MEMS made in a Small Scale Research Lab – Opportunities for Functional Targets

TECHNISCHE UNIVERSITÄT DARMSTADT

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Institute of Electromechanical Design
Institut für **E**lektro**m**echanische **K**onstruktionen **EMK**

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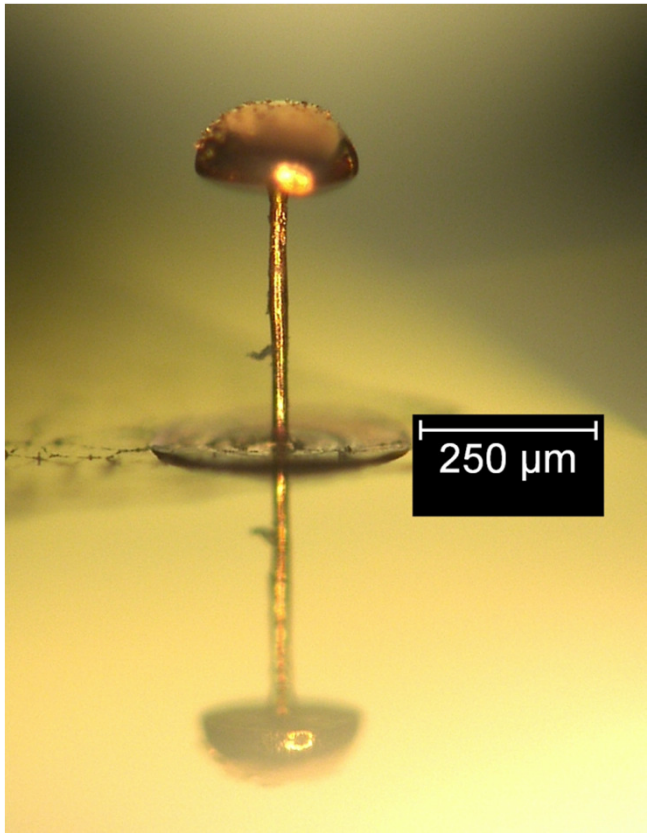

Institute for Electromechanical Design – EMK
Institut für Elektromechanische Konstruktionen

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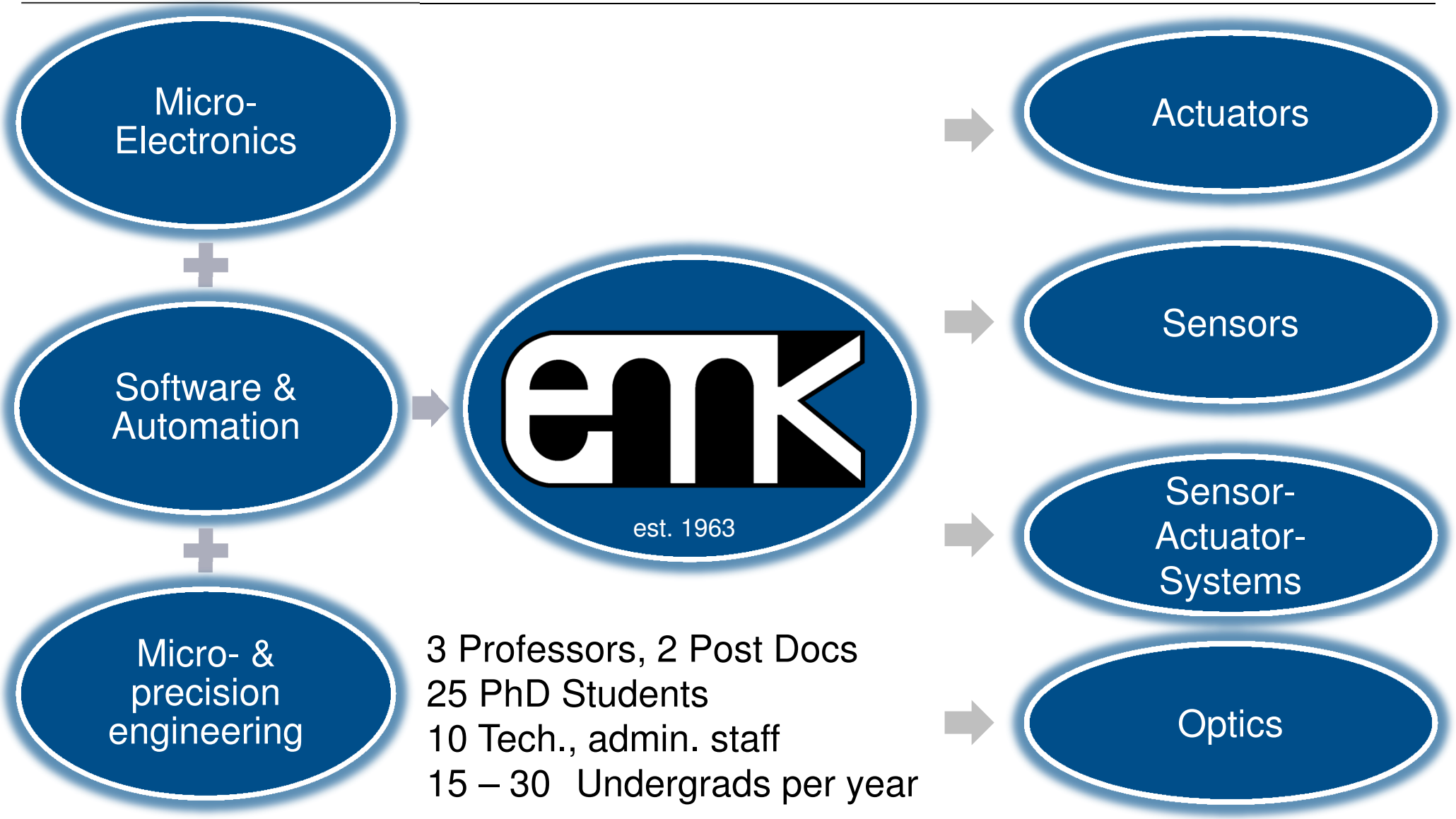

