Welcome to the
MID SUMMIT & MID WORKSHOP 2022
a joint event of:

3-D MID

Hahn Schickard

Wednesday, 21st September 2022

9:30 Opening: Prof. A. Zimmermann, Hahn-Schickard & Prof. J. Franke, 3-D MID e.V.

Welcome by Ministerial Council Claus Mayer, Ministerium für Wirtschaft, Arbeit und Tourismus Baden-Württemberg

10:00 MID Applications

- New Applications
  Thomas Hess, HARTING AG
- Si-Wafer Replacement and MID LDS Transformer
  Dr. Sebastian Bengsch, Ensinger
- Metalized-plastic Technology Enabling 3D Millimeter-wave Components
  Prof. Jan Hesselbarth, Uni Stuttgart – IHF
- Advantages of 3D Circuit Design in an ECAD Tool
  Christian Röck, Altium

Wednesday, 21st September 2022

12:00 Lunch, Networking, Exhibition and Poster Session

13:00 New Materials and Technologies

- Metallization of Oxide Ceramic Substrates via Laserinduced Direct Metallization
  Philipp Ninz, Uni Stuttgart
- Evaluation of printed strain gauges on 2.5D substrates
  Felix Häußler, FAU Erlangen-Nürnberg - FAPS
- 3D Printed Chip Packaging
  Dr. Ashok Sridhar, TNO Holst Centre
- Contacting Inkjet-Printed Silver Structures and SMD
  Jonas Jäger, Hahn-Schickard

Wednesday, 21st September 2022

15:00	Networking, Exhibition and Poster Session
16:00	General Meeting 3-D MID e. V. or Excursion to Hahn-Schickard (organized bus ride to Stuttgart)
19:00	Evening Event

Thursday, 22nd September 2022

9:00 Keynote „Smarter Surfaces for a Smarter Future“: Markus Thamm, Salcon International

9:30 Networking and Poster Session of Current Research Projects

10:00 Additive Manufacturing Processes

- Retrofit Sensor Technology
  Peter Peetz, IMS Connector Systems
- Rapid Prototyping of MID by Stereolithographic Printing
  Dr. Hendrik Mohrmann, Contag
- Functionalized Otoplastic (MikroBO)
  Hartmut Richter, Audifon
- Pad printing electronics – enabling the future of 3D connected surfaces

Thursday, 22nd September 2022

12:00 **Lunch, Networking, Exhibition and Poster Session**

13:00 **MID and Beyond Workshops**

- **New Research Areas**
- **Printed Hybrid Electronics**
- **Sustainability**
- **Market Research**
- **Solution approaches: thermal resistance vs. reliability**

15:00 **Networking, Exhibition and Poster Session**
15:30 **Round up of MID and Beyond Workshops**
16:00 **Closing Statement**

SUNWAY COMMUNICATION

Powerlyze GmbH
Test- & Prüflabor
für elektronische Baugruppen

3-D MID

Hahn Schickard

Exibitors

Henkel

Fraunhofer IEM

MICRO-EPSILON

IFKB Universität Stuttgart

IMS CONNECTOR SYSTEMS

SENIN TECHNOLOGIES

CENTER FOR PHYSICAL SCIENCES AND TECHNOLOGY

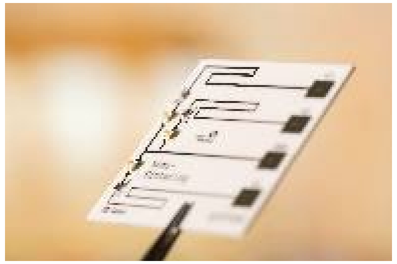
Neotech AMT
Advanced Manufacturing Technologies for 3D Printed Electronics

mechatronic

Ensinger

KNOWARE®

MID and Beyond Workshops



Printed Hybrid Electronics

New Research Areas

Market Research

Sustainability

Solution approaches: thermal resistance vs. reliability

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

Hahn Schickard

Applied research, development and foundry services for industry

40,9 M € (2021)

- 12,9 M € industrial revenue
- 7,7 M € financial support from federal government in BW

261 FTE Employees in 2021

Institute of Microassembly Technology
Stuttgart (ISO 9001:2015)

Institute of Micro and Information Technology
Villingen-Schwenningen (ISO 9001:2015)

Institute of Microanalysis Systems
Freiburg (ISO 13485:2016)

Institut of Microanalysis Systems
Ulm

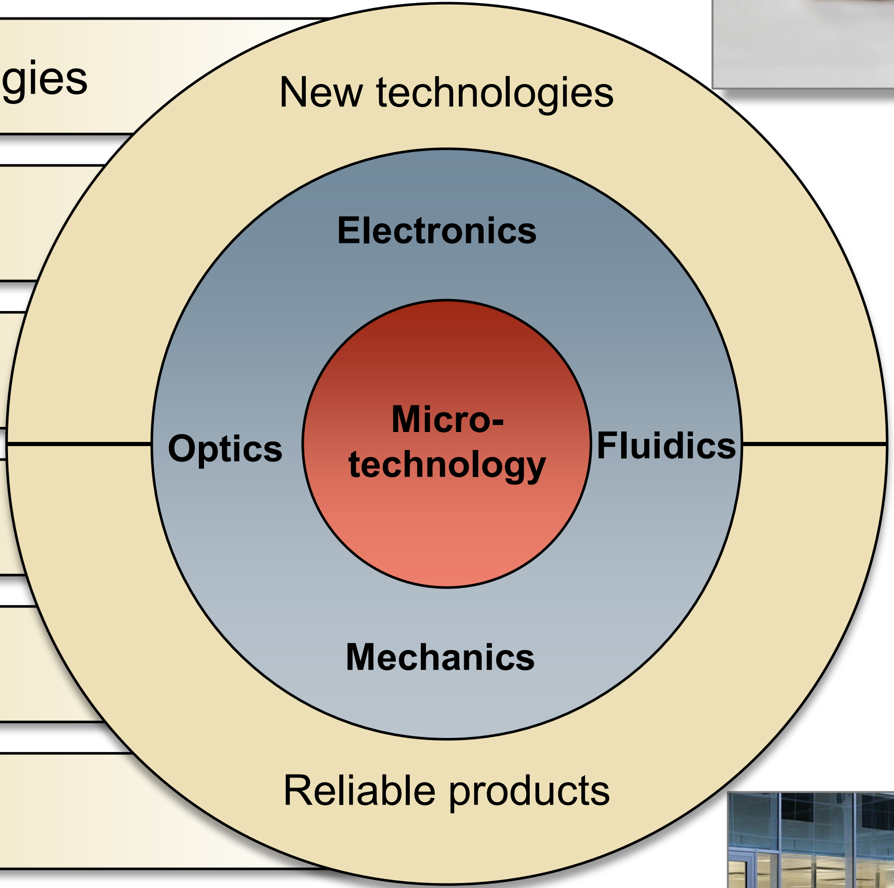
AiF Member

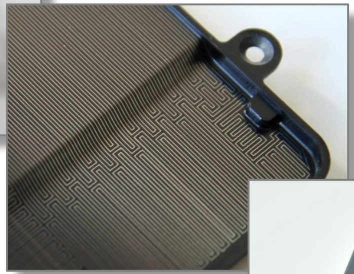
innBW INNOVATIONSALLIANZ BADEN-WÜRTTEMBERG

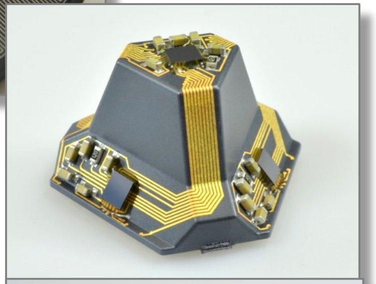
Core competences

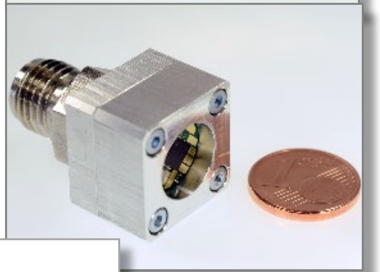
Hahn Schickard

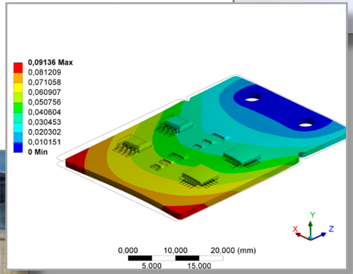
- Precision machining + polymer technologies
- Functionalization of surfaces + MID
- Micro assembly + packaging
- Sensors + systems
- Modeling + reliability
- Production











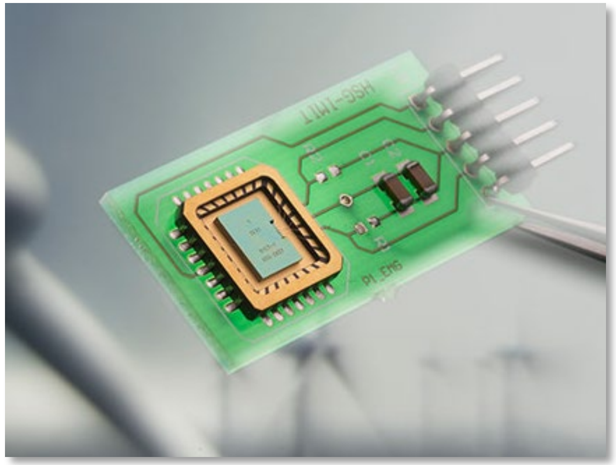
Business fields

Researching

Exploring
the future

Engineering

Developing
tailored products



Manufacturing

Making
it happen

Venturing

Creating
future values

AiF Member

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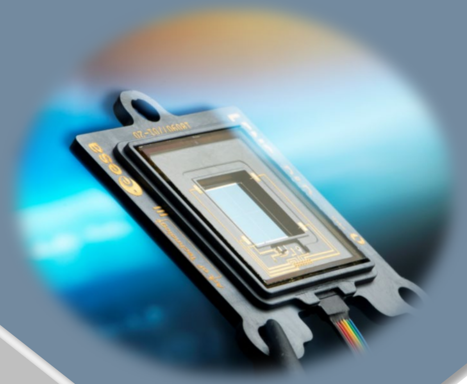
Application examples from various industries

Touch sensor ID.3

Automotive



Sensors and packages

Space

Inclination sensor

Industrial

Leica Geosystems

Consumer

3D Display

TRI LITE

Medical

Ischemia sensor

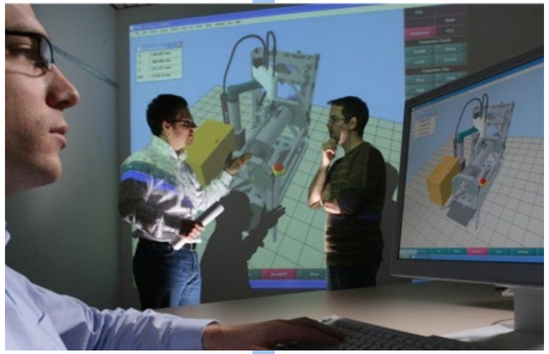
Sensocure
Early warning – Early action

AiF Member innBW INNOVATIONSALLIANZ BADEN-WÜRTTEMBERG

3-D MID e.V. was founded 1992 and is the world's largest network in the field of Mechatronic Integrated Devices (MID).

Small & medium-sized companies | **Large companies** | **Research institutes**

Platform for innovation and market development
for future-oriented mechatronic integrated systems



Community research

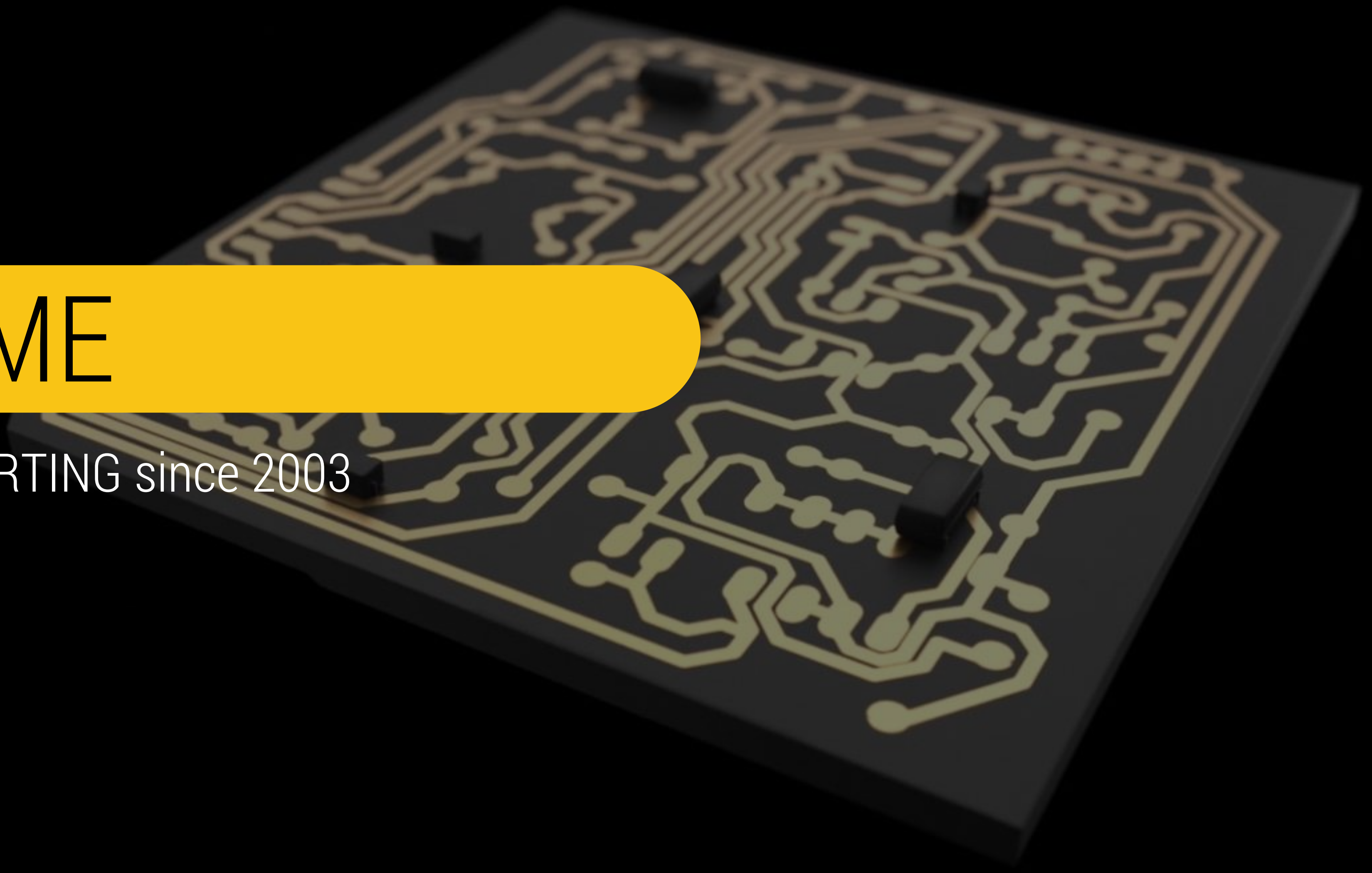
Network platform

Technology transfer

HARTING Pushing Performance Since 1945

WELCOME

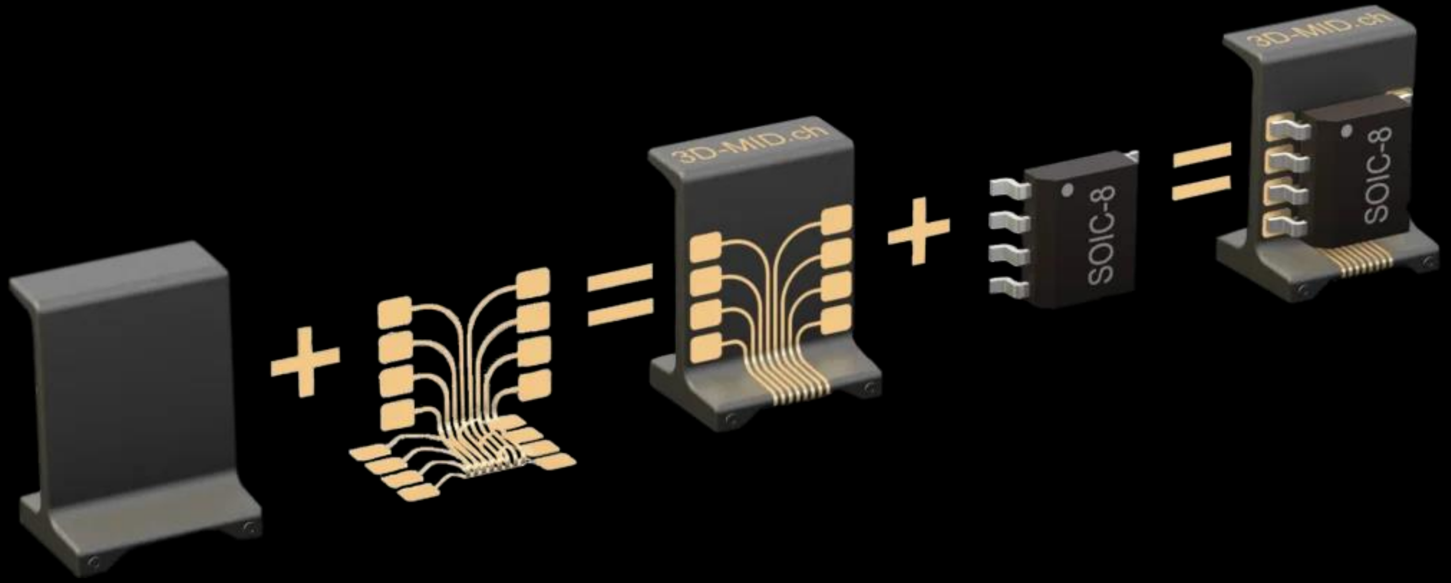
3D-Circuits by HARTING since 2003



What is 3D-MID Technology

MID

Molded **I**nterconnect **D**evice or
Mechatronic **I**ntegrated **D**evice



LASER DIRECT STRUCTURING

LDS -PROCESS

Focus Markets

Positioning

Until 2020

100% customized solutions

Build-to-print

High quantities

High investment cost

2020

Transition phase

Development of customizable standard products

2025

From 2025

customized solutions 50% 50% standard products

HARTING's concept for success

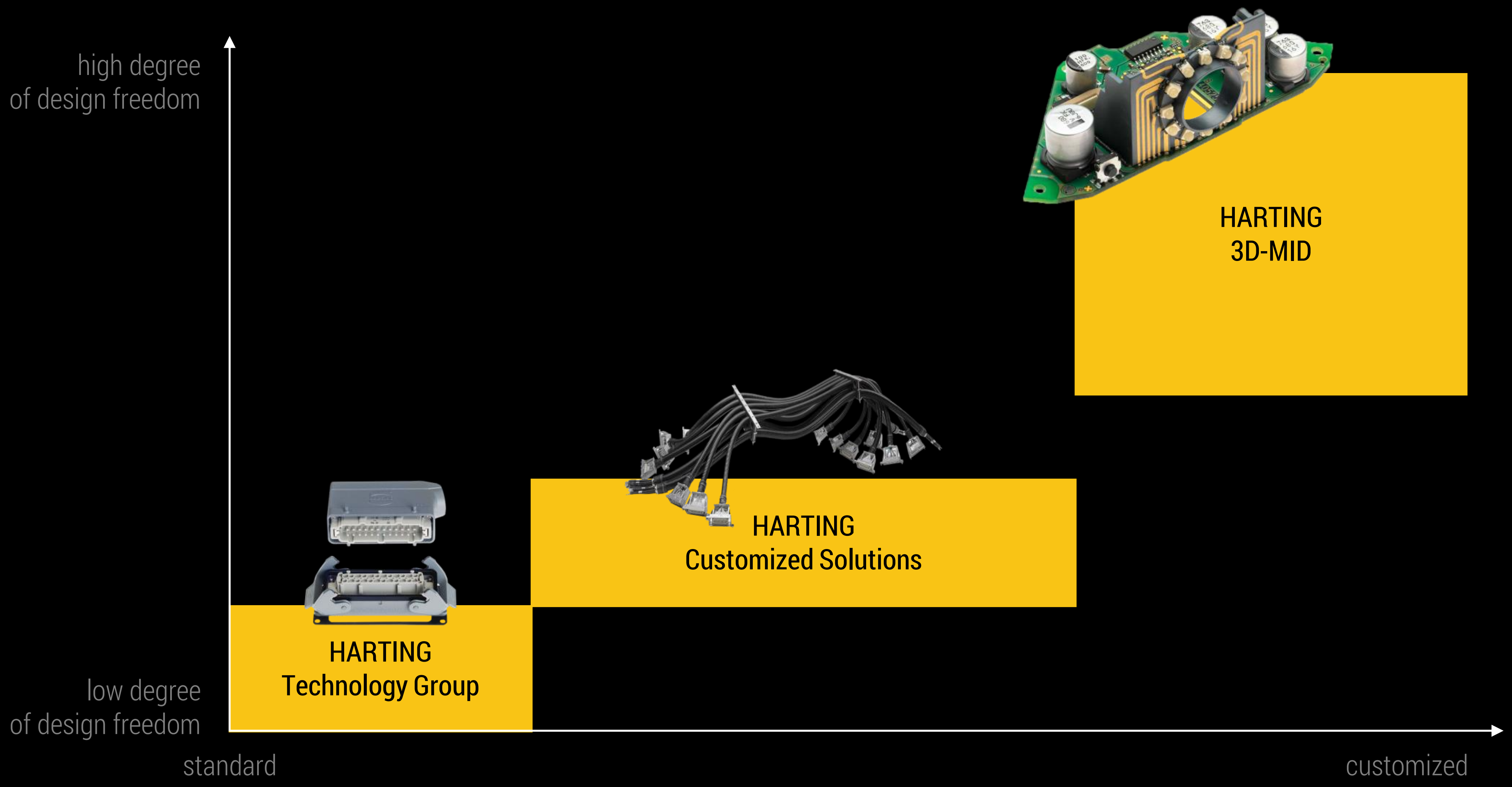
standardization

Low entry barriers to technology

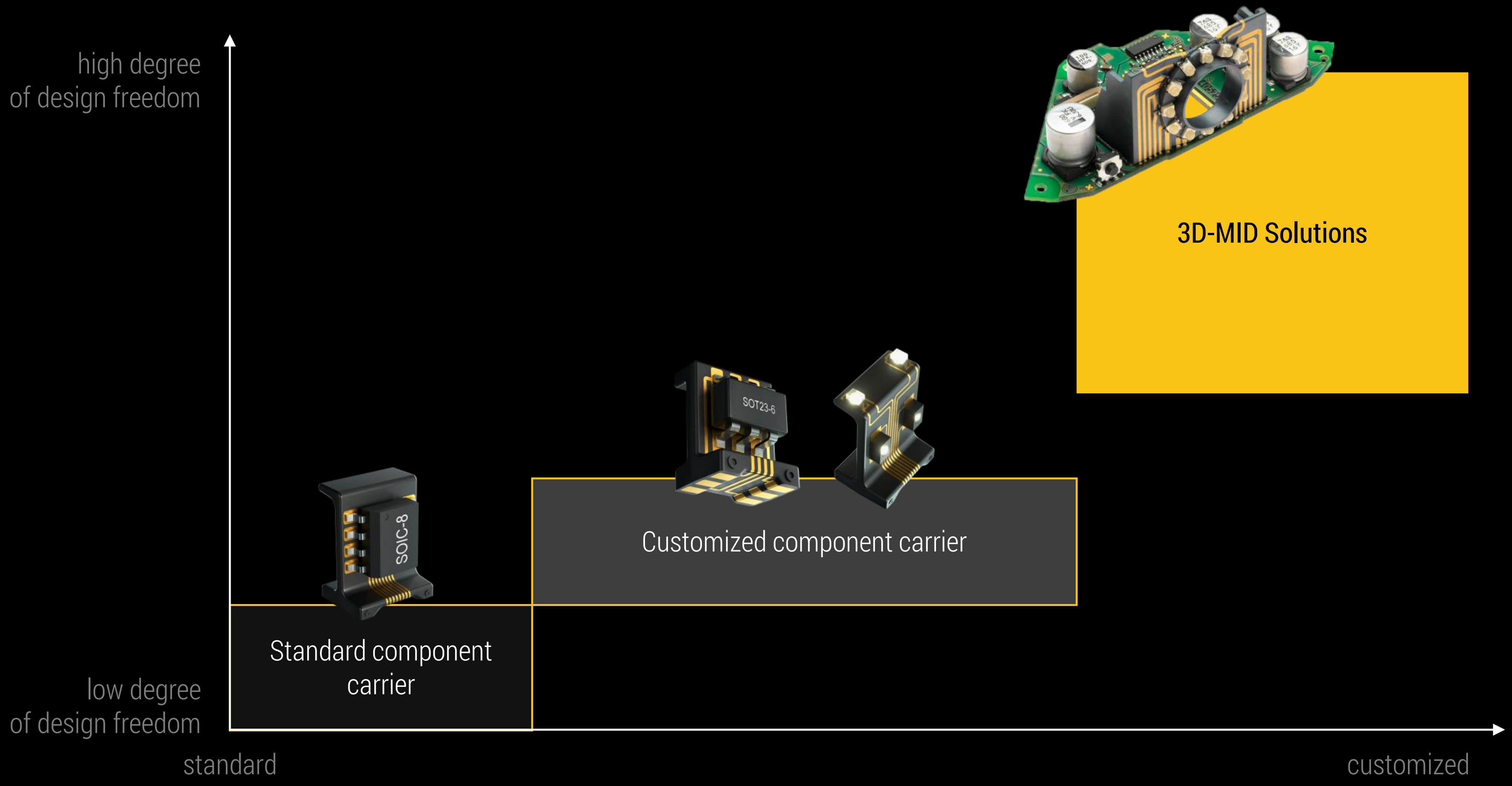
Supplier with focus on Europe and North America

Trusted supplier

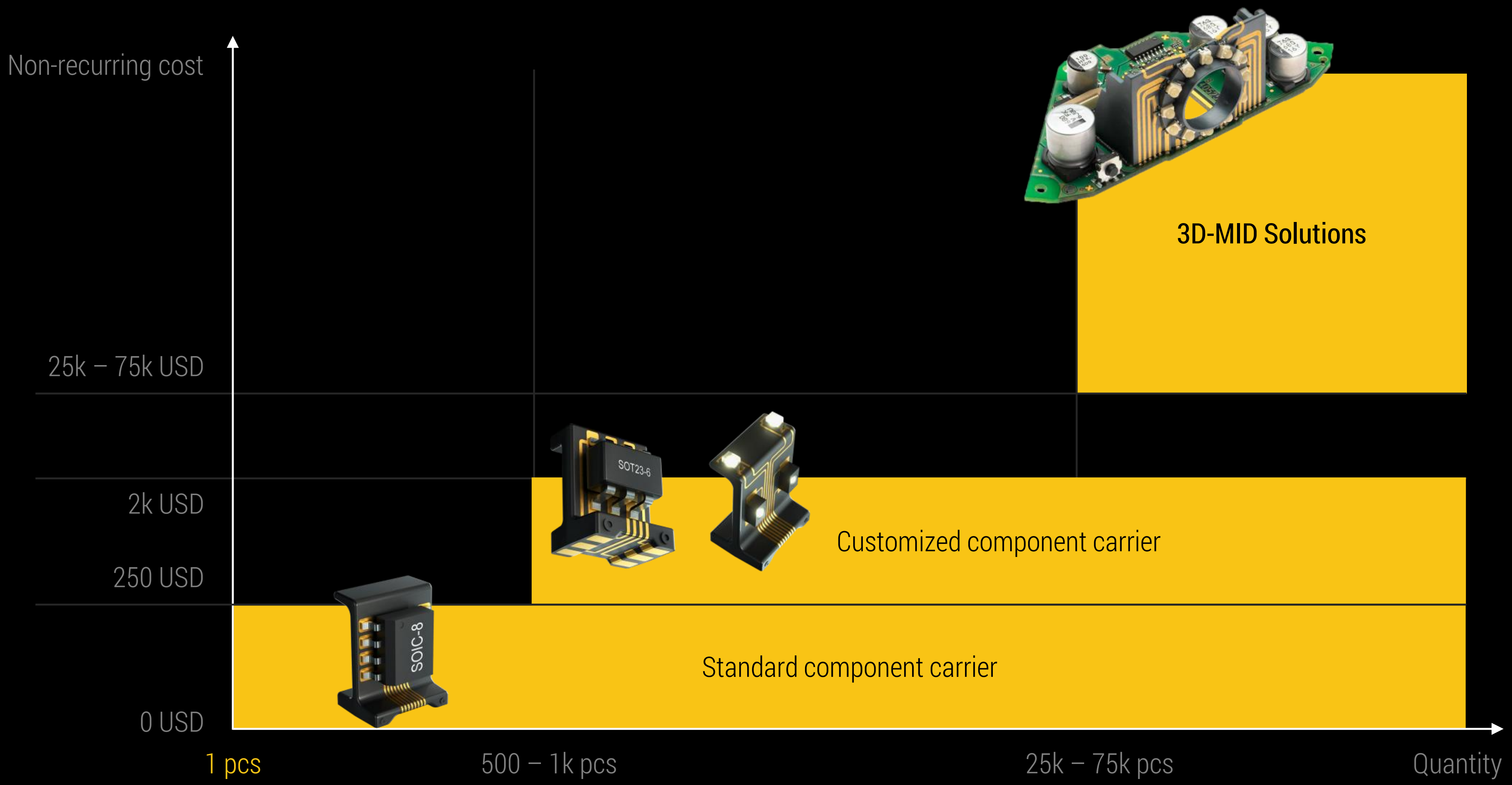
HARTINGs Product Portfolio



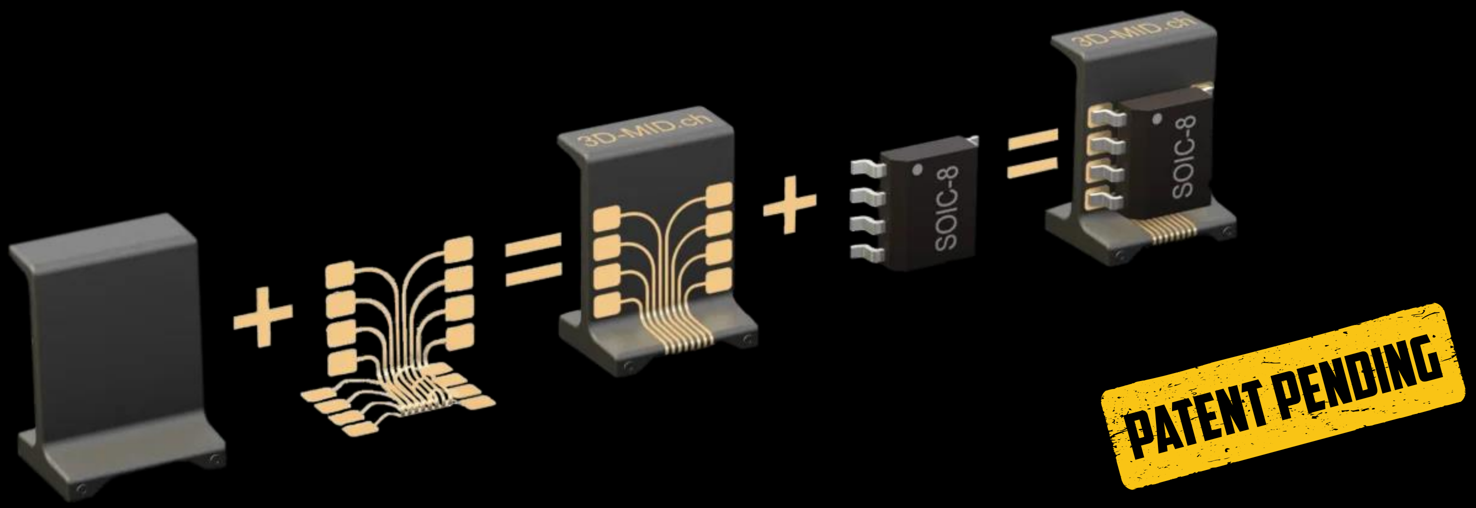
HARTINGs 3D-Circuits Portfolio



Low entry barrier



3D-MID component carrier



Universal design of substrate

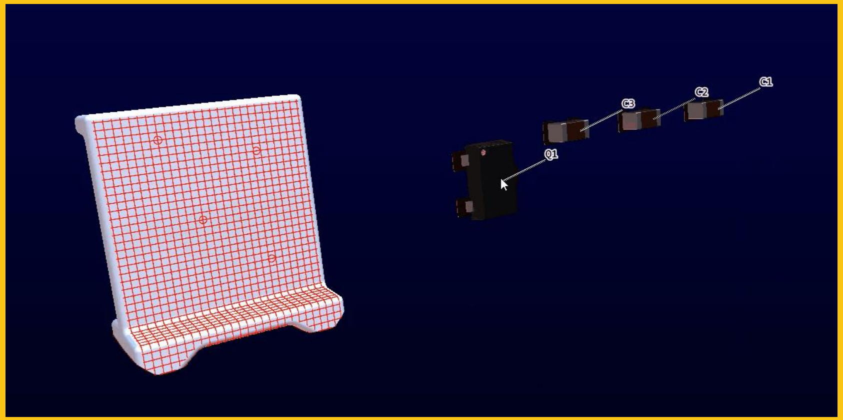
Customized layout for traces

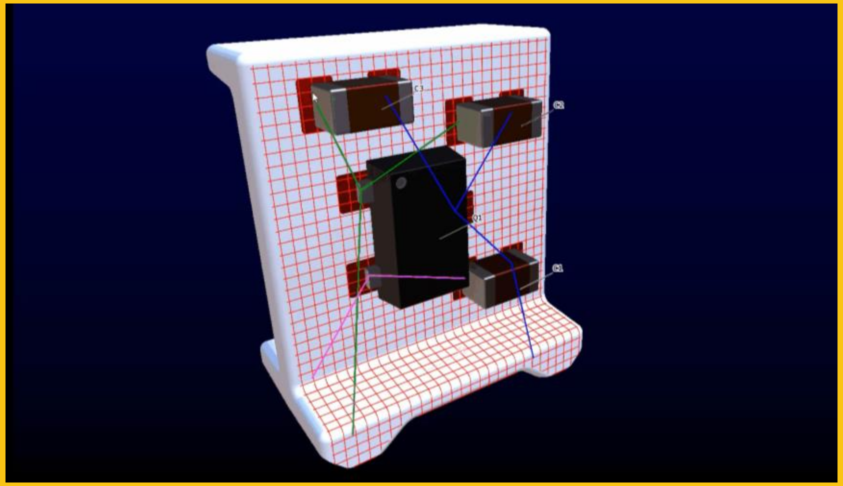
Use of high temperature plastic for reflow soldering

Shipped in tape & reel as sub-assembly for fully automated SMT processing

Significant cost savings due to elimination of mounting elements and simplification of assembly process

3D-Layout Tool

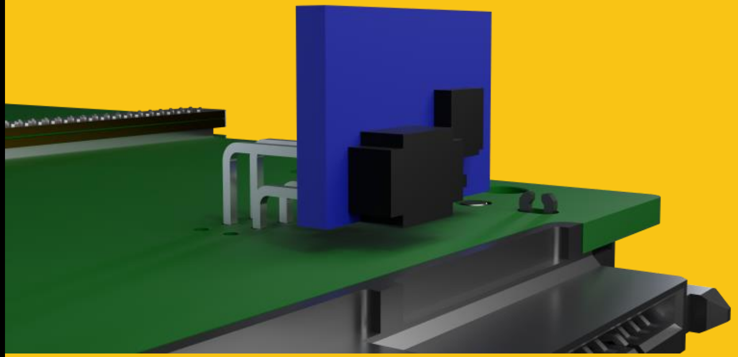


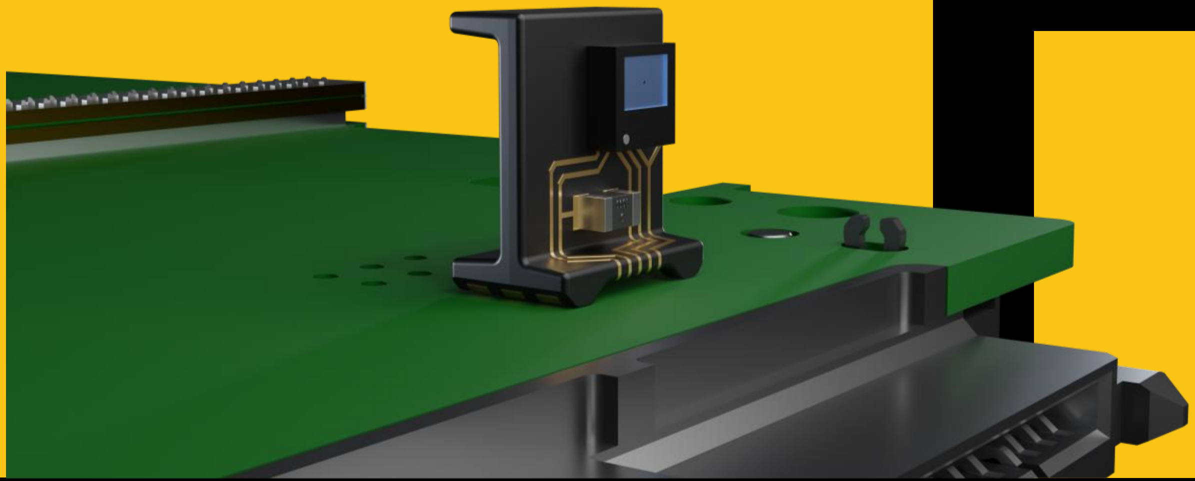


Further information

- Soon by Mr. Christian Röck – 11:30am
- MIDs make comeback - Altium.com
- True 3d Circuit Design - Altium.com

3D-MID Applications – Chip Carrier





- Customer:
  Data storage company
- Industry:
  Industrial Electronics
- Description:
  FIR Sensor for high precision non-contact temperature measurements (Far Infrared)

Added Value

- Scanning of the objects must be perpendicular to the PCB
- Fully automated SMD process at high volumes of 200k+ pcs per year
- Elimination of manual assembly step

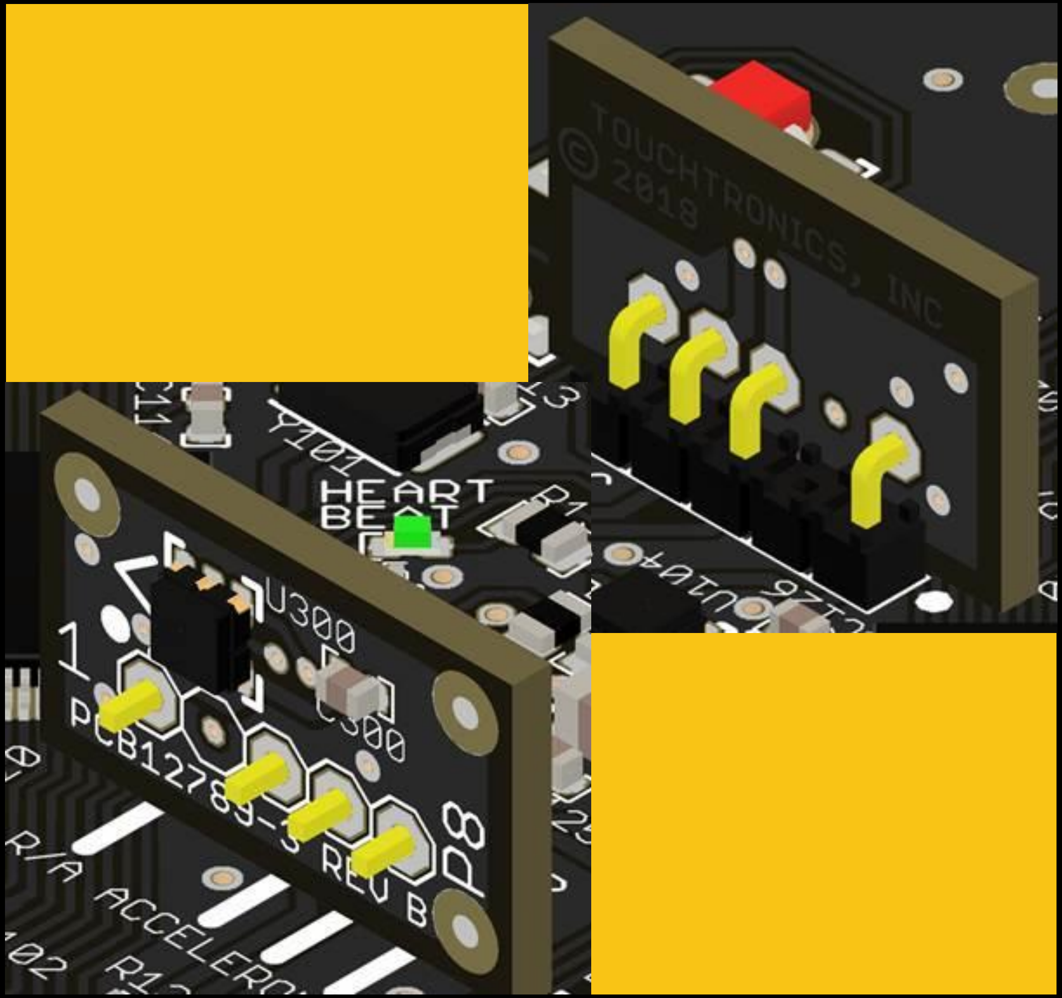
3D-MID Applications – Secure Cover

- Customer:
  Grid+
- Industry:
  Finance
- Description:
  Hardware Wallet for crypto currencies

Added Value

- 4 secure zones combined in one part
- Higher security
- Less sensitive to hacking attempts

