SMT 2015: MID-Forum

Jetting of functional structures on injection molded 3D-devices

Jetten von Funktionsstrukturen auf spritzgegossenen 3D-Baugruppen

Bernhard Polzinger, Nürnberg, 07.05.2015

Hahn-Schickard
Stuttgart, Germany

Contents

Hahn-Schickard-Gesellschaft für angewandte Forschung e.V.

Angewandte Forschung, Entwicklung + Fertigung für die Industrie

- Haushalt 2014: 18,5 Mio. € (5,1 Mio. € Industrie)
- Mitarbeiter 2014: 152 FTE (172 Personen)
- Teil der Innovationsallianz Baden-Württemberg

DIN EN ISO 9001:2008

Institut für Mikroaufbautechnik
Stuttgart

Institut für Mikro- und Informationstechnik
Villingen-Schwenningen

Institut für Mikroanalysesysteme (ab 2016)
Freiburg

Hahn-Schickard Stuttgart und IFM

Hahn-Schickard Stuttgart

www.hahn-schickard.de

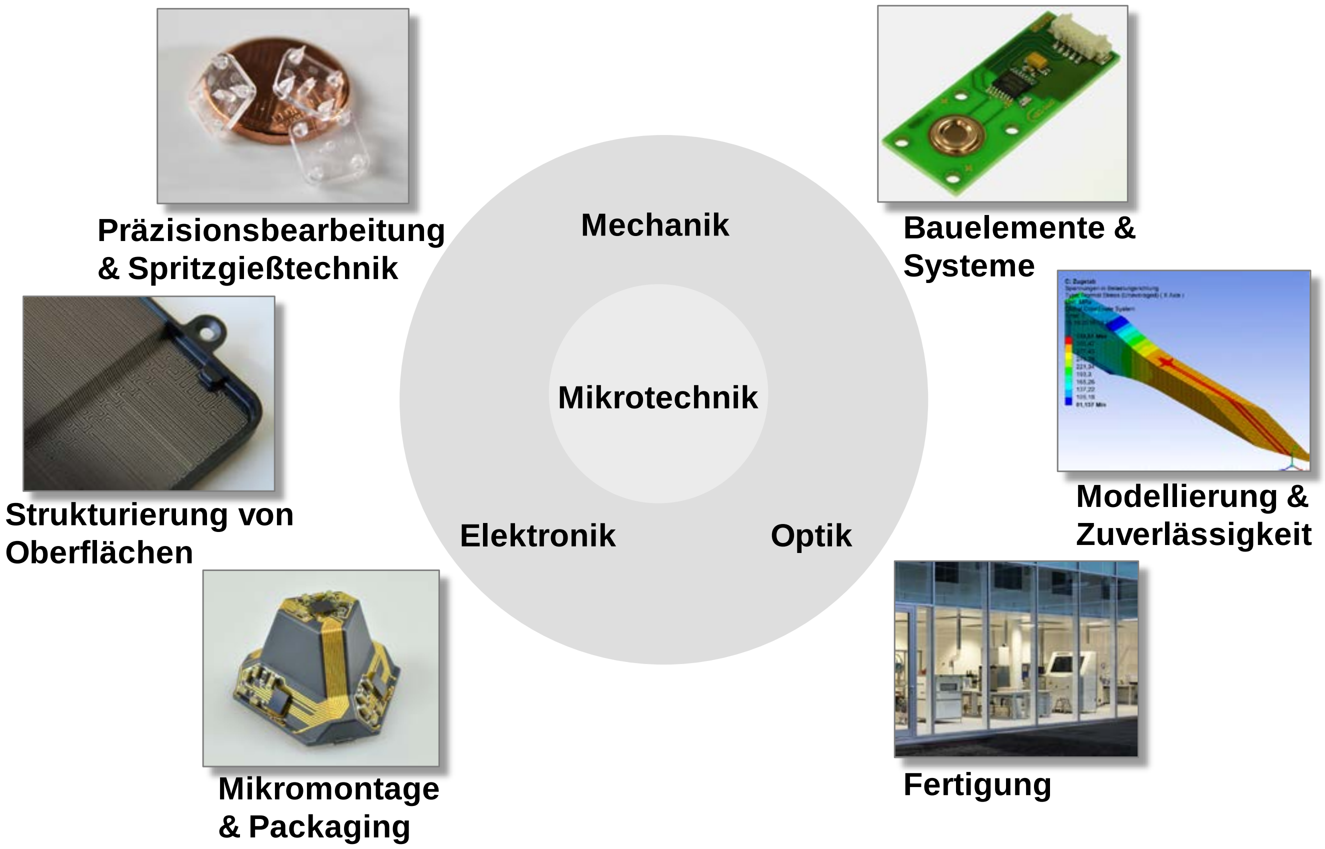
Institut für Mikrointegration der Universität Stuttgart

www.ifm.uni-stuttgart.de

Wir gestalten Innovationen von der Forschung bis zum Transfer in die Industrie

Portfolio

- Mikrotechnik – ein interdisziplinäres Forschungsgebiet
- Branchenübergreifende Schlüsseltechnologie
- Wichtiger Enabler für innovative Produkte



Mikrotechnik – interdisziplinär, branchenübergreifend, innovativ.

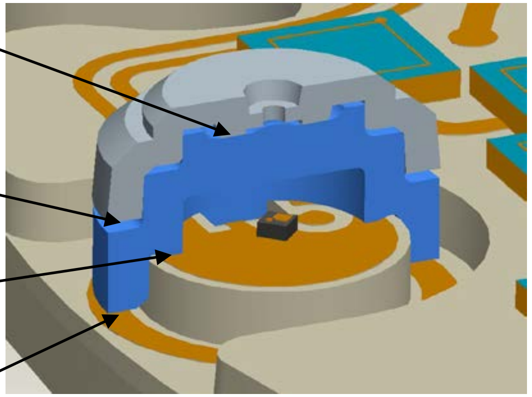
Molded Interconnect Device (MID)

Advantages of MID

- Integration of circuitry in 3 dimensions
- Integration of different functions in one device (mechanical, electrical, …)
- Miniaturization
- Short development cycles
- Less components, manufacturing and assembly costs

Ref.: Hahn-Schickard

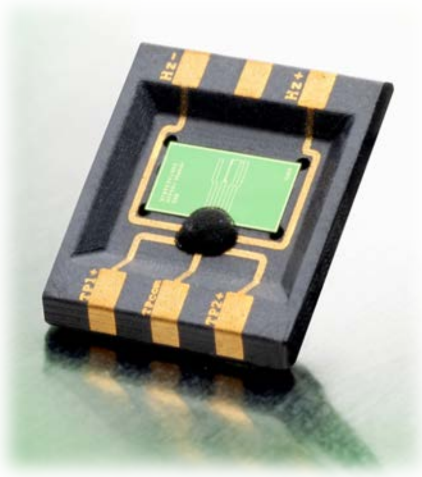
High Precision Optical MID-readout module



Schematic of set up for minimum mechanical tolerances (~10-20 µm)

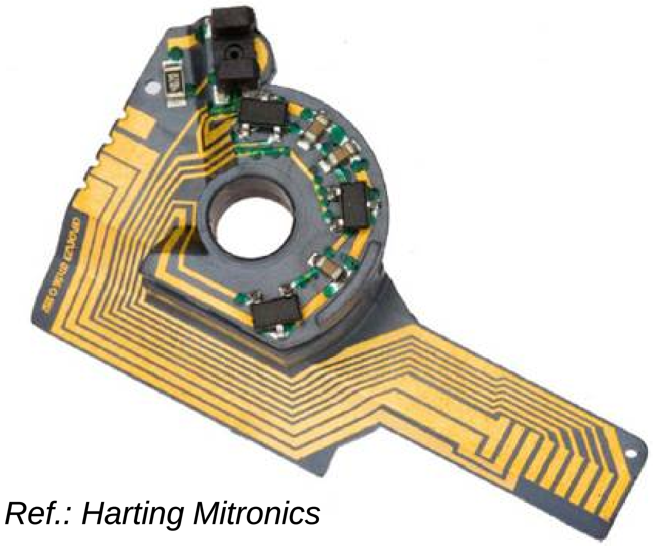
State of the art in MID

Thermal Flow Sensor



Ref.: 2E mechatronic

Distance Radar Module



Ref.: Harting Mitronics

Pressure Sensor for ABS and ESP

Ref.: Bosch

Basic features:

- Special thermoplastics
- Laser machining/ 2 shot molding
- Electroless plating

Inkjet and Aerosol Jet® process

Advantages of printing technologies on polymeric substrates

- Fully additive process
- No etching, no electroless plating, no mask
- Resource and environmentally friendly
- High productivity due to short process chains
- Very flexible to layout changes and redesign
- Many printable materials are available
- Large variety of substrate materials
- Non-contact process
- Printing on 3D devices

Printed microstructures

Additional features for microstructures on polymer devices

Materials

- Conductive (polymer/metal)
- Semiconductive
- Resistive
- Dielectric
- Insulating
- Protective lacquer
- Solder resist lacquer
- Carbon nanotube based

Functions

- Electrical components
  - ➢ Interconnects
  - ➢ Multilayer circuitry
  - ➢ Resistors and capacitors
  - ➢ Transistors
- Sensor elements
  - ➢ Temperature and humidity sensors
  - ➢ Strain sensors
  - ➢ Gas sensors
  - ➢ ....