3 Professors, 2 Post Docs
25 PhD Students
10 Tech., admin. staff
15 – 30 Undergrads per year

Cleanroom Laboratory for Microtechnology

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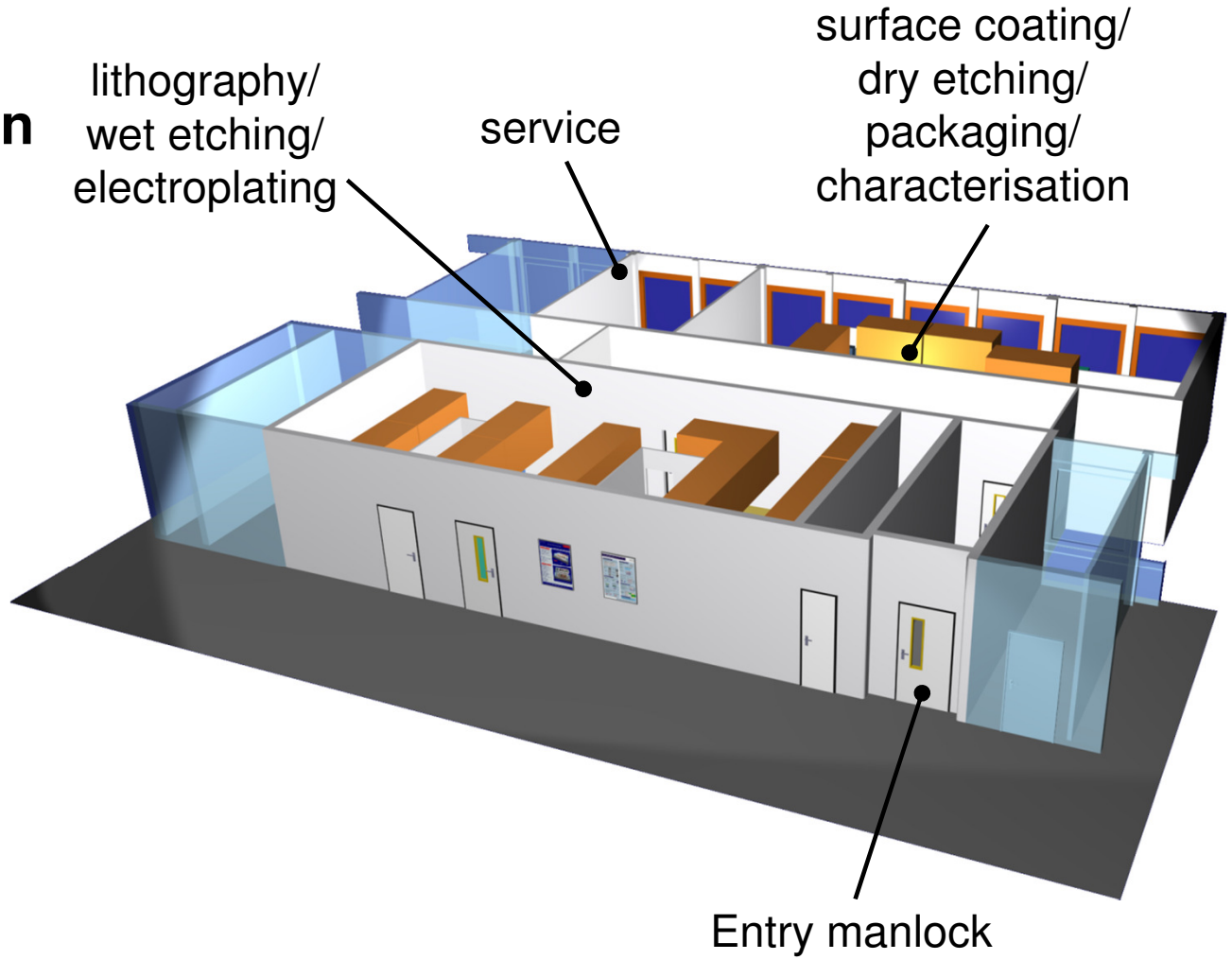
Clean room classification

1.000 - 100 within the laminar airflow boxes

Functionality

- about 60 m² for photolithography, wet etching, electroplating
- about 60 m² for packaging, surface coating, measurement



http://www.emk.tu-darmstadt.de/en/institute/equipment/

Technology Overview
Substrate Pretreatment

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Sputtering

Alcatel

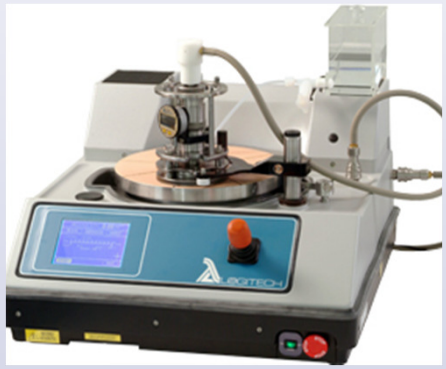
- DC/ HF Sputtering with RF-Bias
- 4 Cathodes
- Al, Cr, Cu, SiO_2
- Deposition Rates up to 1000 nm/min
- Vacuum Prechamber

Vapour Deposition

Balzers BAK 600

- Electron Beam and Resistance Evaporator
- Al, Cu, Cr, Ni, Ag, Ti, Au, Al_2O_3
- Thickness Controll through Quartz Resonator

Polishing Machine



Logitech PM5

- Precision Polishing Jig with vacuum adapter
- Up to 4“ wafer
- Plate Speed: 0-70 rpm
- Chemical Mechanical Polishing option