3D-MID Applications – Chip Carrier

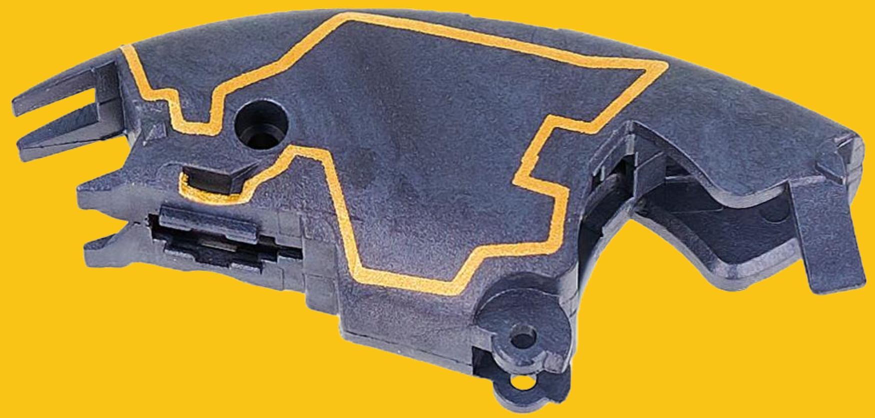


- Customer:
  Touchtronics, US
- Industry:
  Industrial Electronics
- Description:
  Accelerometer

Added Value

- Fully automated SMT assembly
- Elimination of manual assembly process
- Cost savings by >50%

3D-MID Applications – Hearing Aid



- Customer:
  European Hearing Aid Manufacturer
- Industry:
  Medical
- Description:
  Antenna implemented on housing

Added Value

- Integration of antenna structure directly on housing
- Elimination of flex PCBs
- Reduction of complexity in the assembly process

Conclusion

Customizable products

Universal design
of substrate

Build-to-print

High quantities

High investment cost

Low entry cost

No need of injection molding
tool

Layout can be done with Altium
3D Layout tool

Building trust
Tests can be carried out
inexpensively

Attractiveness

No need of injection molding
tool

Economically attractive for
small quantities

Technology attractive for a
larger number of customers

HARTING Pushing Performance
Since 1945

Thank you

Ensinger Microsystems

Si-Wafer Replacement and LDS MID Transformers

Property of *Ensinger* GmbH

Engineering and Production Competence in High-Performance Plastics

Fig. a: Ensinger Nufringen, Germany

Fig. b: Ensinger Seewalchen, Austria

Founded: 1966

Managing Directors: Dr. Roland Reber, Dr. Oliver Frey, Ralph Pernizsak

Headquarters:
Nufringen, Baden-Württemberg

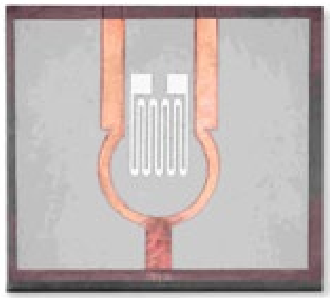
Employees:
appr. 2.600

Turnover:
appr. 500 Mio. Euro

Locations Worldwide: 35

Materials:
Engineering plastics and HT plastics

LDS Competence within the Ensinger Group

Compounds	Injection Moulding	New Business Factory Microsystems	New Business Factory Additive Manufacturing
			
Nufringen - Germany	Ergenzingen - Germany China, Brasil	Nufringen - Germany	Nufringen - Germany

Content

- Si-Wafer Replacement (Ensinger Microsystems Technology)
  - State of the Art LDS
  - Initial Situation / New Technology
  - The Process / Comparison Silicon
  - Advantage “No Packaging”
  - Benefits of Ensinger Microsystems
- LDS MID Transformer
  - SoA and Benefits
  - Advantage “No Packaging" when Combined with LDS
  - Application Example LAN Transformer
- Further Application Examples
- Use Cases of Ensinger Microsystems Technology
- Value Chain

Ensinger

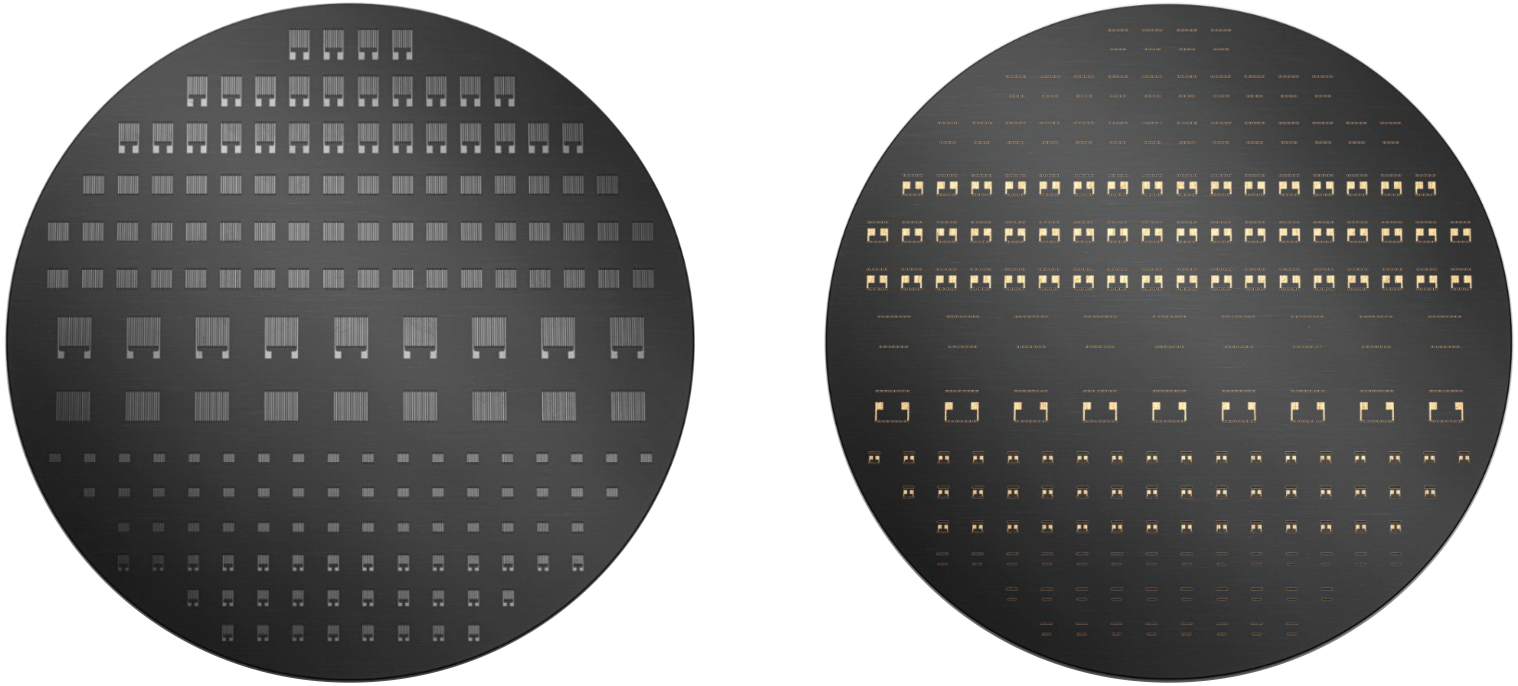


Fig. 1: Wafer Front- and Back-Side

Si-Wafer Replacement

Ensinger Microsystems Technology

State of the Art - Laser Direct Structuring

Ensinger

TECACOMP® LDS
Compounds for Laser-Direct-Structuring

Fig. 3: LDS Process Chain

Fig. 4: LDS Antenna Smartphone

Fig. 5: *Apple® AirPods®* –
Well established technology at the market

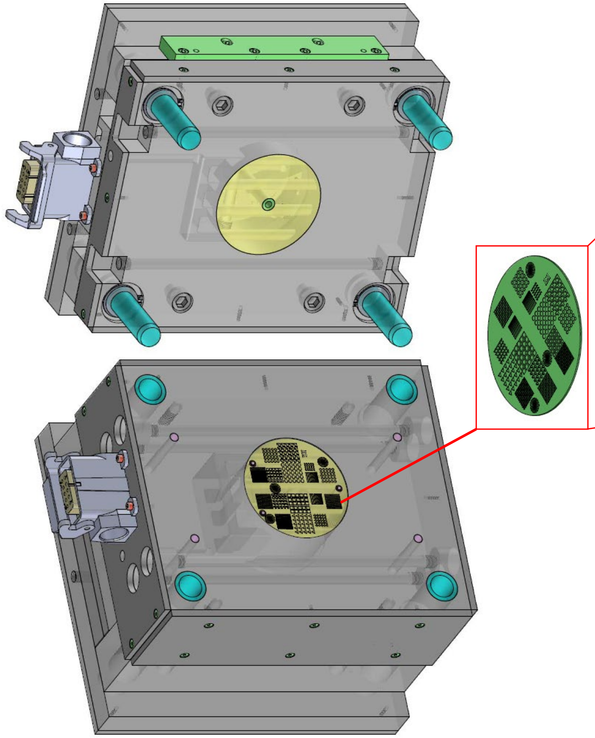
– LDS is a technology that has proven itself in large-scale production for years. Ensinger Compounds is networking in the LDS / MID world and supplies PPA, LCP and PEEK based TECACOMP LDS compounds to "MID processors".

– The **limits** of this technology ends well **above microstructures** as often **required** in microsystem technology.

Initial Situation / New Technology

- Worldwide growth and bottleneck market for wafers - based almost 100% on silicon wafers.
- IMPT (Leibniz University of Hanover) has developed a process to produce wafers from TECACOMP PEEK LDS.
- Microstructures can be realized directly on the PEEK surface.
- In combination with LDS, finished systems such as AMR sensors can be produced without a silicon chip with significant cost savings.
- Precision: ICs and transistors are technically not possible. The field of application is in the area of sensors, such as ABS sensors, camshaft sensors, strain gauges, PT elements, etc....
- The *Ensinger New Business Factory Microsystems* plant has conceptualized the industrial production and is looking for interested customers with specific projects.

The Process / Comparison Silicon I



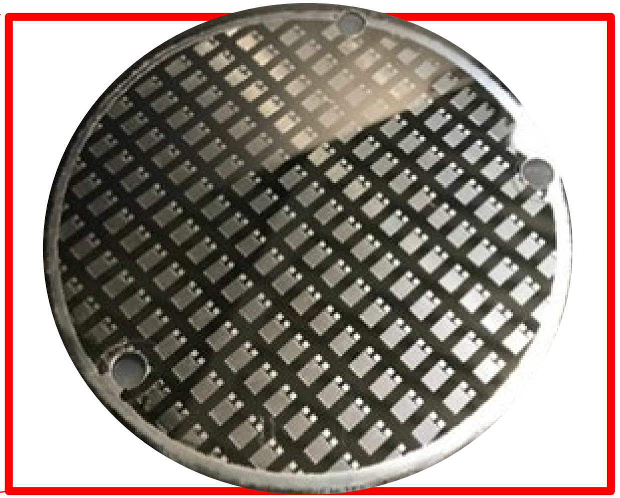


Fig. 9: Mold-Inlay

Fig. 10: PEEK Wafer (blanks)

The Process / Comparison Silicon II

Ensinger

Advantages manufacturing (new concept):

- Wafer blank already structured
- Reduction from 7 to 3 manufacturing steps
- No clean room required
- No lithography required

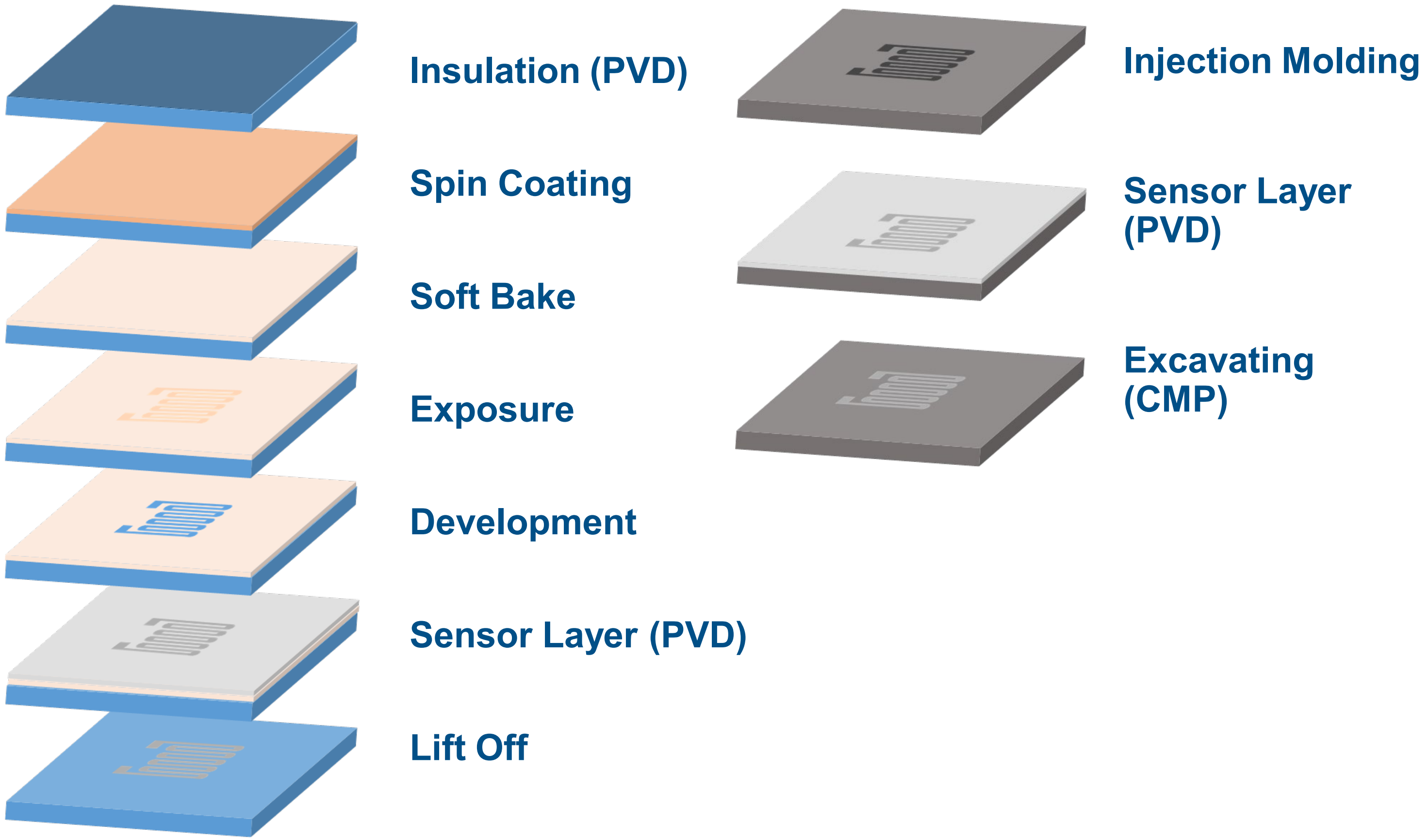
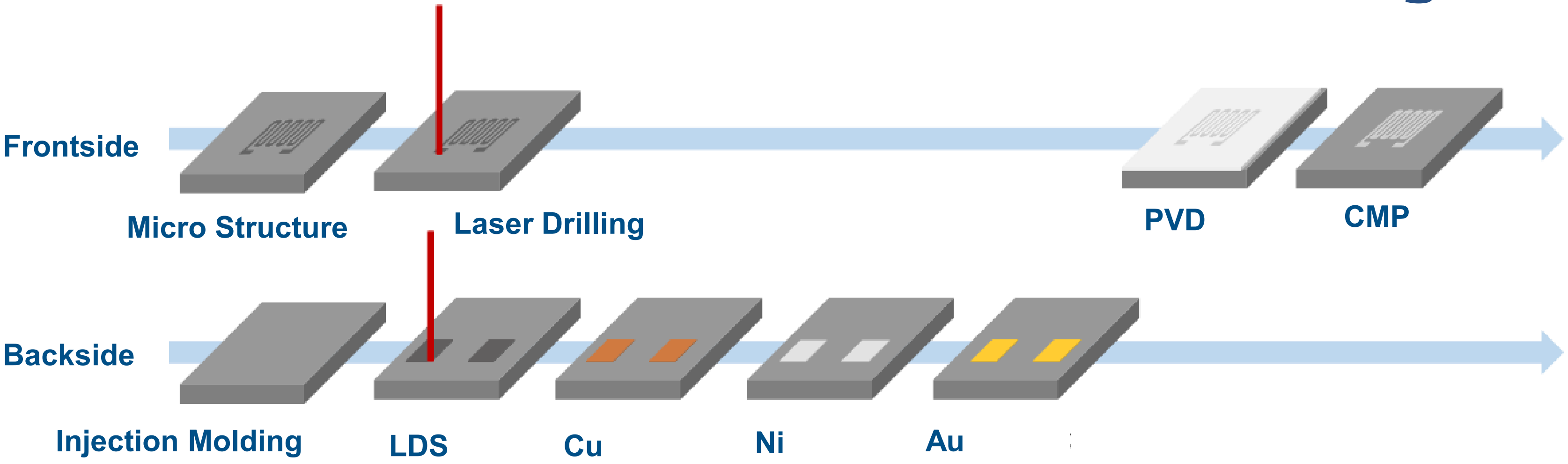


Fig. 11: Left: known process based on silicon , right: new process based on PEEK LDS

Advantage "No Packaging" in Combination with LDS

Ensinger

- Laser-drilling of vias through LDS technology
- Thus soldering of backside contacts possible
- **No wire bonding**
- **No housing necessary**



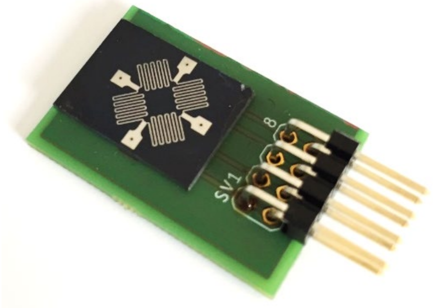


Fig. 12: Finished AMR/GMR sensor on soldered PEEK chip

(Wheatstone Bridge)

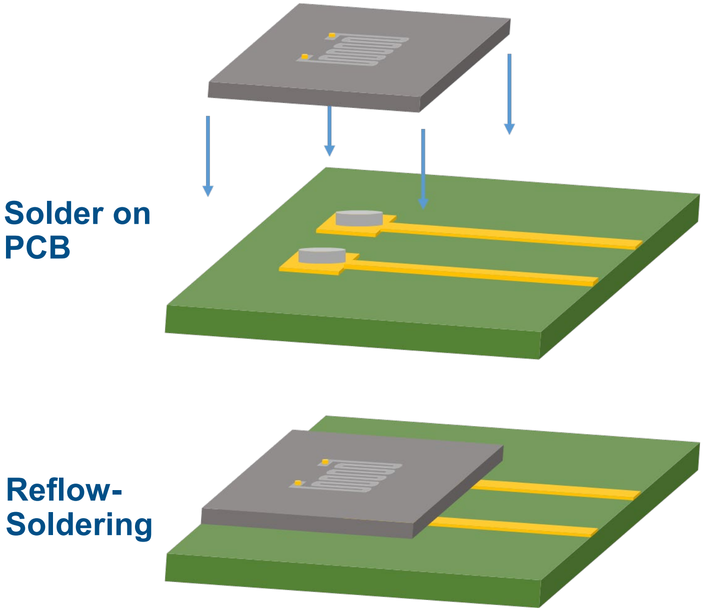


Fig. 13: Process chain Incl. back-end

Benefits of Ensinger Microsystems

Fig. 6: Clean Room at *Bosch* Fab Reutlingen

Fig. 7: Silicon Wafer by *Siegert Wafer*

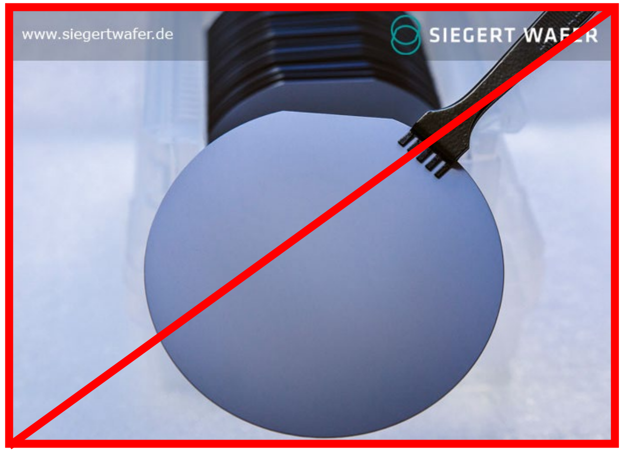


Fig. 8: Wire Bonder by *Palomar*

- ✓ Clean room technology can be neglected!
- ✓ We realize thin film technologies on a plastic substrate instead of silicon!
- ✓ Less infrastructural invest in machines!

- ➢ Lower material costs due to the use of polymer materials.
- ➢ We combine the technology with the well-known LDS.
- ➢ **We save costs!**

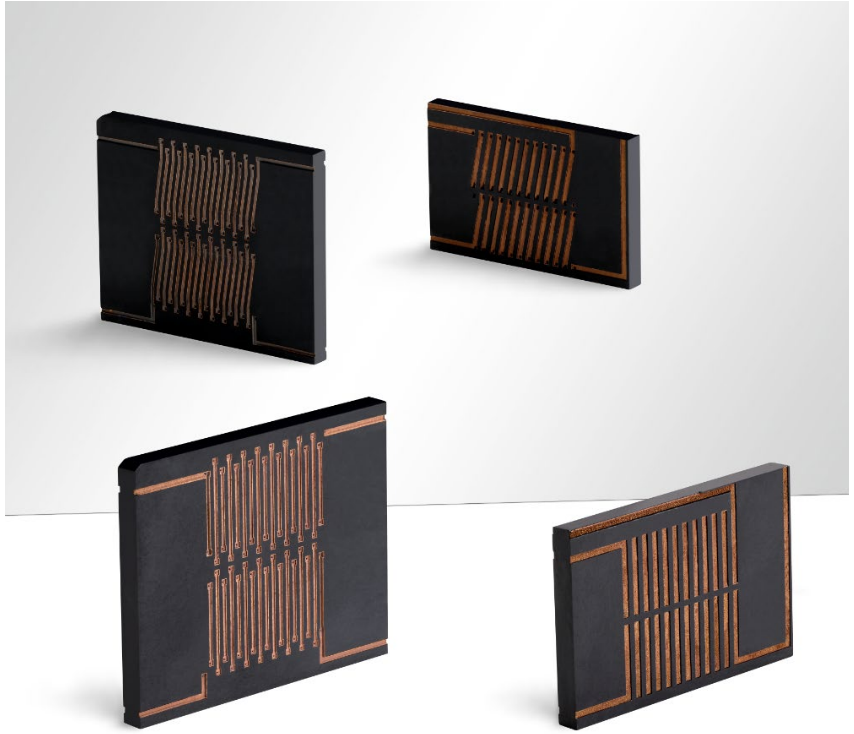


Fig. 19: MID Transformers

MID-Transformers

TECACOMP® LDS

SoA and Benefits: SMD Coils/Transformers/Filters etc.

Ensinger

Fig. 20: Variety of SMD coil systems

Quelle: Würth Electronic

- Wound coils for transformers/inductors and filters are state of the art
- Winding technology is complex and cost-intensive
- Construction height is limited by winding technology and core
- Additional packaging increases volume
- Contacting via SMD package is usually challenging
- Laser-drilling of VIAs (Vertical Interconnect Access - VIA) through LDS technology
- Thus soldering of backside contacts possible
- **No winding technology**
- **No package necessary**
- Core integrated in MID component
- Winding of the conductor path via "daisy-chain" (LDS)

Advantage “No Packaging" when Combined with LDS

Ensinger

- Insertion of vias through LDS technology
- Thus "daisy-chain" windings and soldering of backside contacts possible
- **No winding** technology
- **No housing** necessary
- **Volume savings** of up to **80 %** possible
- **Weight savings** due to significantly lower copper content
- **Material savings** on core, housing and copper leads

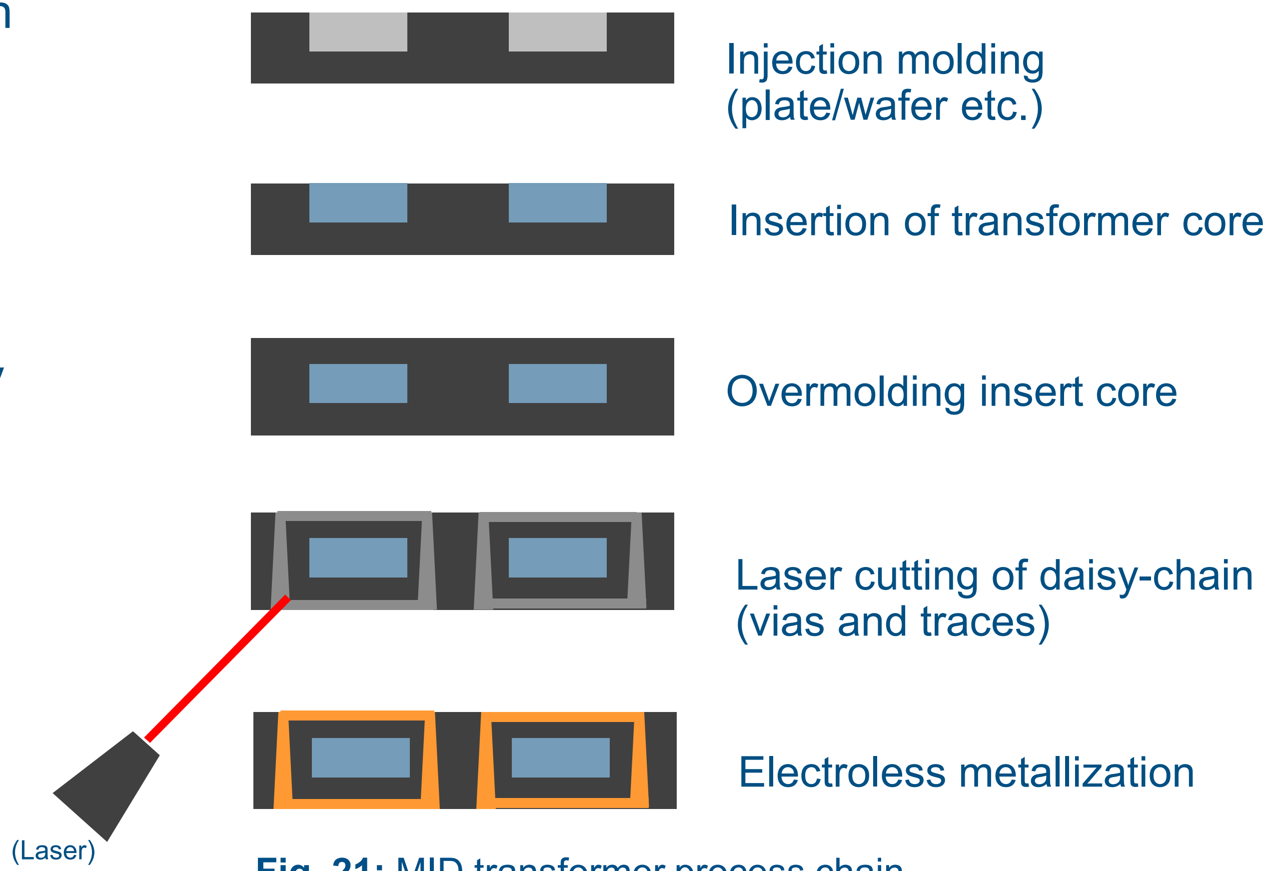


Fig. 21: MID transformer process chain

Application Example LAN Transformer

- Reduced number of production steps
- Requirements for plant technology and equipment significantly reduced
- Elimination of winding technology and packaging
- Short supply chain
- Example LAN transformer (component costs with winding technology between 5 - 12 € per component)

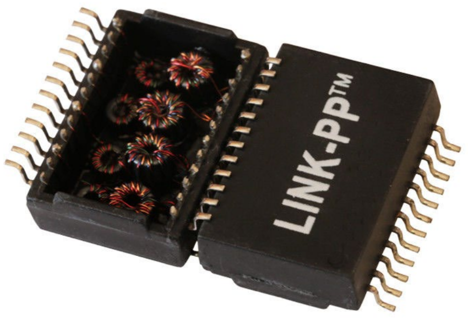


Fig. 22: LAN transformer SMD coil systems

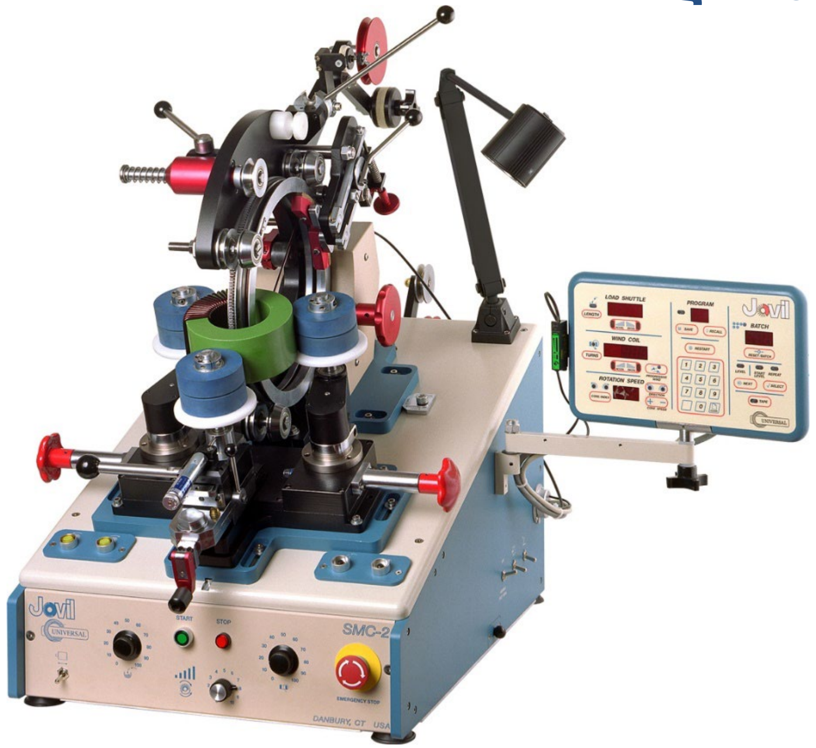


Fig. 23: Winding machine

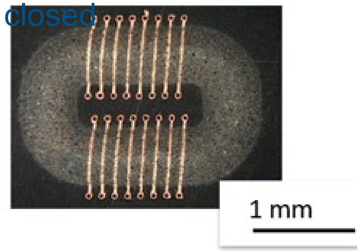
Quelle: www.armaturewindingmachine.com

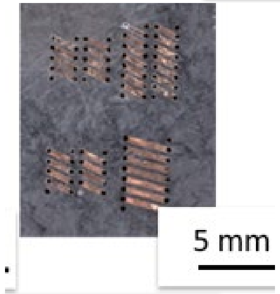
Further Application Examples

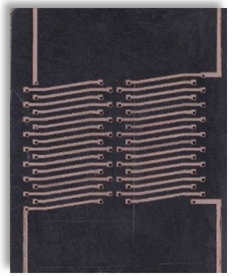
Ensinger

Passive Components

Fig. 24: Micro-Transformer
Gap on the market between wound coil transformers and Si-SMD transformers can be closed







Magnetic Field Sensors

Fig. 25: Eddy Current-Sensor
Distance, displacement or position measurement

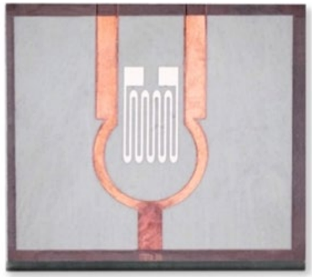
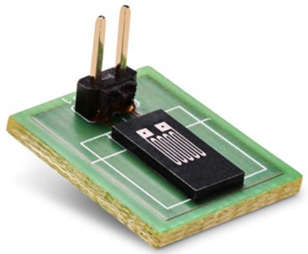
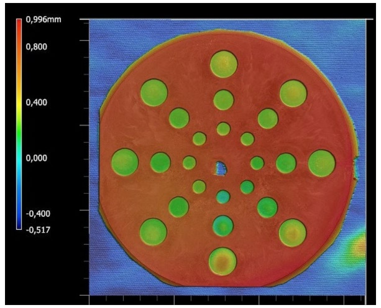


Fig. 26: AMR/GMR-Sensor
Distance, displacement or position measurement



DMS/Temp./Strain Gauges

Fig. 27: Pressure Sensors/Membranes / Strain-Gauges Pt-Elements
Displacement, pressure, strain, stress, temperature



Optical Components

Fig. 28: Bragg Grating
Light-coupling, strain-gauge, CO2-sensors etc.

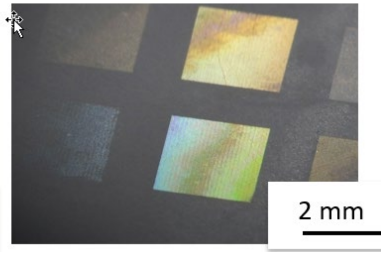
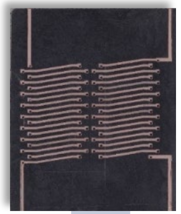


Fig. 29: Waveguide
Directly in the PEEK surface from 5 µm

Use Cases of Ensinger Microsystems Technology

Passive Components

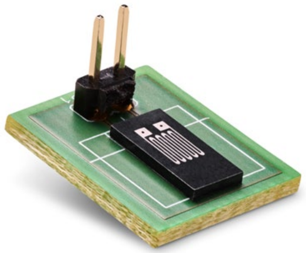
Fig. 30: Micro-Transformer
Gap on the market between wound coil transformers and Si-SMD transformers can be closed.



Power supply *Apple® MacSafe®*

Magnetic Field Sensors

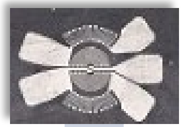
Fig. 31: AMR/GMR-Sensor
Distance, displacement or position measurement.



Angle measurement by *Heidenhain GmbH*

DMS/Temp./Strain Gauges

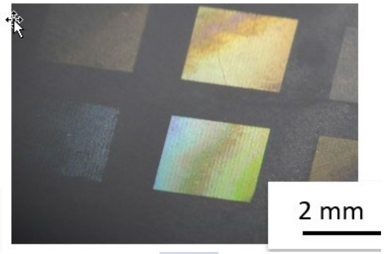
Fig. 32: Pressure Sensors /Membranes /Strain-Gauges /Pt-Elements
Displacement, pressure, strain, stress, temperature.



Tensile test bench *ZwickRoell GmbH*

Optical Components

Fig. 33: Bragg Grating
Light-coupling, strain-gauge, CO2-sensors etc.



CO2 sensor *E+E Elektronik*

Value Chain Ensinger Can Provide

- Ensinger and its partners may provide every manufacturing step.
- From compound to finished component – You choose!
- Short supply chain: **Made in Germany!**

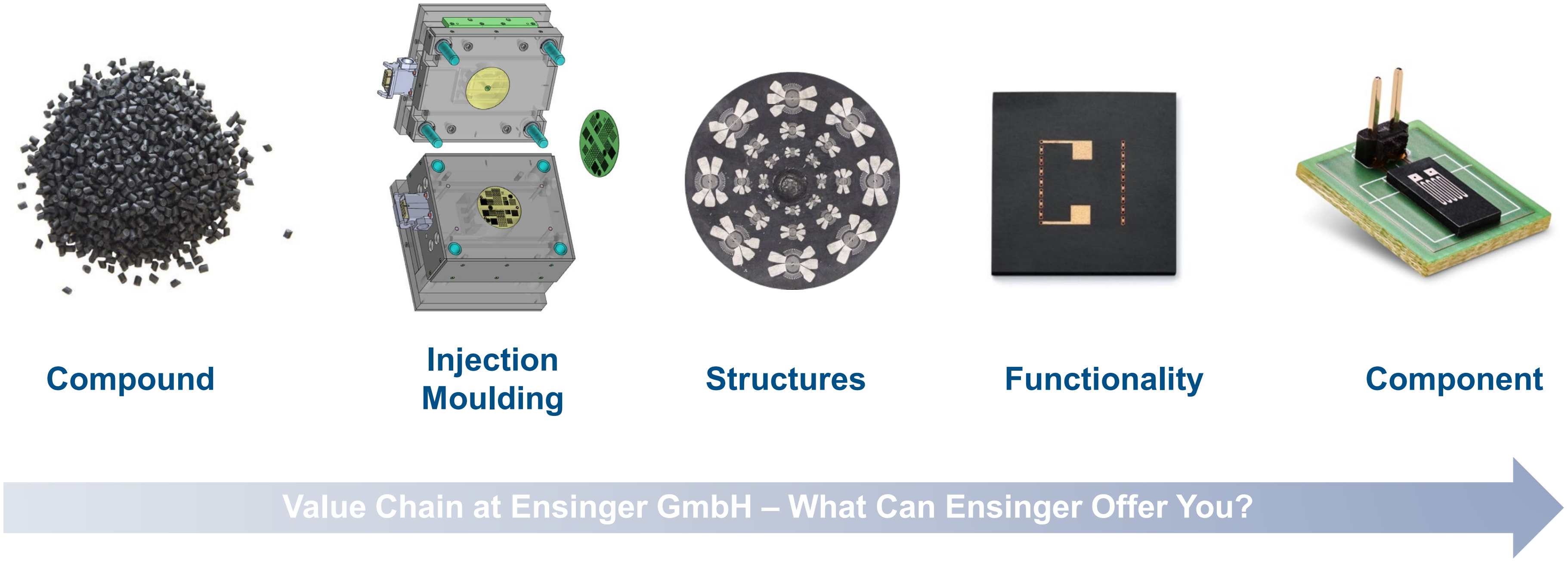


Fig. 34: Value Chain

Ensinger

Your Contact

Dr.-Ing. Sebastian Bengsch
Project Manager Microsystems
Mobil +49 176/30541223
Mail:sebastian.bengsch@ensingerplastics.com

Stefan Bur
Application Segment Manager
Mobil: +49 151 148 339 32
Mail:stefan.bur@ensingerplastics.com

Ensinger New Business Factory

Ensinger GmbH
Rudolf-Diesel-Str. 8,
D - 71154 Nufringen,
Deutschland
Tel. +49 170/5662055
sebastian.bengsch@ensingerplastics.com
ensingerplastics.com

Ensinger Compounds

Ensinger Sintimid GmbH
Ensingerplatz 1
A - 4863 Seewalchen
Österreich
Tel. +43 7662 88788 302
compounds@ensingerplastics.com
www.ensingerplastics.com

Metalized-plastic technology enabling three-dimensional millimeter-wave components

Jan Hesselbarth

University of Stuttgart

Outline:

- **Definitions of terms and problem**
- **Metalized-plastic structures in comparison to other technologies**
- **Drawbacks of metalized-plastic structures technology**
- **Examples**
- **Conclusion**

Term definitions:

- frequency range of interest:

1.5 GHz … 150 GHz : wavelength 200 mm … 2 mm

Component size: ½ … few wavelengths

Feature size: roughly 10% of wavelength

Tolerance: approx. less than 1% of wavelength

- "passive component" of interest:

Transmission lines + connectors ("interconnects")

Resonators / frequency filters

Antennas / arrays

- signal/power loss issue:

The higher the frequency, the more precious is power

Loss/power is proportional to field/current squared

Field/current density reduction asks for distribution/size

3D is best for lowest loss

Statement of problem:

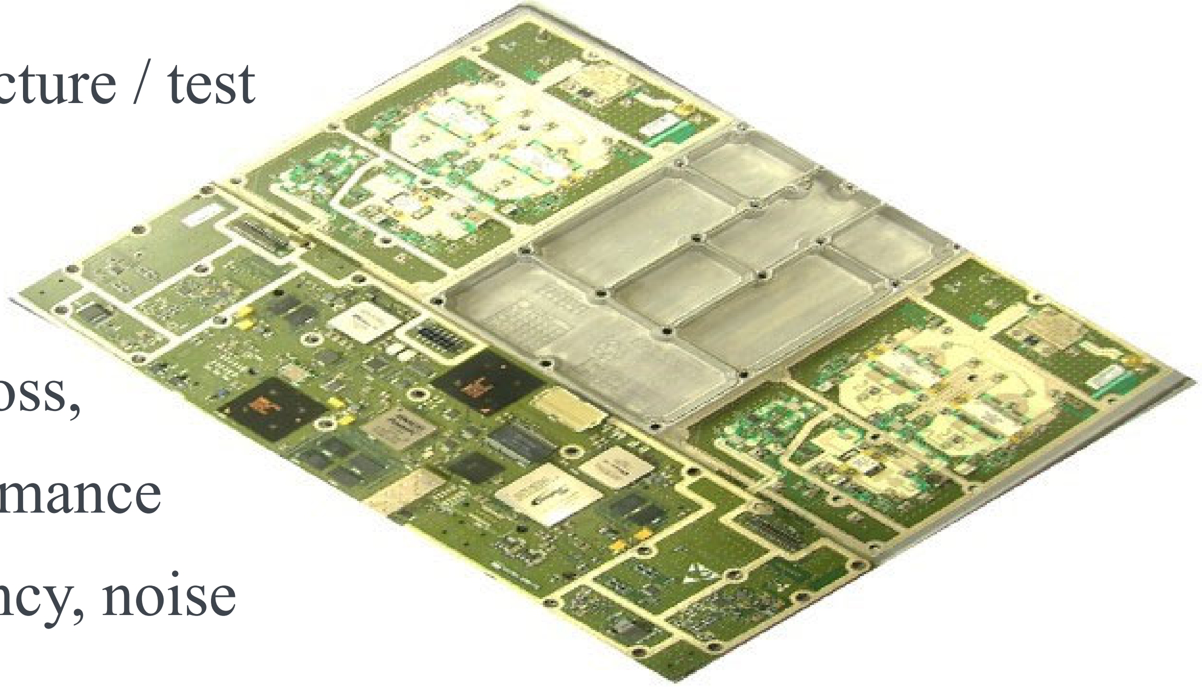
- the high-frequency electronic circuit on a circuit board:

Easy design / manufacture / test

Low cost

Compact

Large signal/ power loss,
thus poor RF performance
w.r.t. power, efficiency, noise



- the ideal "low-loss" microwave / mm-wave circuit & component:

Complicated design / manufacture / test

High cost

Large volume

Low loss, thus best
RF performance w.r.t.
power, efficiency, noise

Metalized-plastic structures in comparison:

- compared to metal machining:

+ comparable dimensional accuracy (with molding, not necessarily with 3D-printing)

+ low cost at high quantity (with molding, not necessarily with 3D-printing)

+ low weight

+ solderable (low heat capacity)

- compared to planar board technologies:

+ real 3-D shapes for RF performance and functionality

Metalized-plastic structures — drawbacks:

- no need (for incremental improvement of subsystem performance in existing applications) ??