Challenges of Inkjet printing

Hahn Schickard

Printable materials

- Solvent based suspension
- Viscosity (1-30 mPas)
- Particle size (<500 nm)
- Surface tension (25-45 dynes/cm)
- Availability

Compatibility to the substrate

- Wetting behaviour
- Adhesion
- Pre processes
- Post processes and curing

Reliability

- Temperature und humidity
- Mechanical stress
- Ampacity
- Drift of resistance

Inkjet technology

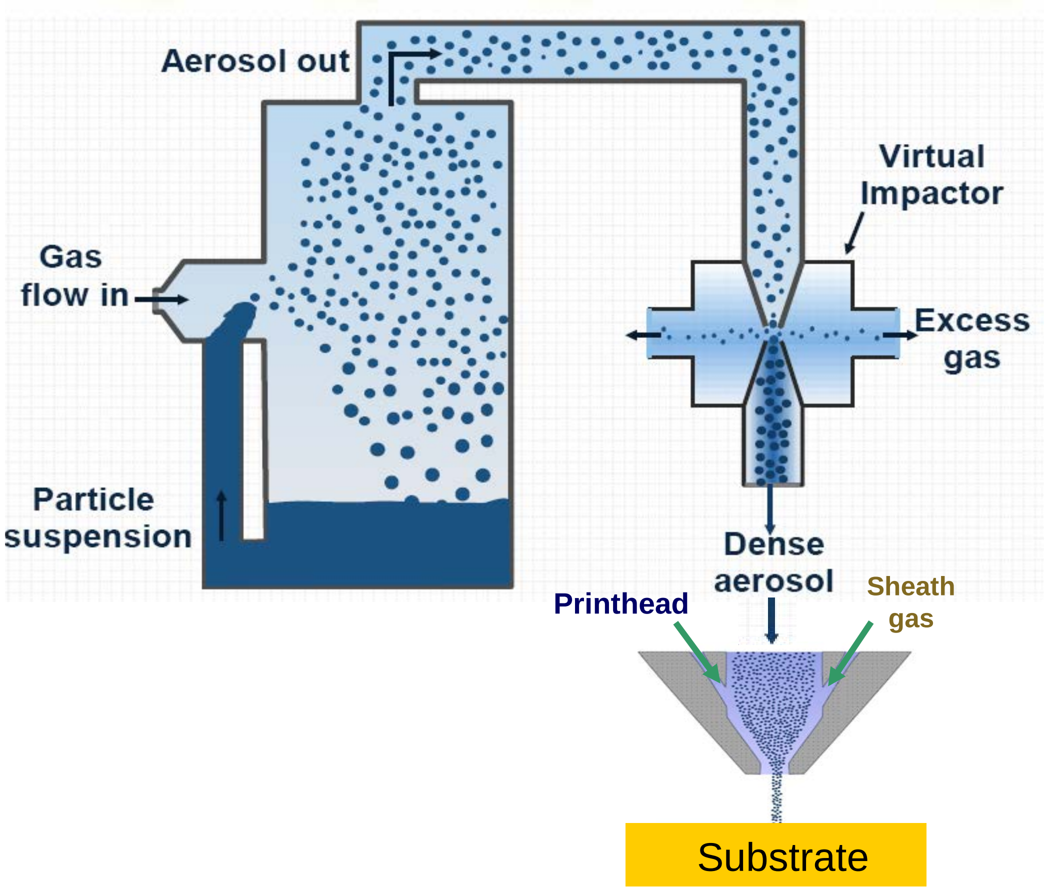
- Maskless and non-contact printing technology
- Drop-on-Demand (DoD)
- Dimatix DMP2831
  - ➢ 16 nozzles á 10pl drop size
  - ➢ Fiducial alignment
- Dod300: Printhead Spectra SE-128AA
  - ➢ 128 nozzles á 30 pl drop size
  - ➢ Max. printing temperature 95°C
  - ➢ Edge- and fiducial alignment
- Layout requirements: Black and white image file
  ➔ enables quick layout changes

Dimatix DMP2831

Schmid DoD300

Aerosol Jet® technology

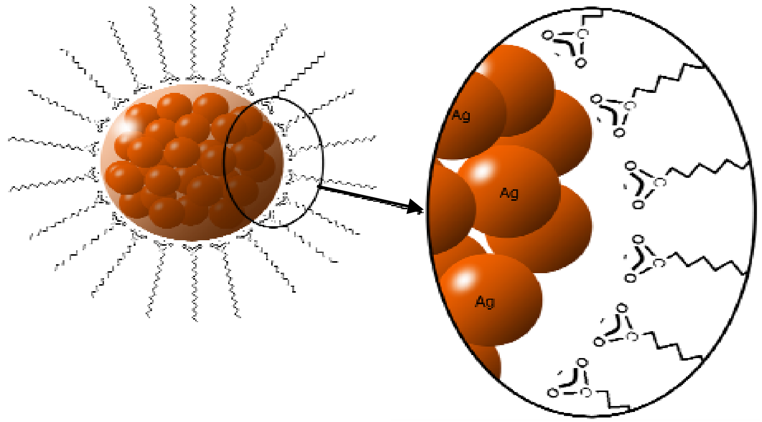
- Maskless and non-contact printing technology
- Aerodynamically focussed aerosol flow, depth of sharpness approx. 5 mm
- Fiducial alignment
- Layout requirements: dxf-format,
  ➔ enables quick layout changes



Printable conductive materials and suitable substrate materials

Conductive inks

- Metal nanoparticle
  - Ag
  - Au, Pt, Pd (expensive)
  - Cu (increasing importance, avoid of oxidation during curing)
- Organic
  - E.g. PEDOT:PSS



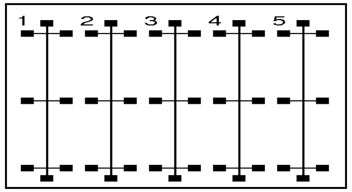
Silver nanoparticel with carboxylic acid as capping agent

Ref.: J. Perelaer, Microstructures Prepared via Inkjet Printing and Embossing Techniques, 2009

Substrate materials

- Thermoplastic (high temperature resistance, e.g. LCP, PA6/6T)
- Foils (e.g. polyimide)
- Ceramic
- Thermoset
- Glass

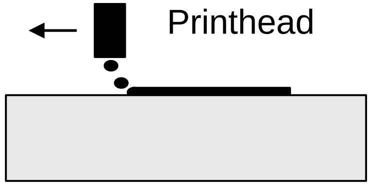
Process flow



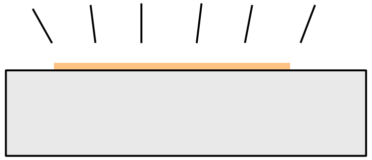
Layout design

Substrate

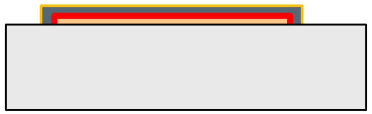
Optional: pretreatment
(e.g. oxygen plasma)



Printing process



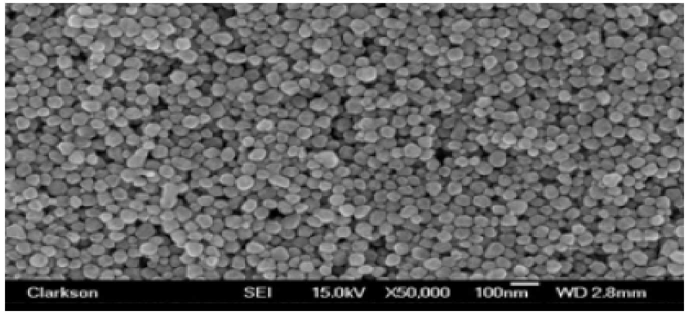
Curing (e.g. thermal, photonic)



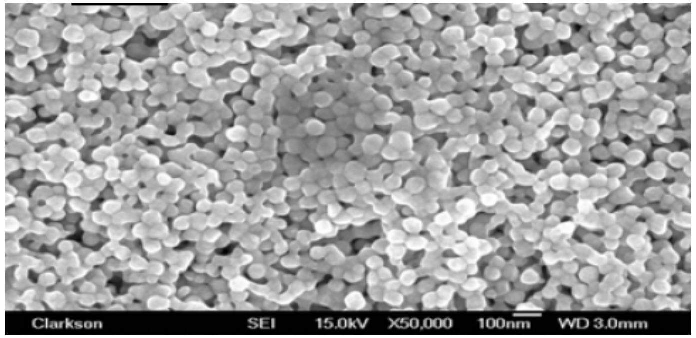
Posttreatment

Optional: protective coating

Optional: electroless or galvanic plating e.g. Cu/NiP/Au



Silver ink before curing



Silver ink after curing
(90 min/175°C)

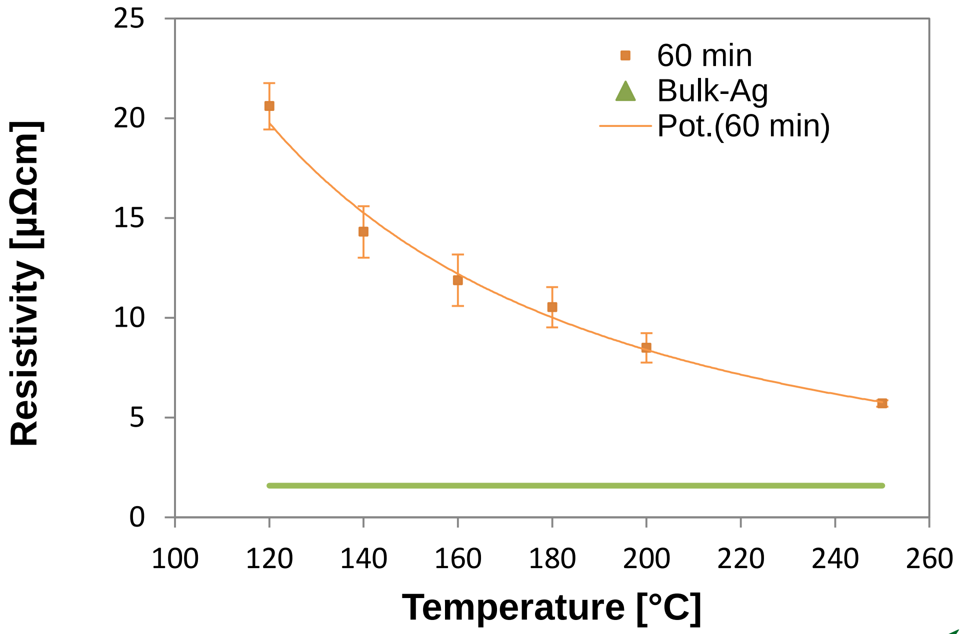
Ref.: K. Balantrapu et al, Inkjet Printing of Silver Nanoparticles for Electronic Applications