Technology Overview
UV-Lithography I

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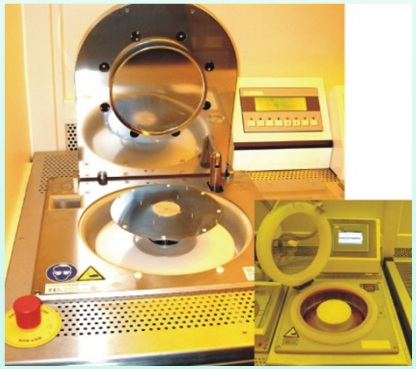
Spin Coater

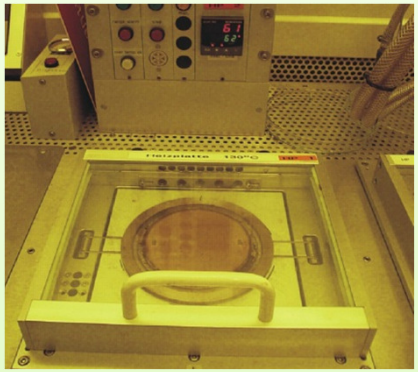


SÜSS Delta 80 BM
- Rotating Lid
- Up to 4000 rpm

SÜSS LabSpin 6
- Up to 8000 rpm

Photo Resists
- SU-8 2000/3000
- AZ 9260
- AZ 15, 125 (n)XT

Hotplates



2x Hotplate 400
- Programmable Single Plate
- Up to 130 °C

3x GESTIGKEIT PR 5-3T
- Programmable Double Plate
- Up to 300 °C

IR Oven

FH Zwickau
- IR dry system for photoresist
- Up to 6“ wafer
- Max. heat 130 °C
- Maximum substrate weight 150 g

Technology Overview
UV-Lithography II

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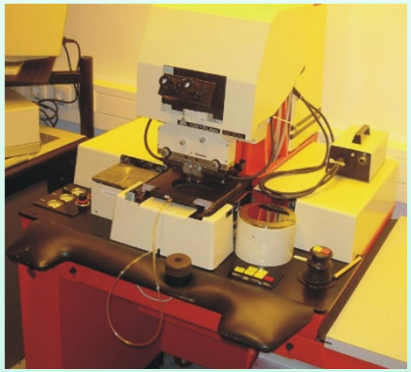
Mask Aligner



SÜSS MA 56 M
- 350 W UV-Lamp
- Up to 4“ Masks
- Manual Alignment
- Up to 20 mW/cm²
- Process Monitoring

Filters
- g, h, i - Line
- g, h - Line
- i - Line

Developer

Sonosys 500
- Frequency 1 MHz
- Power 50 - 500 W

Multi-Bio-3D
- Orbital Shaker

Developer
- mr-Dev 600
- MIF 326, 826
- AZ 400k

Technology Overview
Micro- and Nano Electroplating

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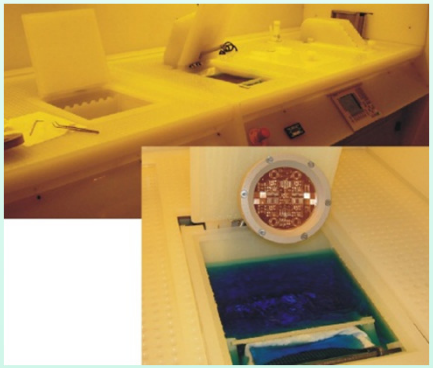
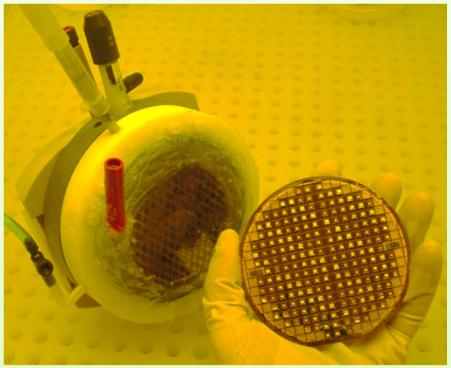
Micro Electroplating



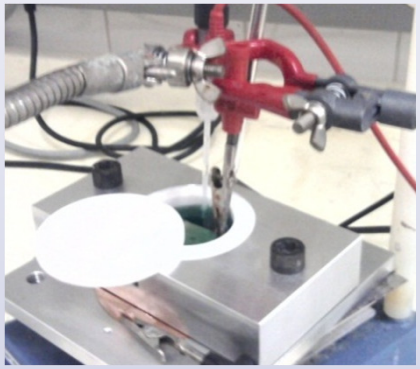
M-O-T µGalv
- Additive free Electrolytes
- Nickel (pH 4), Copper (acid)
- Currents up to 10 A
- Puls-Plating Option
- Plating rate up to 4 µm/min

Micro & Nano Electroplating



silicet trio clip
- 3 electrodes cell for 4“ wafer
- Ion membrane for use with additives
- 1 µA - 3 A reverse pulse plating to extend to 100 kHz
- 2 l volume with particle filter

Nano Electroplating



Nano Electroplating Cell
- Potentiostatic and Galvanostatic Plating
- Pulse- & Reverse-Puls-Plating up to 100 kHz
- Currents down to several nA

Technology Overview
Plasma Activation & Etching

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Isotrop Etching

Muegge STP 2020

- Remote Downstream Plasma Reactor for Polymer Etching (e.g. SU-8, BCB)
- O_2, CF_4, N_2
- RF-Power: 3000 W at 13,56 MHz

Anisotrop Etching

Plasma Technology RIE80

- Parallel Plate Reactor for Substrate Cleaning and Polymer Etching
- O_2, CF_4, N_2
- RF-Power: 300 W at 13,56 MHz

Surface Activation

Technics 300-E Plasma

- Barrel Reactor for Substrate Cleaning and Surface Activation
- O_2, CF_4, N_2
- RF-Power: 300 W at 13,56 MHz