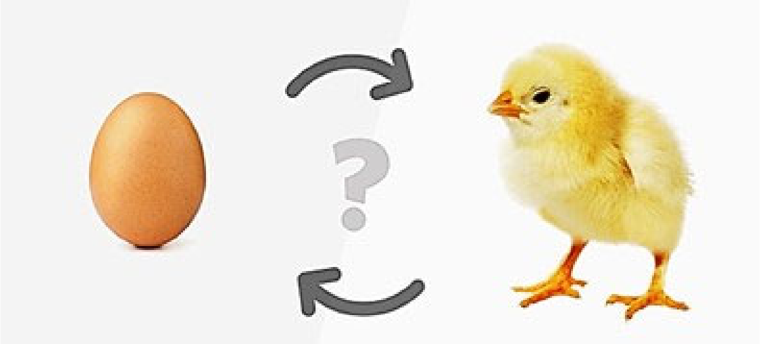
- “complicated”:

+ no standardized / structured design process

+ final RF performance difficult to predict

+ high NRE costs

→ Looks like a chicken-and-egg-problem …



[wikipedia]

… to be solved by accumulating examples/experiences

Examples of microwave / millimeter-wave components based on metalized-plastic:

- fully metalized (molded plastic part fully coated by thin metal)

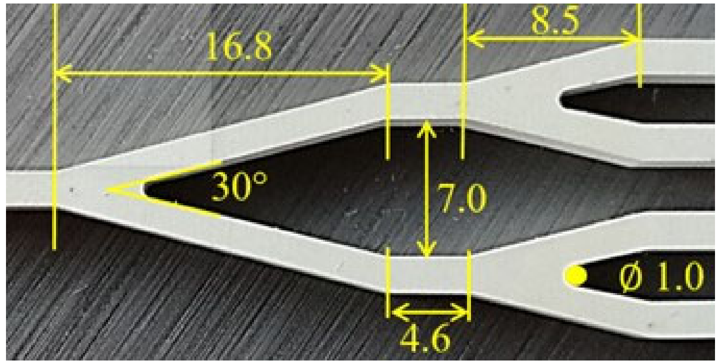
+ pro arguments: structural complexity, accuracy vs cost, solderability, weight

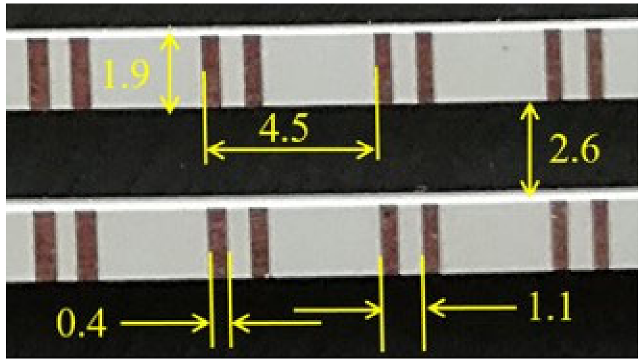
- partly metalized (dual-molded plus metal, laser-actuated metalization)

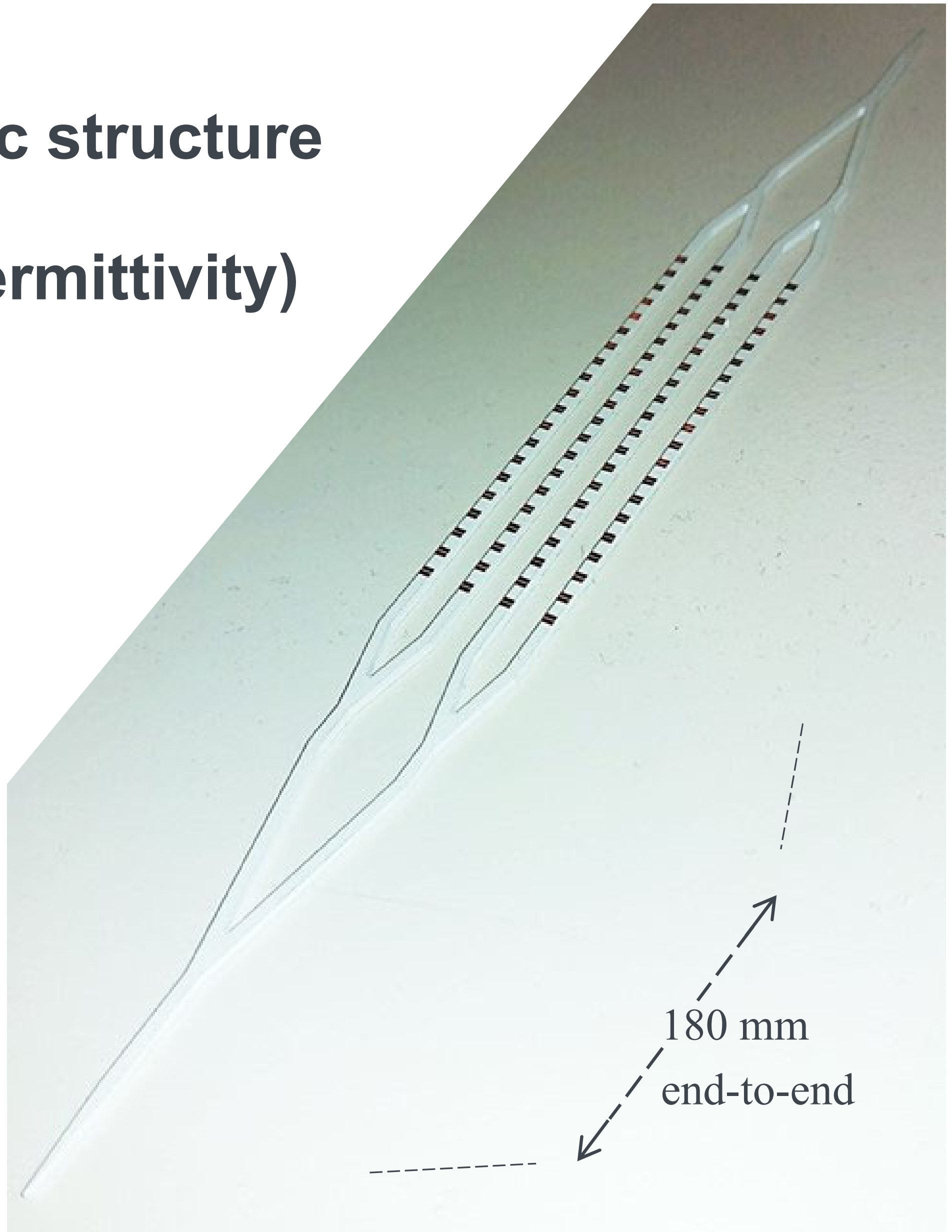
+ pro arguments: further enhanced structural complexity

Example 0 : Antenna : “conventional” : milling of etched copper-plated circuit board

- dielectric waveguide leaky-wave antenna array (~ 35 GHz)
- con: limited degrees of freedom in design of metal / dielectric structure
- pro: use of “microwave dielectric” (low loss tangent, high permittivity)

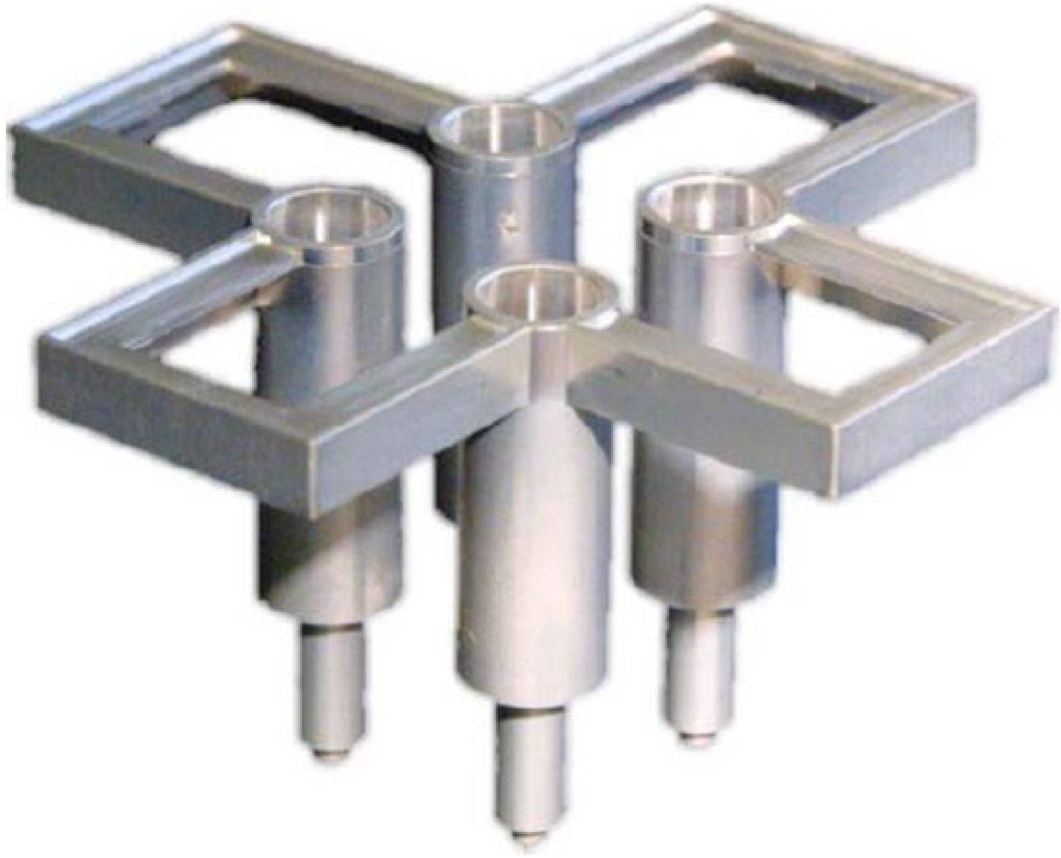


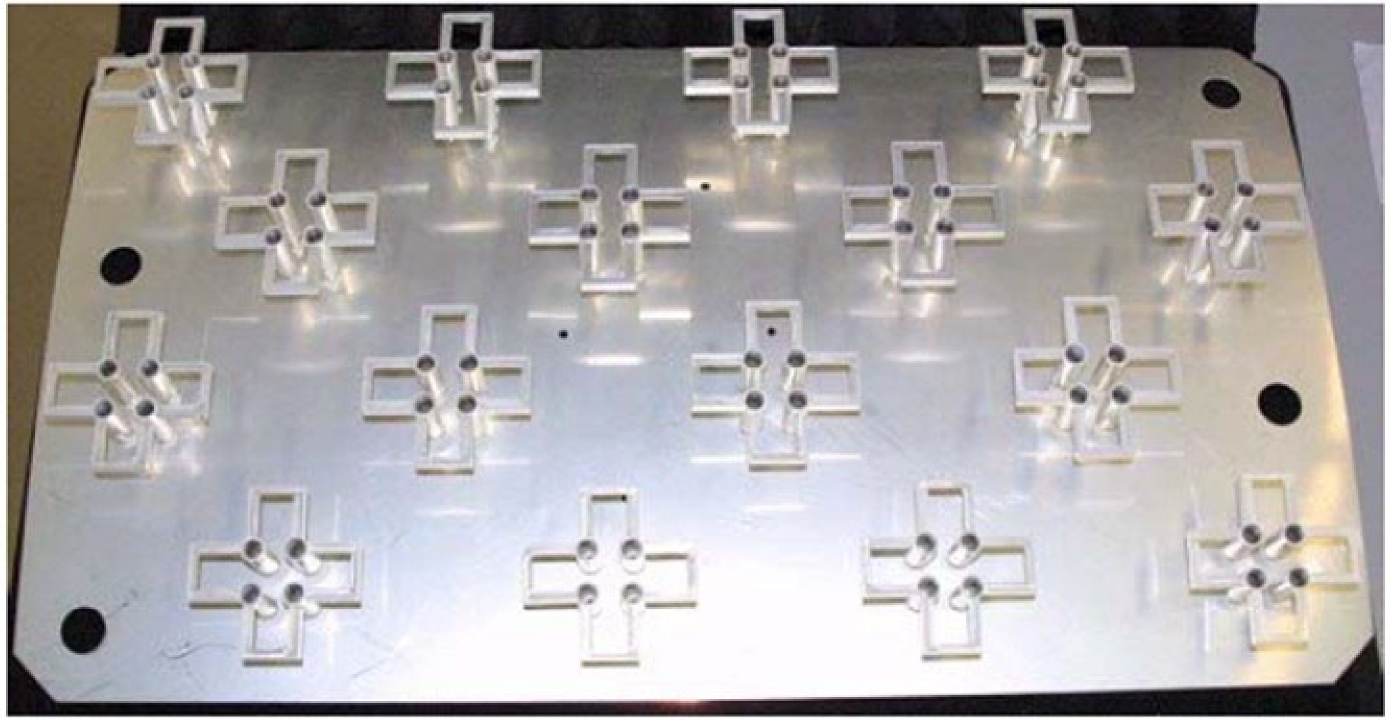




Example 1 : Antenna : fully metalized molded plastic

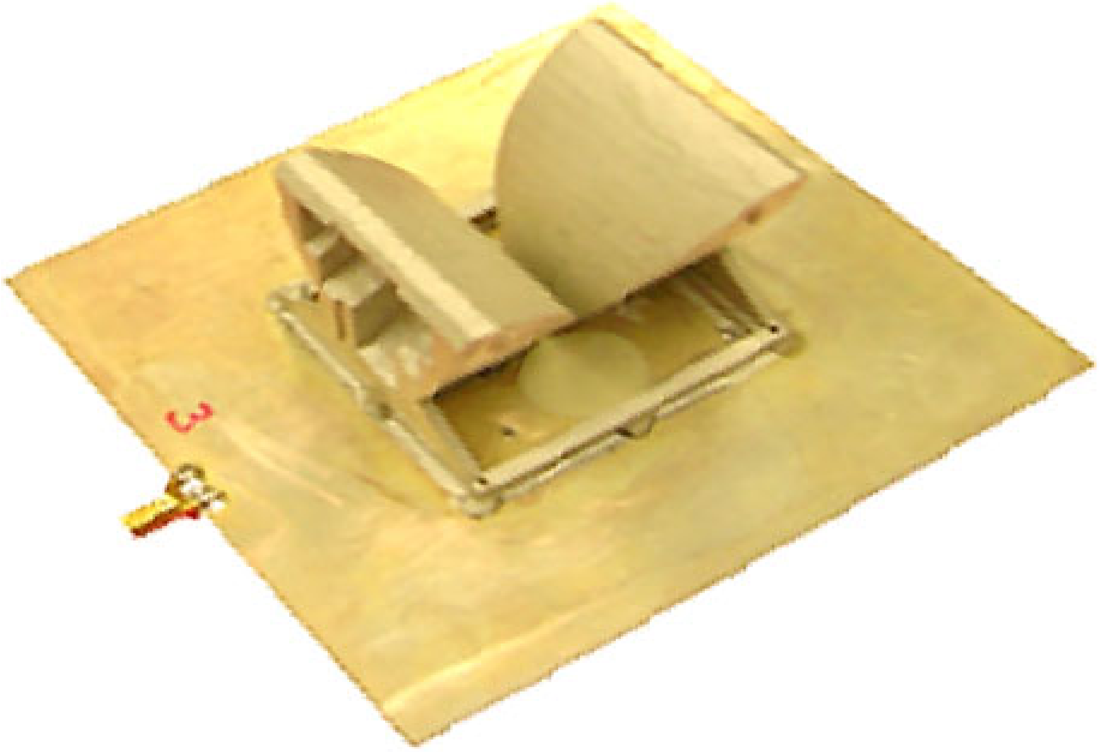
- **SMT mounted/soldered dual-polarized dipole-over-ground radiator for cellular (~ 2 GHz)**
- **large frequency bandwidth (result of structural complexity), low weight, mounting features**

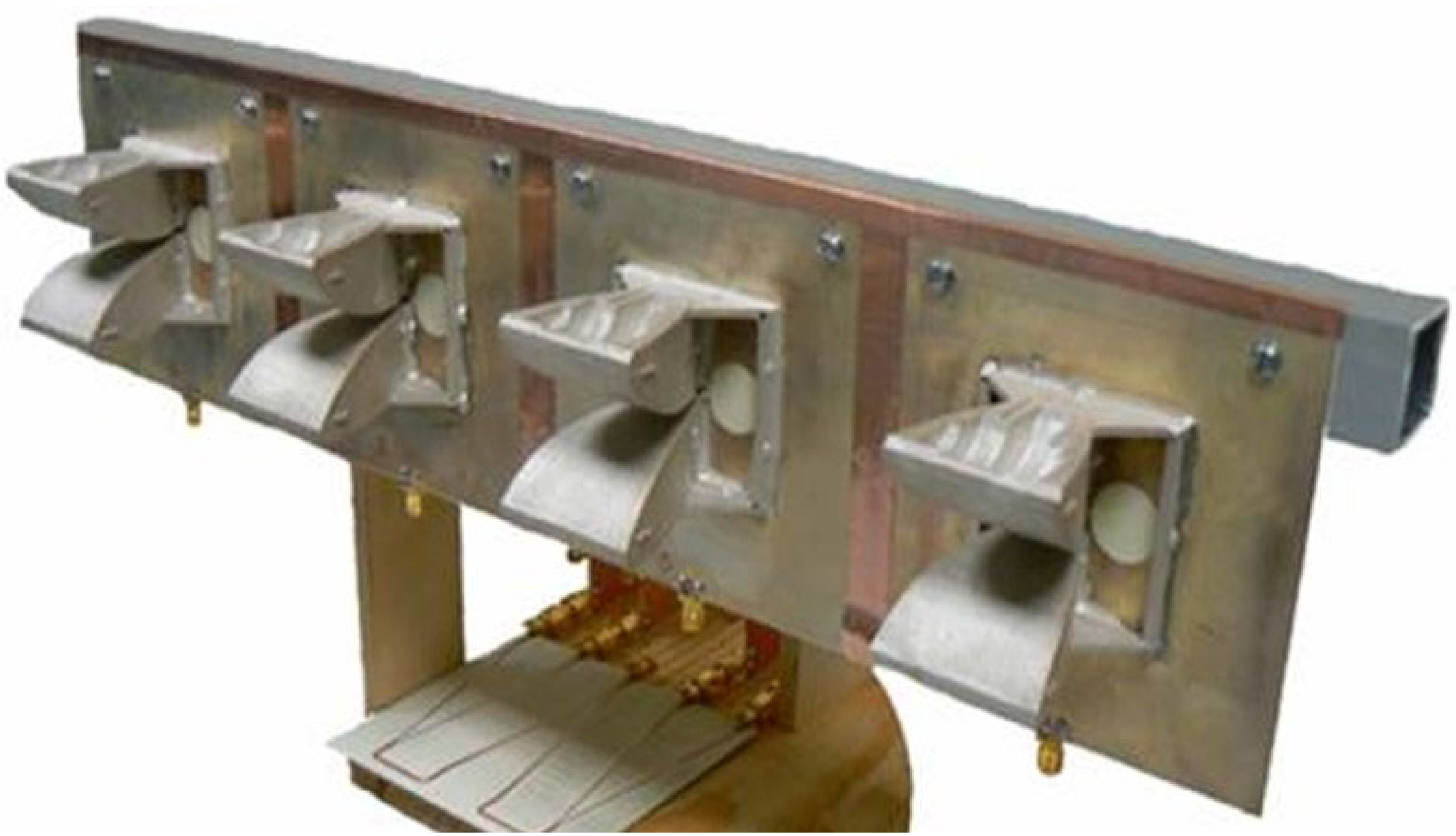




Example 2 : Antenna : fully metalized 3D-printed plastic

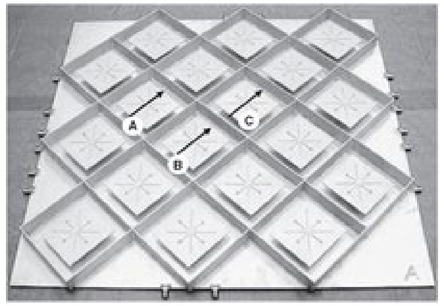
- research prototype 3D Vivaldi-type radiator for UWB (scaled, 1.9 GHz – 3.3 GHz)
- frequency-stable beam shape & large frequency bandwidth (result of structural complexity)

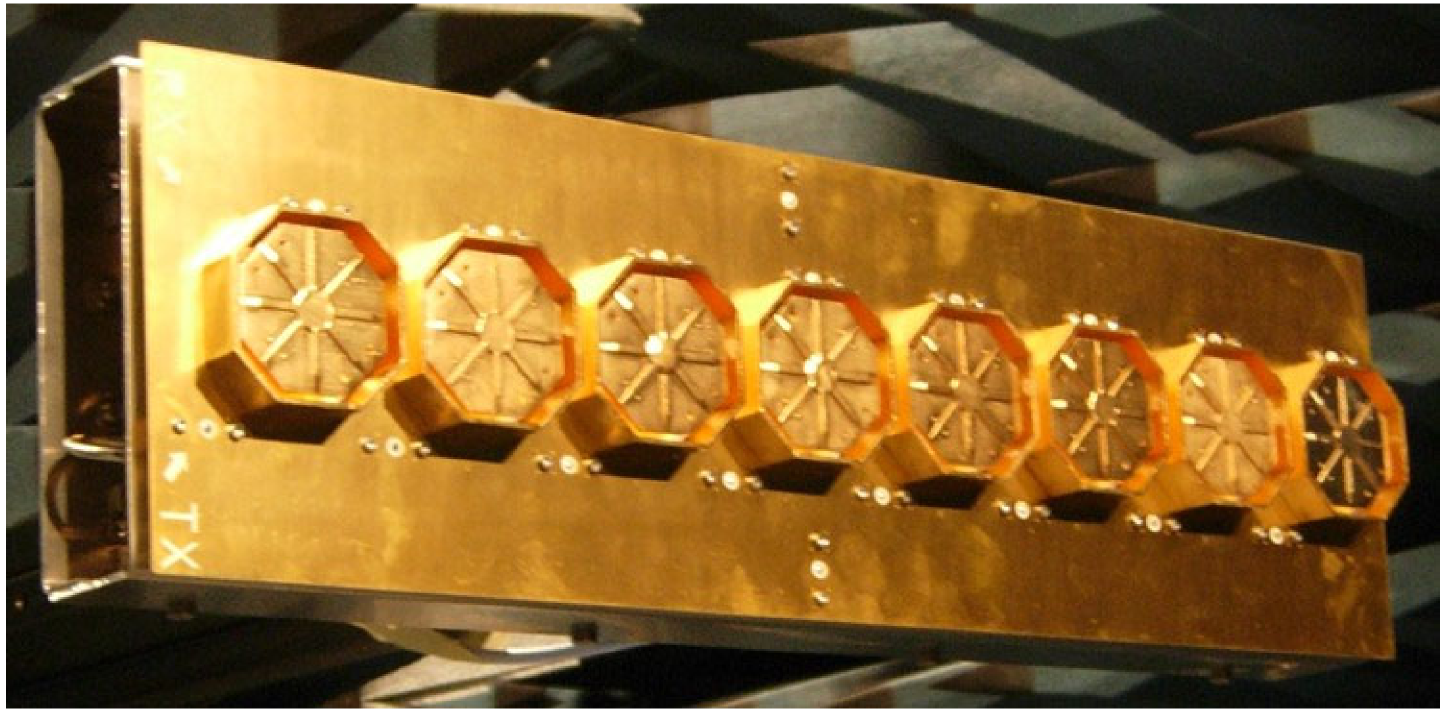




Example 3 : Antenna : fully metalized 3D-printed plastic

- research prototype 3D substrate-less dual-polarized patch antenna for cellular (~ 2 GHz)
- large frequency bandwidth (result of structural complexity), low weight, mounting features
- *unique*: no dielectric substrate for patch radiator (cost, weight, intermodulation, recycling)

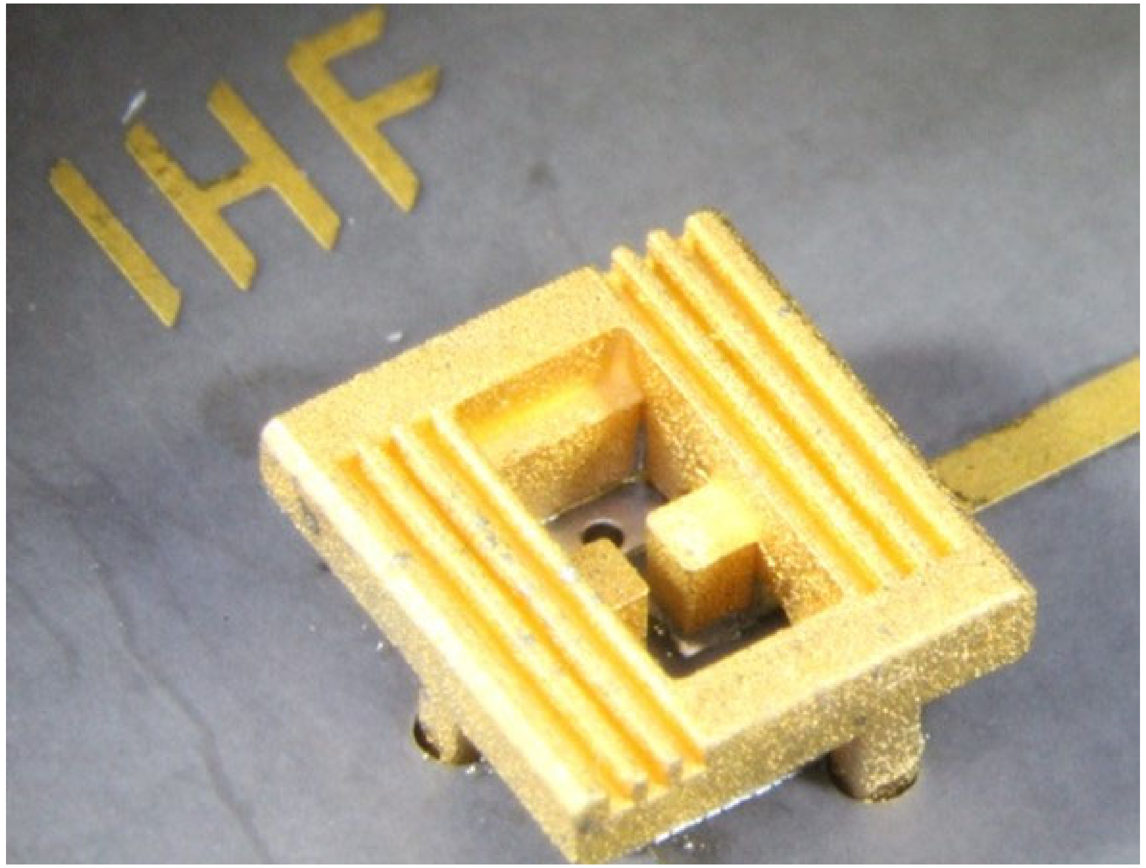


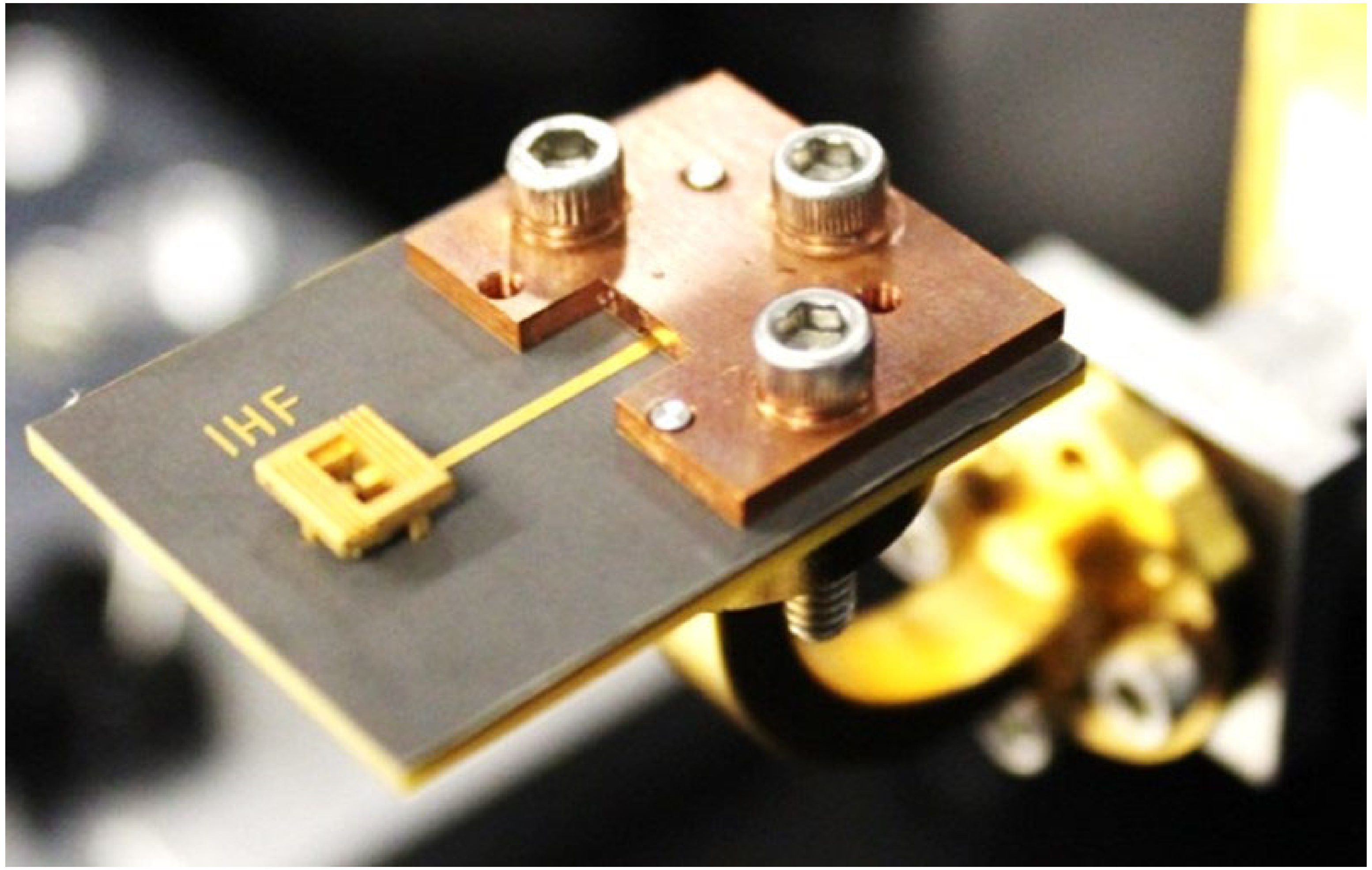


Example 4 : Antenna : fully metalized molded plastic

- **SMT mounted/soldered horn-type radiator for 60-GHz frequency band**
- **large frequency bandwidth (result of structural complexity), record-high efficiency (low loss)**

[component of IMS Connector Systems]





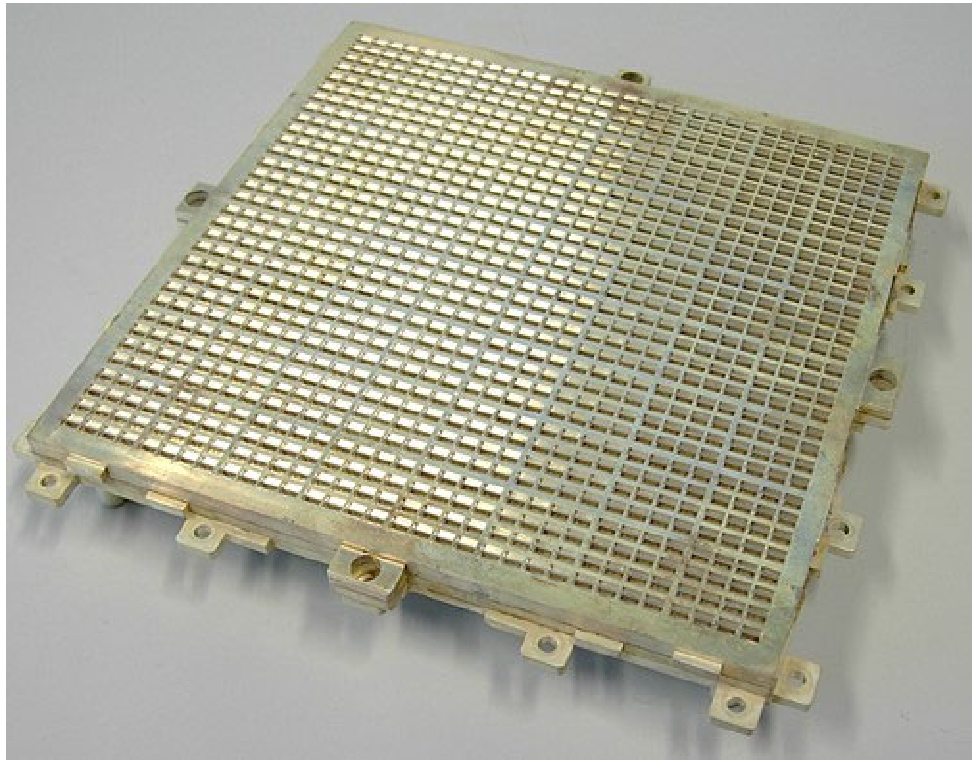
Example 5 (1/2) : Antenna : fully metalized molded plastic

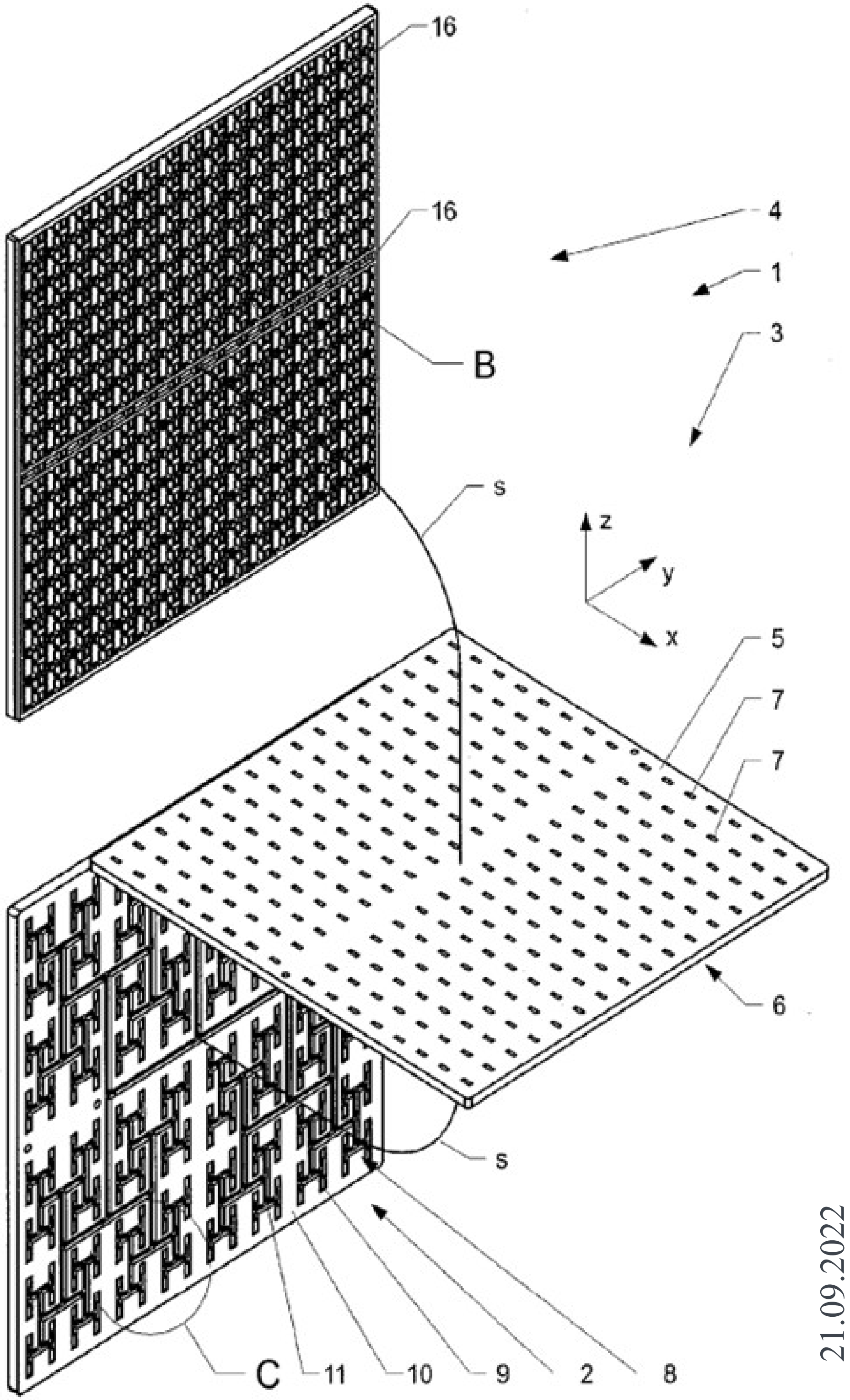
- connectorized 32x32-element open-ended-waveguide array with 1:1024 divider (60-GHz-band)

- large frequency bandwidth (result of structural complexity), record-high efficiency (low loss)

- *unique*: smaller size (both area and depth) than equivalent parabolic mirror antenna

[component of Huber+Suhner]





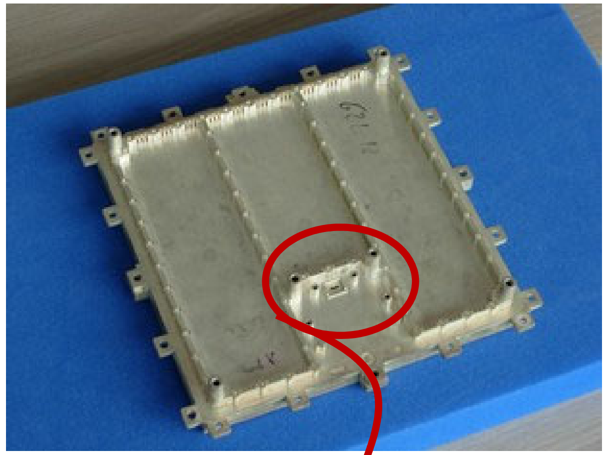
Example 5 (2/2) : Antenna : fully metalized molded plastic

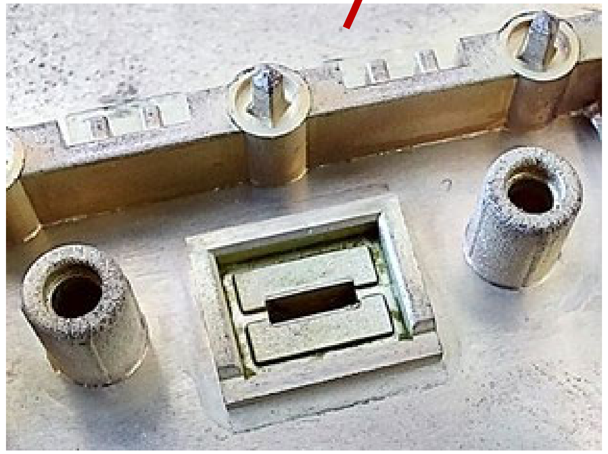
- connectorized 32x32-element open-ended-waveguide array with 1:1024 divider (60-GHz-band)

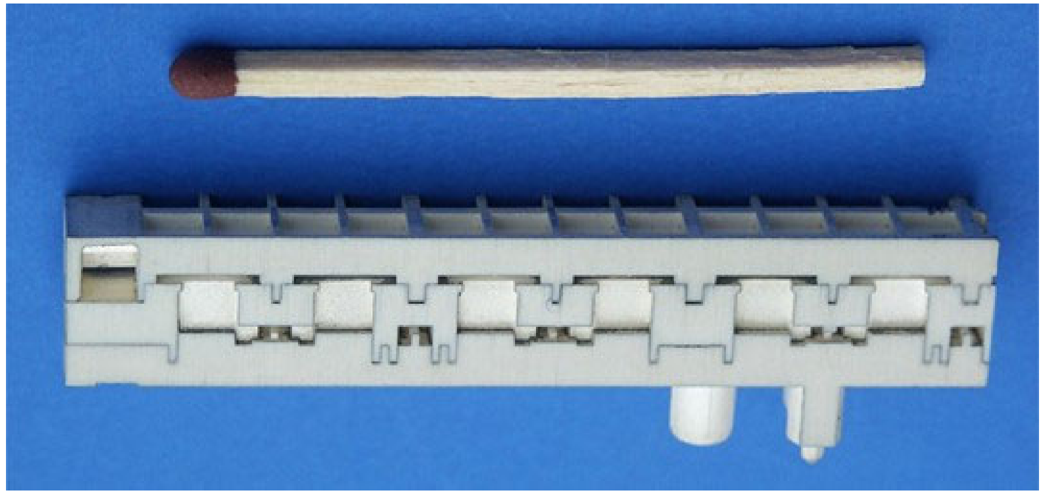
- large frequency bandwidth (result of structural complexity), record-high efficiency (low loss)

- *unique*: smaller size (both area and depth) than equivalent parabolic mirror antenna

[component of Huber+Suhner]