Properties of printed silver tracks

	Inkjet	Aerosol Jet®
Thickness (1 pass)	~1-2 µm	~0,1-0,5 µm
Width of conductive tracks	>40 µm	>10 µm
Pitch of conductive tracks	>80 µm	>30 µm

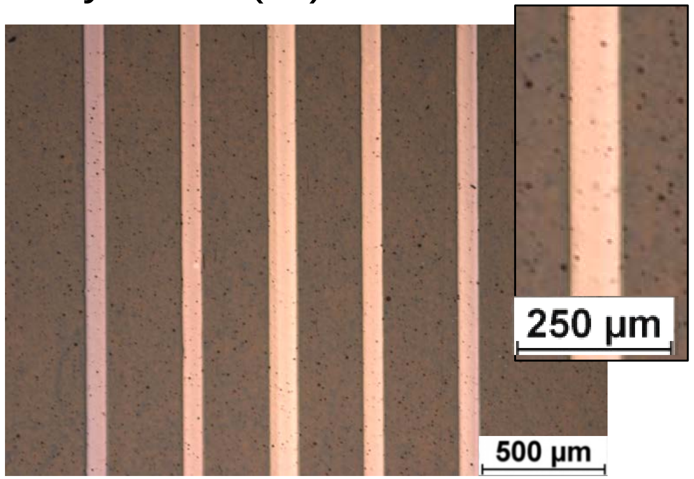
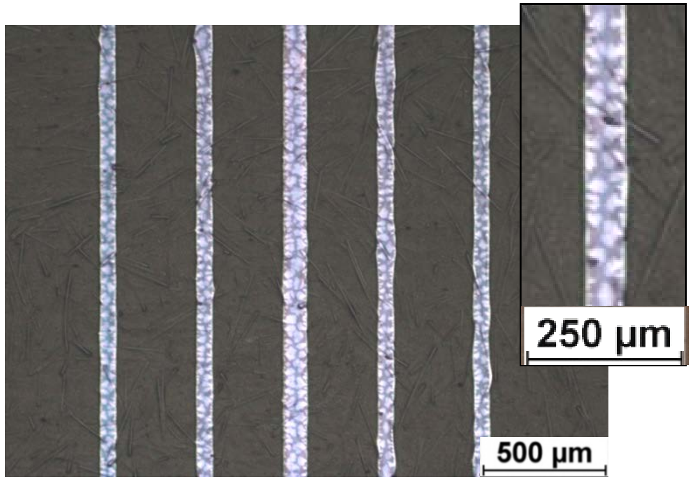
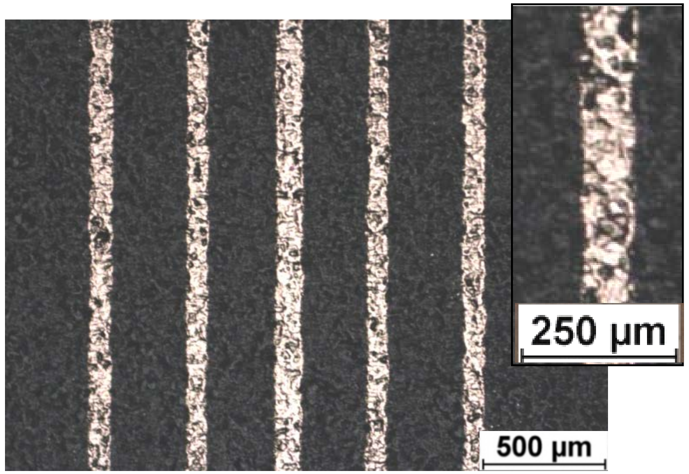
Adhesion: Tape test will be passed on many materials

Resistivity: > 3 times bulk silber



Conductive tracks on polyimide and thermoplastic substrates

Ink: Silver nano ink

	Polyimide (PI)	PET+PBT	LCP E840i LDS
			
Roughness R_z:	0,3 µm	2,1 µm	3,4 µm
Average track width:	85 µm	85 µm	95 µm

Comparable printing results on substrates with different substrate roughness

Conductive tracks on polyimide and thermoplastic substrates

Substrates:

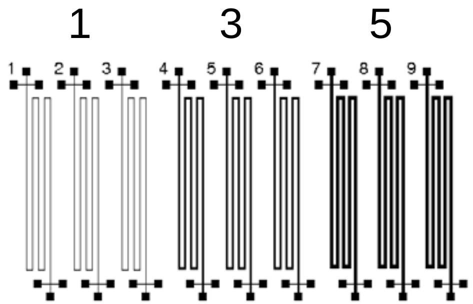
Polyimide (PI)
PET+PBT
LCP E820i
LCP E840i LDS

Sintering:

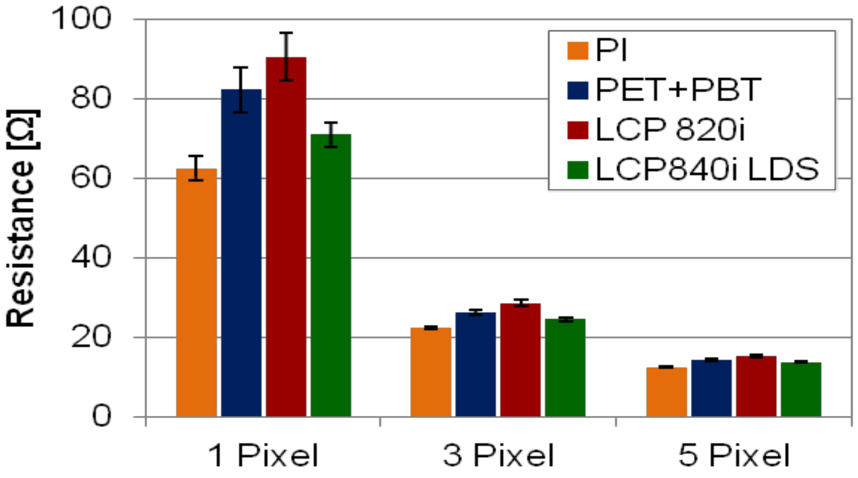
1 h/ 200°C

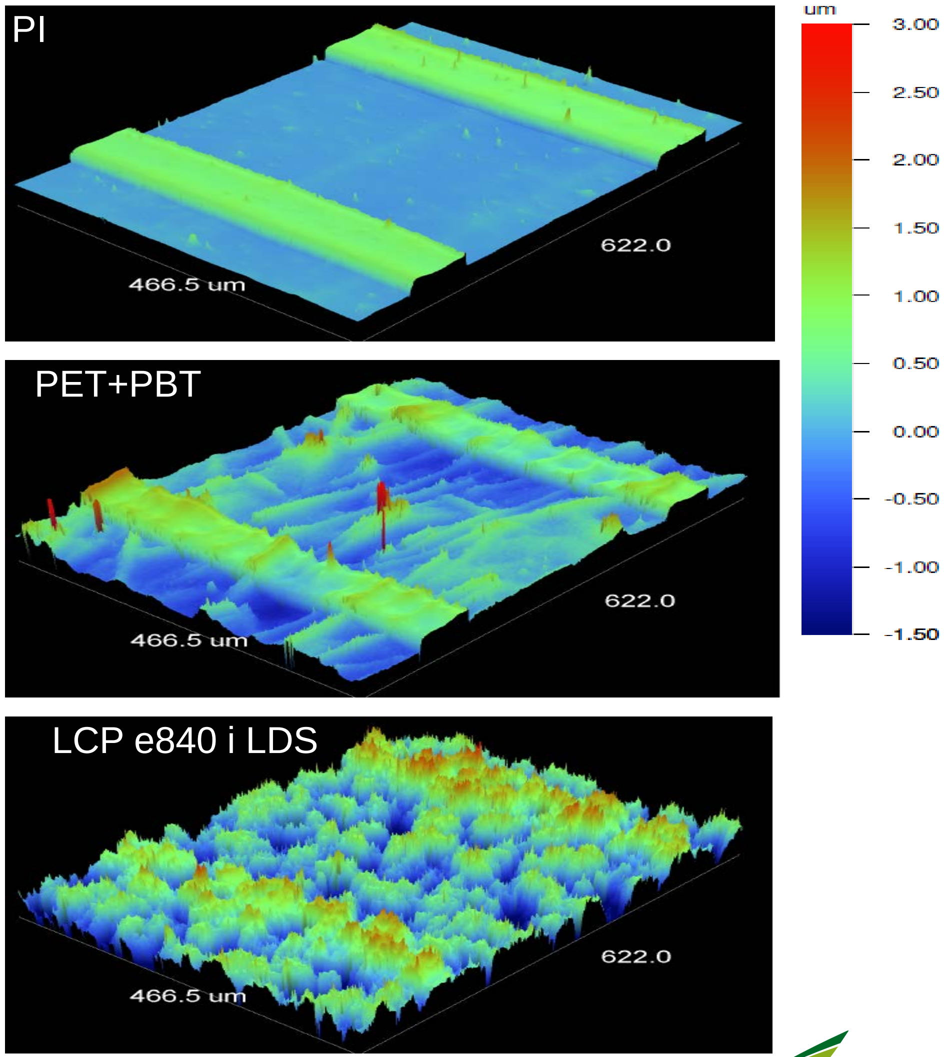
Layout:

Width of the silver track in dots



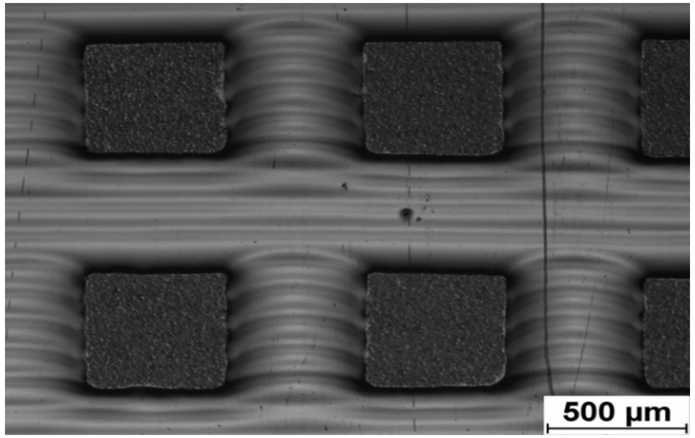
Results:

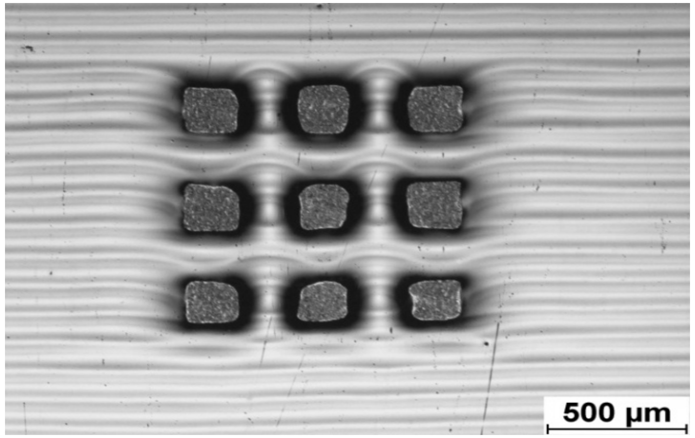


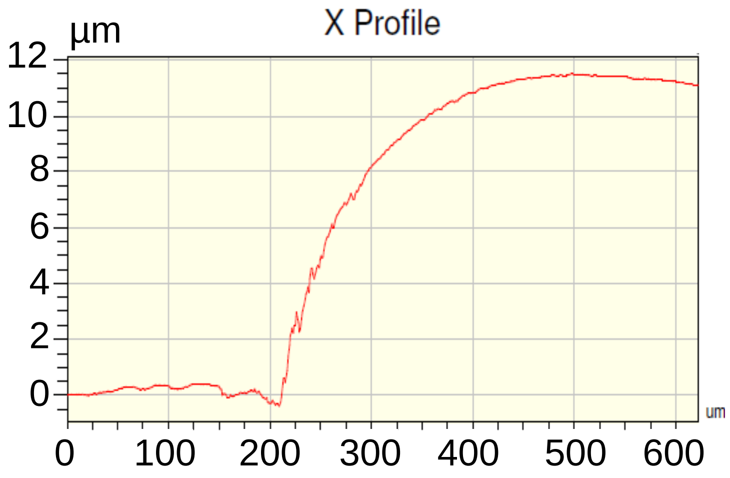


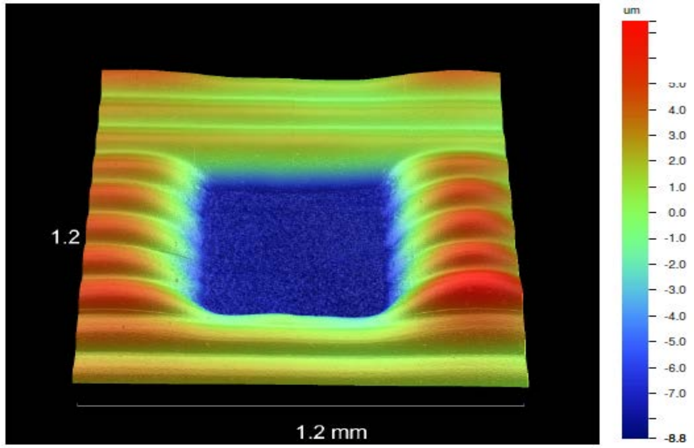
Isolation layers on polymer substrates

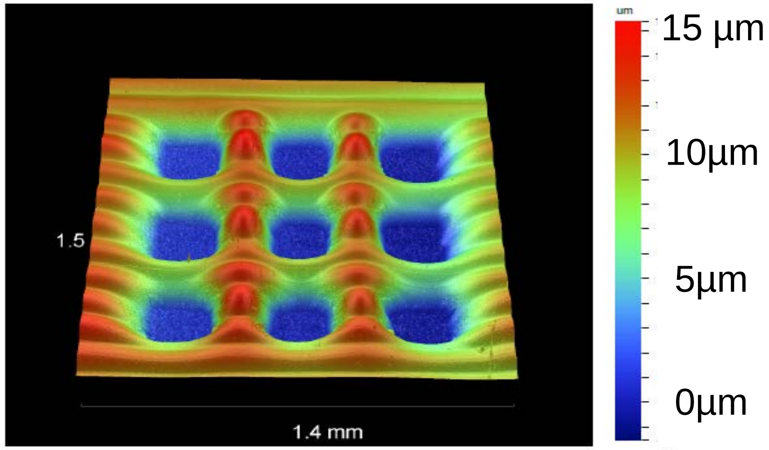
Ink: acrylic-based (UV-curing) **Substrate:** LCP

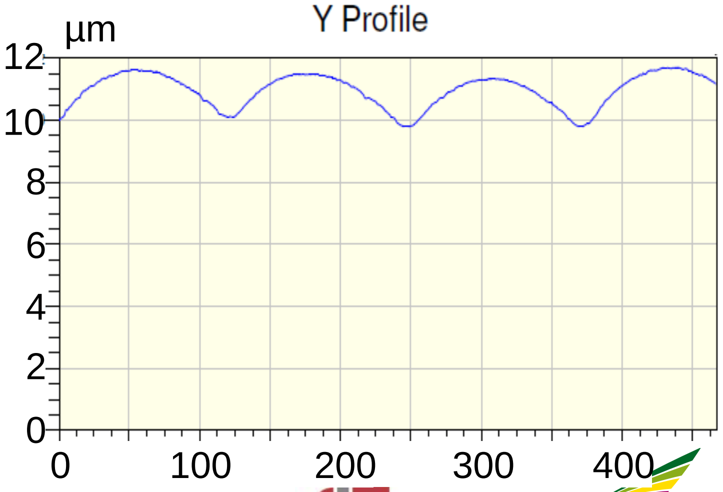










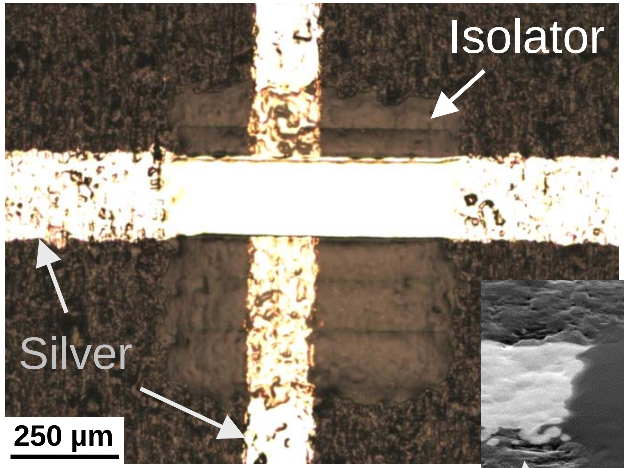


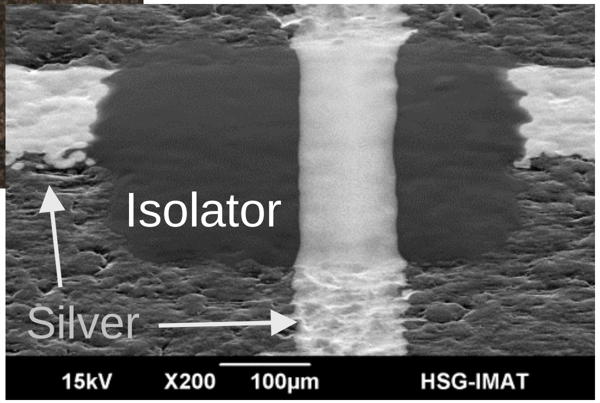
Conductor crossover

Inks

- Conductive tracks: Silver nano ink
  Sintering 1h for 200°C
- Isolator: Acrylic-based ink (UV-curing)