Wet Etching Machine

BUNGARD, Splash Center

- Etching medium: Fe-III-Cl
- Line definition: 100 µm
- Max. board size: 210 x 300 mm

Technology Overview
Packaging Technologies

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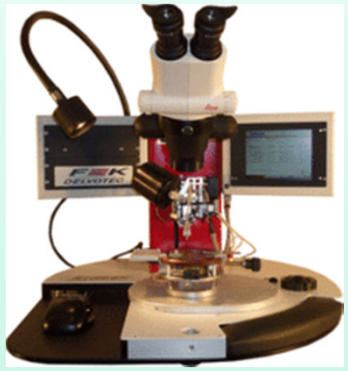
Wire Bonder



F&K Delvotek 53xx-BDA Bonder

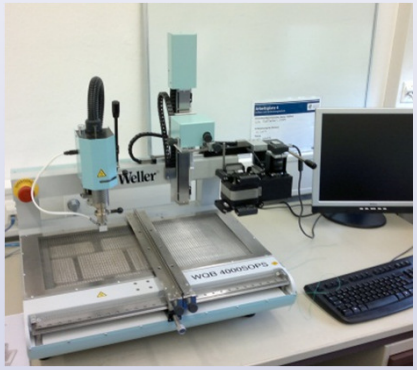
- Ball Bonding down to 18 µm gold wire
- Deep access wedge bonding
- Automated y-axis for automated loops

Micro Assembly

Arteos TOMM 1

- Pic and placer
- Plate- and air-heater
- UV-curing
- Micro-dispenser
- Vacuum chuck

Pick and Place



Cooper Hand Tools WQB 4000SOPS

- Operating range 630 x 630 mm²
- Soldering temperature 50 - 400 °C
- Down to smallest package sizes

Vacuum Furnace

Heraeus, Nabertherm & Co

- Vacuum option
- Protective gas option e.g. N
- Temperature profile option
- High temperatures up to 1100 °C

Technology Overview
Optical Inspection & Characterization

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Thermography

FLIR SC655
- 640 x 480 Pixel
- -20 °C to +150 °C
  0 °C to 650 °C
- Sensitivity:
  <0.05 °C @ +30 °C

Optical Inspection

Keyence VHX-600
- 3CCD Camera
- 54 Mio Pixel
- Magnification up to 1000x
- 3D Measurement Option
- Measurements of Structural Widths

Laser Vibrometer

Polytec OFV 2502
- 2 sensor heads (OFV 534)
- Velocity demodulation
- 1.5 MHz

Polytec OFV 3001
- Velocity demodulation
  0.3 µm/s…10 m/s

High Speed Camera

Mikro GmbH
- 1280x1024 pixel
- 502 fps
- 55 min recordtime

Technology Overview
Electro Mechanical Characterization I

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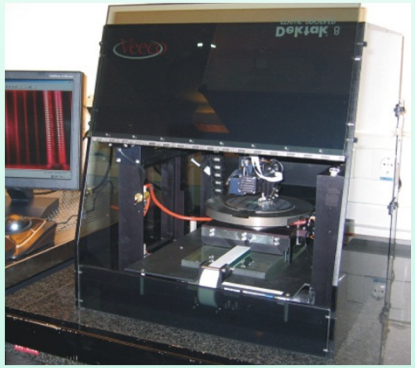
Surface Profiler



DEKTAK 8 Profiler

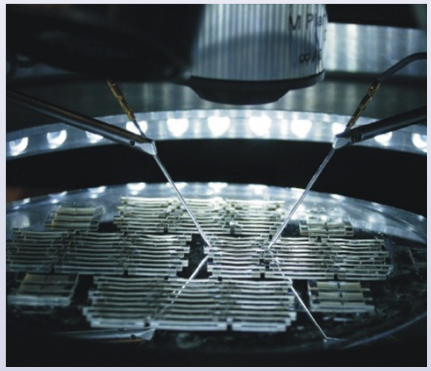
- Measurement of Layer Thickness and Surface Profile
- Range from 10 nm up to 1 mm
- Stylus Force up to 0,09 mg

Bond Shear Tester

dage Microtester 22

- Testing strength of solder joints, wire bonds and more
- Stitch Test Failure Detection
- 20 gm & 10 kg Load
- Resolution +/- 0,5% of load

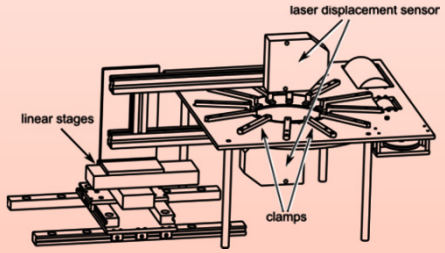
Motion-Analyzer



MEMS-Analyzer

- 2048 x 2048 Pixel
- 15 fps, 800 MBit/s
- Repeatability < 30 nm
- Force Measure-ments up to 1 N
- Field of View up to 11,7 x 11,7 mm²

EAP Characterization



EAP-Analyzer

- Static / dynamic deflection (line scan)
- Frequency response
- Preload simulation
- Sheet resistance
- Force-displacement

Technology Overview
Electro Mechanical Characterization II

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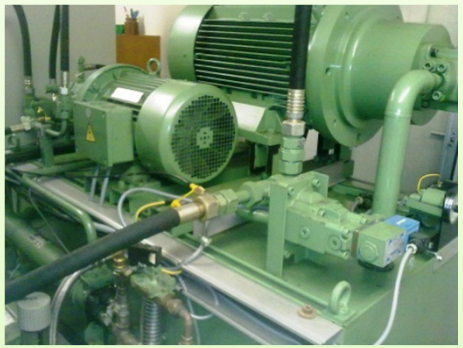
High-Pressure Static Tester

COP-7000
- 500 MPa=5000 bar
- silicon oil
- Room temperature

Pressure sensor
- P3MBP 5000 bar (HBM)