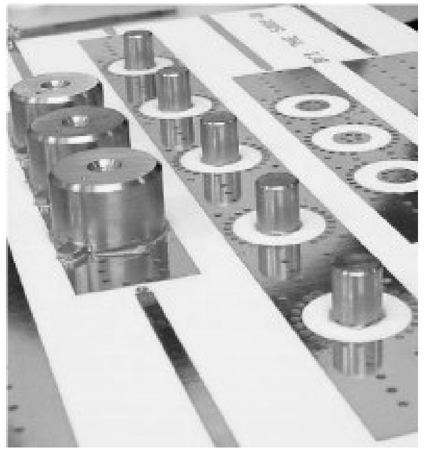


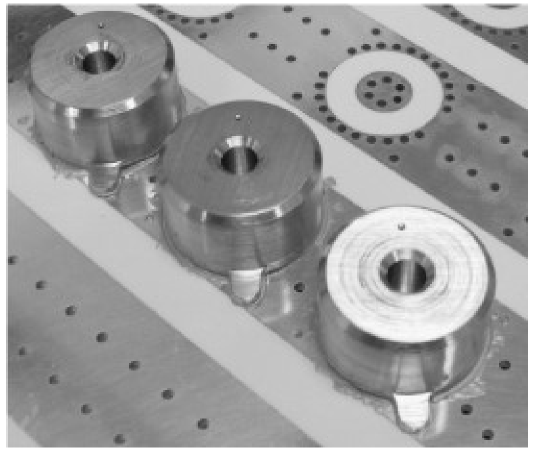


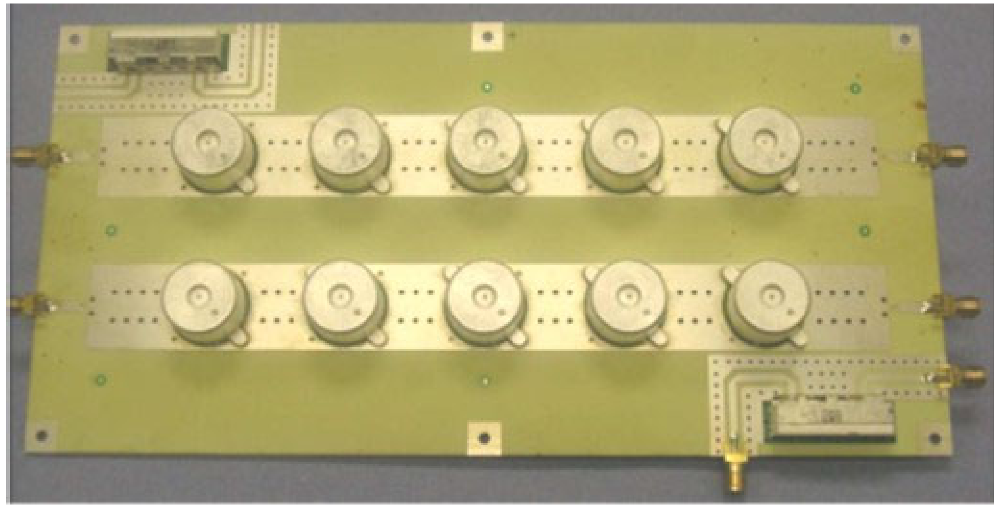
Example 6 : Bandpass frequency filter : fully metalized molded plastic

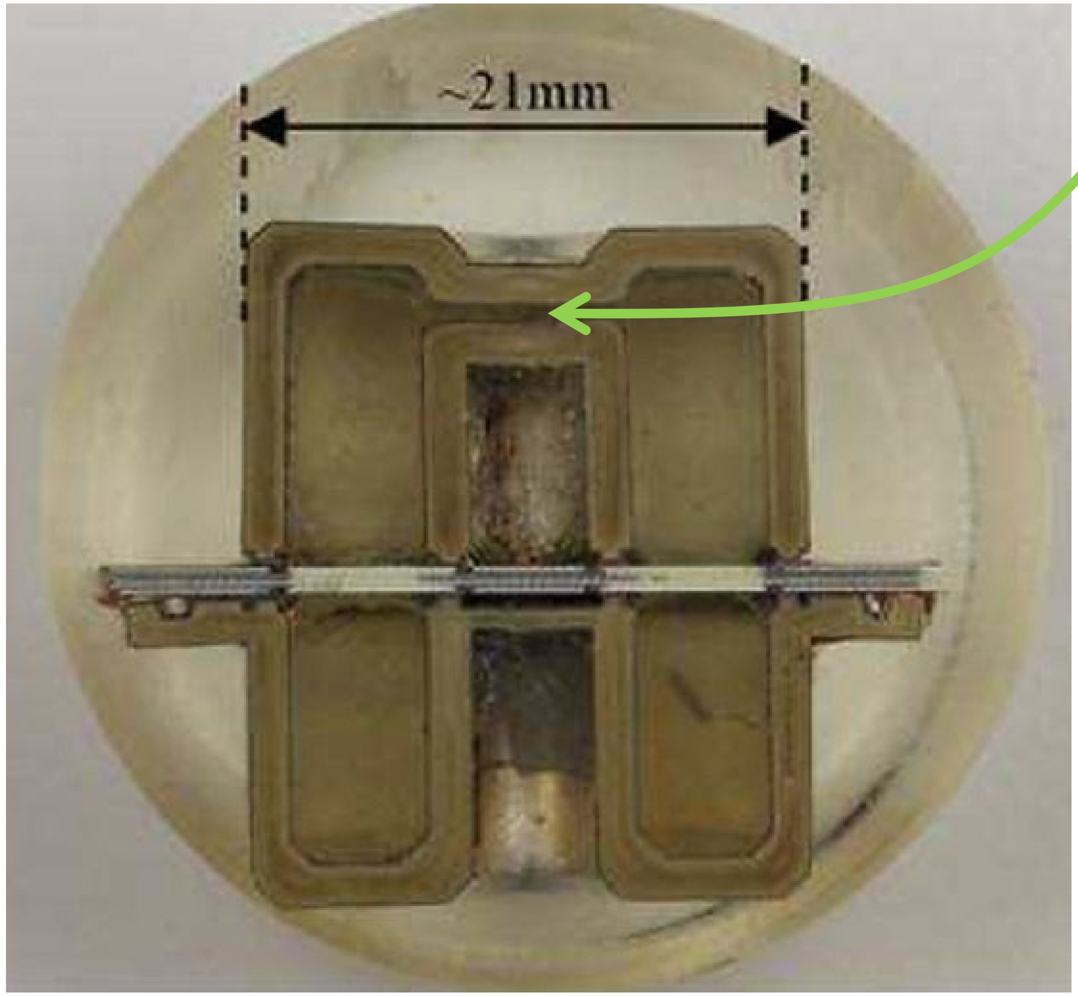
- SMT mounted/soldered re-entrant coax resonator(s) (~2 GHz)

- *unique*: much lower loss than board-based filters, much simpler than full-3D filters





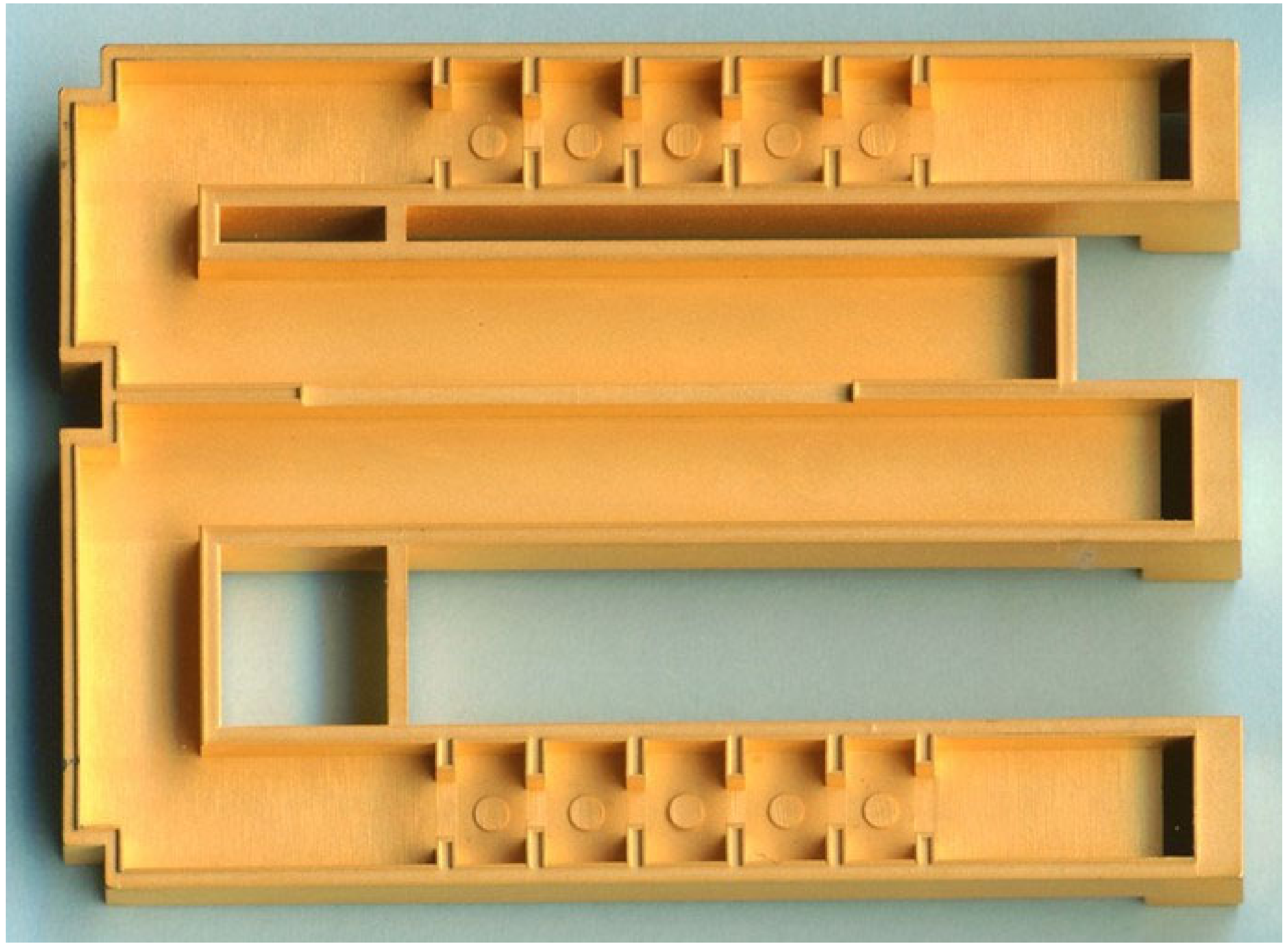




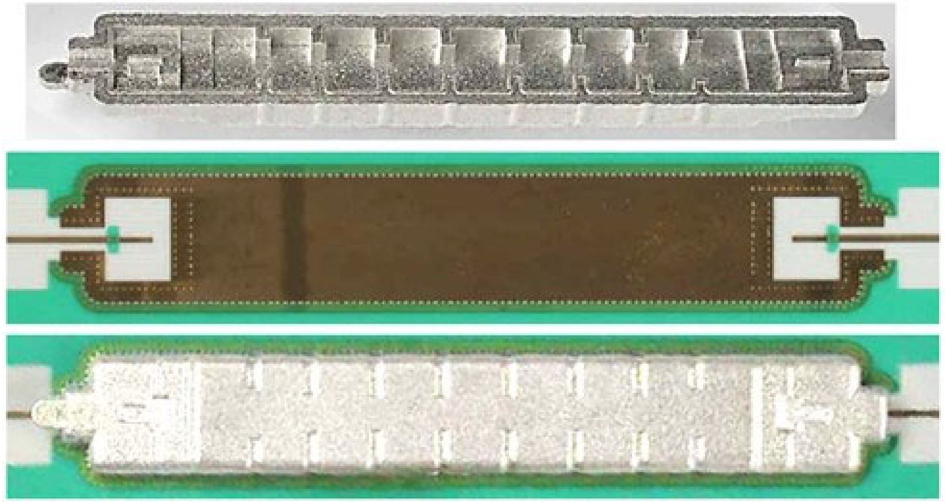
critical gap distance
(dielectric spacer?)

Example 7 : Bandpass frequency filter : fully metalized molded plastic

- SMT mounted/soldered rectangular waveguide iris filter (diplexer) (~33 GHz)
- rods in molding form to adjust for parts-shrinkage and large-quantity abrasion correction



Assembly concept:

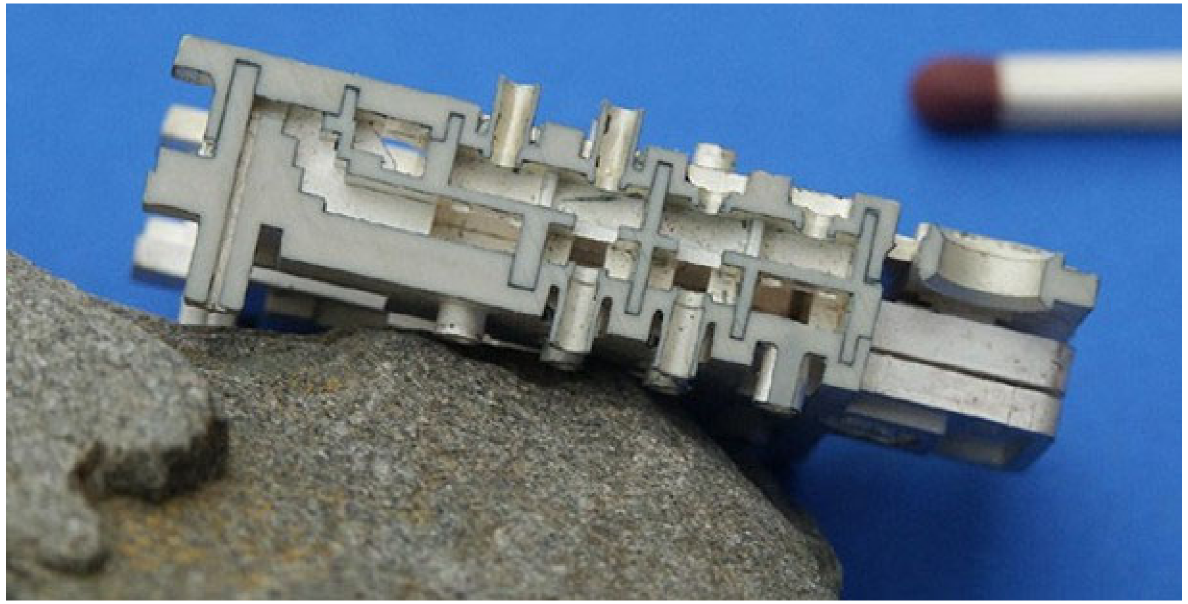


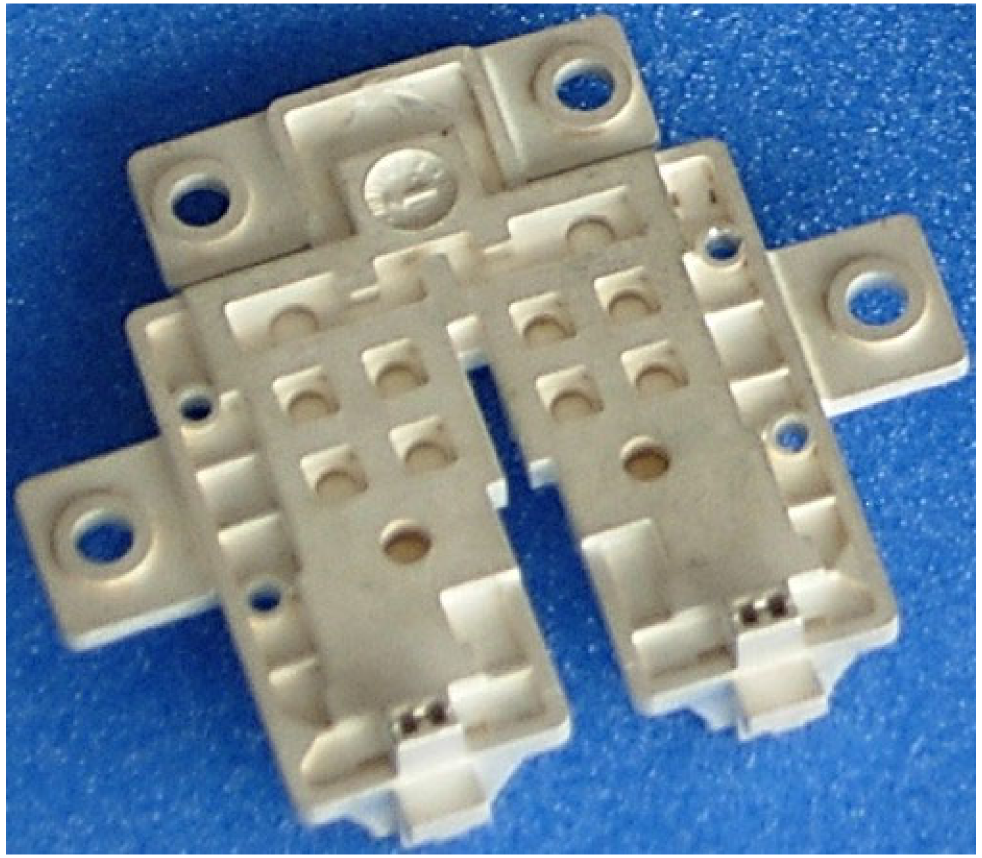
[component of EADS]

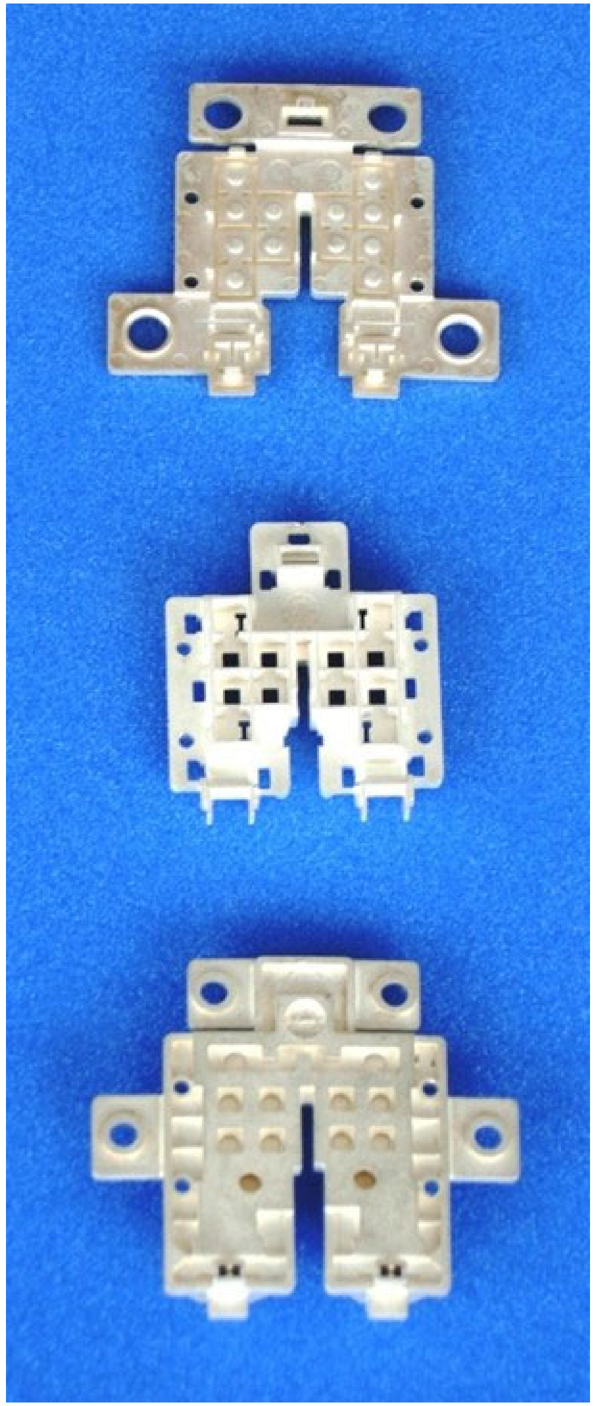
Example 8 : Bandpass frequency filter : fully metalized molded plastic

- rectangular waveguide iris filter (diplexer) (~60 GHz)
- rods in molding form for adjustments
- *unique*: specific in/out connections (replacing screwed flanges)

[component of Huber+Suhner]



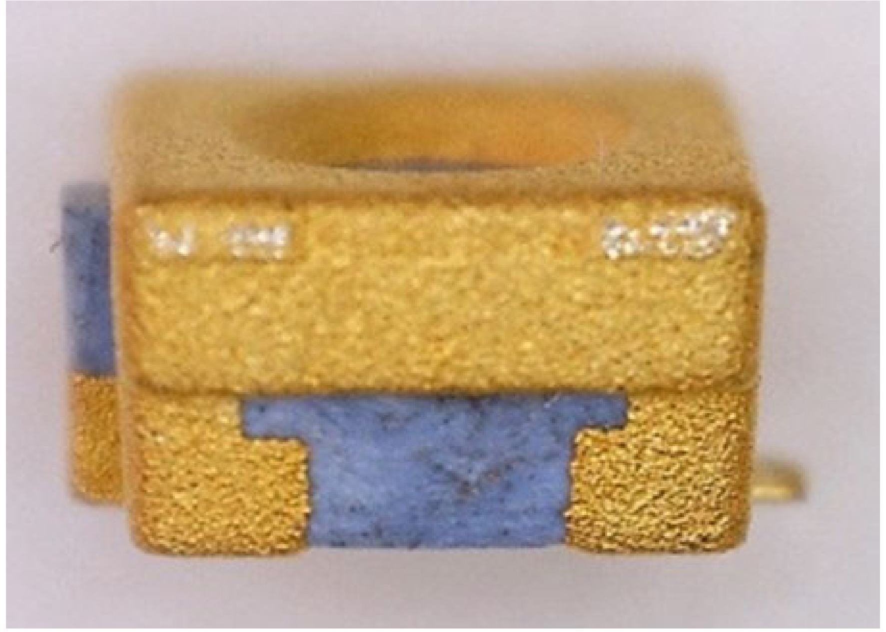


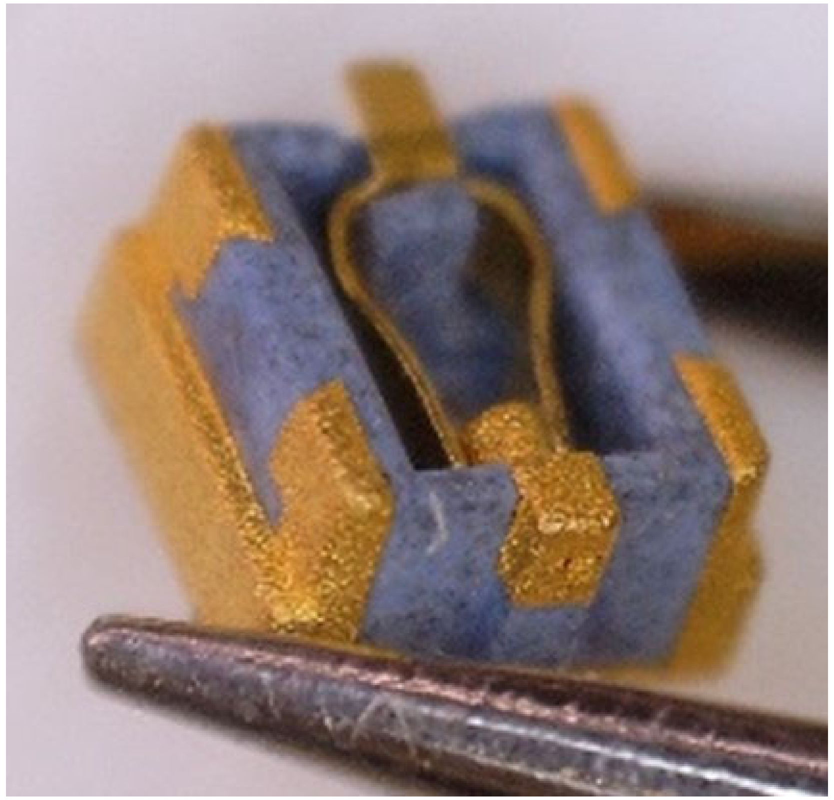


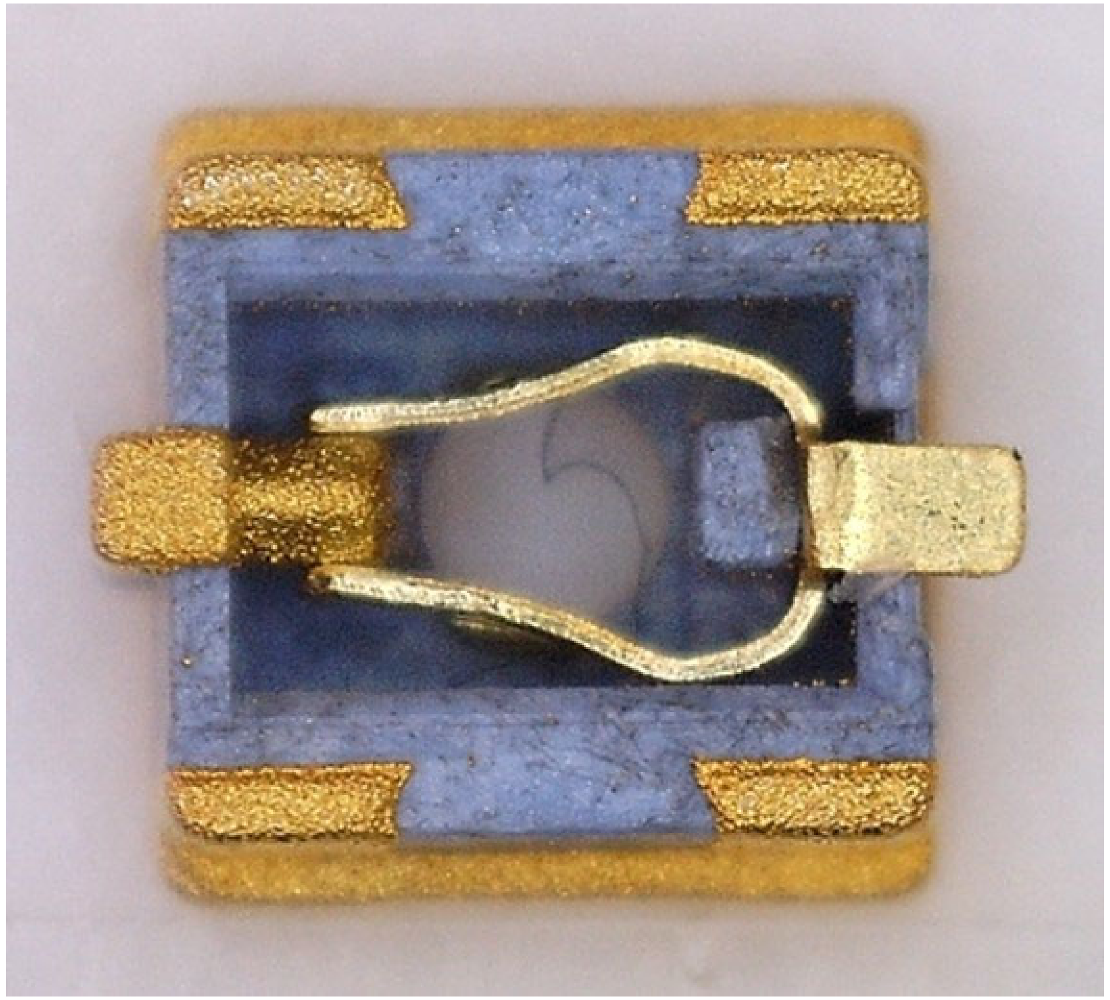
Example 9 : Connector : partly metalized dual-molded plastic

- SMT mounted/soldered coaxial connector with switch (3 GHz)

[component of IMS Connector Systems]





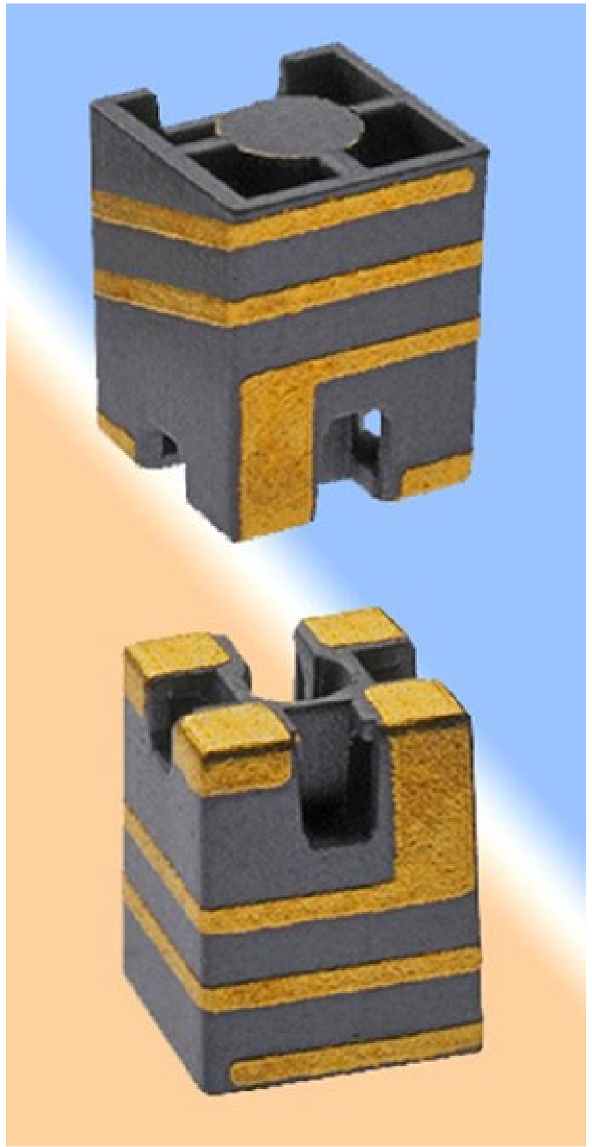


Example 10 : Antenna : partly metalized (laser-actuated metalization) molded plastic

- SMT mounted/soldered LDS antennas

[pictures taken from catalogue/datasheets of Molex]

bi-filar helix antenna (2.4 GHz)



PIFA (1.575 GHz)

12 x 12 x 6mm^3

dual-band (2.4 GHz & 5-6 GHz)

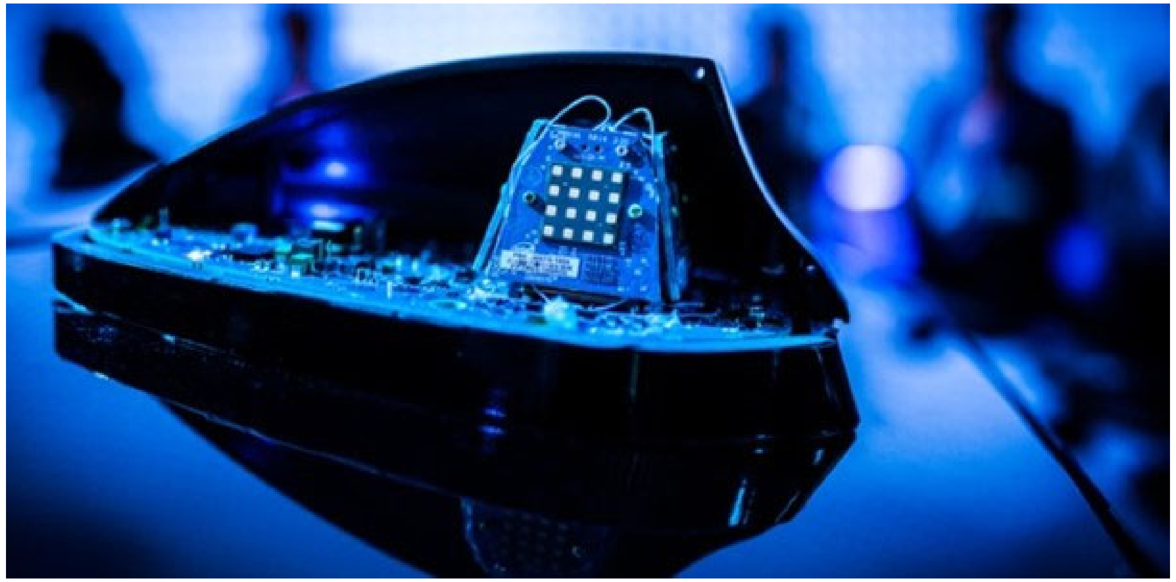
3 x 5 x 4 mm^3

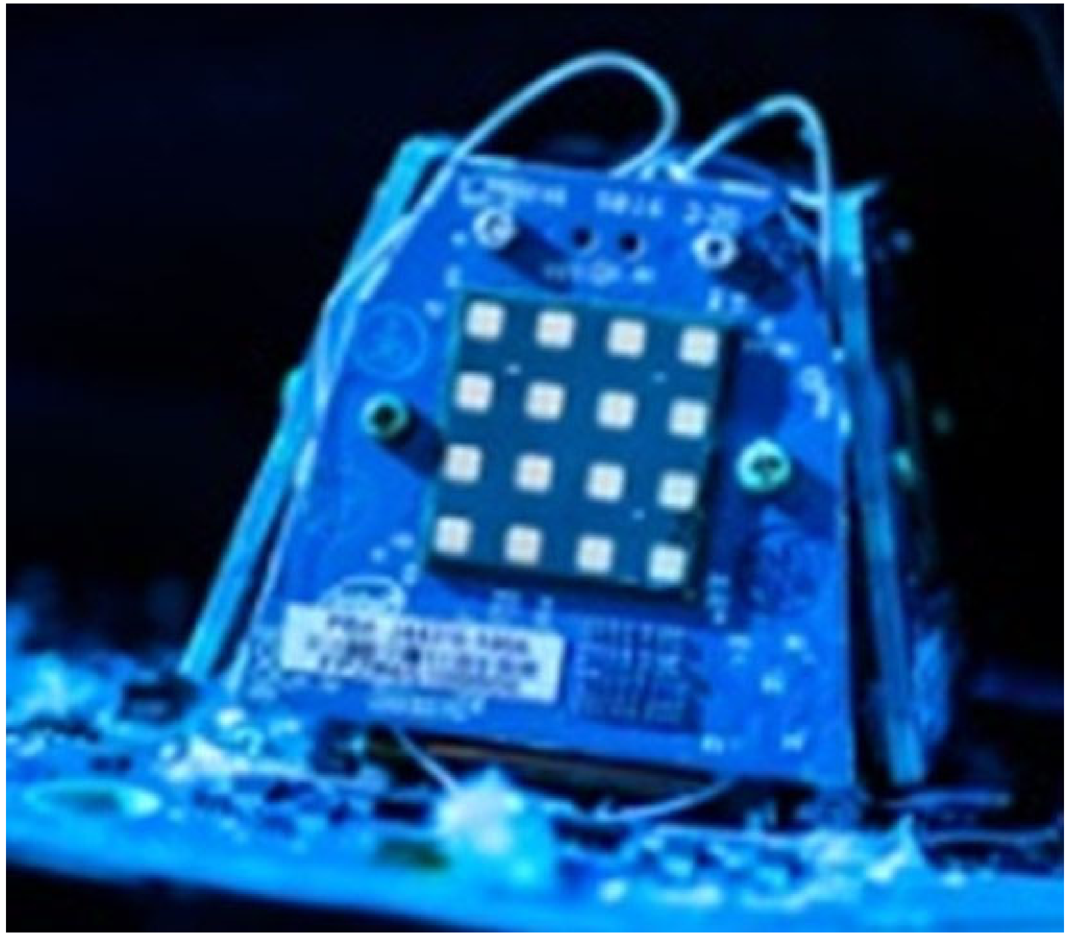
Example 11 (1/4) : sub-system : partly metalized (laser-actuated metalization) molded plastic

- project "KOM-MID": 28 GHz LDS-MID sub-system with active electronics and antennas

- problem: 5G shark-fin car-roof antenna with hemi-spherical coverage: ridiculous packaging

[Ericsson/Intel 5G trial, 2017]

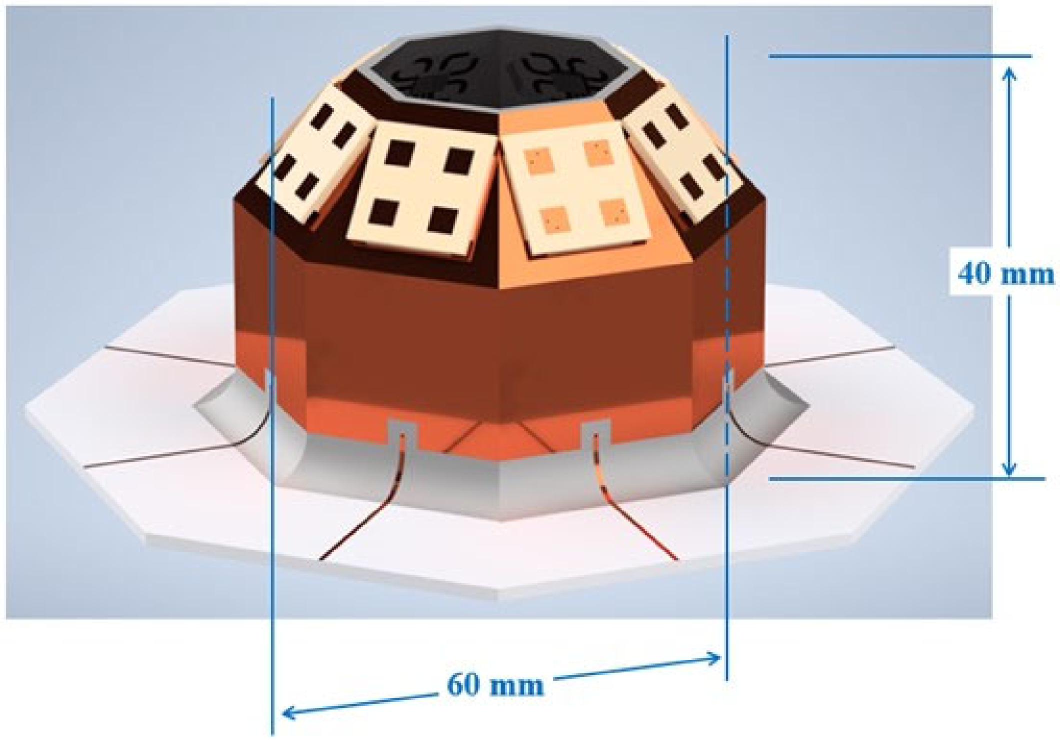


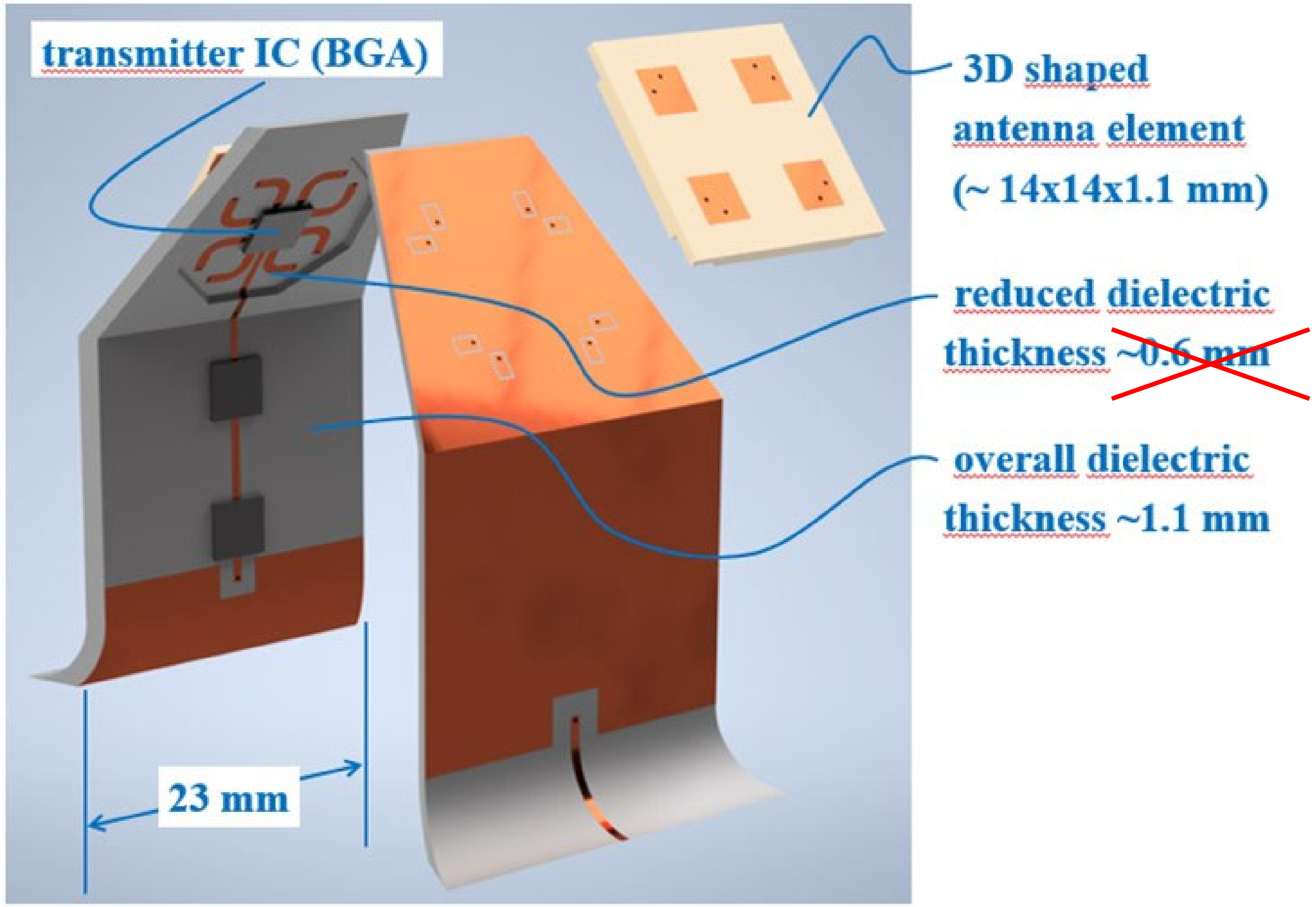


Example 11 (2/4) : sub-system : partly metalized (laser-actuated metalization) molded plastic