Conductor crossover on LCP

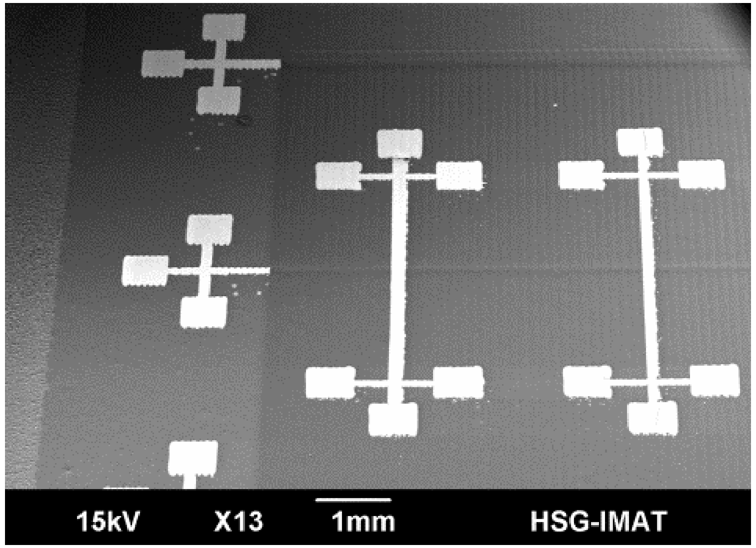




Results

- Isolating resistance: >200 GΩ
- Adhesion: Tape test is passed

2 conductor layers on LCP



Inkjet printed temperature sensors

Layout: Meander structures

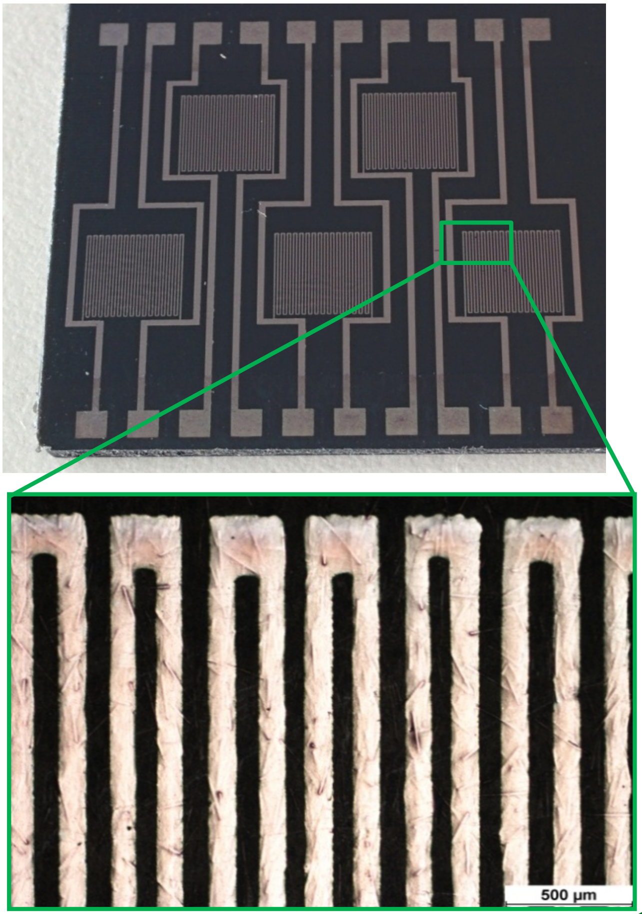
Pitch: 200 µm

Sensitve material: Silver nano ink

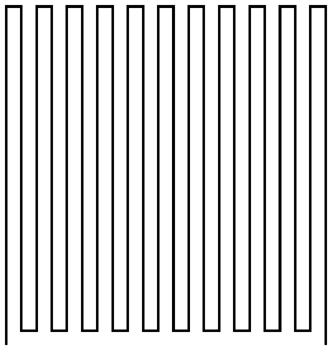
Resistance: ~180 Ω

Characterization: 4 wire resistance measurement in a temperature and humidity controlled climatic chamber

PET+PBT substrate with 5 temperature sensor structures



Layout of investigated sensor structures

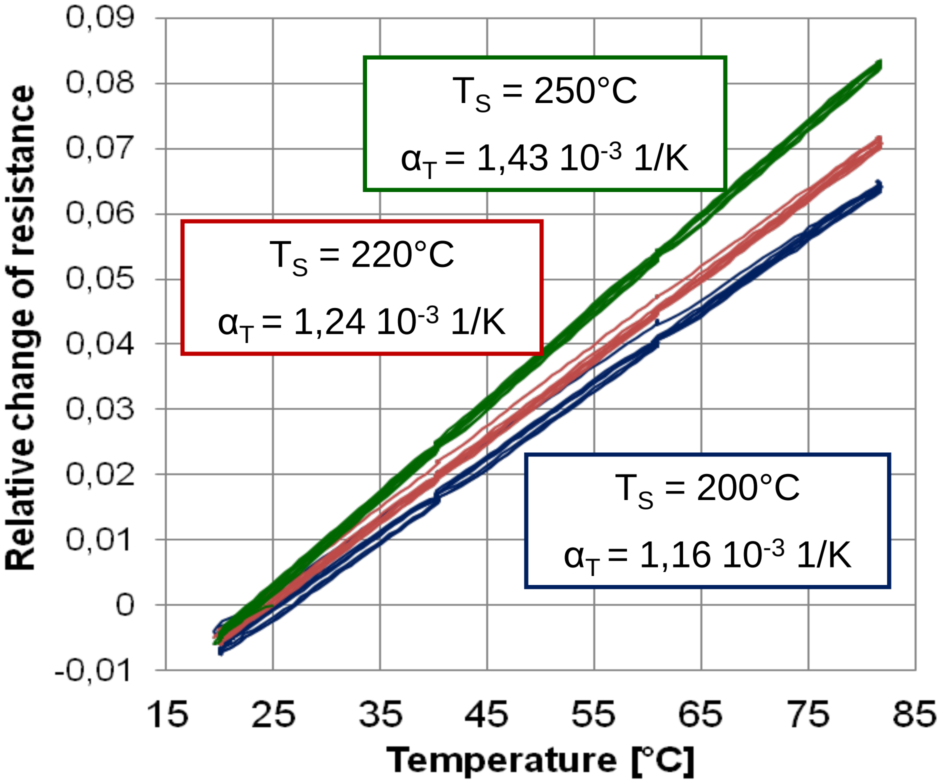


Ref.: BMBF funded project Pronto-Drusym

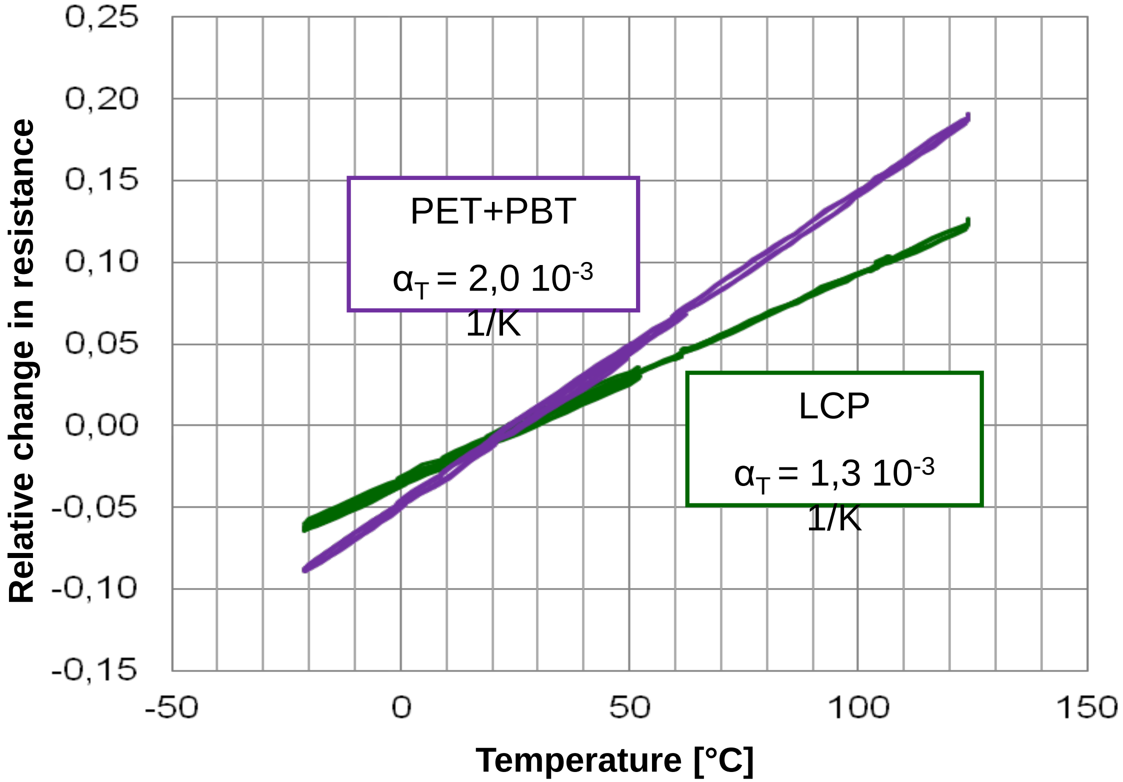
Characteristic of inkjet printed temperature sensors

Hahn Schickard

Variation in sintering temperature



Variation in substrate material



Temperature coefficient of printed silver structures is dependent of sintering temperature and substrate material