Piston gauge
- 5ppm @ 5 000 bar
- 1 kg / 50 bar

High-Pressure Dynamic Tester



MAXIMATOR
- up to 1000 bar
- Periodic load at 0.1 Hz to 20 Hz
- Curve shape rectangular, trapezoid or sinus
- 4 pressure connectors

Technology Overview
Electrical Measurement Equipment

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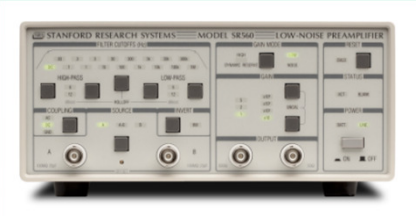
Signal Conditioning



Stanford Research SR 560
- low-noise preamplifier
- battery operating option

Krohn-Hite 3382
- programmable dual-channel filter
- 0.1 Hz – 200 kHz
- Butterworth or Bessel response

Impedance Analysis

Agilent 35670A
- dynamic signal analyzer
- 122 µHz - 102.4 kHz, 16-bit
- swept sine option
- GPIB

HP 4284 A
- Precision LCR-Meter
- 20Hz – 1 MHz
- GPIB

DAQ-Systems

Data Acquisition
- DMM, LCR-Meter
- Multi-Purpose DAQ (16 bit, 1,25 MSa)
- 8ch Bridge Input Module (24 bit, 25 kSa)

Universal Control
- PXI, cRIO
- AI, AO, DIO, SPI, Bridge

Peripherals

LeCroy WaveRunner 44Xi-A
- 400 MHz, 5 GSa

Agilent DSOX3024A
- 200 MHz, 4GSa

Hameg HMP4040
- programmable power supply

Hameg HMF2525
- 25 MHz Arbitrary Signal generator

High AR Metal Pillars
UV Direct LIGA Processing

Si + SiO2 Cr Al
Cu SU-8 AZ 125nXT

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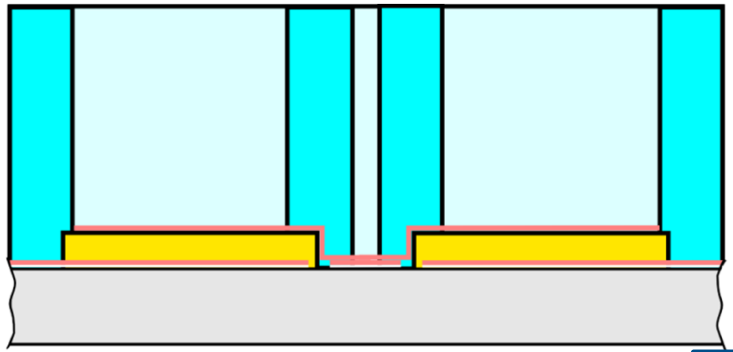
- Structured electrode layer: Cr + Cu 100 nm

- Sacrificial layer: SU-8 5 µm

- Structured seed layer:
  Cu 200 nm + Al 20 nm

- Exposed photoresist, undeveloped:
  AZ125nXT 400 µm

$$l_W = 400\ \mu m, d_W = 30 - 50\ \mu m$$



High AR Metal Pillars
UV Direct LIGA Processing

Si + SiO2 Cr Al
Cu SU-8 AZ 125nXT

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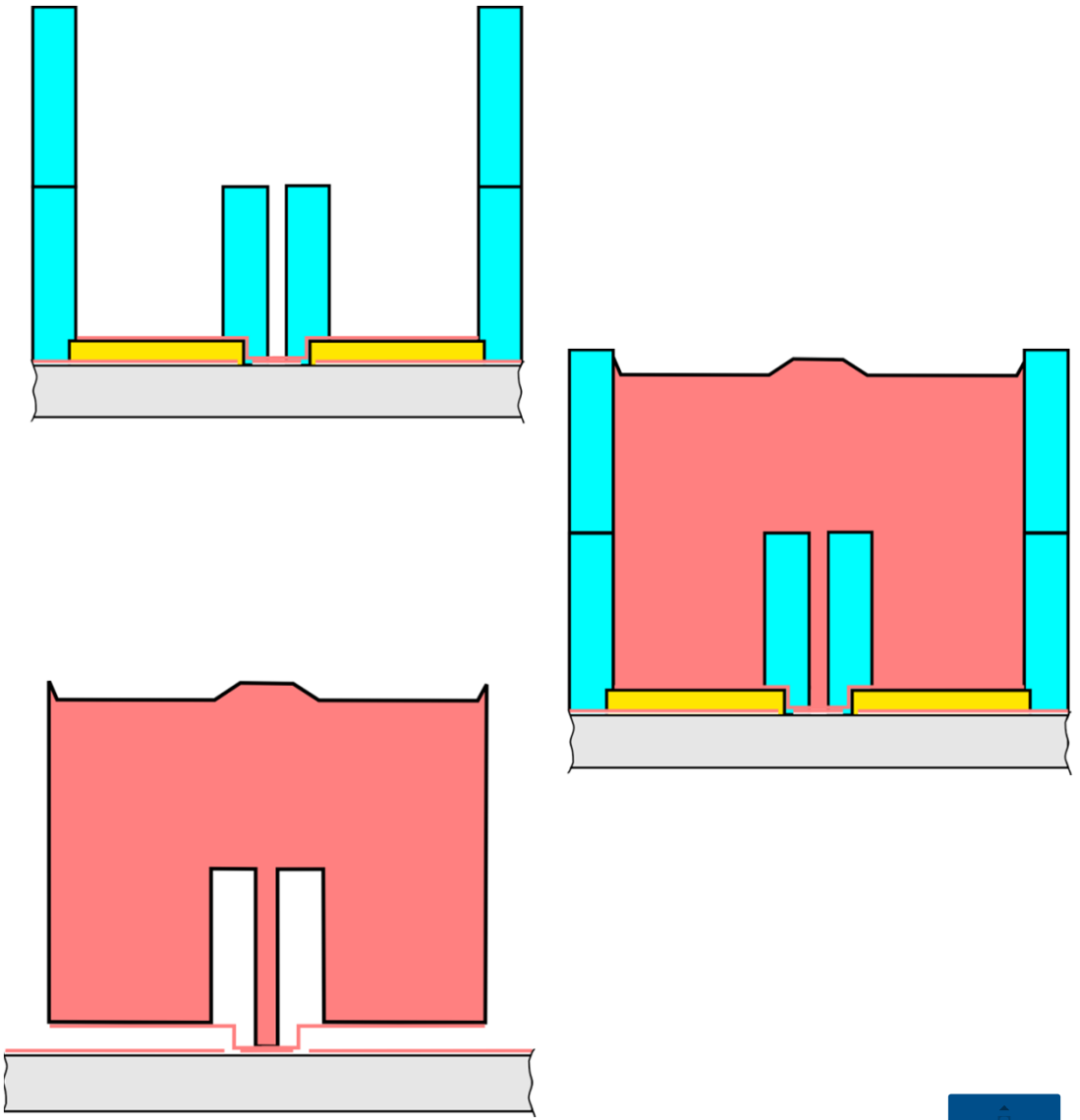
- Structured mold for electroforming: AZ125nXT 2 x 400 µm