- project "KOM-MID": 28 GHz LDS-MID sub-system with active electronics and antennas

+ basic 3D structure for hemi-spherical beam steering:





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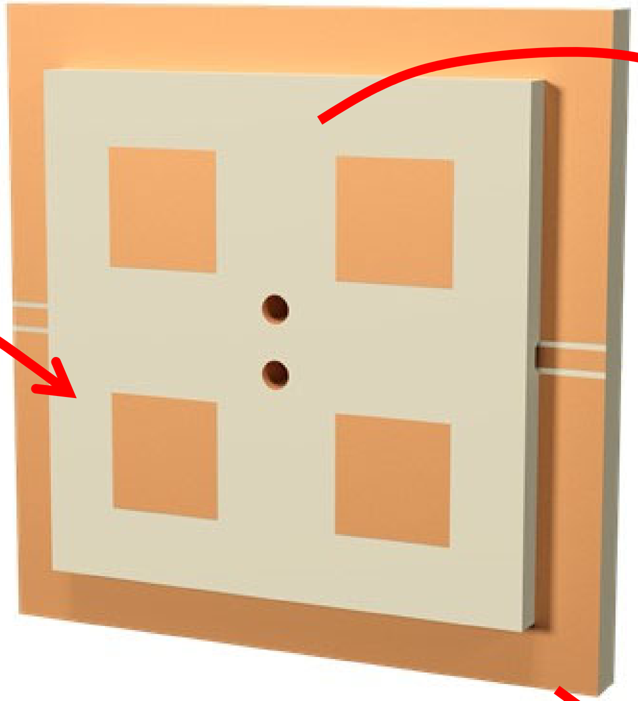
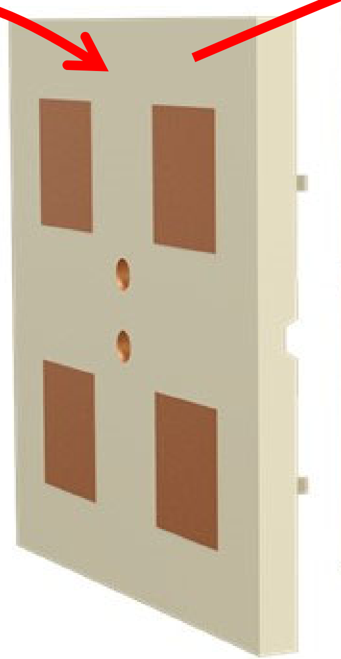
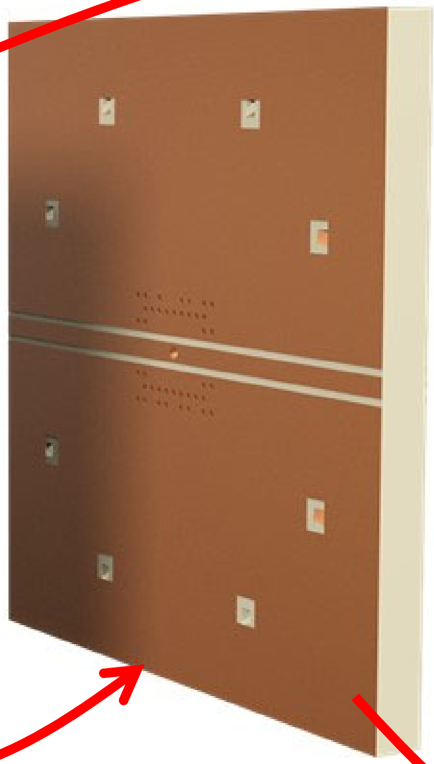
Example 11 (3/4) : sub-system : partly metalized (laser-actuat

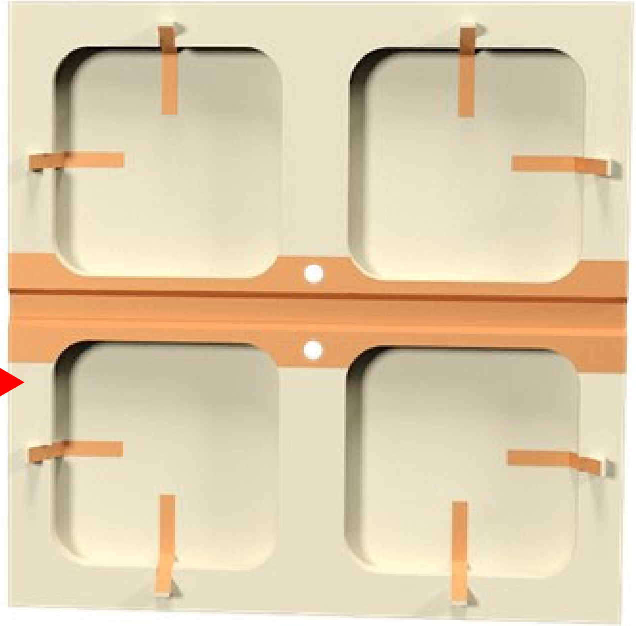
- project “KOM-MID”: 28 GHz LDS-MID sub-system with activ

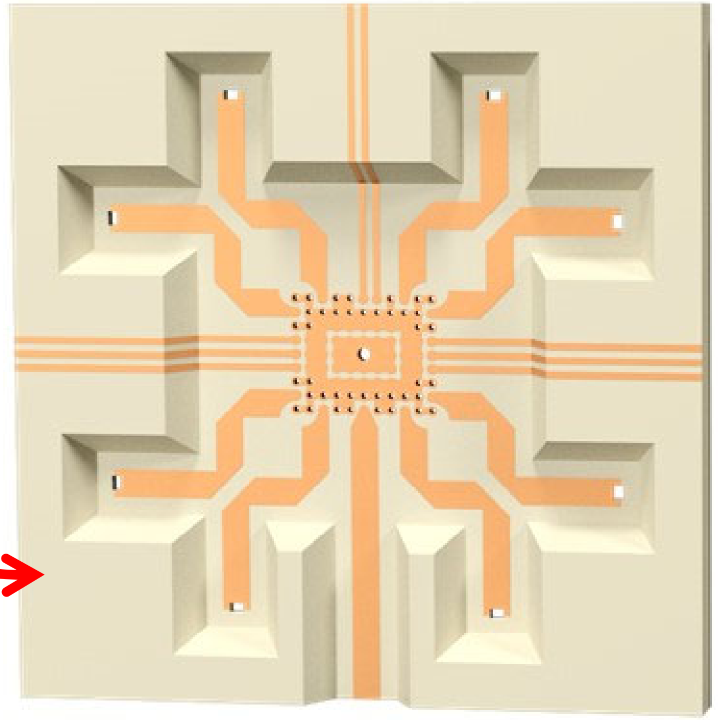
+ LDS-MID 3D parts: “antenna” mounted on “sector”:











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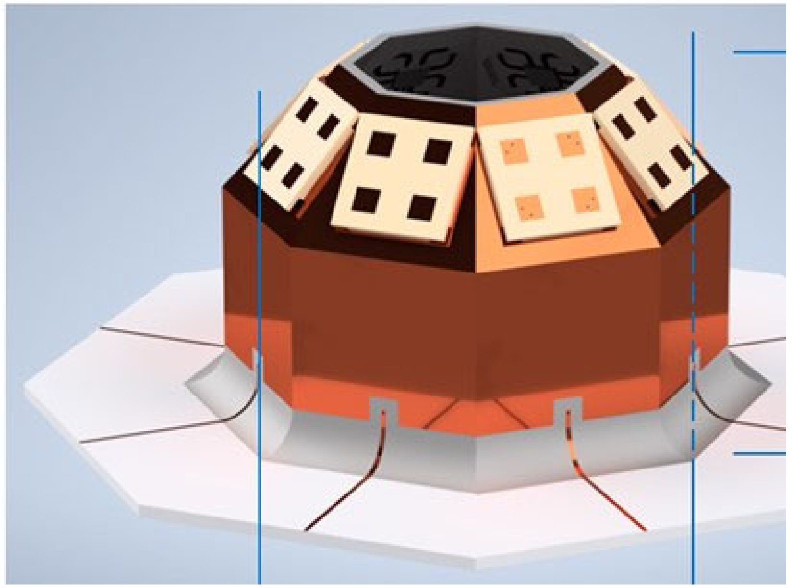
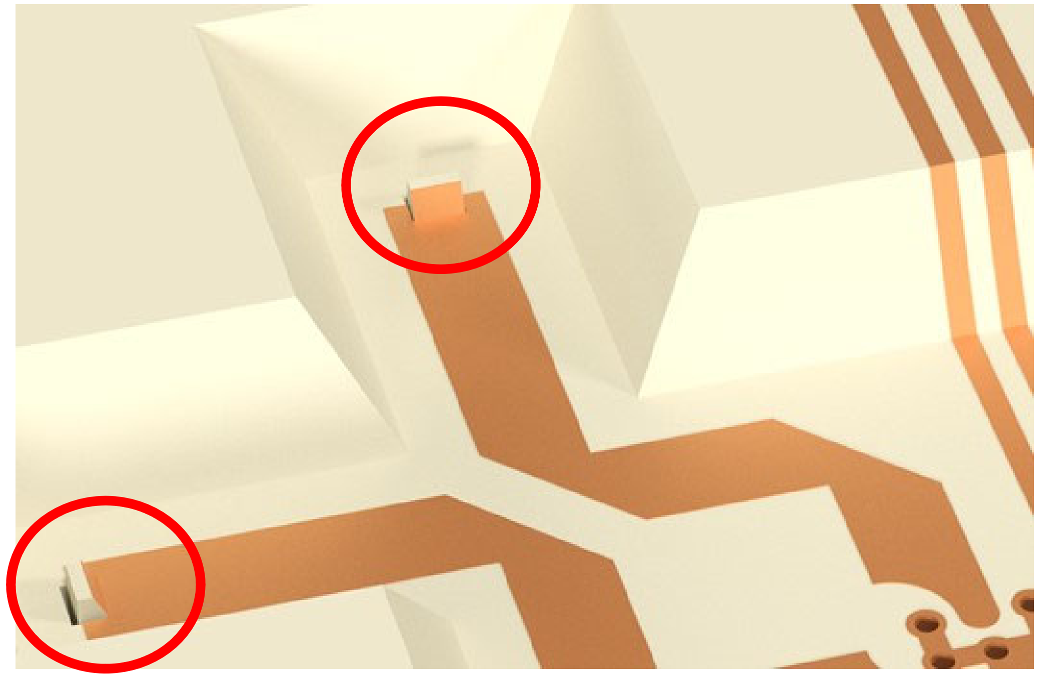
Example 11 (4/4) : sub-system : partly metalized (laser-actuated metalization) molded plastic

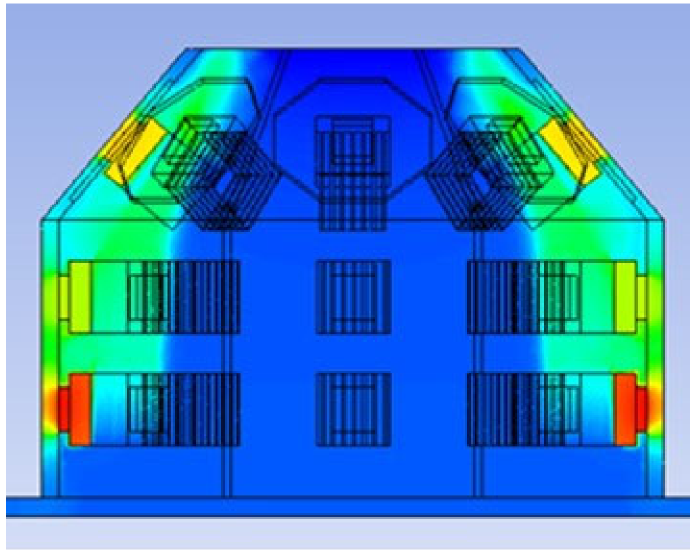
- project "KOM-MID": 28 GHz LDS-MID sub-system with active electronics and antennas

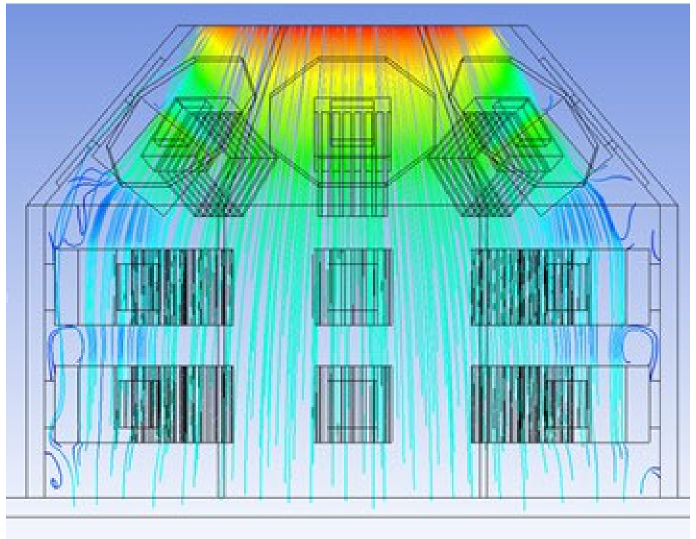
+ technical challenges: connection for 28 GHz; thermal management





metalized tilted slope plug+pin





forced flow of air with cooling fins (temp, flow):

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Conclusion:

- **specifics of metalized-plastic technology must be respected in applications of mm-wave**

  + structural shape (indentations, shadowing), detail size & accuracy, quantity & NRE-costs

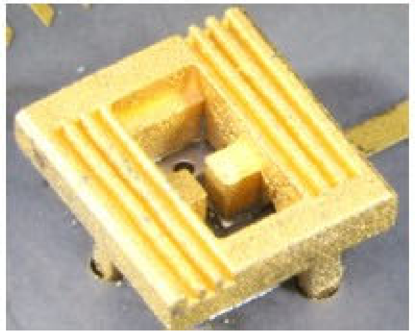
- **suitable application cases result in unique performance and competitive cost**

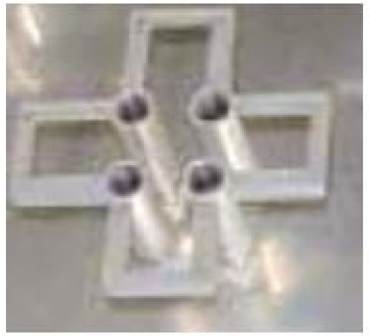
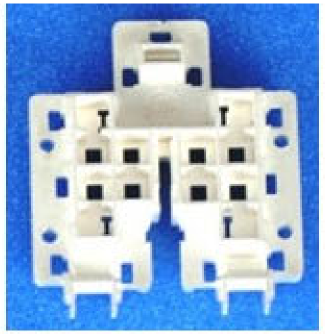
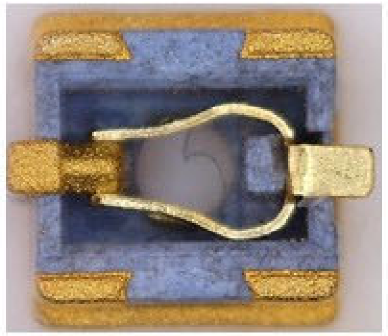
  low RF signal loss

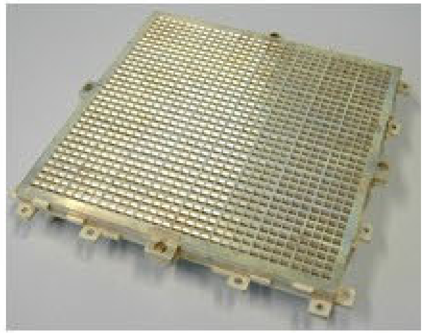
  complex features (interconnects, cooling, assembly)

  standard solderability

  low weight

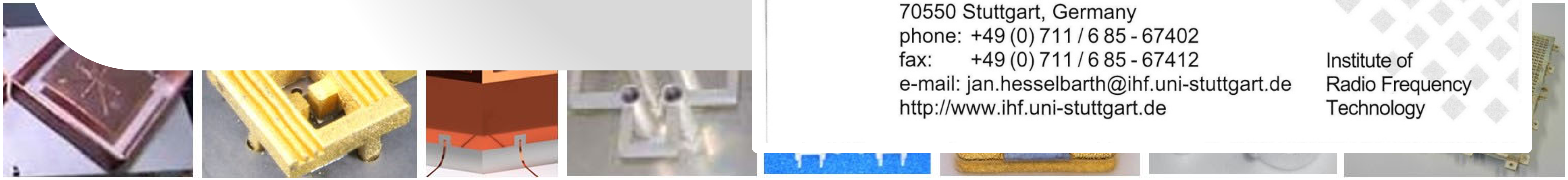





Thank You

Questions?

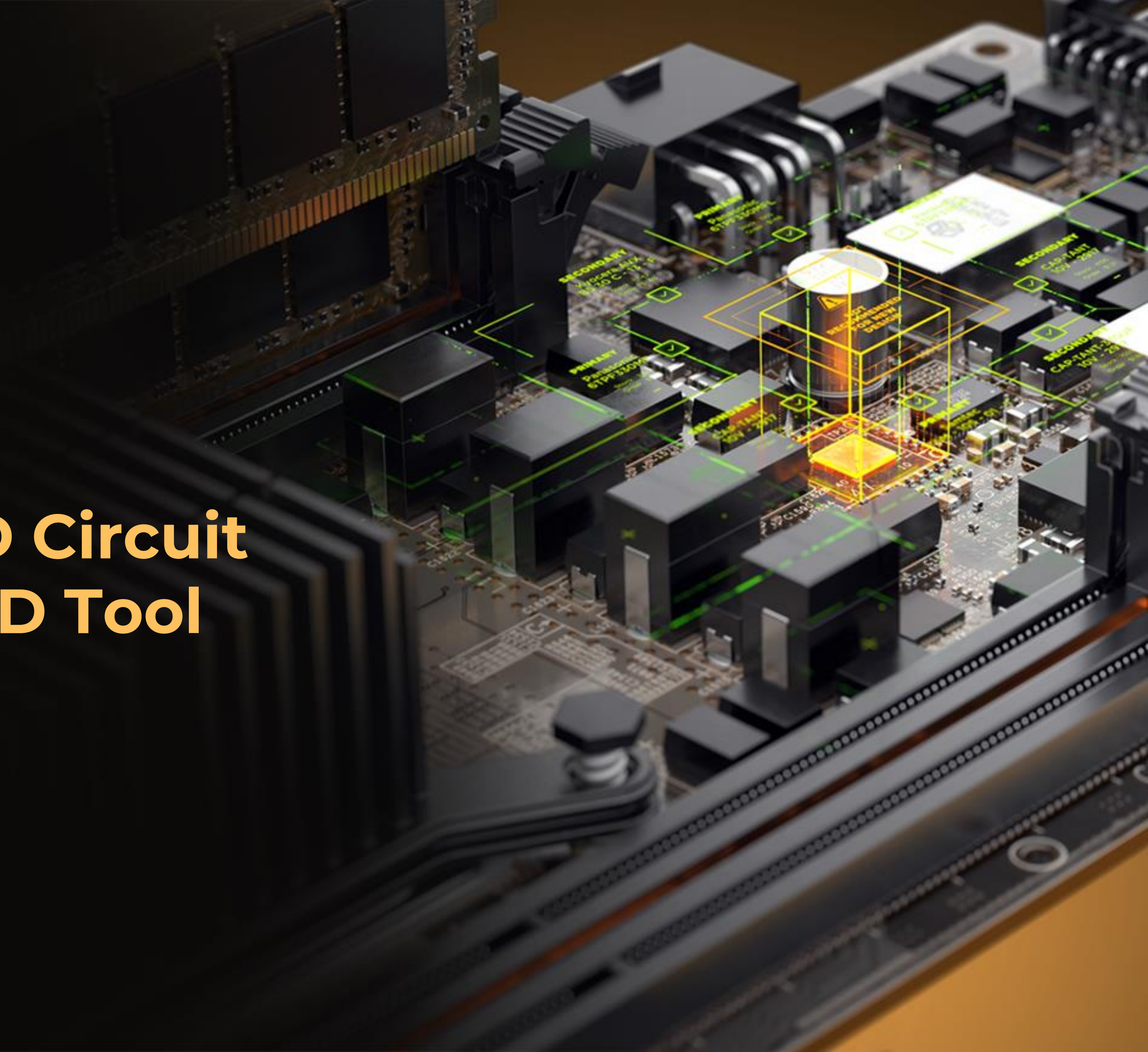


Altium

Advantages of 3D Circuit Design in an ECAD Tool

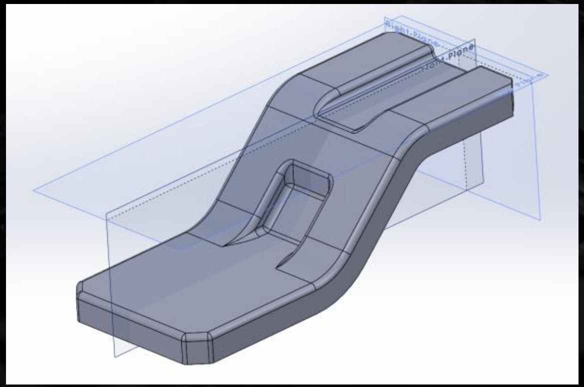
September 21, 2022

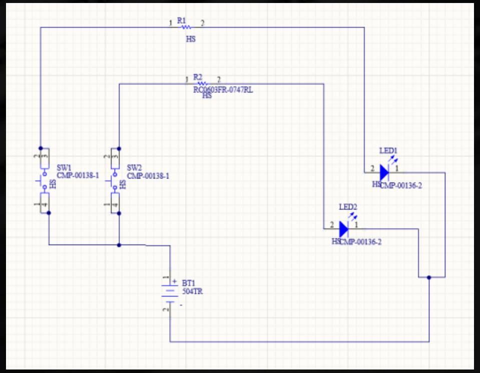
Christian Röck
Field Application Engineer



Current situation

- **MID - Who's domain is that ?**
  - Mechanical or Electrical
  - actually both as it is a combination
- **What tools are used ?**
  - Mechanical tools
    - used for the mechanical part
    - electrical either complex and multiple exchange based on 2D files
    - or time consuming "Freehand" Design
  - Electrical tools
    - not able to support 3D
    - need complex import - export based on 2D File formats
    - multiple repeats of manual file exchange





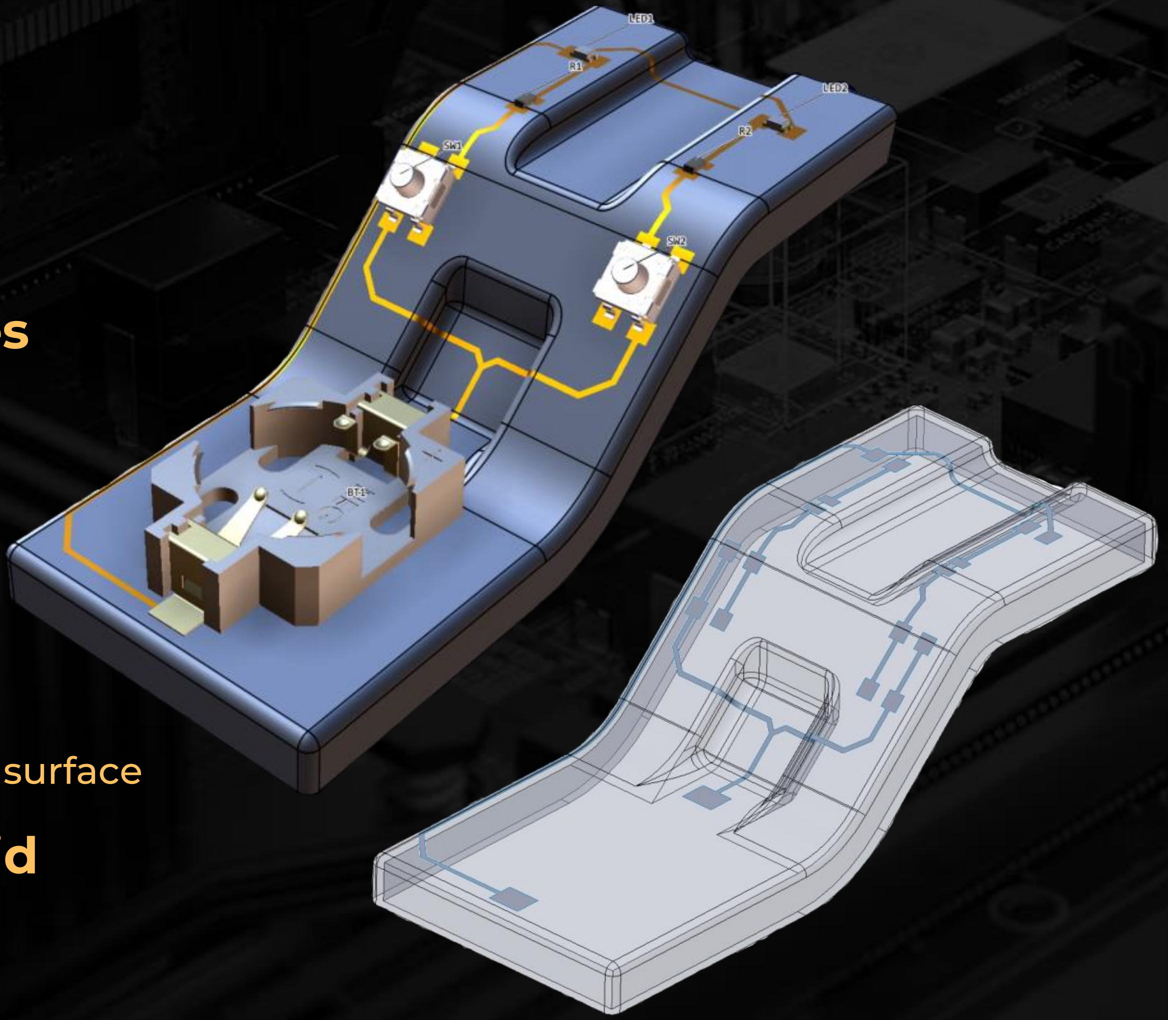
Designing with MCAD only

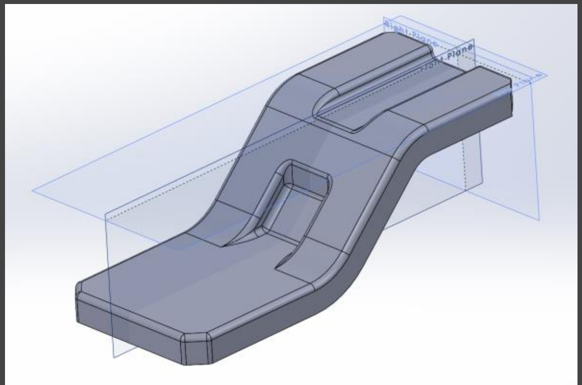
- Disconnected and Distorted Projected Trace Sketches
- Logically Disconnected
- No ECAD Component Library
- Time Consuming "Freehand" PCB design

A Better Solution

Altium®

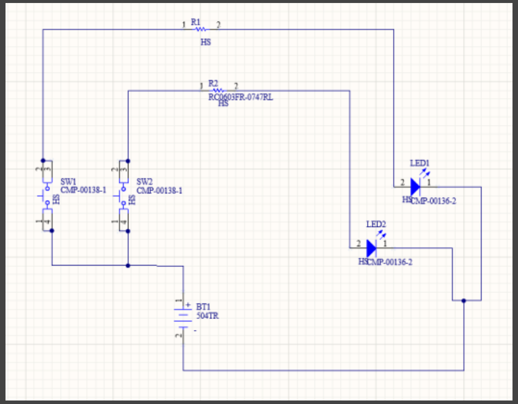
- **Netlist Displayed Connections**
  Optimize routing with better component placement
- **Clearance and Connection Check Rules**
  Prevent mechanical and electrical problems
- **100.000s Components Available**
  Save time making use of existing component models
- **Direct 3D Routing Over Substrate**
  Speed up routing by laying traces directly over the 3D surface
- **Output Formats STEP, IGES or Parasolid**

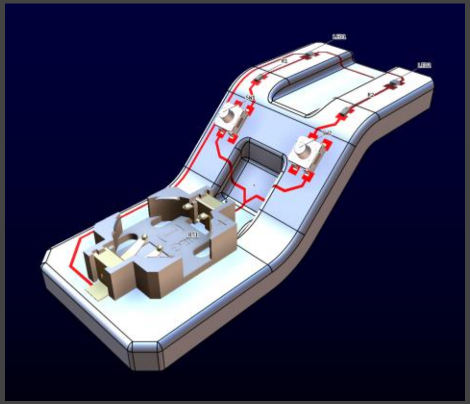




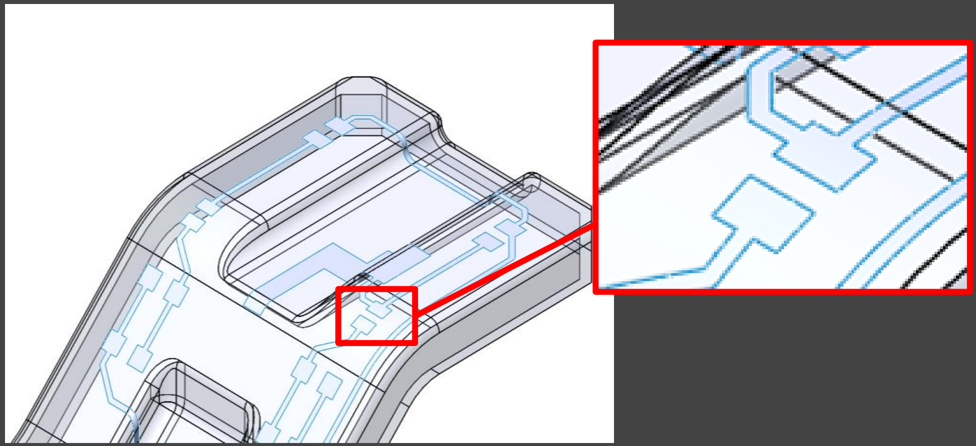
Substrate Design in MCAD

STEP/IGES





Circuit Design in Altium Designer



STEP/IGES/PARASOLID

Thank you

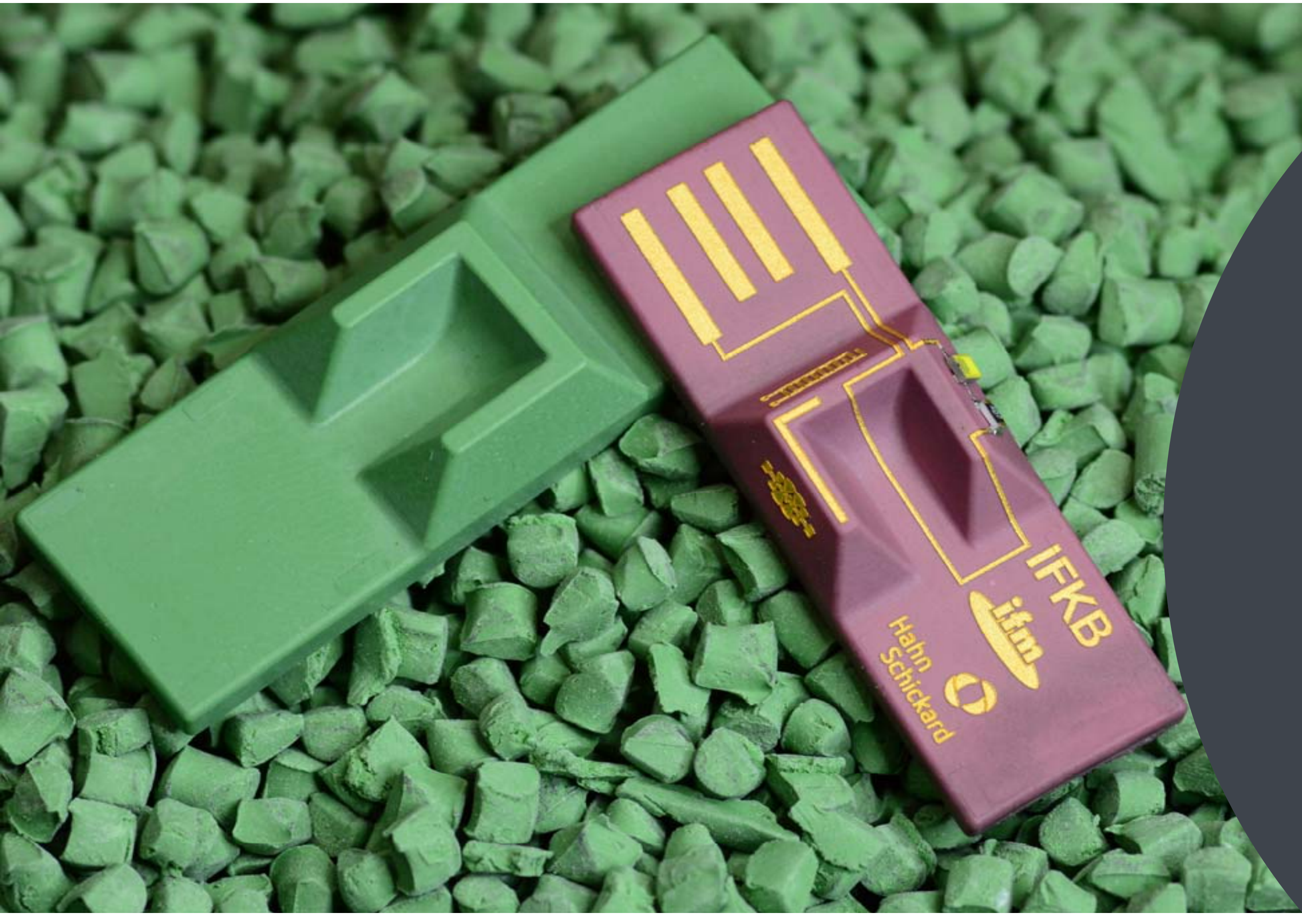
christian.roeck@altium.com

University of Stuttgart
Institute for Micro Integration
ifm

University of Stuttgart
Institute for Manufacturing Technologies of Ceramic Components and Composites
IFKB

Hahn Schickard
Visions to Products

3-D MID



Metallization of oxide ceramic substrates via laser-induced direct metallization

Dr. Ing. Philipp Ninz

M.Sc. Alexander Schilling

At the MID Summit & MID Workshop 2022, Böblingen, Germany

By th Research Association Mechatronic Integrated Devices 3-D MID e.V.

Who we are and what we do

Universität Stuttgart

Institute for Manufacturing Technologies of Ceramic Components and Composites

IFKB

Contact: Apl. Prof. Frank Kern
Dr. Philipp Ninz

Research Focus on Ceramics:

- High Performance Ceramics
- Surface and Coating Technologies
- Composite Materials

Temp. Director: Apl. Prof. Andreas Killinger

Institute for Micro Integration

ifm

Contact: M.Sc. Alexander Schilling

Research Focus:

- Micro- and Nanostructuring
- Functional Packaging
- Basic research for and with Hahn-Schickard

Director: Prof. André Zimmermann

Hahn Schickard Stuttgart

Applied research, development and production services for industry

Contact: Dr. Andrea Knöller

Research Focus on Microtechnology:

- Sensors. Everywhere!
- Optical Microsystems
- Rapid Manufacturing
- System-in-foil
- 3D electronics

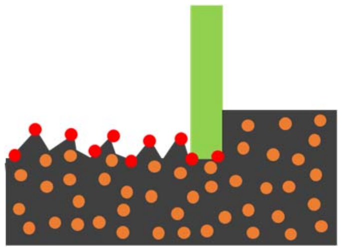
Director: Prof. André Zimmermann
Dr. Karl-Peter Fritz

State of the art: Polymeric 3D-MID via LPKF-LDS

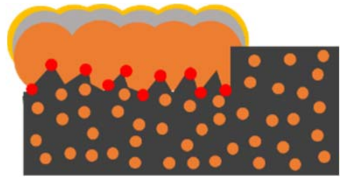
MID: Mechatronic integrated device
Structural part + metallic conducting paths

eg. LCP: Liquid Crystal Polymer

Molded part with laser activatable additives

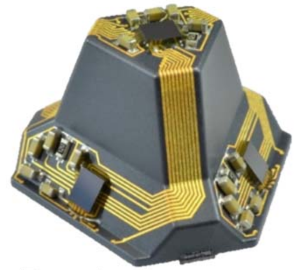


Laser structures and activates surface



Electroless Cu/Ni/Au plating

Antenna module
[Molex]

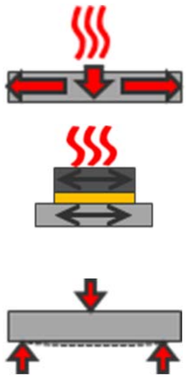


Proximity sensor
[Hahn-Schickard]

Sensor carrier
[Harting AG]

Motivation for ceramic 3D MID

Limitations of polymers → Why use ceramics



Property	Unit	LDS-LCP	Al_2O_3
Thermal conductivity	W/(K·m)	0.8-1.6	25-30
CTE (RT-150 °C)	10^{-6} K^{-1}	16-40	5-9
Young‘s modulus	GPa	11.5	300-400
Strenght	MPa	90	300-400 Up to 1000°C

Example applications of ceramic components

Heat exchanger

Grinding disc

Endoscop nozzles

Connector with filter

Vacuum insulator

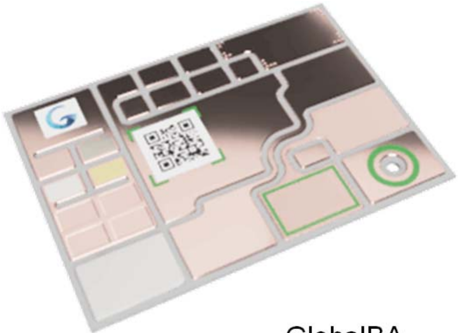
Alumina Systems

Hip joint prothesis

Pump wheel

Sensor housing

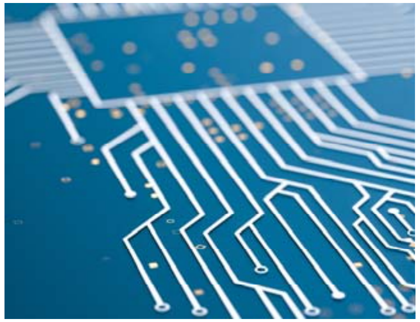
Al_2O_3 DCB Substrate

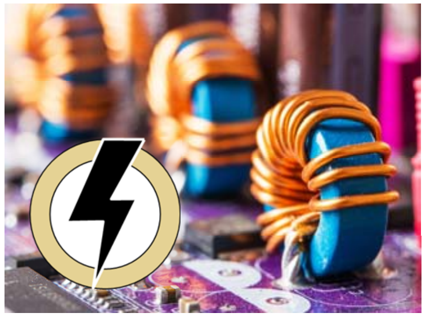


GlobalBA

Possible new fields of application for ceramic 3D-MID



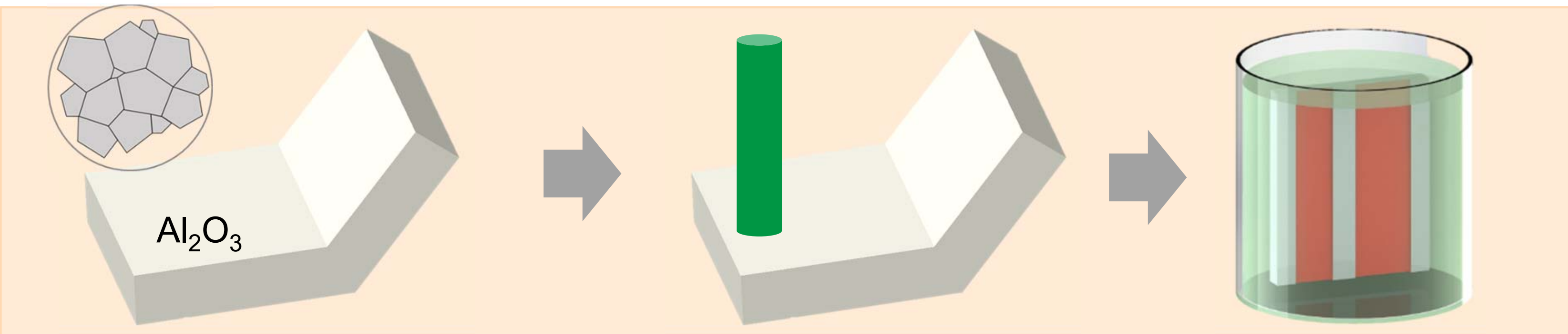

Direct laser induced metallization of ceramics

General process chain

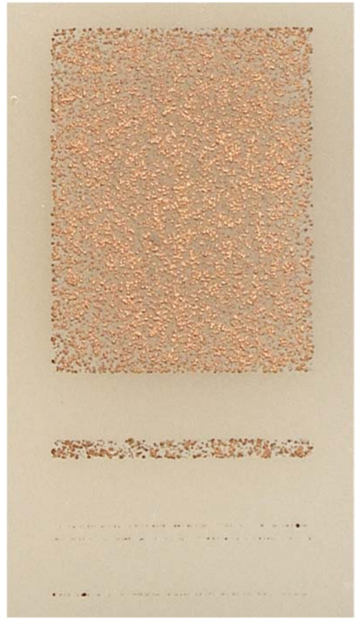
Substrate fabrication

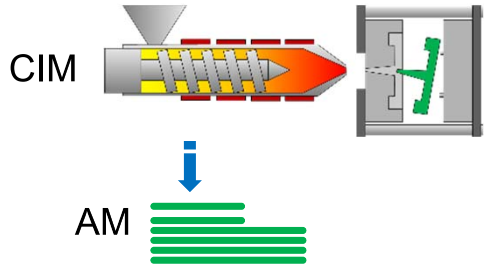
Laser activation with pulsed laser

Autocatalytic metallization with Cu(/Ni/Au)