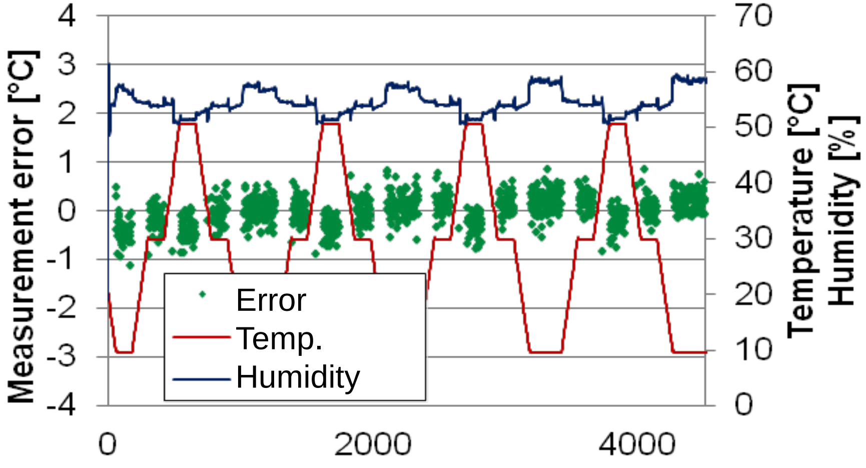
PRONTO Drusym

Ref.: BMBF funded project Pronto-Drusym

AiF Mitglied innBW INNOVATIONSALLIANZ BADEN-WÜRTTEMBERG

Printed temperature sensors on polyimide foil

Measurement error

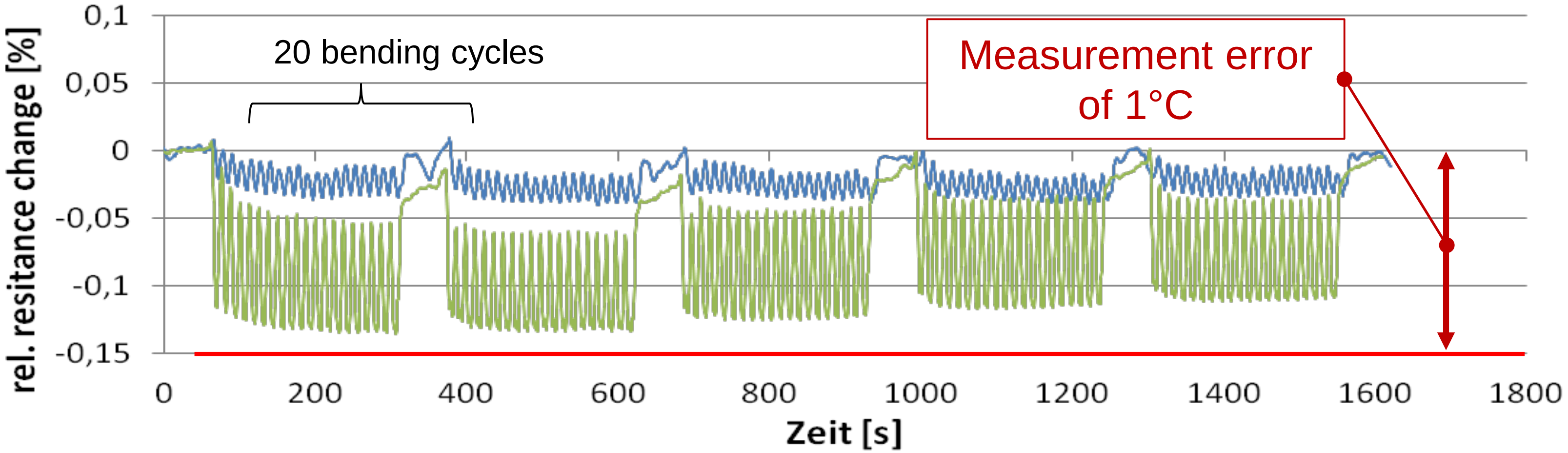


Curing: 1h/250°C

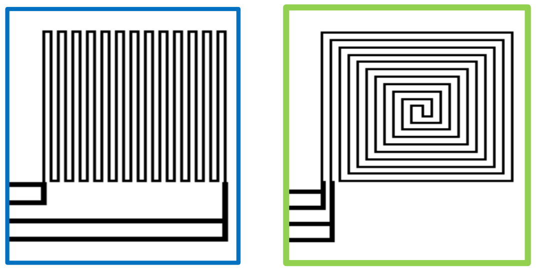
$R_{(10°C)}$ = 102 Ω

α_T=1,5x10^{-3} 1/K

Bending characteristics (radius 15 mm)



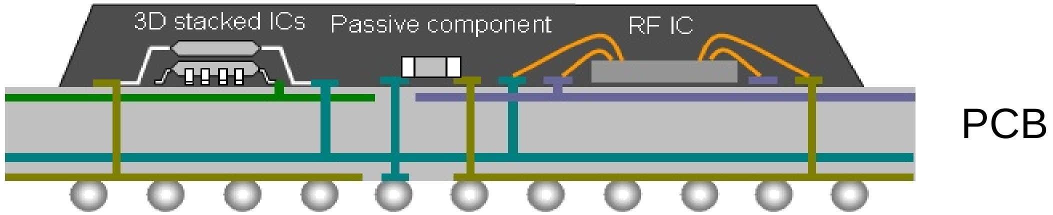
Sensor layout



Ref.: ZIM project Intelligente Einlegesohlen für Diabetiker

Inkjet printing on a transfer molded packages

“System in Package” (SiP): State of the art



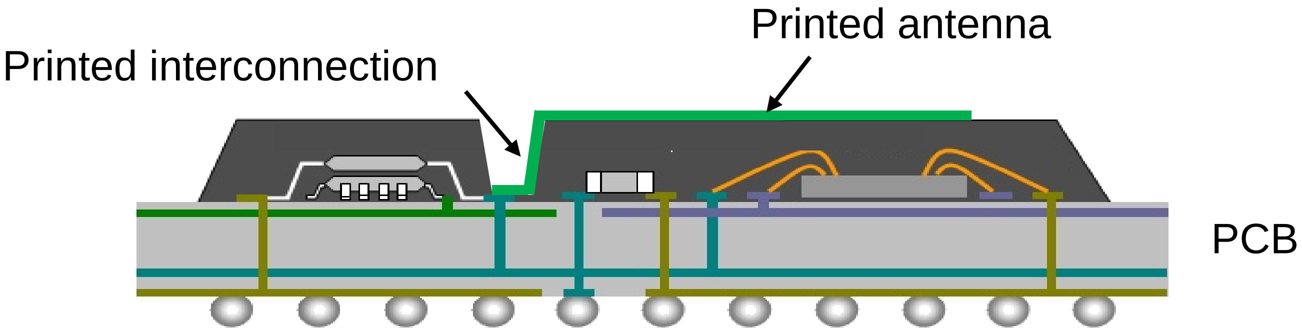
Ref.: Amkor Technology

Motivation

Increase integration level of devices e.g. with printed antennas

Main Challenge

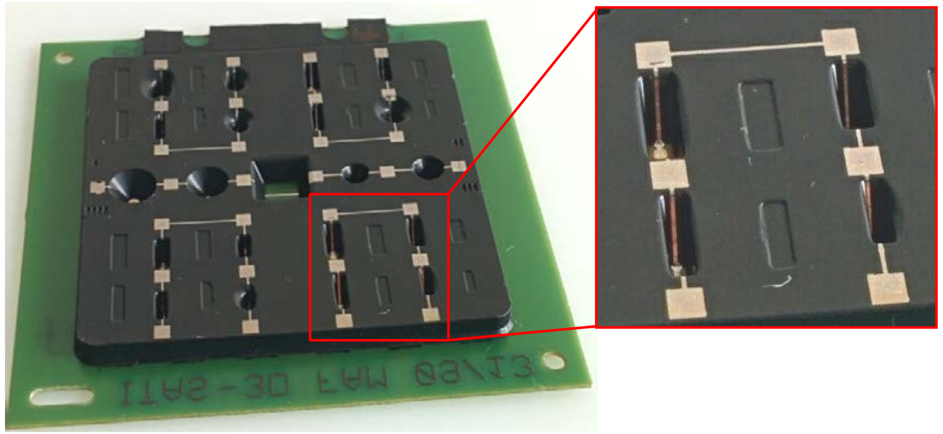
To interconnect devices and antennas with PCB