- Filled mold: 700 µm Cu
  - Current: DC, pulse, pulse reverse
  - Contacting: pillars and blocks grown simultaneously

- Stripping
  - Dry etching with reactive oxygen radicals (muegge/R3T)



High Aspect Ratio (AR) Metal Pillars for Minimal Footprint MEMS Suspension

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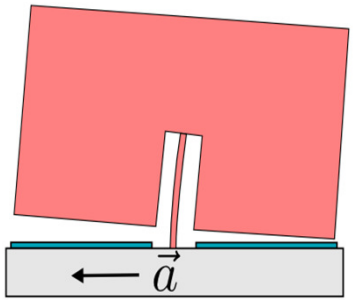
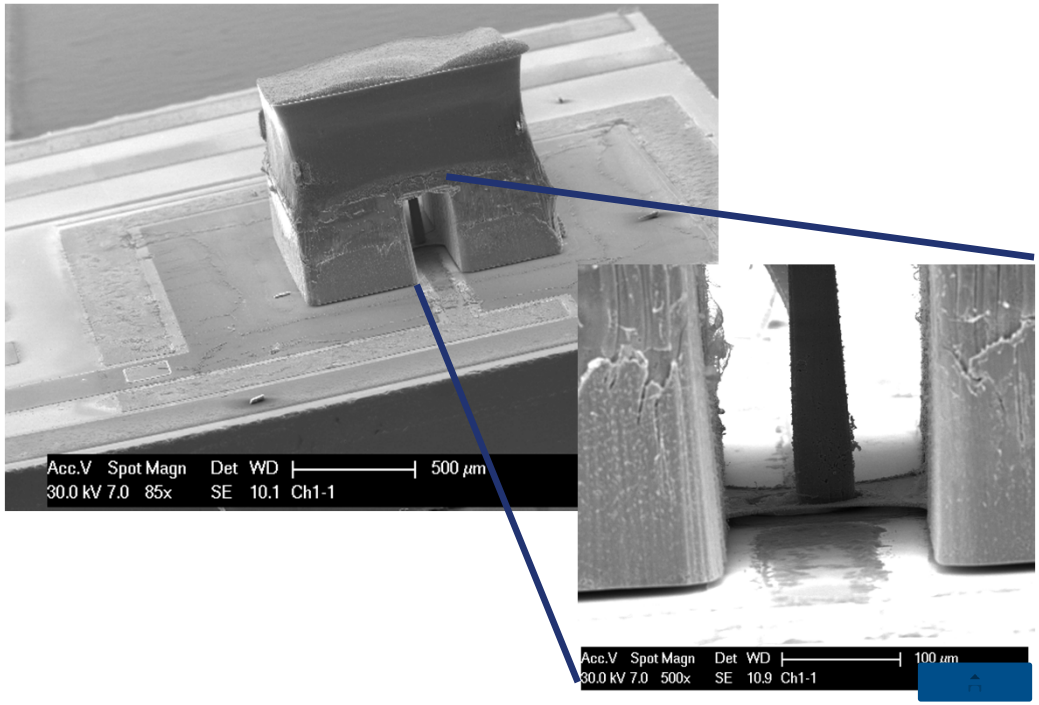
- Inertial sensor
  - 1 device: 2 axes acceleration sensor and 1 axis gear rate sensor
  - Acceleration: seesaw
  - Gear rate: crosstalk due to Coriolis force



- Scale-bridging: wire diameter (*d*)
  - UV lithography: *d* = 40 µm, AR 10:1
  - XR lithography: *d* = 4 µm, AR 25:1
  - IT lithography: *d* = 400 nm, AR 75:1

- Focus on technology
  - Galvanoform with high Aspect Ratio and multiple layers
  - Electroplating with heterogenous AR