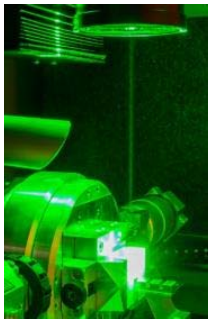


Cu on Al_2O_3





Sintering in air



Picosecond pulsed green Laser

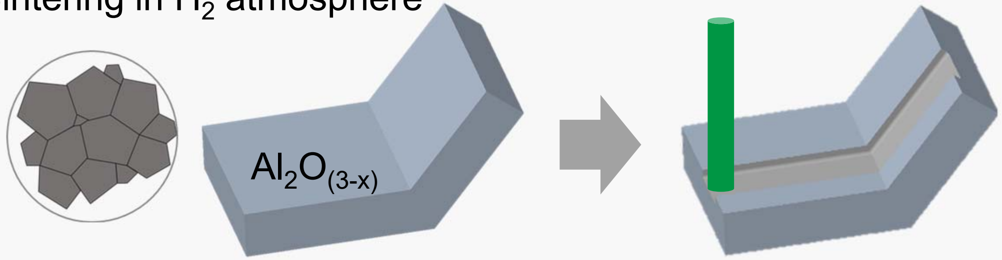
Electrolytes for electroless plating

No homogeneous metallization achieved

Material requirements

Al_2O_3 needs to be modified to enable laser activation

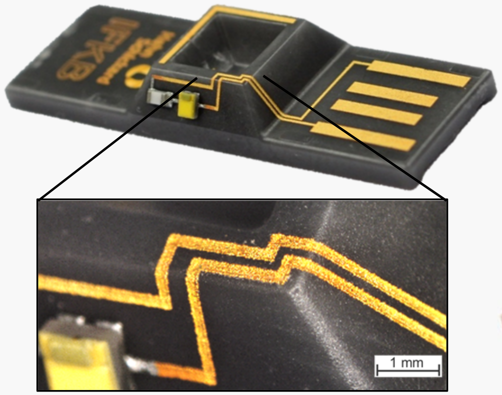
Sintering in H_2 atmosphere

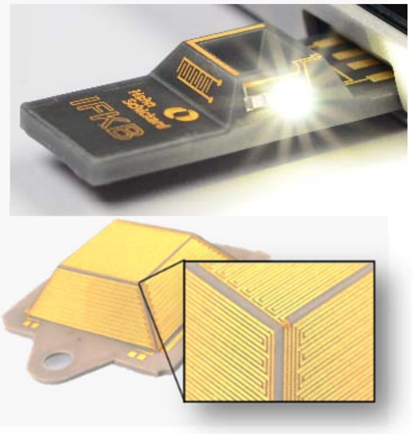


$ Complex process technology

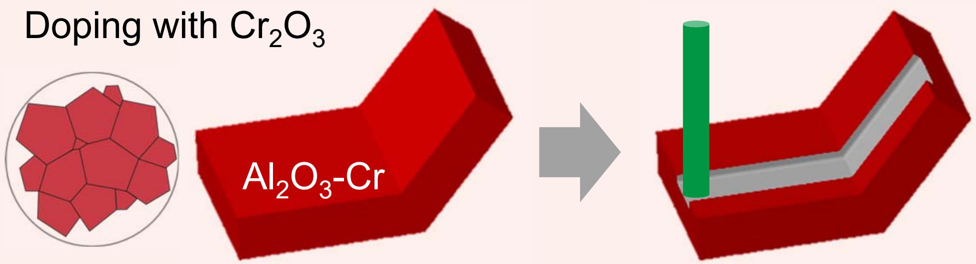
Picosecond pulsed green Laser

IGF LasKer3D





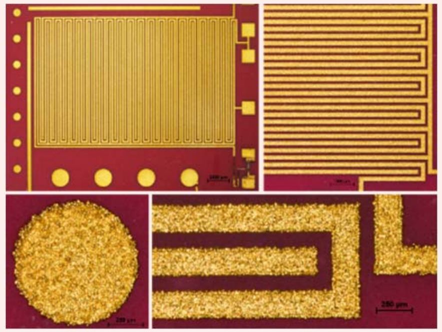
Doping with Cr_2O_3



$ Sintering at ambient atmosphere

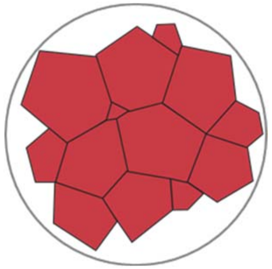
Picosecond pulsed green Laser

IGF LasKer3D



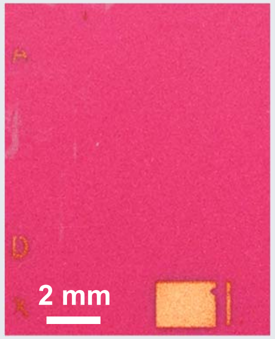
Influences of raw materials

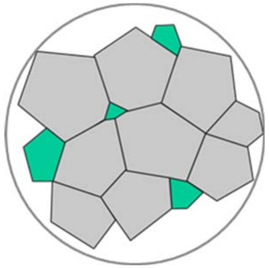
Variation of dopants and ceramic powders



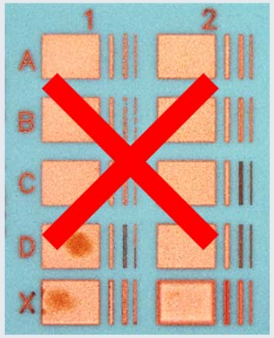
Fine Al_2O_3

2 w% Cr_2O_3





2 w% NiO

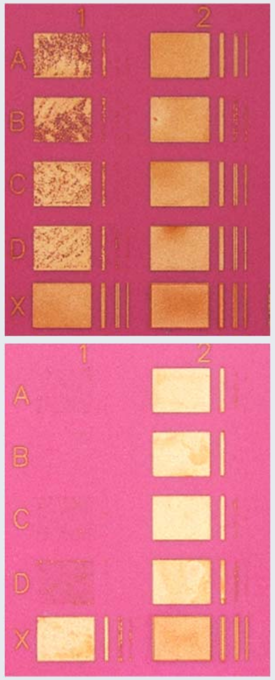


Dopant

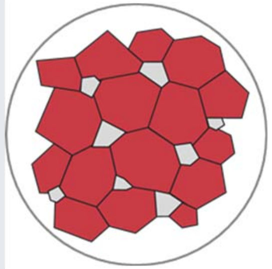
ZTA 2 w% Cr_2O_3

Ts 1550 °C

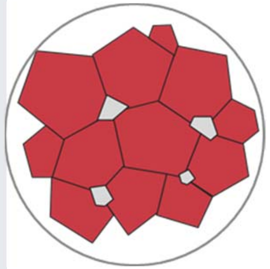
Ts 1600 °C



Sintering temperature

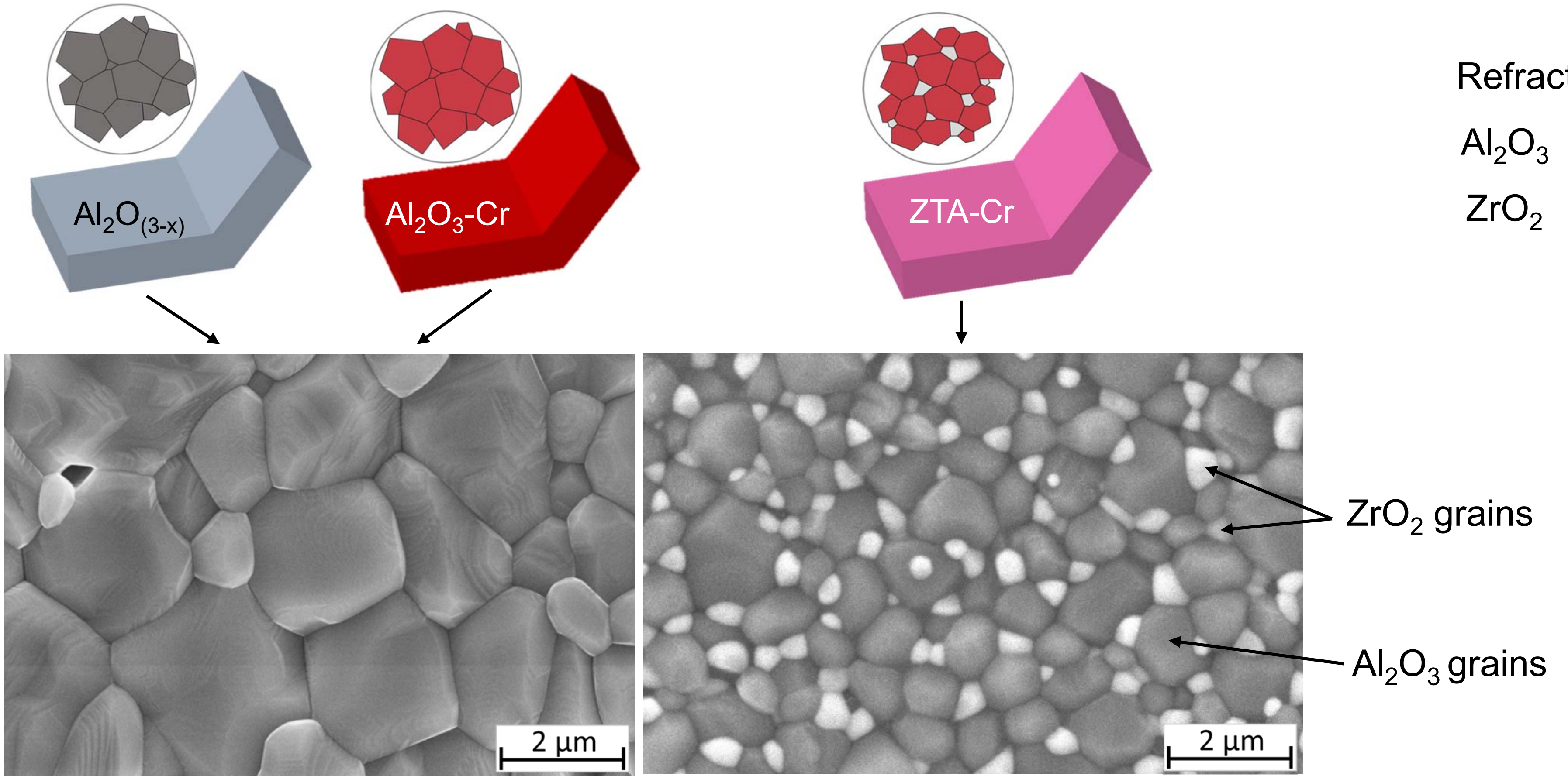


Grain growth



IFKB University of Stuttgart Germany

The ceramic substrate microstructure



Refractive indices

Al_2O_3 n = 1,76

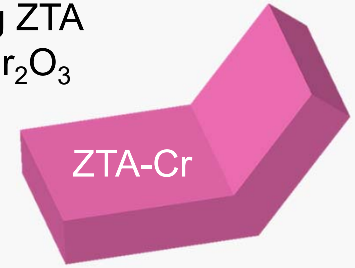
ZrO_2 n= 2,21

Oxygen vacancies, dopings, porosity, grain boundaries and additional phases (can) increase laser absoption

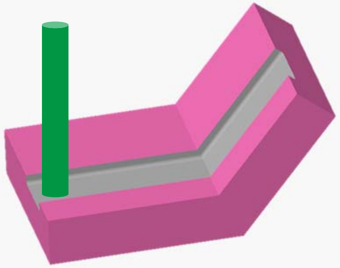
Material and laser variation

ZTA needs to be modified to enable laser activation

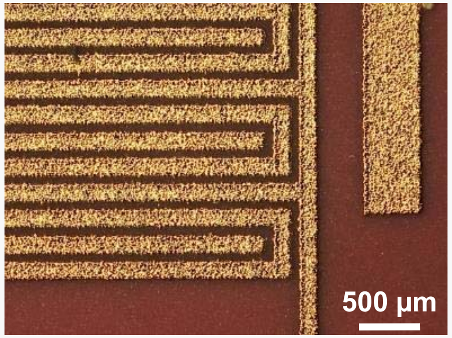
Doping ZTA
with Cr_2O_3

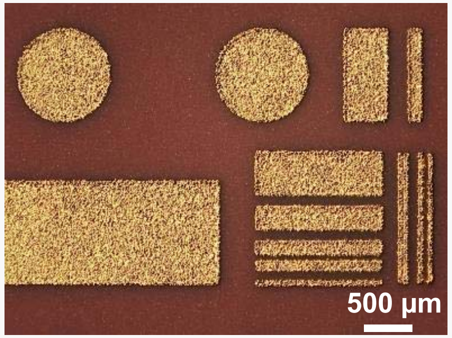


$ Sintering at ambient atmosphere



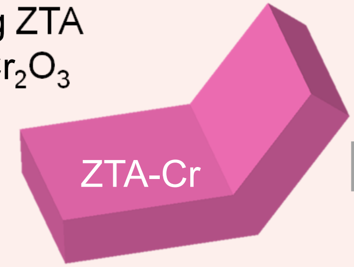
$ Picosecond pulsed green Laser



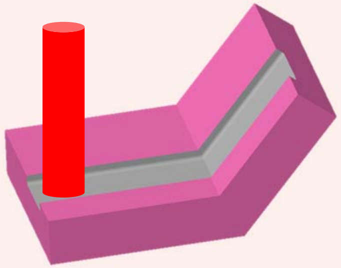


IGF Prokeram3D

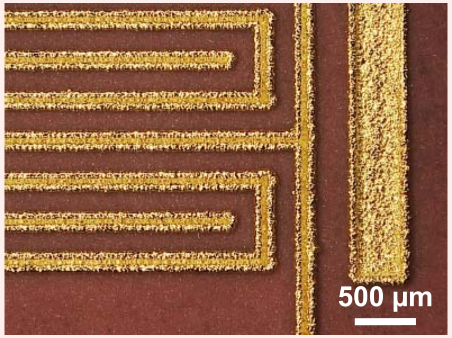
Doping ZTA
with Cr_2O_3



$ Sintering at ambient atmosphere

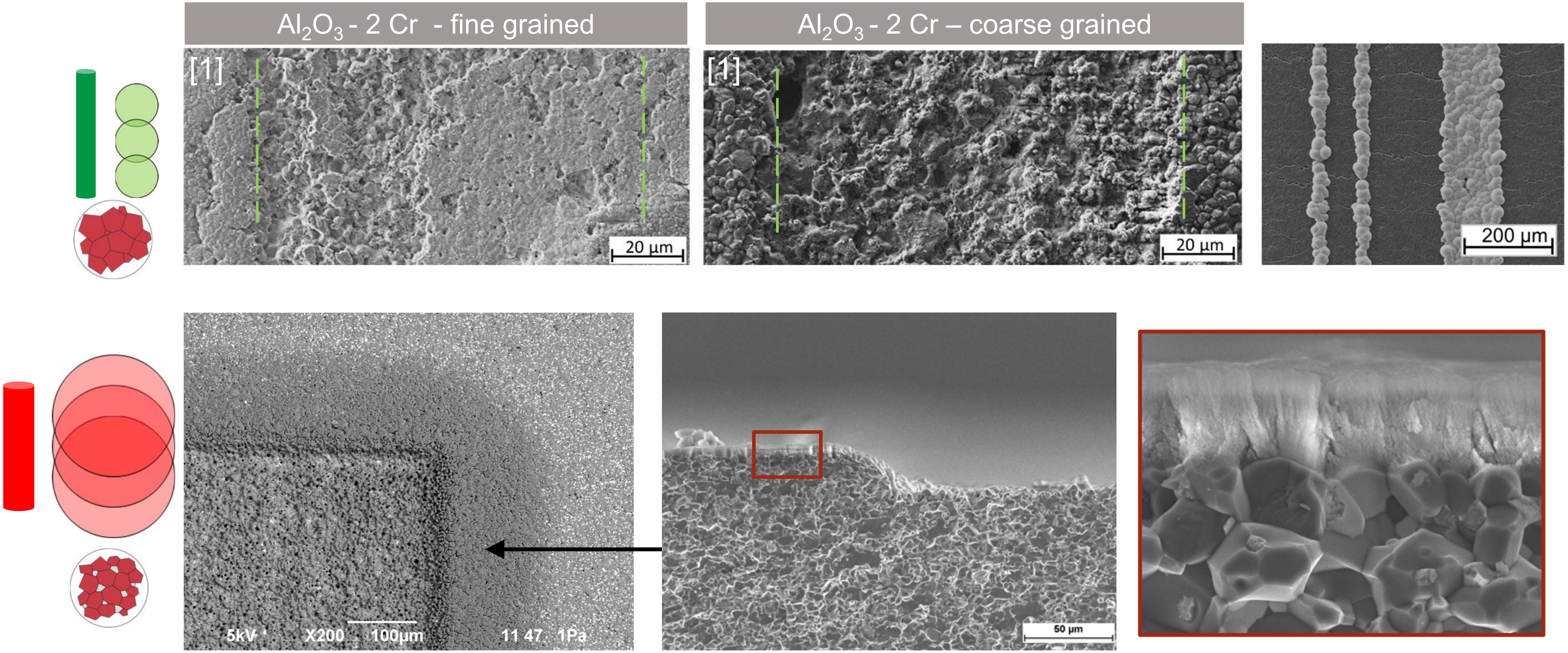


$ Nanosecond pulsed IR Laser



IGF Prokeram3D

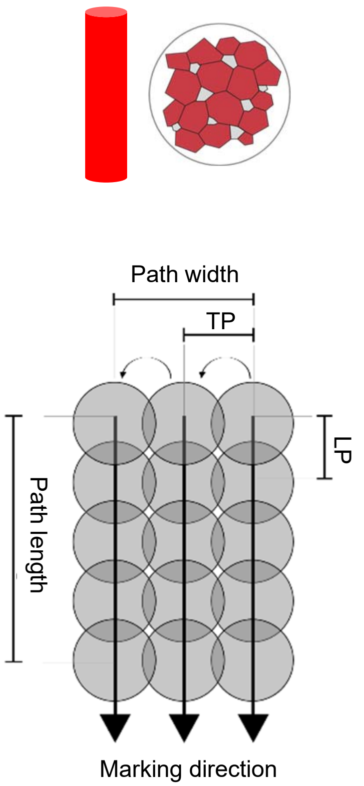
Impression of material and laser influence

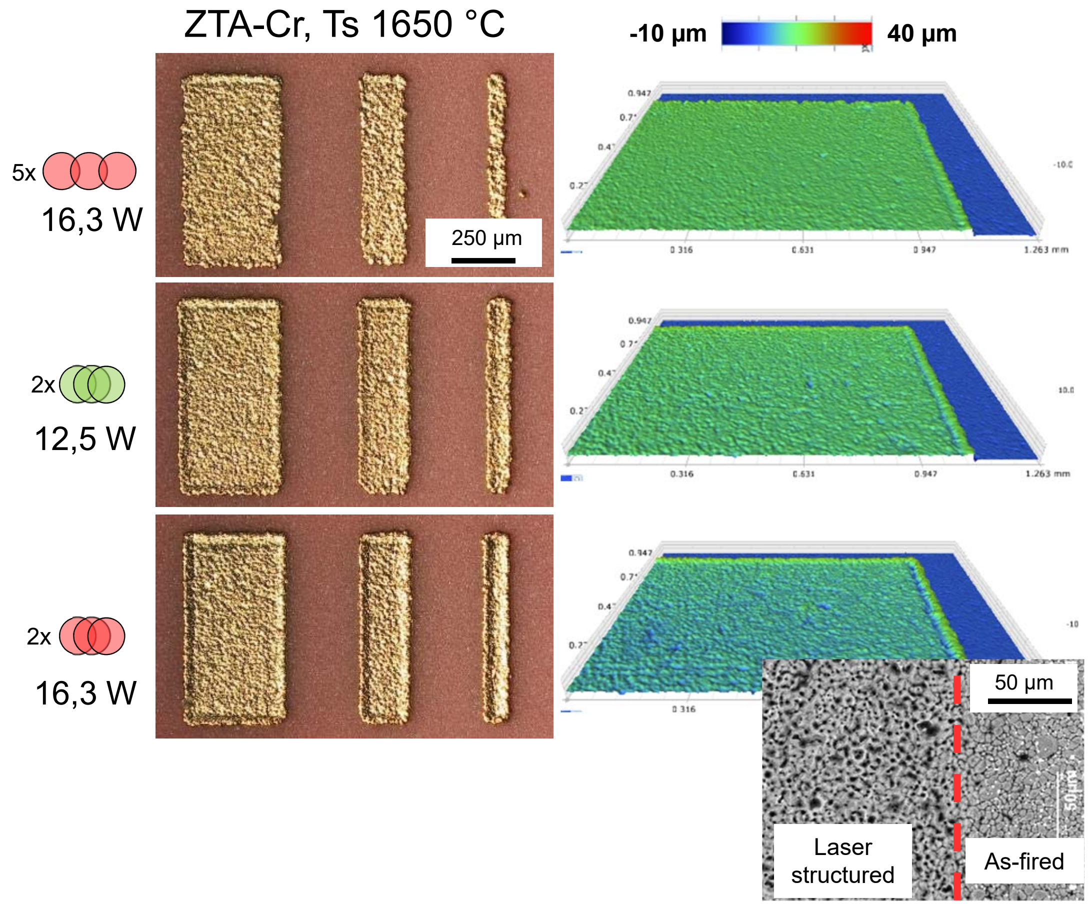


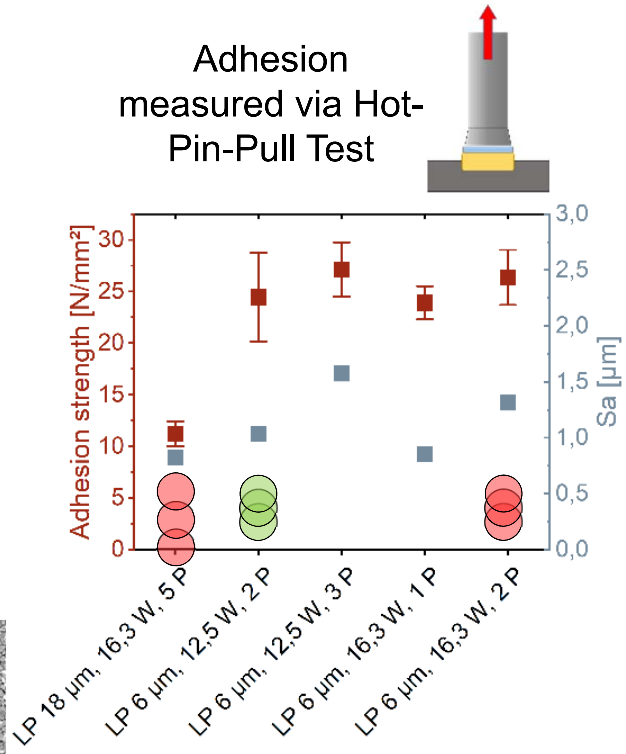
Source [1]: Dissertation Philipp Ninz: „Dotierte Aluminiumoxid Substrate und deren Herstellungsprozessketten für die selektive laserinduzierte Metallisierung“ ISBN 978-3-8440-8446-7 February 2022

Influence of laser parameters with ns-IR laser

Laser parameters have strong influence on metallization







Influences on laser activation of alumina ceramics

Ceramic substrate

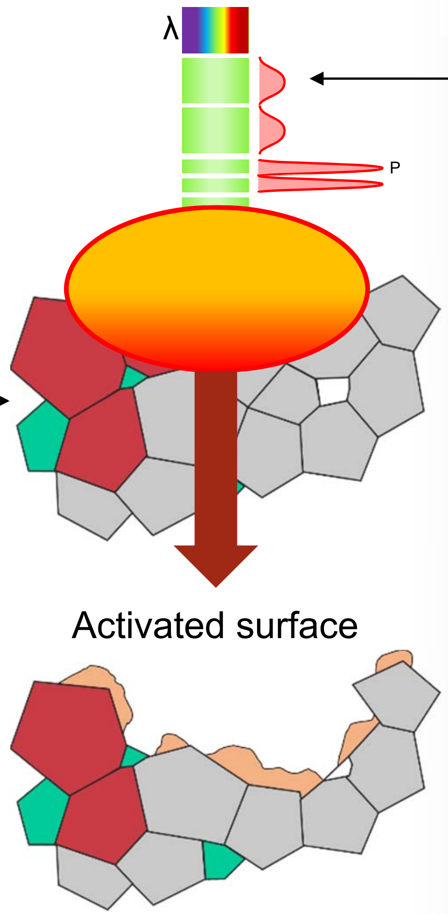
IFKB

Influencing parameters:

- Raw materials / powders
- Dopant materials / powders
- Manufacturing parameters

Substrate properties:

- Grain Size
- Porosity
- Phase composition
- Surface roughness
- Stoichiometry
- Impurity distribution
- Absorption spectrum



Laser activation + Metallization

ifm Hahn Schickard

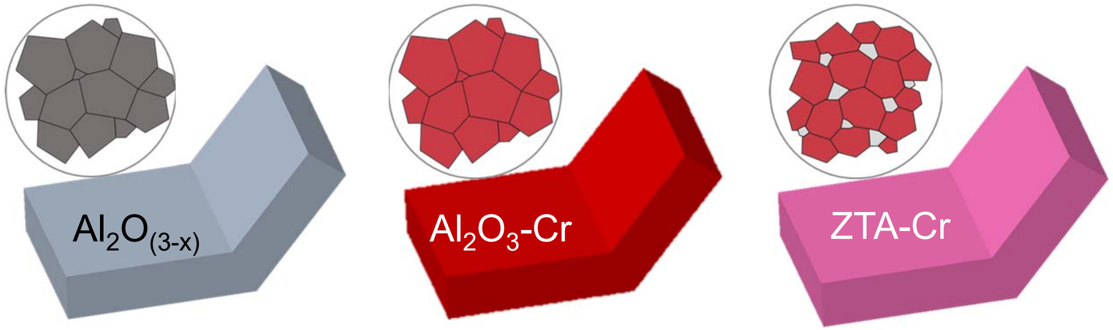
Structuring properties:

- Wavelength λ (Vis, IR, UV)
- Pulse duration (ns, ps)
- Pulse fluence (J/cm^2)
- Pulse overlap / Pitch

Metallization properties

- Plating speed
- Plating time
- Electrolyte composition

Material and laser overview matrix

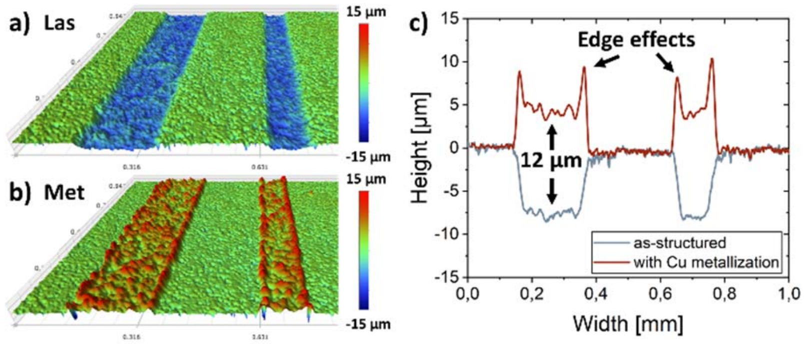


	$Al_2O_{(3-x)}$	Al_2O_3-Cr	ZTA-Cr	Accuracy (Spot size)	Thermal impact
ps-G	✓	✓	✓	10/23 µm	Low
ns-IR	X	X	✓	60/85 µm	High

Design features of ceramic MIDs

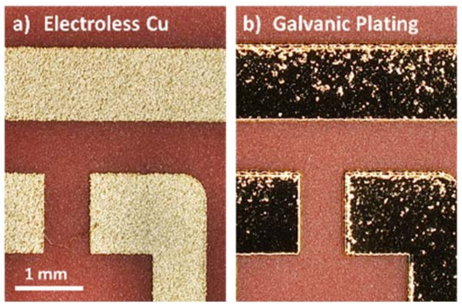
Metallization thickness

Cu thickness after electroless plating

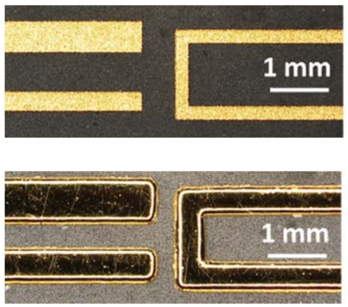


Galvanic plating increases Cu thickness to up to 100 µm

Al_2O_3-Cr

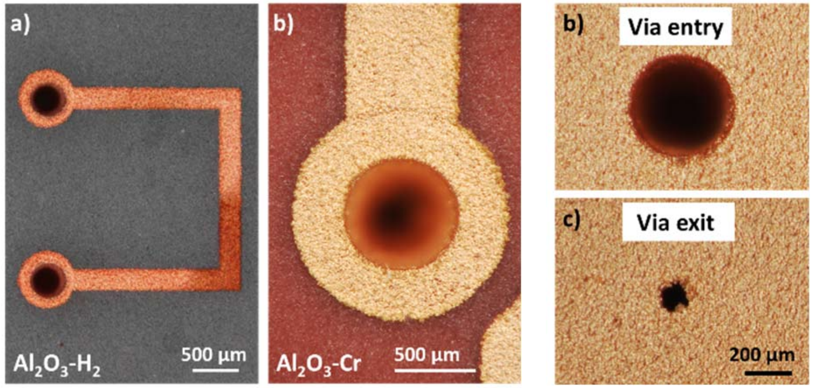


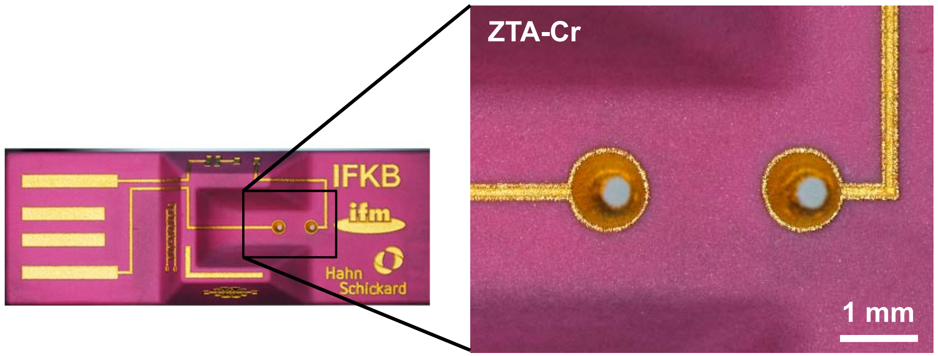
Al_2O_3-H_2



Vias

Vias can be laser drilled and metallized

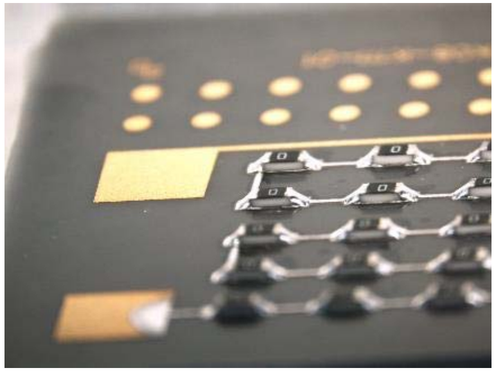


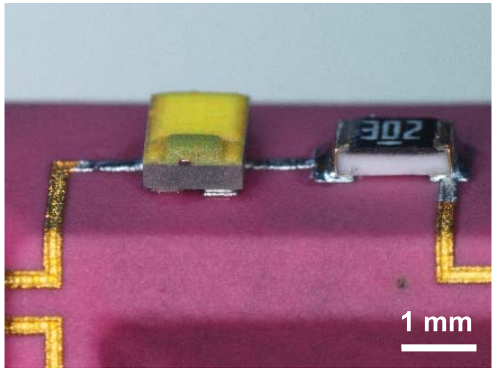


Interconnect technologies

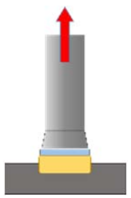
Soldering of components

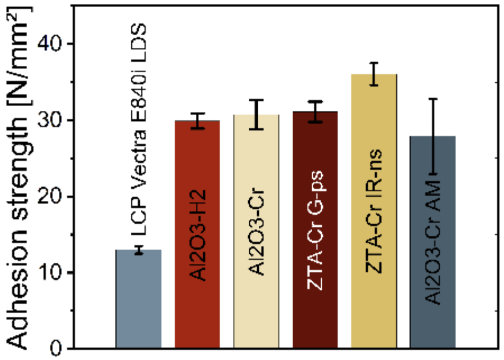
Reflow soldering is possible





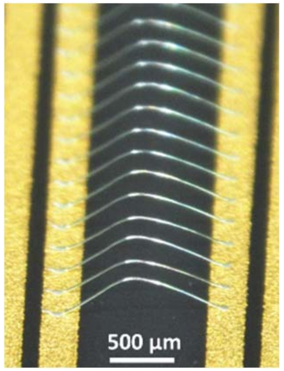
Adhesion measured via Hot-Pin-Pull Test





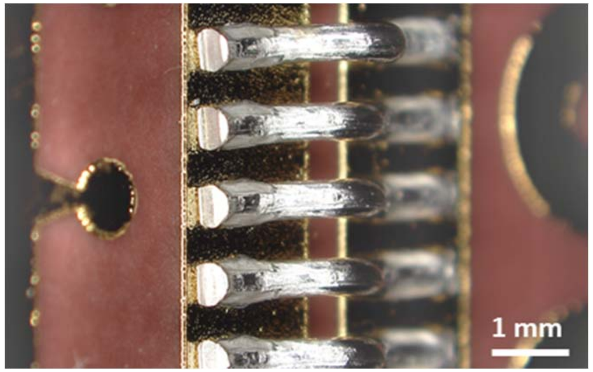
Wire bonding

Wire bonding is possible



Wedge-wedge bonds with Al-wire with 25 µm diameter

- Fulfills DVS2811 norm with 56 ± 12 % medium failure load
- No pads pulled off
- No wire failure

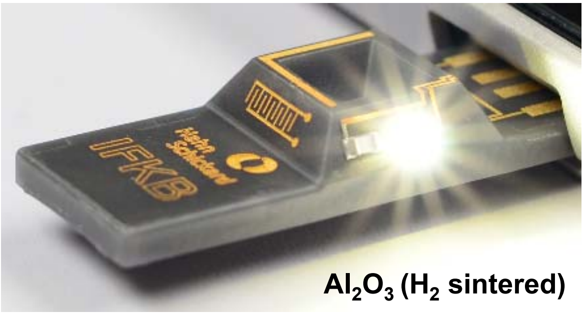


250 µm thick wire bonds on galvanically plated Metallization

Summary and outlook

Industrial application is possible

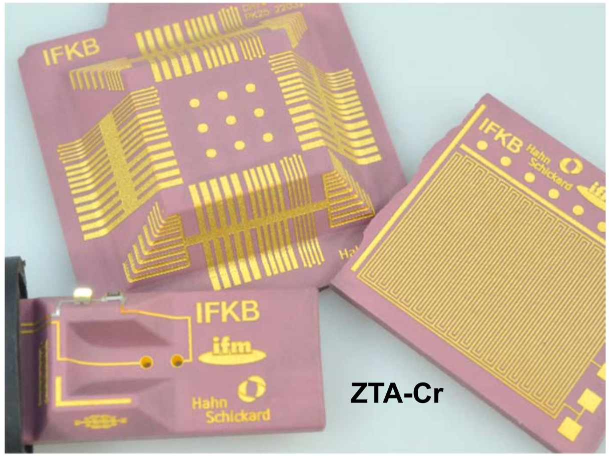
Picosecond pulsed green Laser



Al_2O_3 (H_2 sintered)

Al_2O_3-Cr

Nanosecond pulsed IR Laser



Get creative ! Get in touch with us!

Open research topics

- What’s the nature of the catalytic sites and how can they be quantified?
- Development of flexible production chains for prototyping or small lot sizes → IGF **FlexiKer3D** (22459 N)

We´ll keep investigating

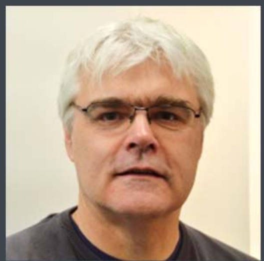
Thank you!

University of Stuttgart
Germany

Institute for Manufacturing Technologies of Ceramic Components and Composites

IFKB

Contact: Apl. Prof. Frank Kern
Dr. Philipp Ninz



Institute for Micro Integration

ifm

Contact: M.Sc. Alexander Schilling

Hahn Schickard Stuttgart

Contact: Dr. Andrea Knöller

Federal Ministry for Economic Affairs and Climate Action

AiF iGF

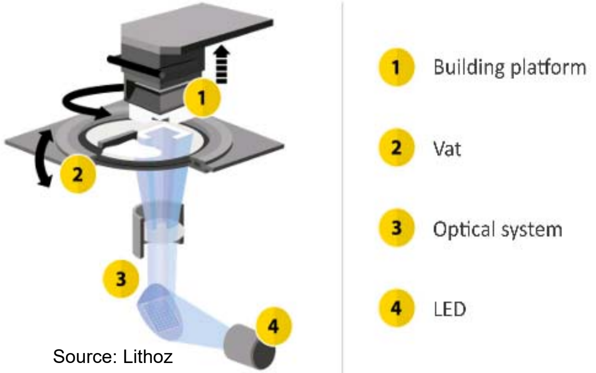
The IGF Projects (AiF 20975 N and AiF 18967 N) were supported via AiF within the program for promoting the Industrial Collective Research (IGF) of the German Ministry of Economic Affairs and Energy (BMWK), based on a decision by the German Bundestag. The project AddPower was supported by the Ministry of Science, Research and Arts of the Federal State of Baden-Württemberg, Germany within the the 'Innovcationscampus Mobilität'.

INNOVATIONSCAMPUS
MOBILITÄT DER ZUKUNFT

Outlook: Additive manufactured laser activatable ceramics

Lithography based Ceramic Manufacturing (LCM) shaped doped Al_2O_3

LCM process



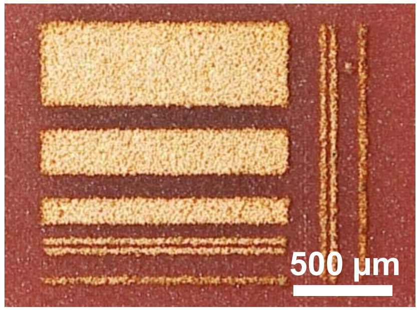
Source: Lithoz

Source: Lithoz

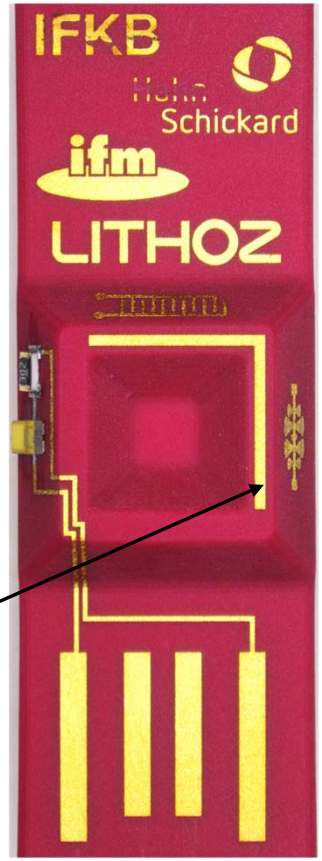
Working 3D Demonstrator

Serial resistor H-LED

Test Structures



Test Structures on Demonstrator



FAPS

Prof. Dr.-Ing. Jörg Franke

Lehrstuhl für Fertigungsautomatisierung und Produktionssystematik

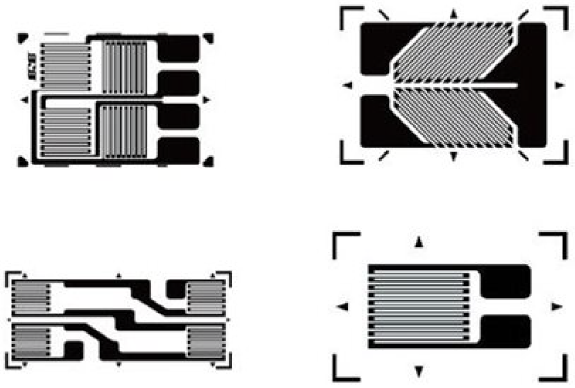
Friedrich-Alexander-Universität Erlangen-Nürnberg

FAU
Friedrich-Alexander-Universität
Technische Fakultät

Printed strain gauges on 2.5D substrates
MID Summit 2022

Felix Häußler - Lehrstuhl FAPS
Jewgeni Roudenko - Technische Hochschule Nürnberg

Strain gauges can be made of resistive materials to allow for strain sensing and physical parameters derived therof.