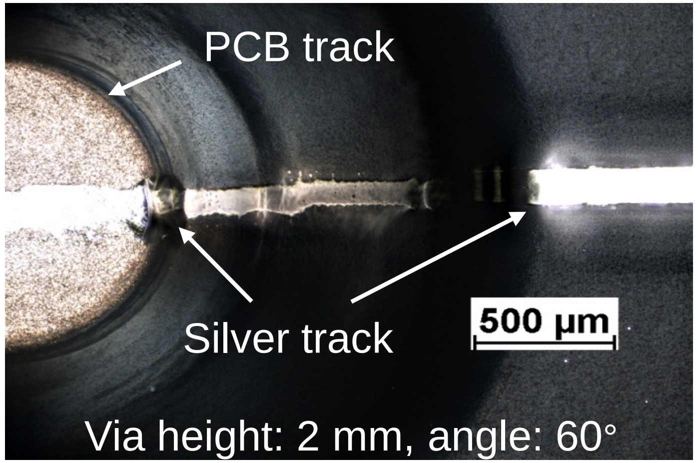


Interconnecting antenna to PCB

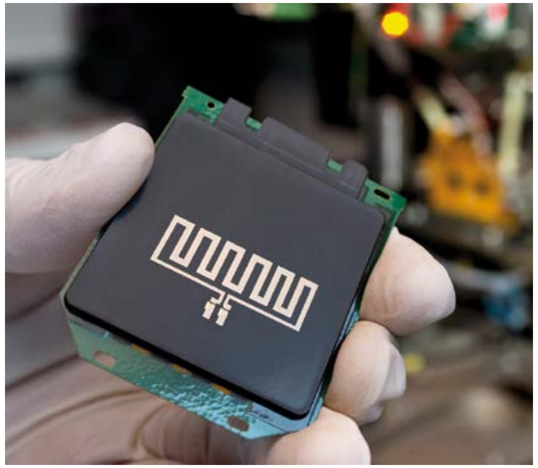
Printing results

Inkjet printed silver tracks over vias on a transfer molded package





Inkjet printed antenna on a transfer molded package



Interconnection from PCB to package surface using inkjet printed silver tracks

Ref.: BMBF funded project SSI-ITAS

LDS MID based Intrusion sensor

Application

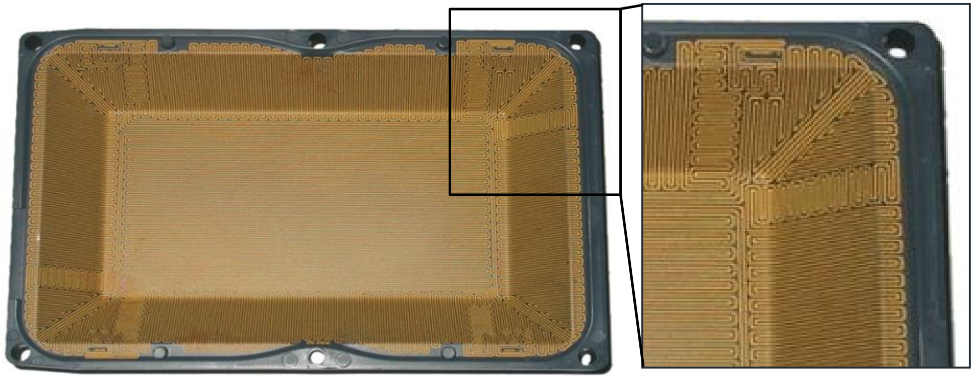
Manipulation and data theft protection of sensitive electric circuits e.g. PIN input devices, bank or ID card readers, access controls

Function

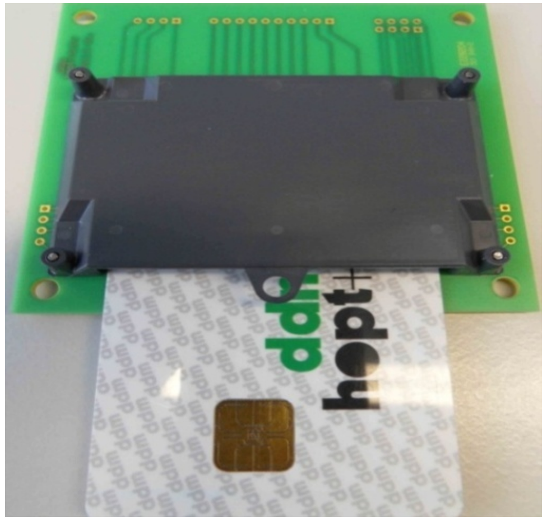
- Three-dimensional polymer cover with closed meshed conductor loop
- Intrusion attack breaks conductor loop
- Reader shuts down

State of the art

- LDS-MID with conductor pitch 300 µm



3D LDS MID intrusion sensor



Intrusion sensor on the reader

Inkjet printing on 3D substrates

Major challenge

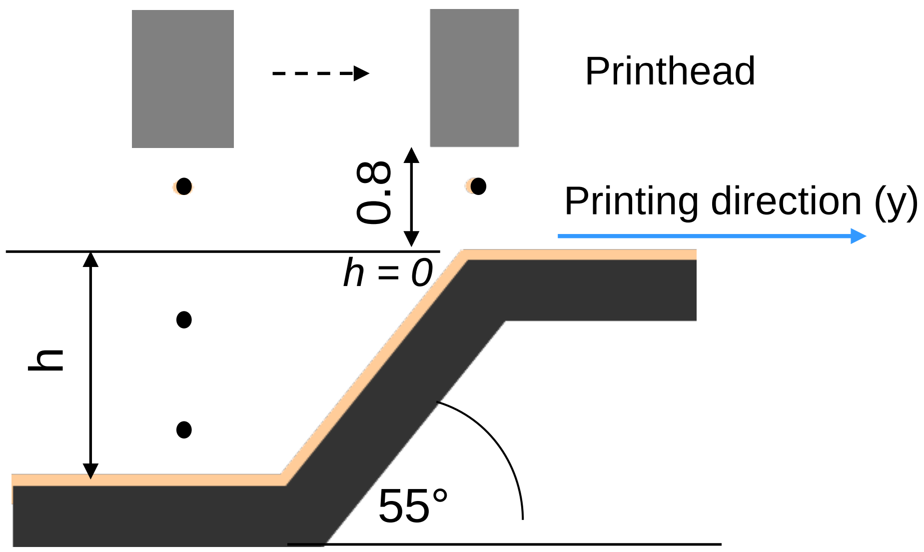
- Good printing quality at higher printing distance

Investigated substrate material for intrusion sensor

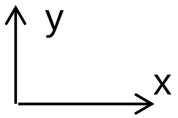
- PBT Pocan DP 7102, melting temp.: 225°C, no pretreatment
- Substrate uniformly heated during printing T_{sub} = 100°C

Investigated 3D shape

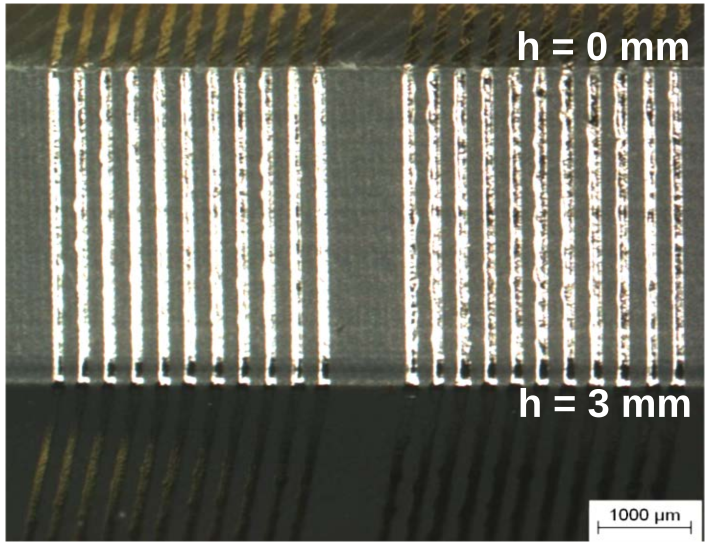
- Height (h): 2.5, 3, 3.8 mm
- Angle: 55°
- Smallest distance to substrate: 0.8 mm



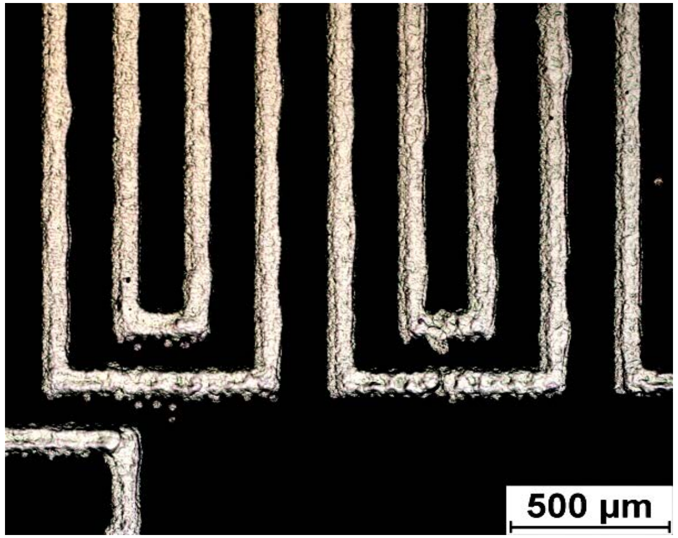
Printing of 100 µm lines on 3D substrate



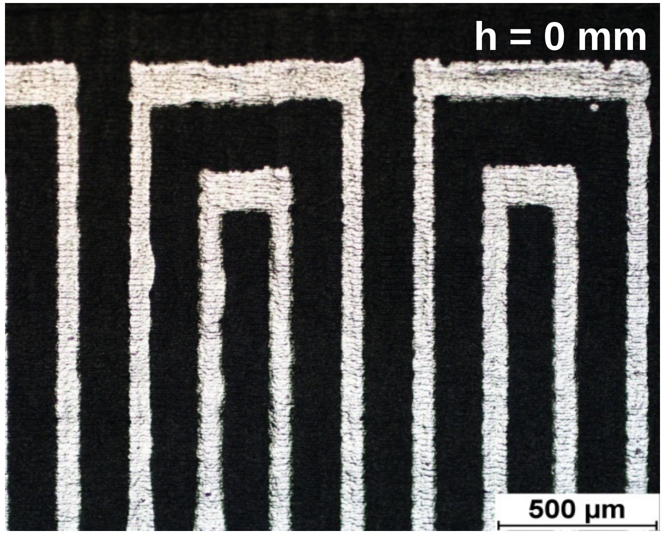
Height of substrate: 3 mm



Height of substrate: 3.8 mm



Bottom of substrate



Inclined surface h = 3.8 mm

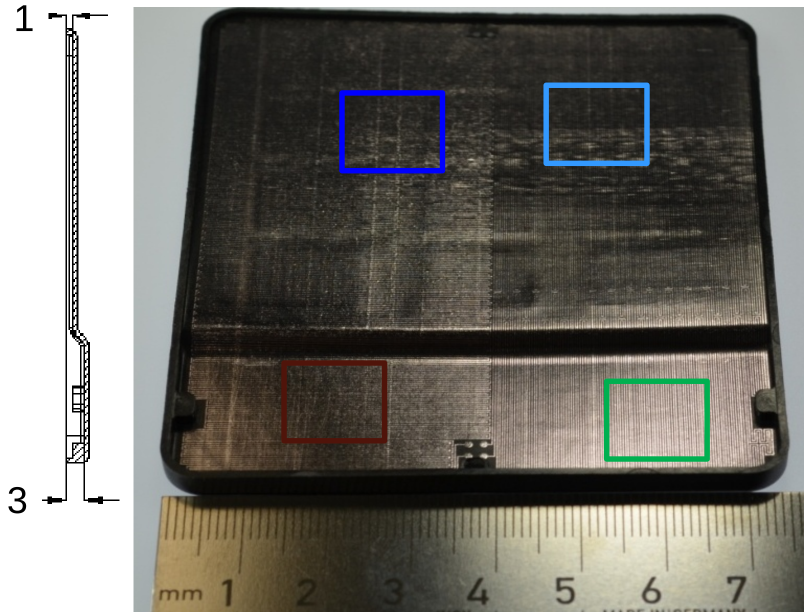
- Tracks on the inclined surfaces and on the bottom of the substrate are comparable and have a homogeneous width distribution
- Tape tests successfully passed
- No cracks on the tracks