ELEMENT - Electromechanical Sensors Based on One-Dimensional Nanostructures

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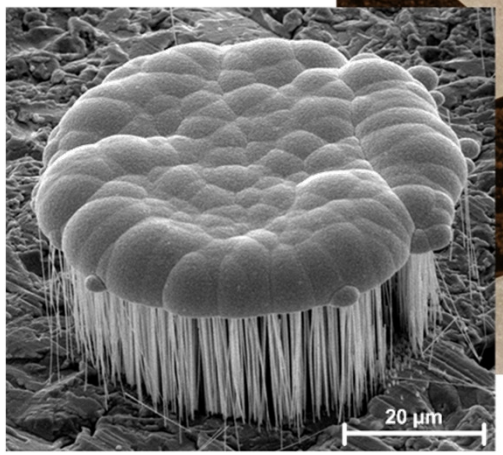
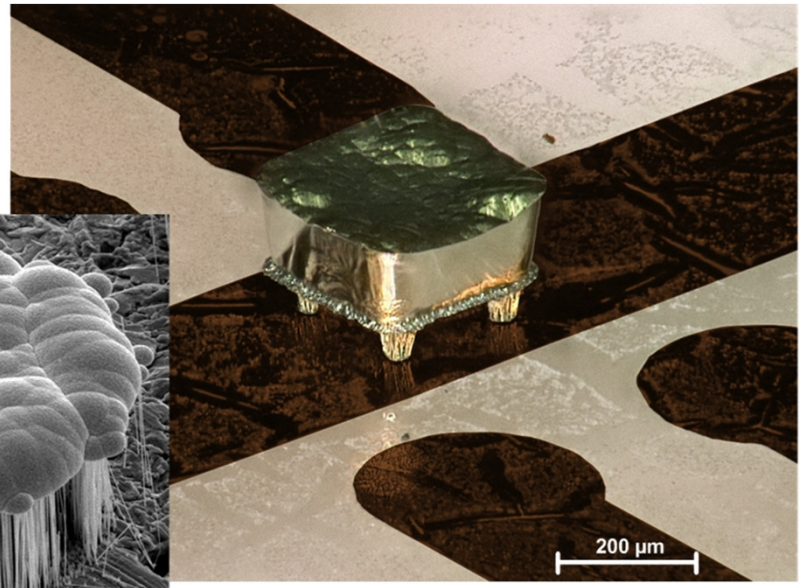
Development of an inertial sensor

- Use of high elastic nanowires with very high aspect ratio (500:1)
- Assembling nanowire-arrays (50 µm diameter) as spring elements
- Nanoscale enables the use of noble metals with excellent physical properties
- Detection of the inertial mass displacement using a magnetoresistive sensor principle



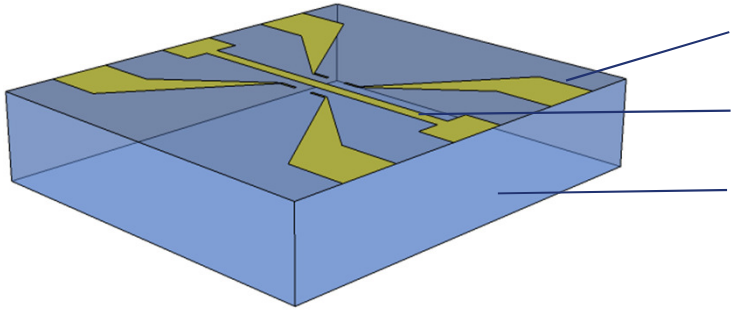
Platinum nanowire array,
wire diameter: 150 nm



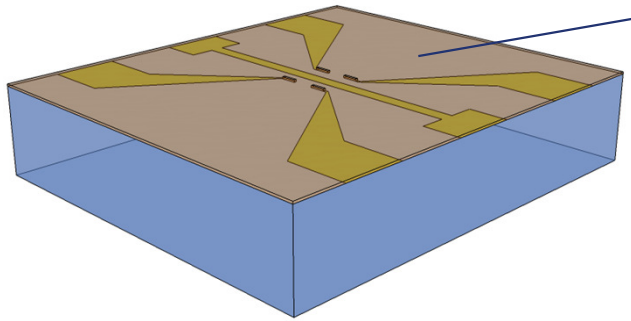
Nickel structure on
vertical wire arrays

Bundesministerium für Bildung und Forschung

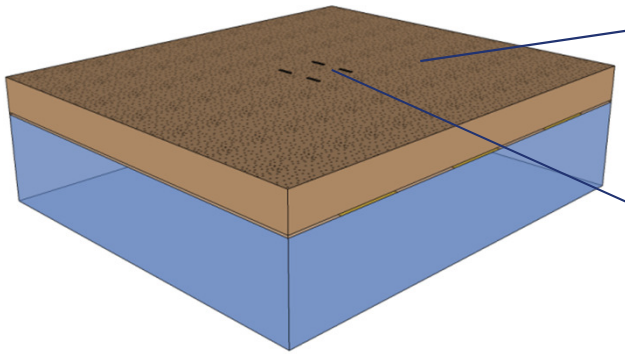
Process for batch nanowire integration in micro systems



- Structuring of heater and circuit paths for the nanowire arrays



- Application of a lamination film
- Structuring of holes for uncovering the seed layer



- Lamination of the ion track etched polymer template
- Electrodeposition into the pores until overgrowth