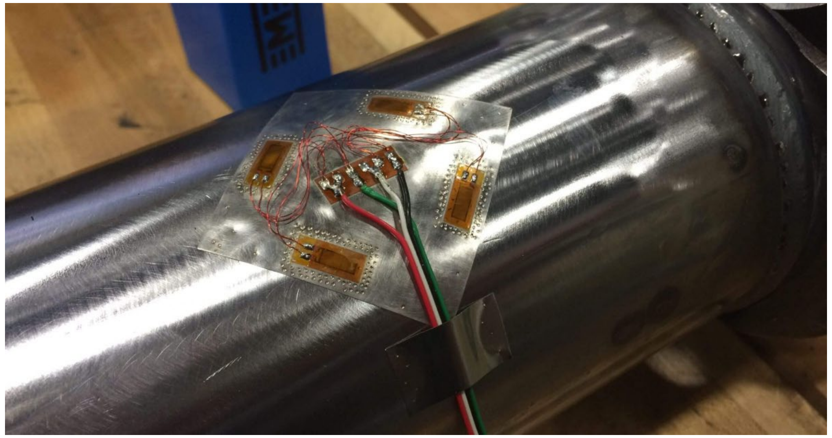
$$\frac{\Delta R}{R_0} = k \cdot \varepsilon \quad \text{with } \varepsilon = \frac{\Delta l}{l}$$

- Torsion measurement
- Strain measurement
- Torque measurement
- Load measurement

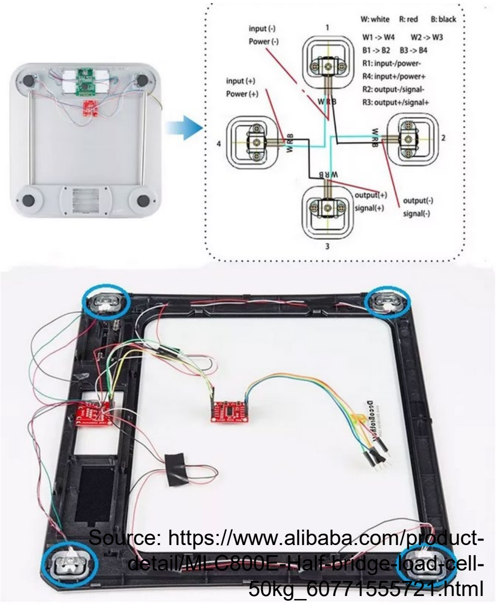
Source: Variohm

Assembly of a foil based strain gauge

Source: HBM



Source: Dewesoft



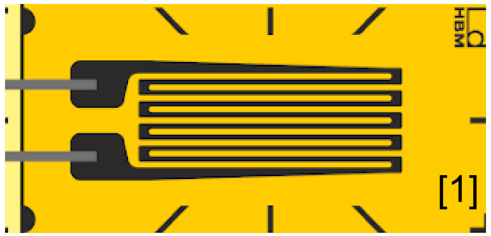
Source: https://www.alibaba.com/product-detail/MLC800E-Half-bridge-load-cell-50kg_60771555721.html

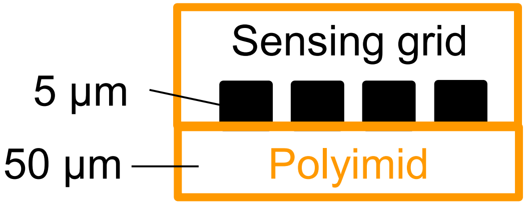
Pressure sensor on ceramic membrane

Manufacturing and application of foil based strain gauges is a tedious process with typically manual application steps required.

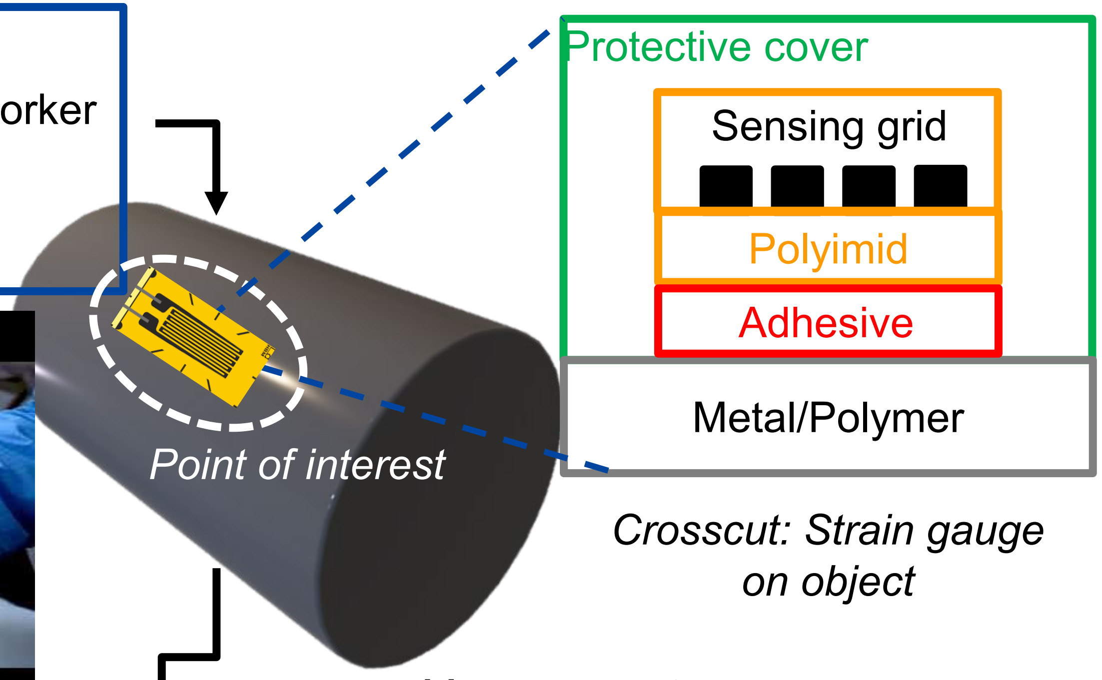
Foil strain gauge production:
- Lithography
- Etch processes

Assembly:
- Manually by experienced worker
- Potential cause of failure
- Costly





Crosscut: Strain gauge



Crosscut: Strain gauge on object

Measurement object

Measurement (monitoring of a component):
- Force conveyed via adhesive
- Strain analysis
  - **Change in length of grid (wire)**
  - **Electrical resistivity R ↑**
  - **GF-Factor known → Strain is detected**

$$\frac{\Delta R}{R_0} = k \cdot \varepsilon \quad \text{with } \varepsilon = \frac{\Delta l}{l}$$

If requirements can be met by additively manufactured and applied strain gauges directly on the object manual assembly steps are avoided and 3D mechatronic application is possible.

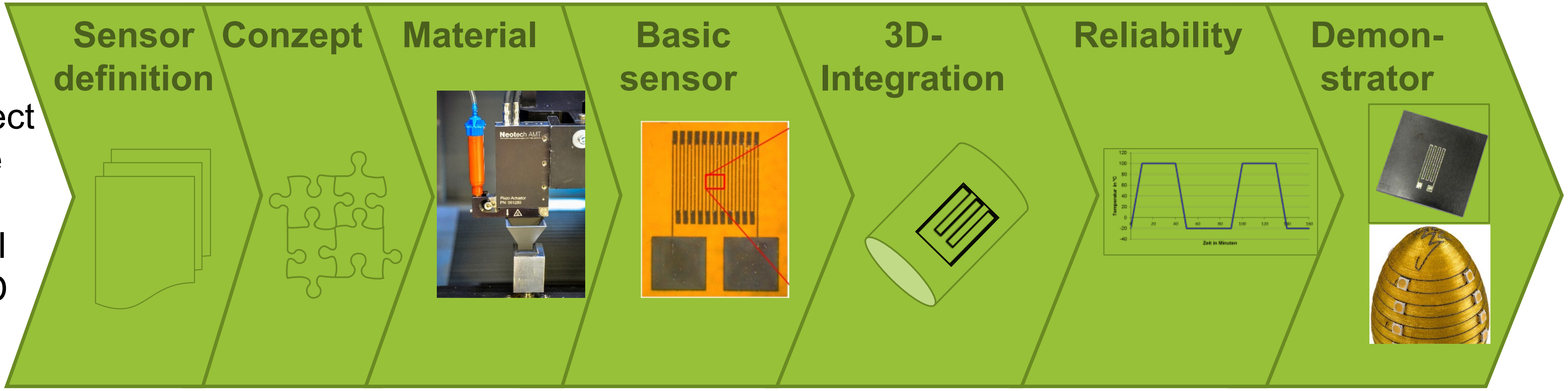
Requirements

- Sensor linearity
- Feasability
- Electical resistivity values suitable for existing instrumentation
- Hysteresis
- Reliability

Challenges

- Compatibility of materials
- Printing strategy
- Limits of printing processes
- Process stability
- Transferability

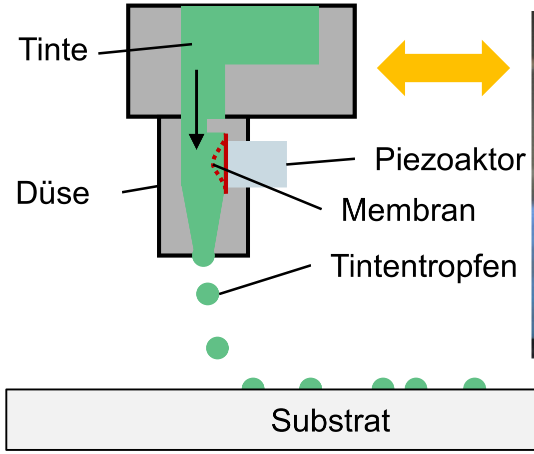
Evaluation within the research project PreSens to define requirements for potential industrial use within 3D MID applications



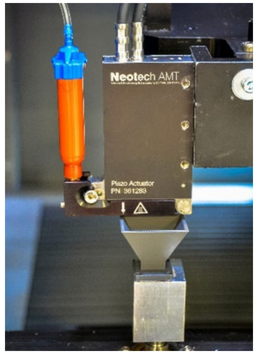
Using inkjet printheads for low and high viscosity inks and the aerosoljet process, functionalized inks and pastes can be applied digitally.

- **Additive metallization**
- **Contactless and mask free**
- **Flexible layer heigths**
- **Direct integration**
- **3D-Geometrien possible**

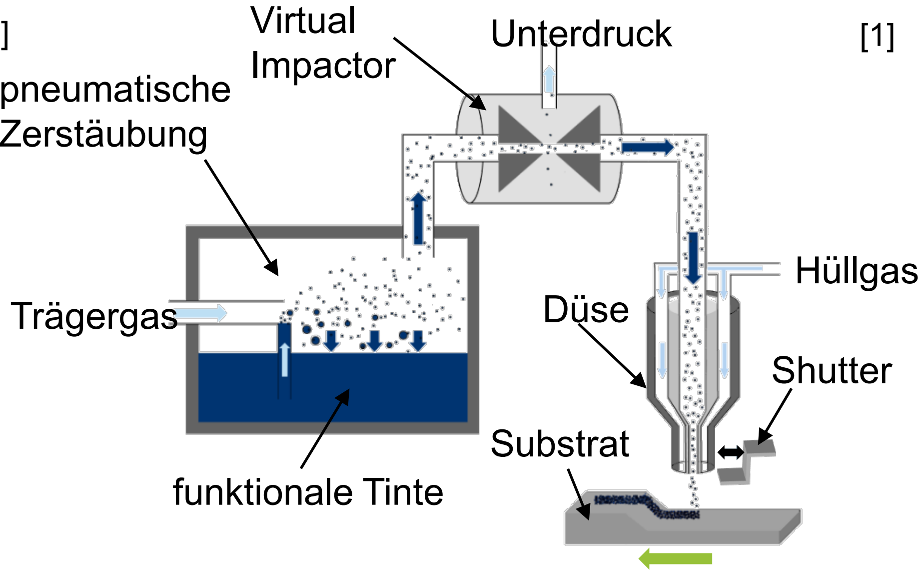
Piezo Jet:



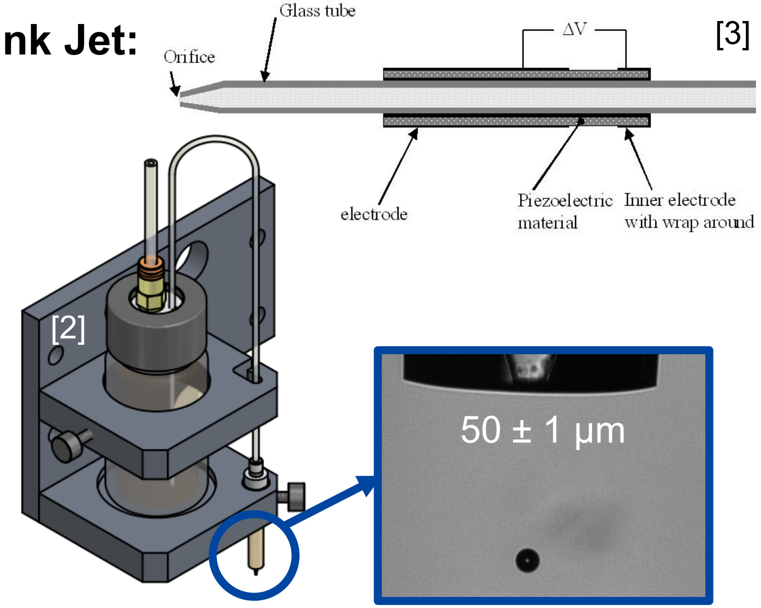
[5]



Aerosol Jet:



Ink Jet:



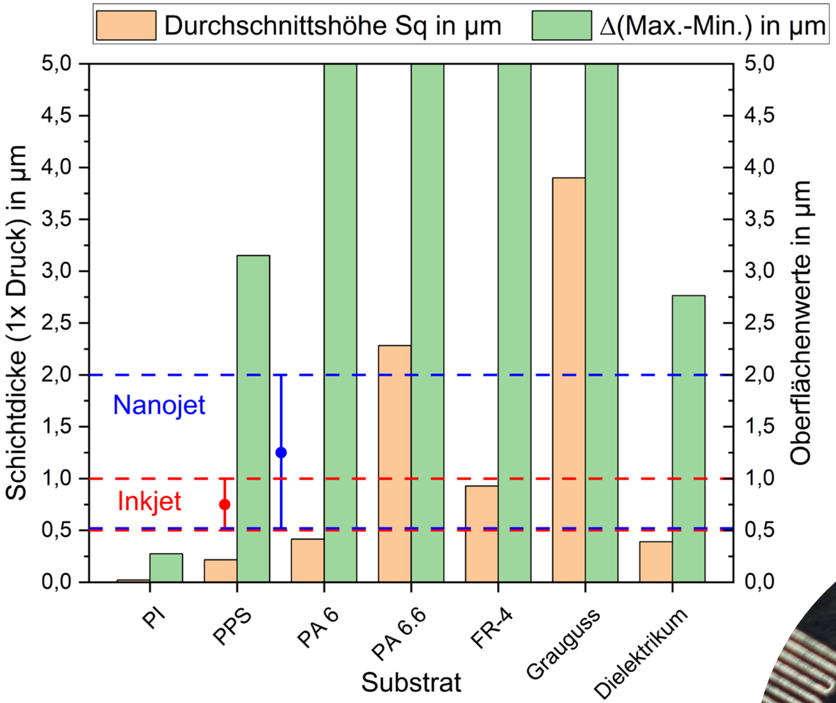
	Piezo-Jet Fa. Neotech AMT	Aerosol-Jet Fa. Optomec	Nanojet (Aerosol)	MircoFab Ink Jet Head
Viscosity	bis zu 200 Pa·s	bis zu 1.000 mPa·s	< 20 mPa·s	3 mPa·s - 20 mPa·s
Line width	300 µm – 500 µm	40 µm – 1000 µm	10 µm - 1000 µm	150 µm – 300 µm
Layer thickness	20 µm – 50 µm	1 µm - 20 µm	0,5 µm - 1 µm	0,5 µm – 1 µm
Examplary material	Ag Paste Henkel (26 Pa·s)	Ag Tinte PARU PG-007	Ag Tinte UT Dots Ag40X	Ag Tinte UT Dots AgIJ

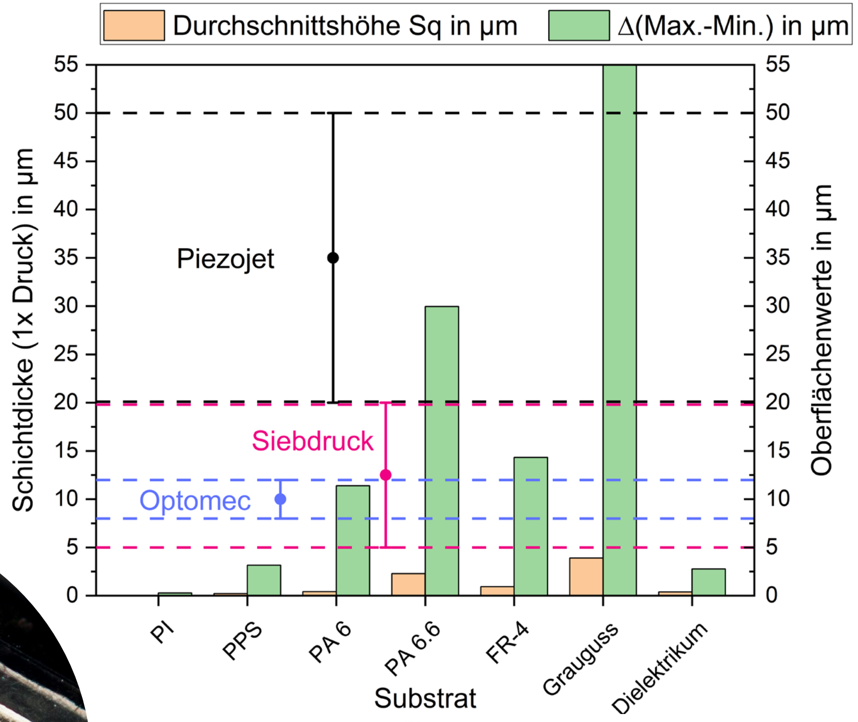
This slide provides an overview on the printing materials used throughout the project.

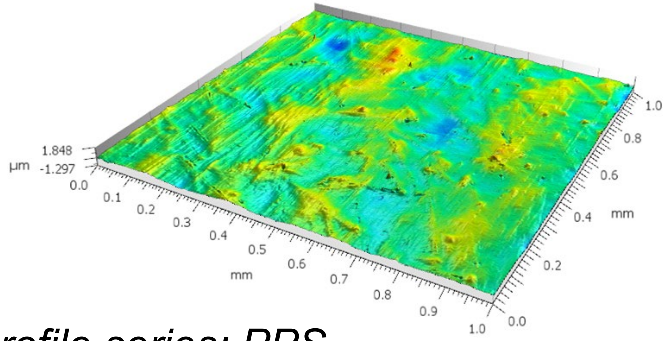
	Drucktechnik-FAPS			Drucktechnik-THN		
Messgitter	**Aerosol (Pneumatisch)**	**Piezojet**	**SuperHiJet**	**Aerosol-Nanojet (Ultraschall)**	**Siebdruck**	**Piezojet**
Ag	PARU PG-007	Henkel ECI 1011		UT Dots Ag40TE	Novacentrix FG-32	
Cu[1]	Dycotec CU-5010	Novacentrix CP-009[2]			Novacentrix CP-009[3]	
CuNi[1]	Applied[4] Nanotech OC5545-T	Applied Nanotech PS5545[5]			Applied Nanotech PS5545[5]	
C	Creative Materials EXP2652-28	Peptech Flexink Conductive 001-GCB		Creative Materials EXP2652-28 verdünnt	Peptech Flexink Conductive 001-GCB	
PEDOT:PSS	Heraeus Clevios P JET 700 N	AGFA Orgacon EL-P-Serie		Heraeus Clevios P JET 700 N[6]	AGFA Orgacon EL-P-Serie	
Dielektrikum			Dupont ME 780		Dupont ME 780	
Schutz			GenesInk Protect S		GenesInk Protect S	
Schutz (manueller Auftrag)	ME Systeme M-Coat C					

Substrate		**Name**
Polymer/Verbund	Polyimidfolie (75 µm)	Dr. Dietrich Müller GmbH FI16005 Flexiso (Referenzsubstrat)
	PA6	BASF Ultramid B3EG6 EQ
	PA6.6	BASF Ultramid A3EG6 EQ
	PPS	Celanese Fortron 1140L4 oder Toray A495MA2B
	FR-4	Shengyi Technology S 1000H
Metalle	Grauguss	Funk Guss GJS 400-18
	Stahl 1.4548	
	Aluminium EN AW 7075	

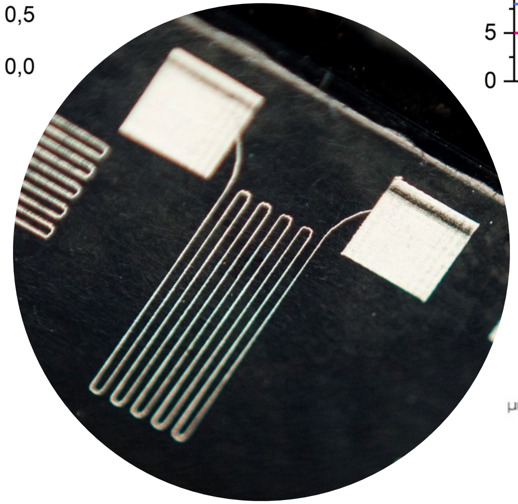
There are several challenges regarding printed strain gauges, e.g. surface roughness and compatibility between inks and substrates are detrimental to a successful functionalization.



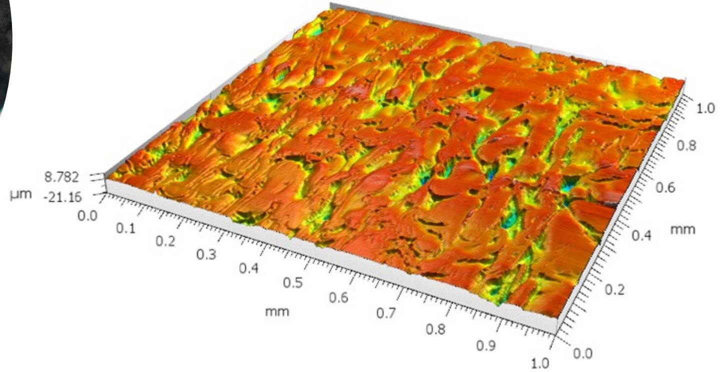




Profile series: PPS

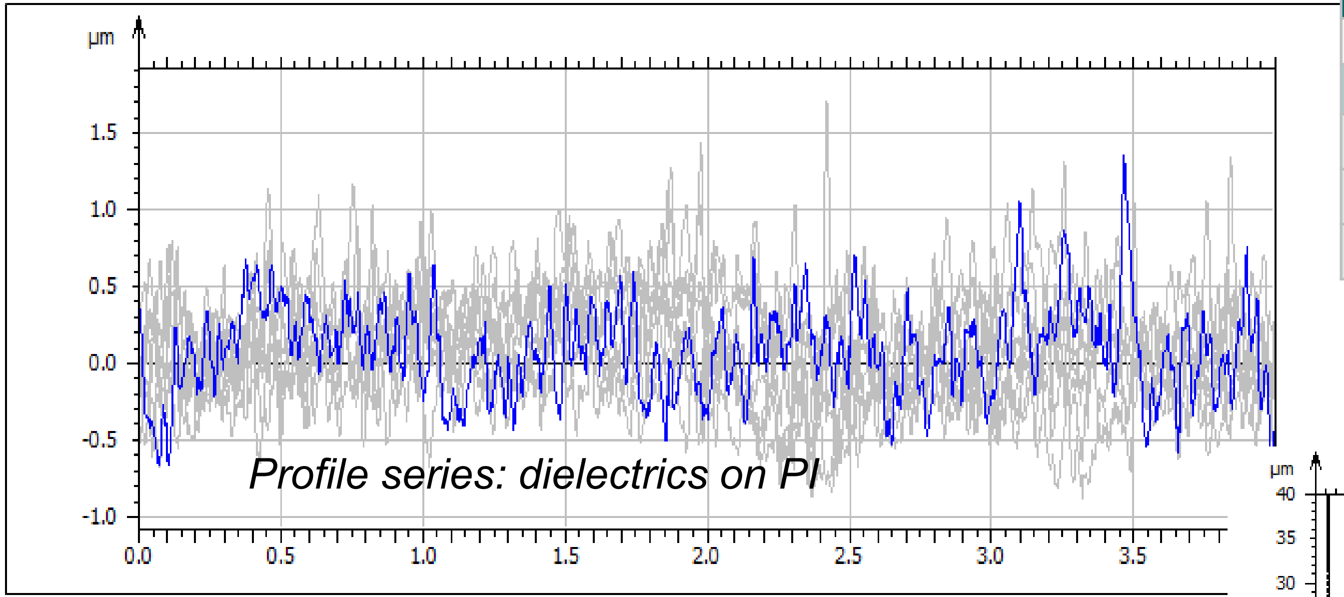


PA6.6



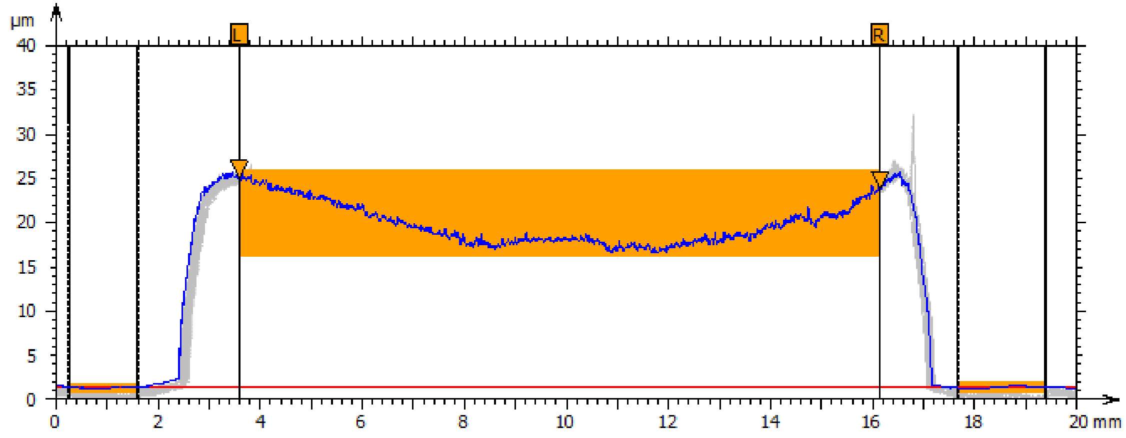
For metallic substrates application of dielectrics is required to allow for sensing giving the possibility to compensate roughness.

Piezojet printed dielectric (DuPont ME780)



ISO 25178 - Primary surface		
S-Filter (λs): Gauß, 8.000 µm		
Höhen-Parameter		
Sq	**0.390**	**µm**
Sz	**2.765**	**µm**
Sa	**0.305**	**µm**

Average height



Information			
Parameter-Anzeigemodus	Statistische Ergebnisse für die Serie		
Parameter	Stat.	Stufe 1	Einheit
Durchschnittshöhe	Mittelwert	19.12	µm
	Std.-Abw.	0.4487	µm

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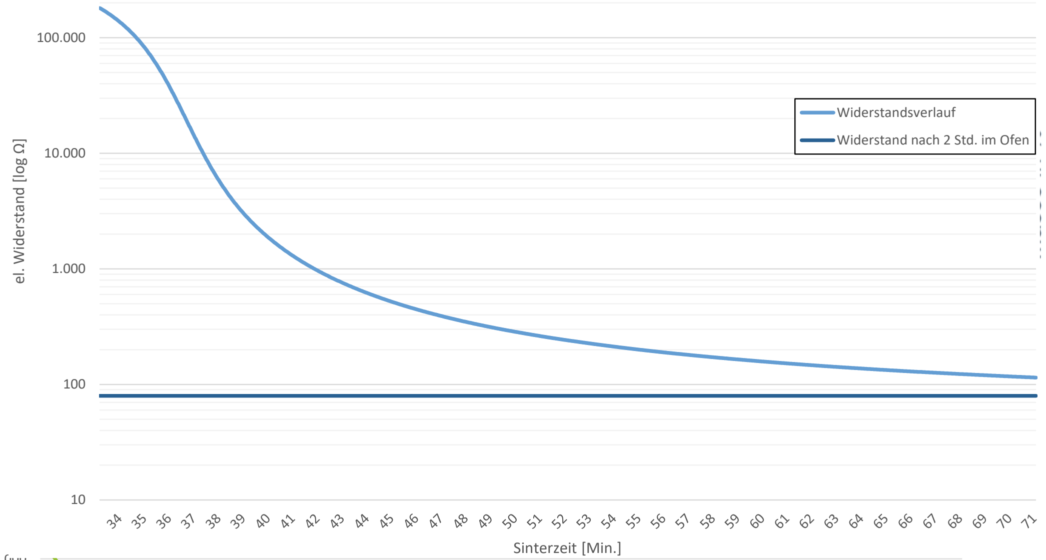
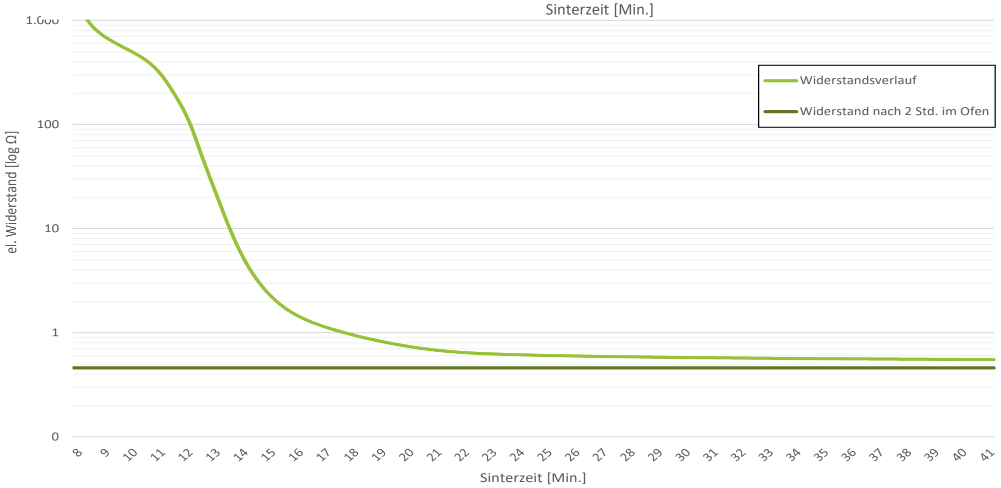
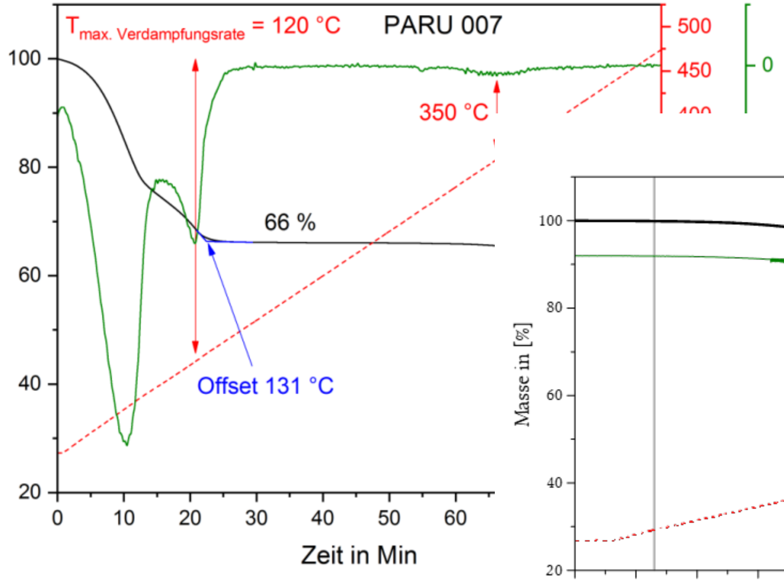
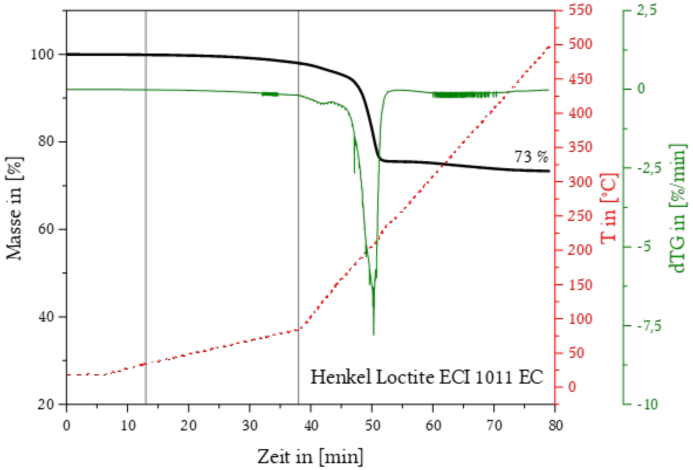
For metal based functional inks resistivity is dependent on time and may change during use.

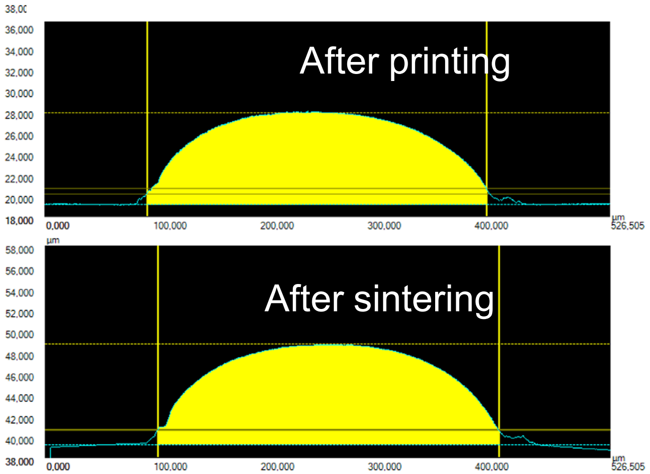




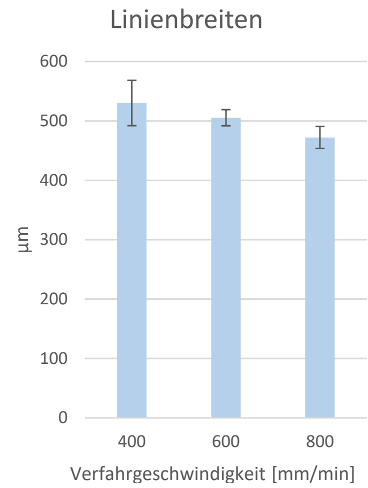


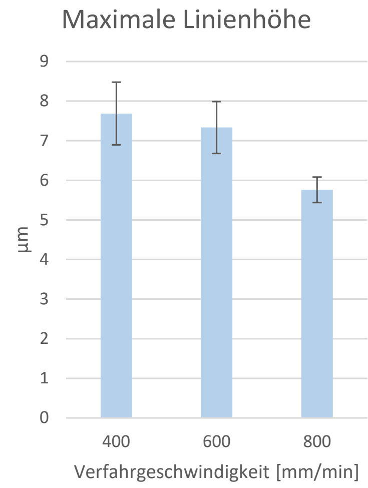


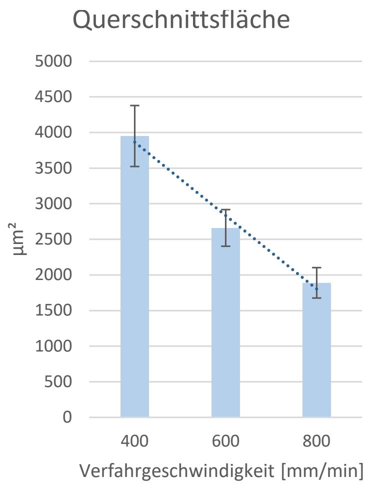
- Potential post-sintering during use
- Sintering material depender

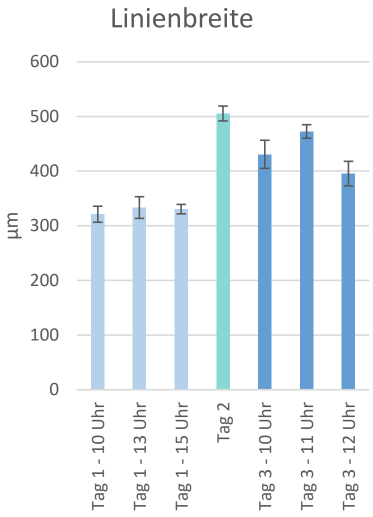


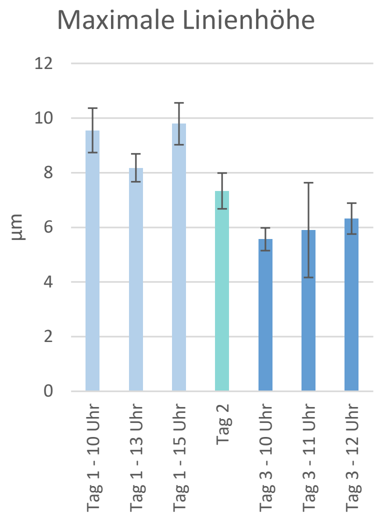
Changes in material deposition over time and between shifts have to be minimized and possibly compensated for in electronics.

