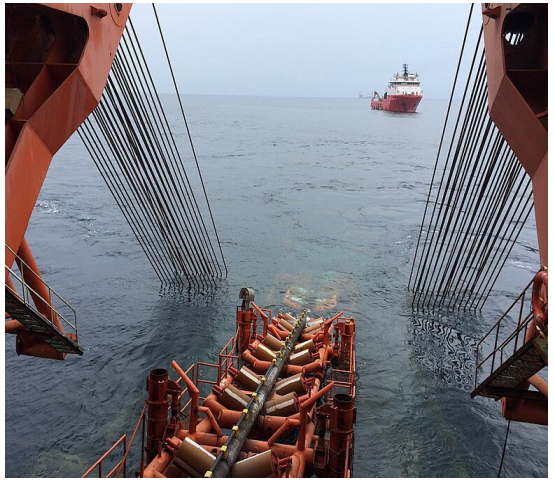

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04

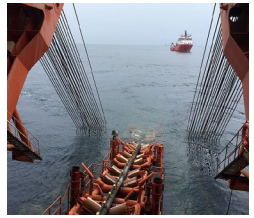
Outlook

Takeaways and Possibilities

Outlook

Takeaways and Possibilities





Potential Applications in Microjoining

- Improved stress monitoring
  - sensitivity as (most?) important parameter
  - no zero-point-offset due to CTE mismatch
- Allows joining of particularly sensitive components and sensors
- Retrofitting of sensors
  - To existing equipment and structures
  - Only where data is required (e.g. critical screws)
  - Portable joining
  - Various material combinations possible

Further Fields of Application

- Lightweight construction
  - hybrid joining (e.g. plastics)
- Aviation and Aerospace
  - Indifferent to environment
- Maritime

Outlook

Takeaways and Possibilities

Future RMS material systems

- Much higher reaction temperatures
  - brazing or solder-free joining
  - more rigidity possible
  - lower layer thicknesses
- Compatibility and cost-effectiveness
  - Biocompatible materials
  - Uncomplicated sourcing, handling and dispatch

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