Process for batch nanowire integration in micro systems

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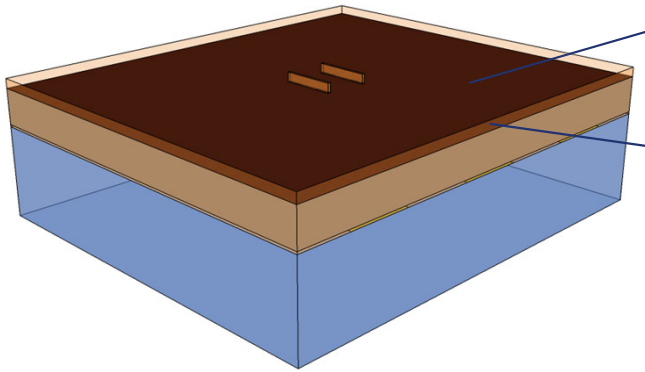
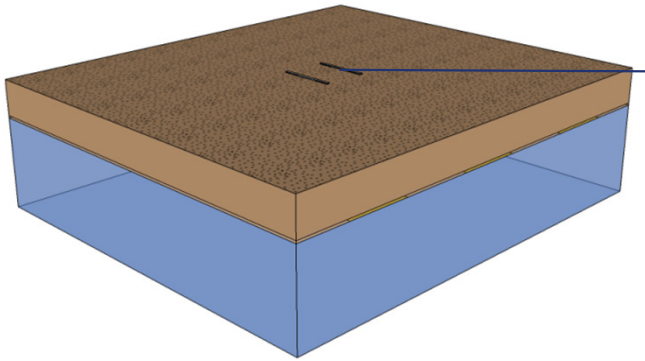
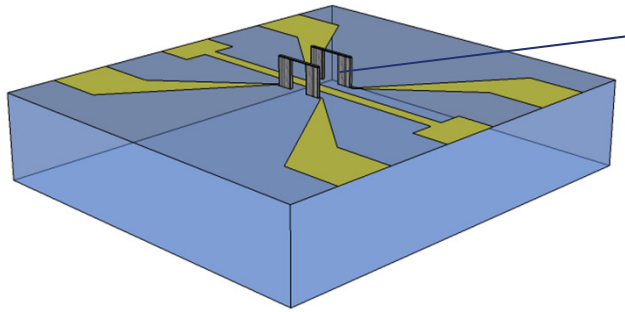


- Application of the Cu seed layer
- Application and structuring of the photoresist that acts as a mold for the bridge
- Electroplating of the bridge



- Stripping of the photoresist
- Etching of the Cu seed layer



- Removal of the polymer template
- Removal of the lamination film

3-DOING – 3-Dimensionale Mikro-Nano-Integration für die Gasflusssensorik

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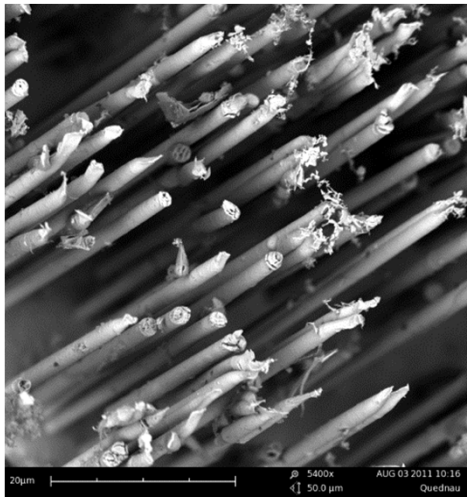
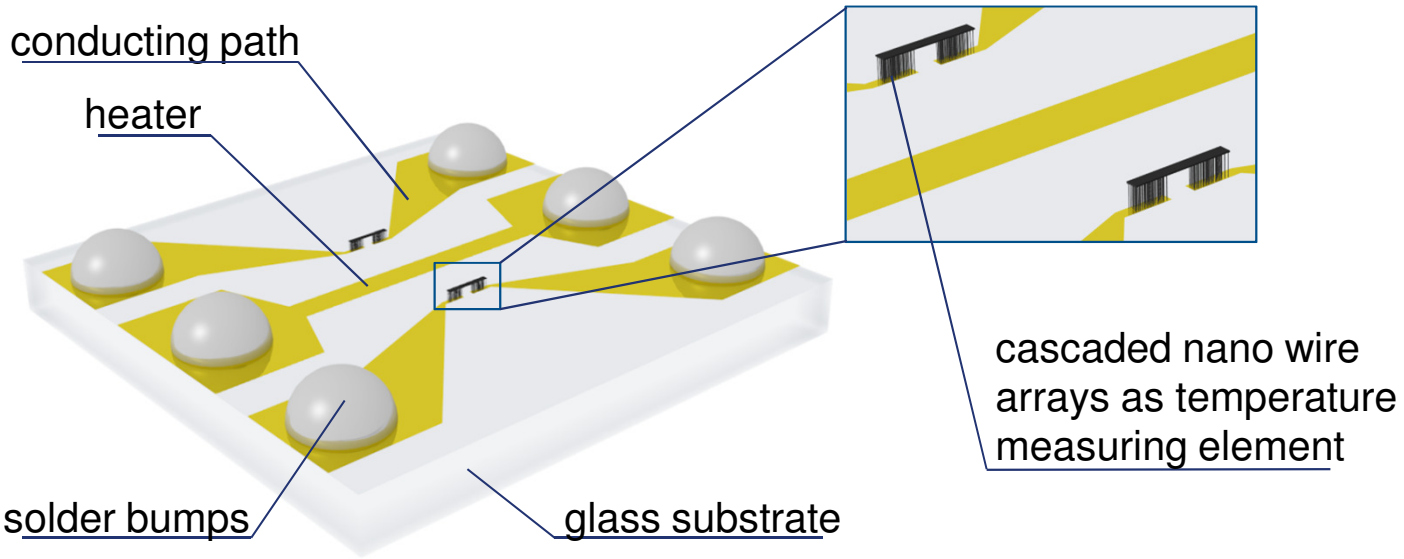
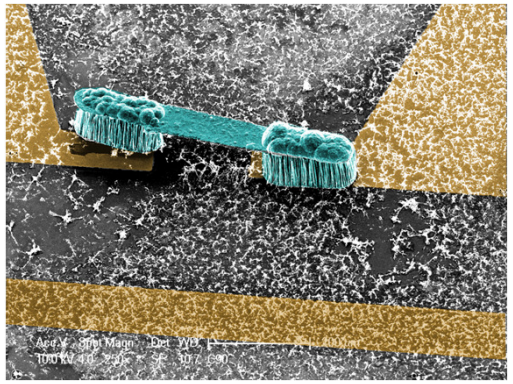
- Funded Project by BMBF, VDI/VDE-IT
- Duration: 01/2011 – 12/2013
- Development of a gas flow sensor which uses metallic nano wires as sensitive elements
- Improvement of the measurement perfomance, especially for photoacoustic devices



Integration of metallic nano wires in micro systems





cascaded nano wire arrays

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Questions?

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