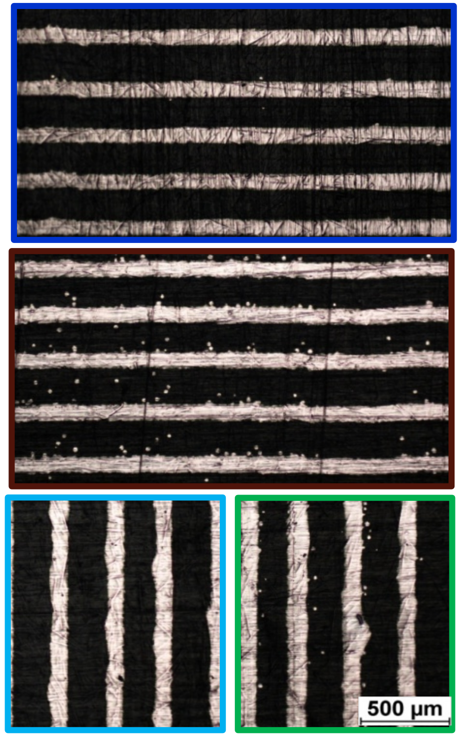
Ref.: BMBF funded project SADINA

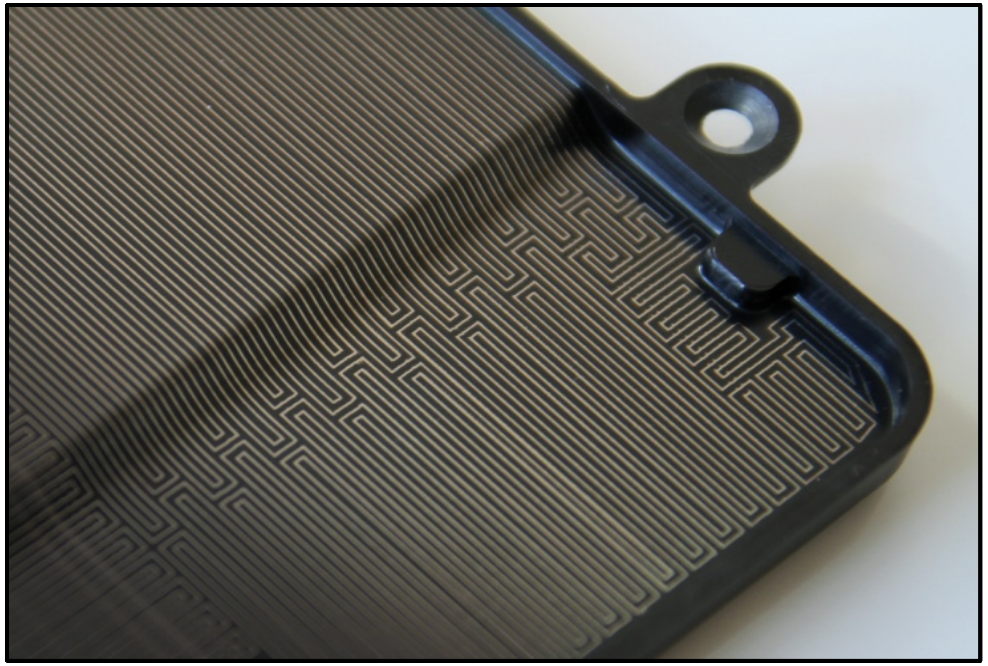
Inkjet printed intrusion sensor

Features

- 4 meanders, length 3.5 m each
- Pitch: 400µm
- Printing distance up to 3.8 mm
- Resistance: 3 kΩ/meander





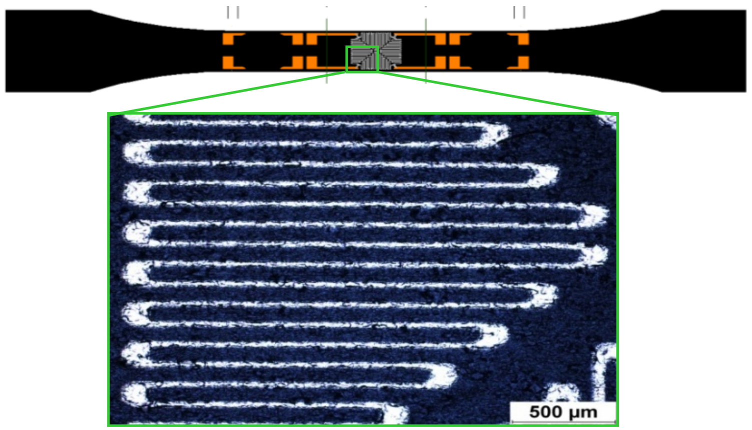


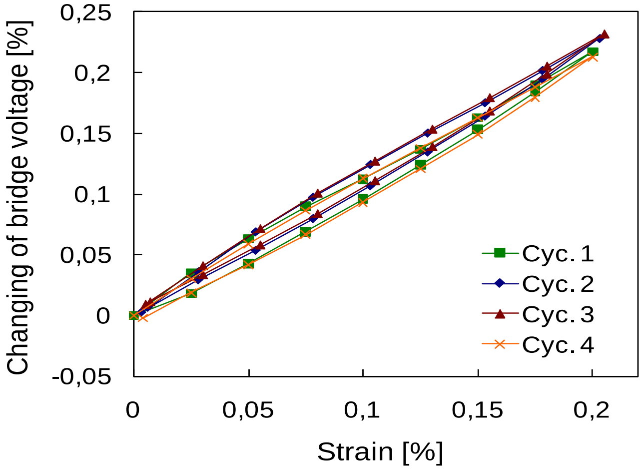
Ref.: BMBF funded project SADINA

Printed sensors on LDS MID

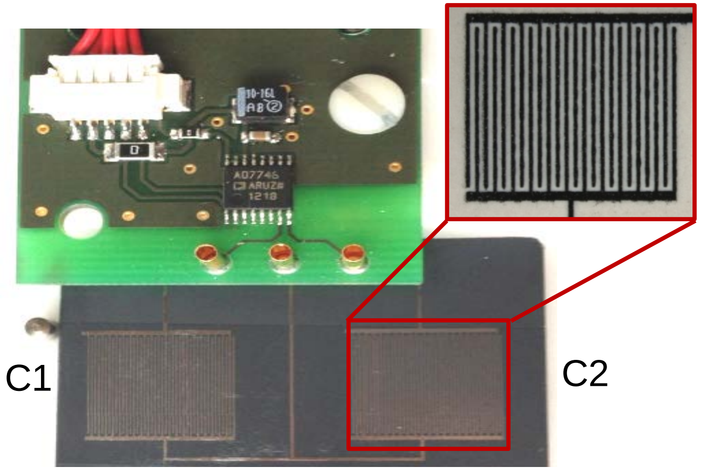
Hahn Schickard

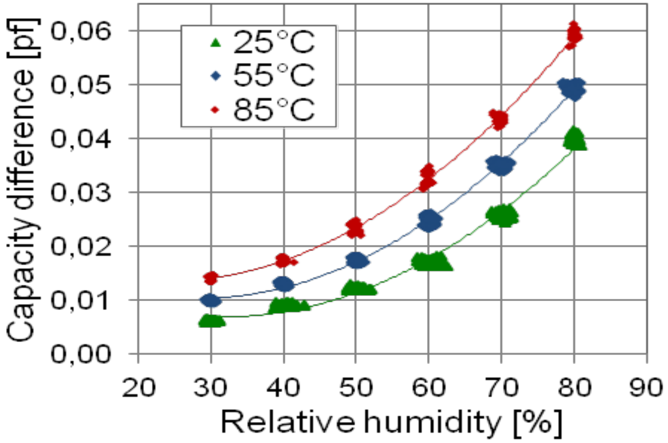
Aerosol Jet® printed strain gauge (Wheatstone bridge)





Inkjet printed humidity sensor





Ref.: IGF funded project Dünnschichtwiderstände mit Mikrodrucktechnik

Summary and conclusion

Inkjet printing is feasible for

- Foils
- Injection molded 3D substrates
- Transfer molded 3D substrates

Inkjet printing allows for system integration

- Circuitry
- Sensors
- Antennas
- …..

Big potential for new innovative applications

Hahn Schickard

Thank you for your attention!

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