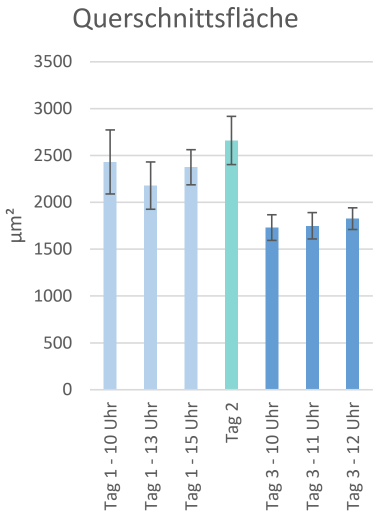


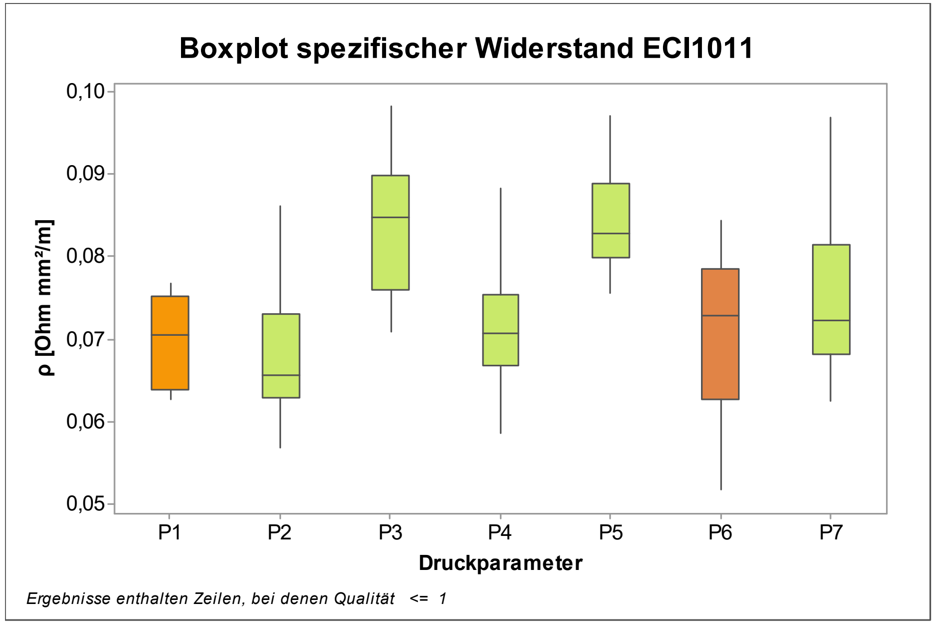








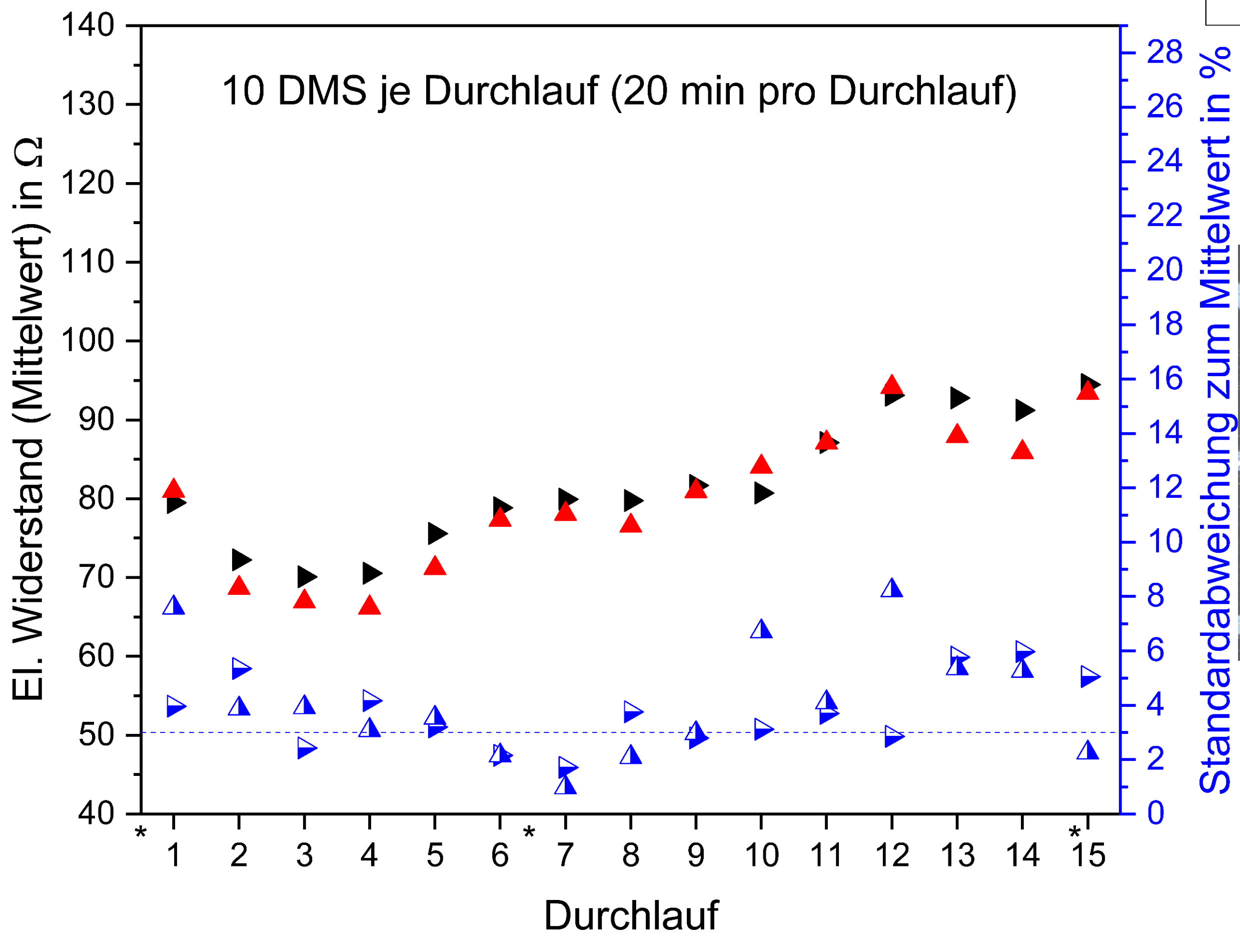


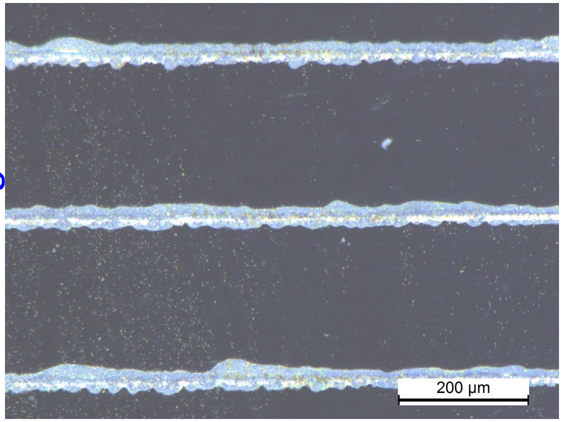


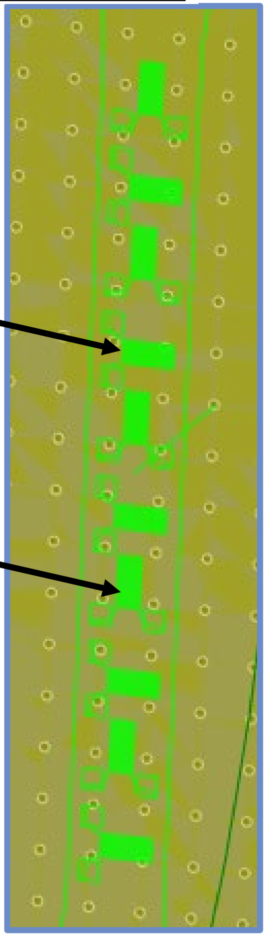
Standard deviation in R approx. 7,2- 11,2%

Smallest geometries comparable to conventional strain sensors could be generated using the IDS aerosoljet printing system with deviations in R around 2 to 6%

FAPS







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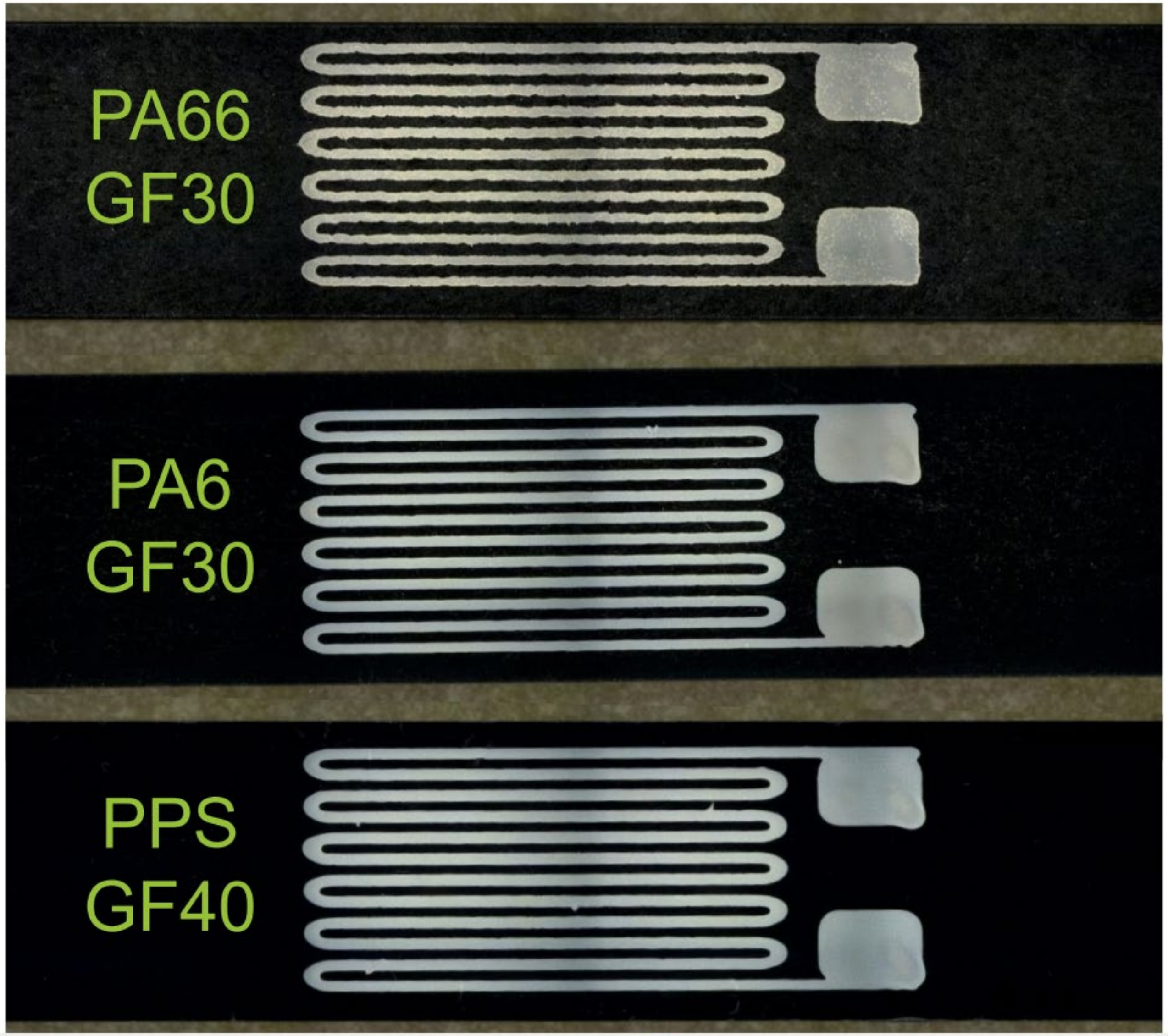
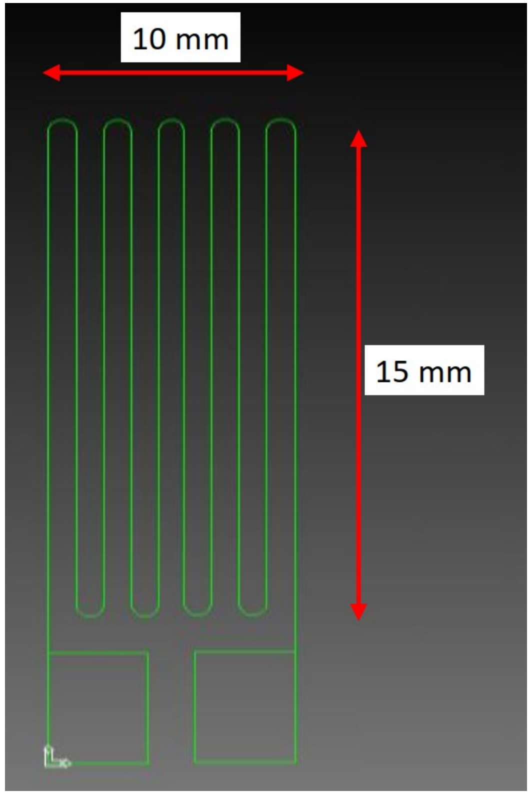
Functionalization using piezojet printing requires larger sensing structures and therefore larger measurement objects.





Line spacing: 1000 µm bzw. 700µm (dep. on ink)

Pad size: ca. 3x4mm²

Pad distance: ca. 4mm

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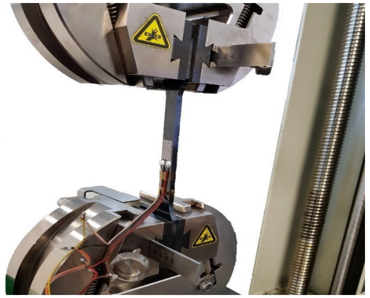
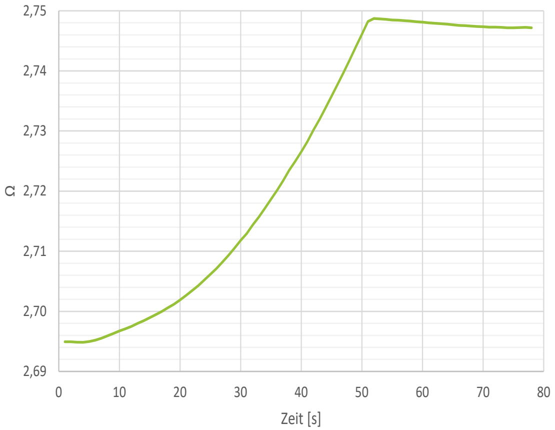
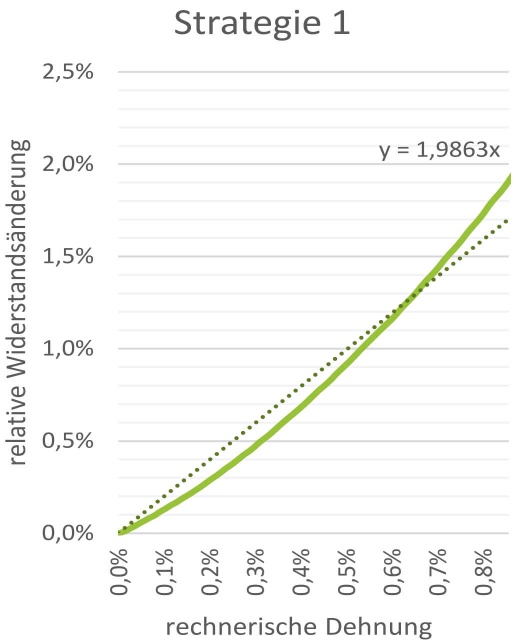
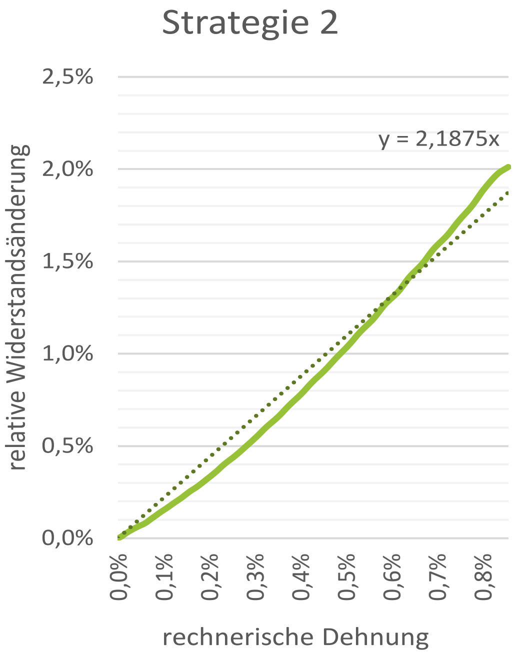
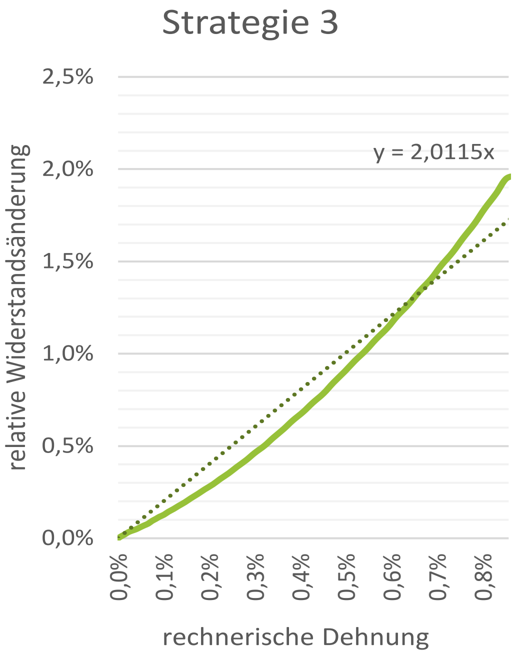
Gauge factors were found to be around 2,3 at a tensile strain of 0,8% for the piezojet printed ECI1011 ink.











P7: k-Faktor: 2,24 P1: k-Faktor: 2,35 k-Faktor: 2,24

Calculation without extensiometer or reference sensor.

Tensile bars according to DIN EN ISO 527 Typ 1A – Material PPS Fortron 1140L6, area 40mm²

Nanojet printing at TH Nürnberg allows smaller structures with a good sensor response for silver ink at about 80 Ohms to 100 Ohms.

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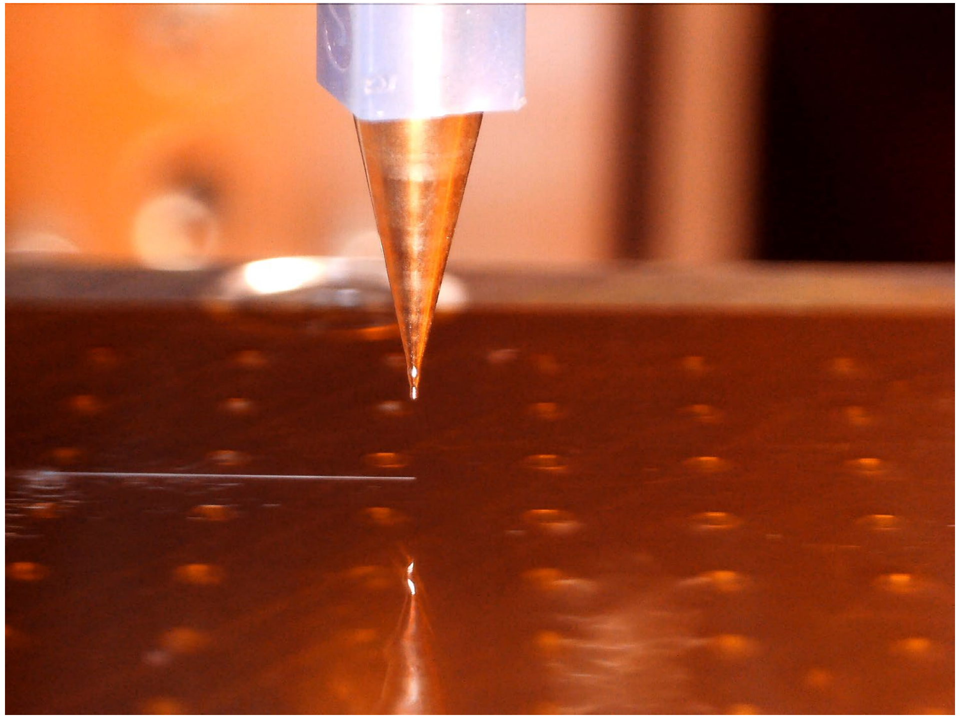
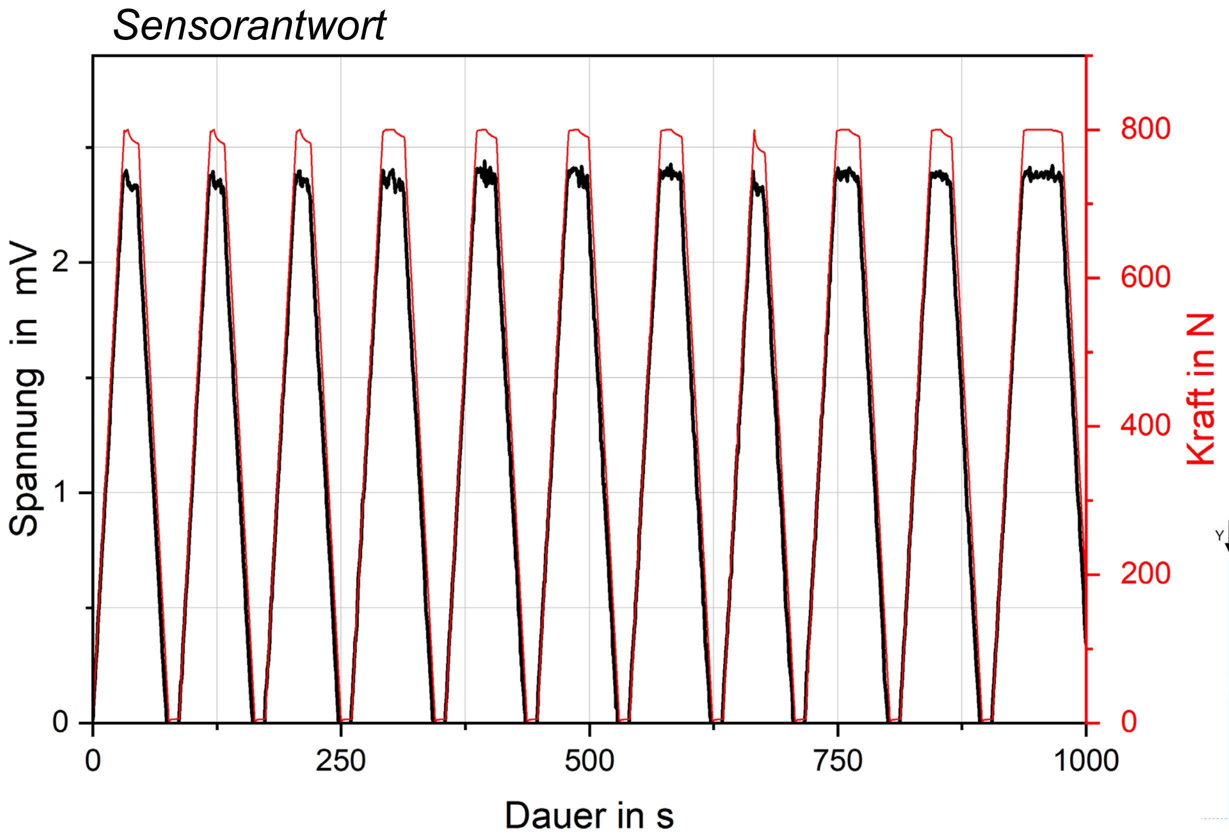
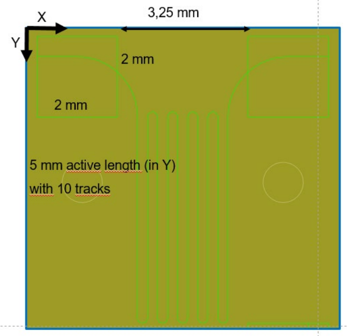
FAPS

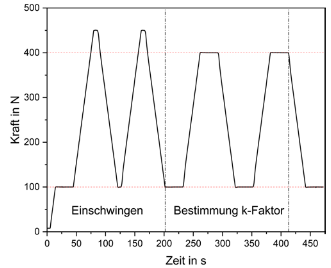
- Silver ink UTDots Ag40X
- Polyimid foil 125 µm
- 200 °C
- 60 min
- Cyclic strain testing
- Aluminium bar

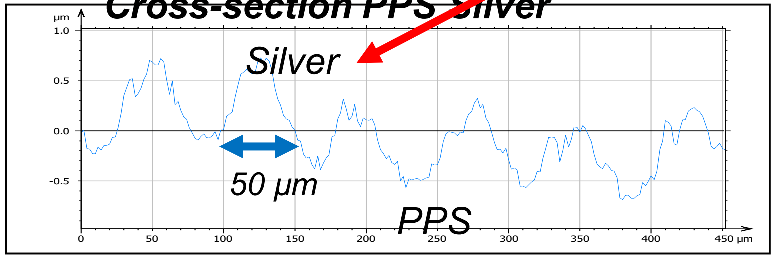


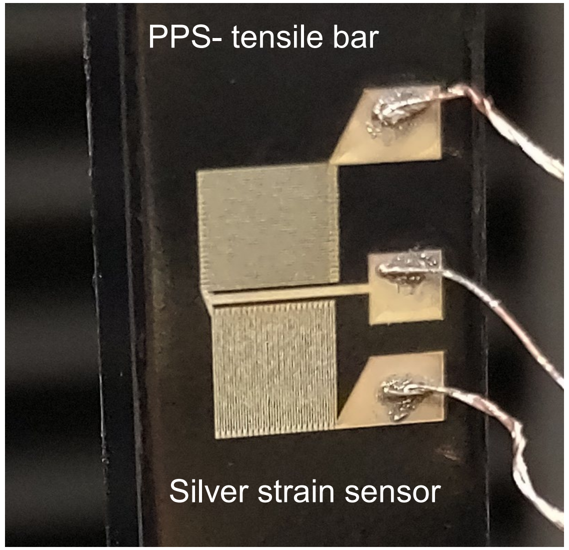


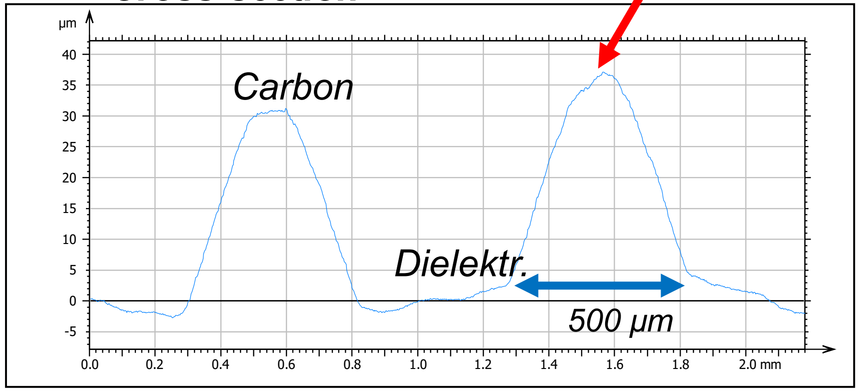


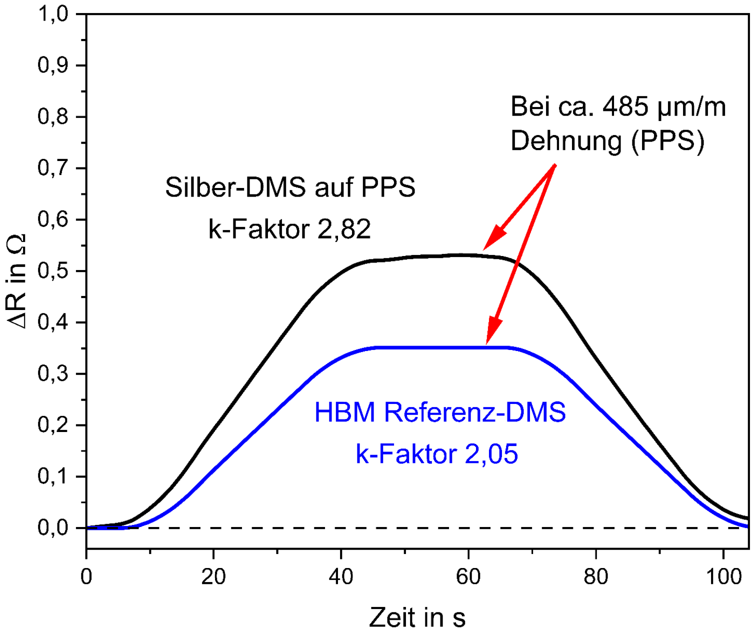
Actual results of printed on tensile bars show values in accordance with literature.

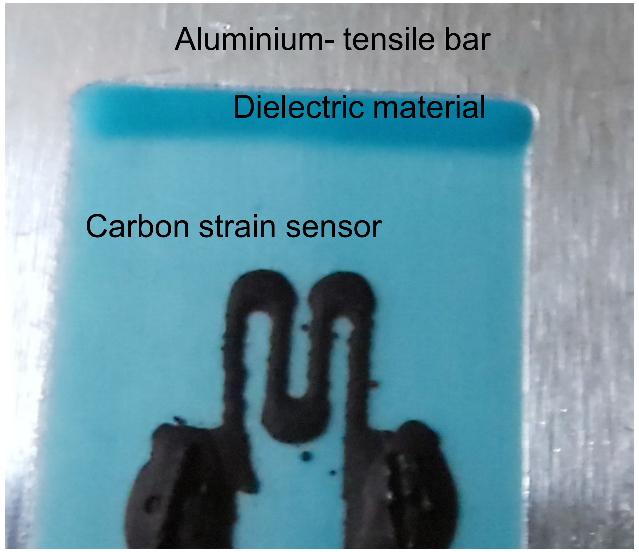


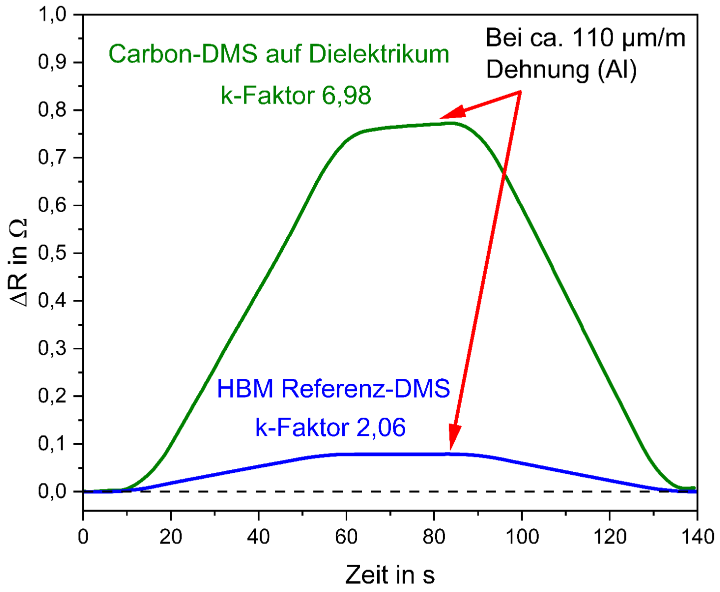






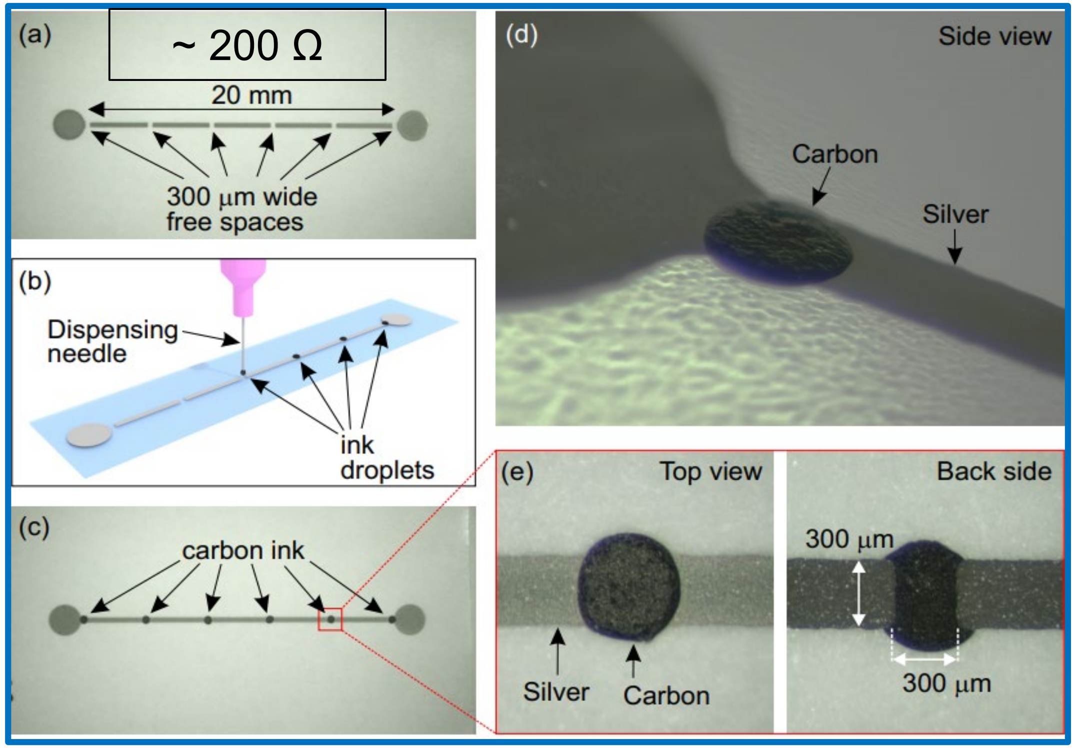






A hybrid concept of silver and carbon inks for high sensitivity, low resistivity sensors was realized using screen printing and dispensing.

Substrat - PET		Stddev in %		Substrat - PI	Stddev in %	
Querschnitt	2296 µm²	14	Ω/mm	2402 µm²	15	Ω/mm
Linienbreite	347 µm	6,5		292 µm	6	
Widerstand	388 mΩ	5	0,23	743 mΩ	4,5	0,44

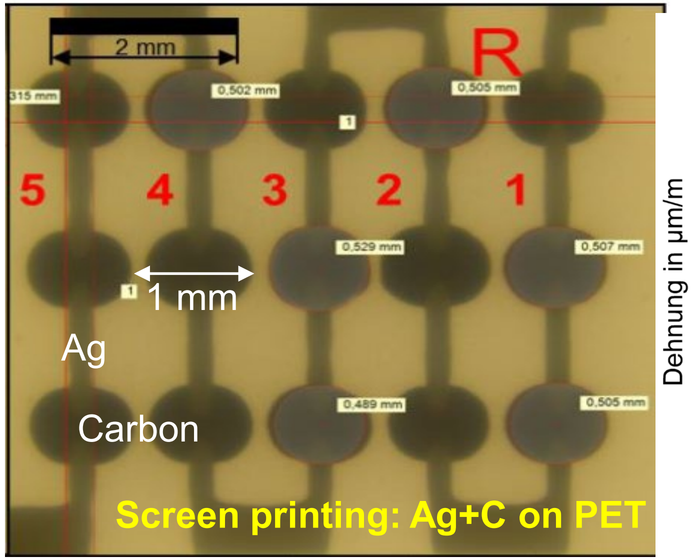


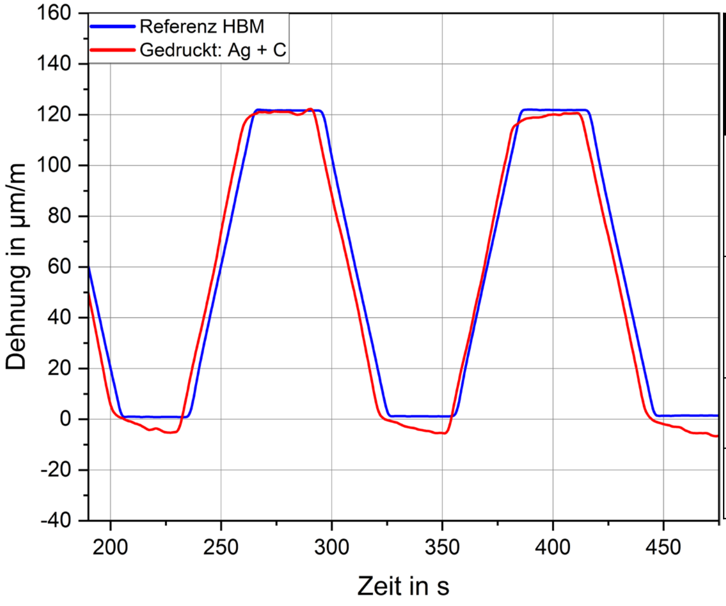
[9]

- High sensitivity (k-Faktor) GF = 7,7
- Sensor mainly made (90%) from silver tracks
- Distributed sensing
- Very local sensing
- Cheap manufacturing (screen, dispensing)

Results of the hybrid concept show factor 10 higher resistivities at high gauge factors.

Process	Standard dev. To average R in %	Ω/mm	Line width in µm	Layer heigth in µm
Nanojet (Ag)	2 - 5	1,3 - 2,3	50	1,5
Screen (Ag)	5	0,3	250	10
Screen (Ag) + Dispensing (C)	8	13	1000	30





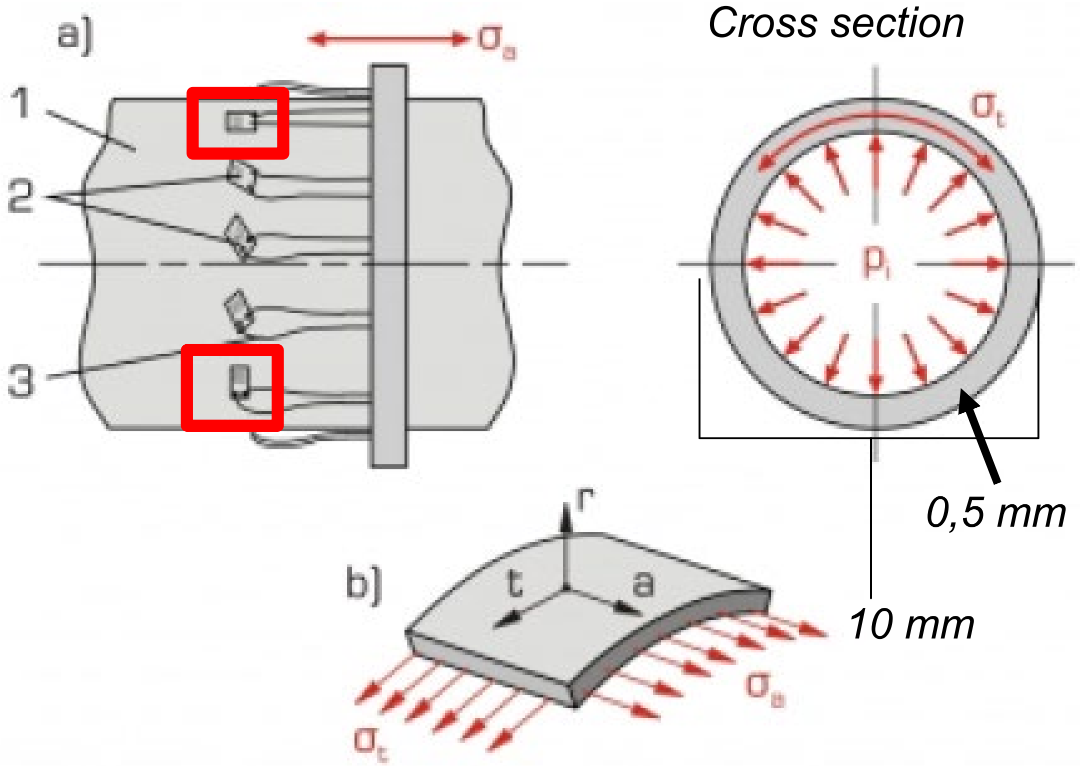
Process	Material	Gauge factor
Referenz (HBM)	Konstantan (CuNi)	2,06
Screen + Dispensing	Ag + C	6 - 7
Screen	Ag	1,21
Nanojet	Ag	2,80

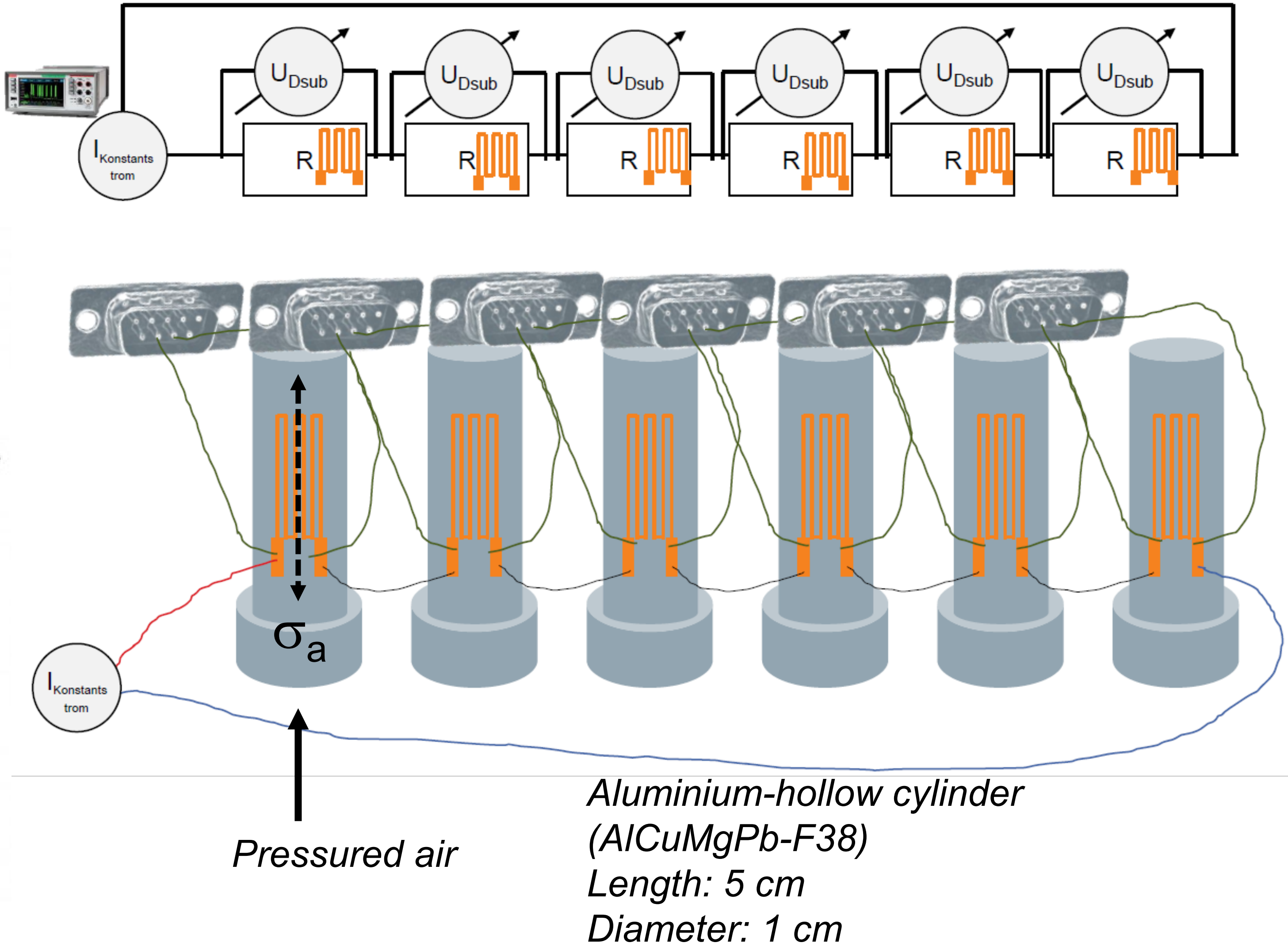
FAPS

For 3D applications a test on a hollow cylinder is planned to have a geometric and directly printed sensor in a pressure chamber.

Overlay of

- Axial-strain (σ_a)
- Tangential-strain (σ_t)

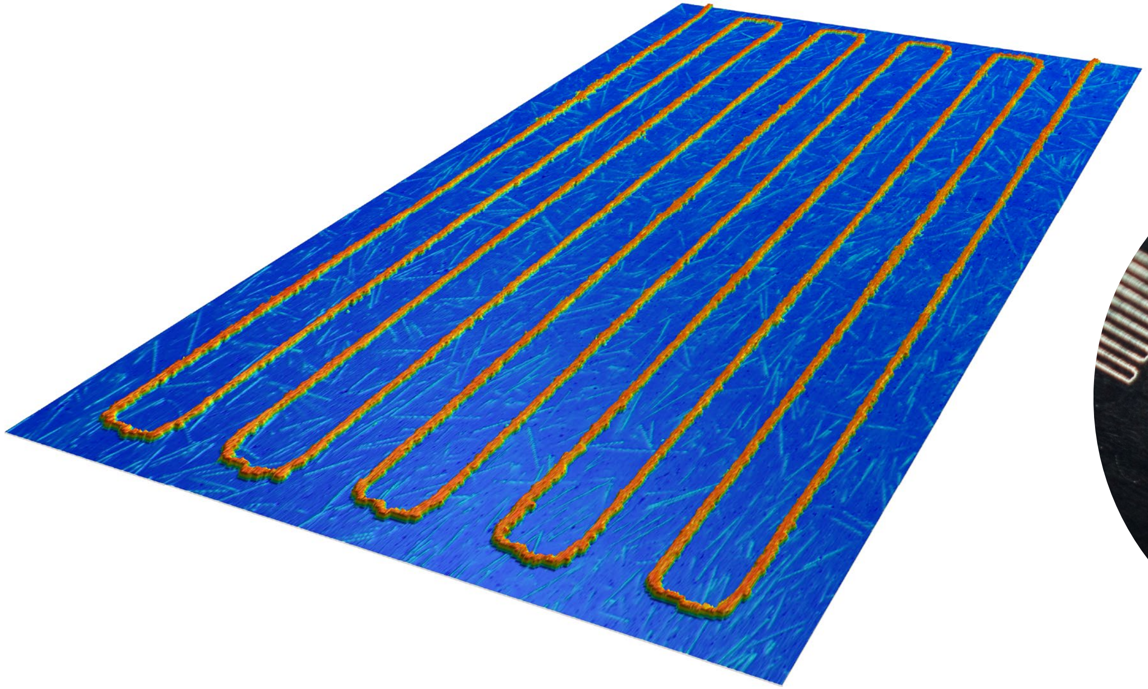


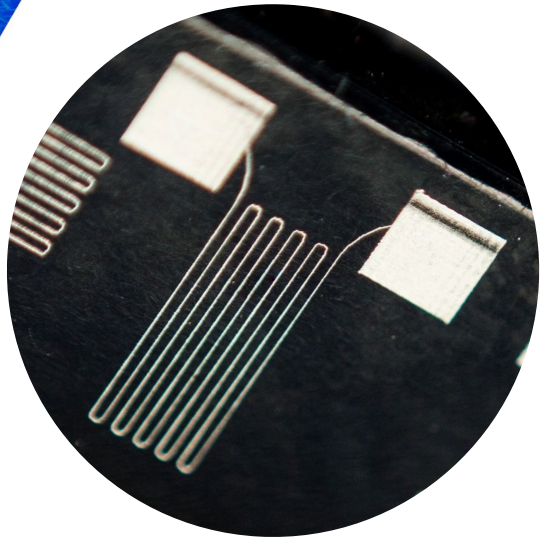


Findings

- Printing of strain gauges directly on geometric surfaces possible
- Suitable printing process application specific
- Fairly low resistivities for metal piezojet combinations
- Aerosoljet process most suitable for fine structures at higher resistivities compatible to existing instrumentation
- To be investigated
  - Encapsulation
  - Reliability (also longterm)
  - Direct application without manual steps on 3D surfaces
- Challenges remain
  - Material compatibility
  - Reproducibility
  - Drift

FAPS





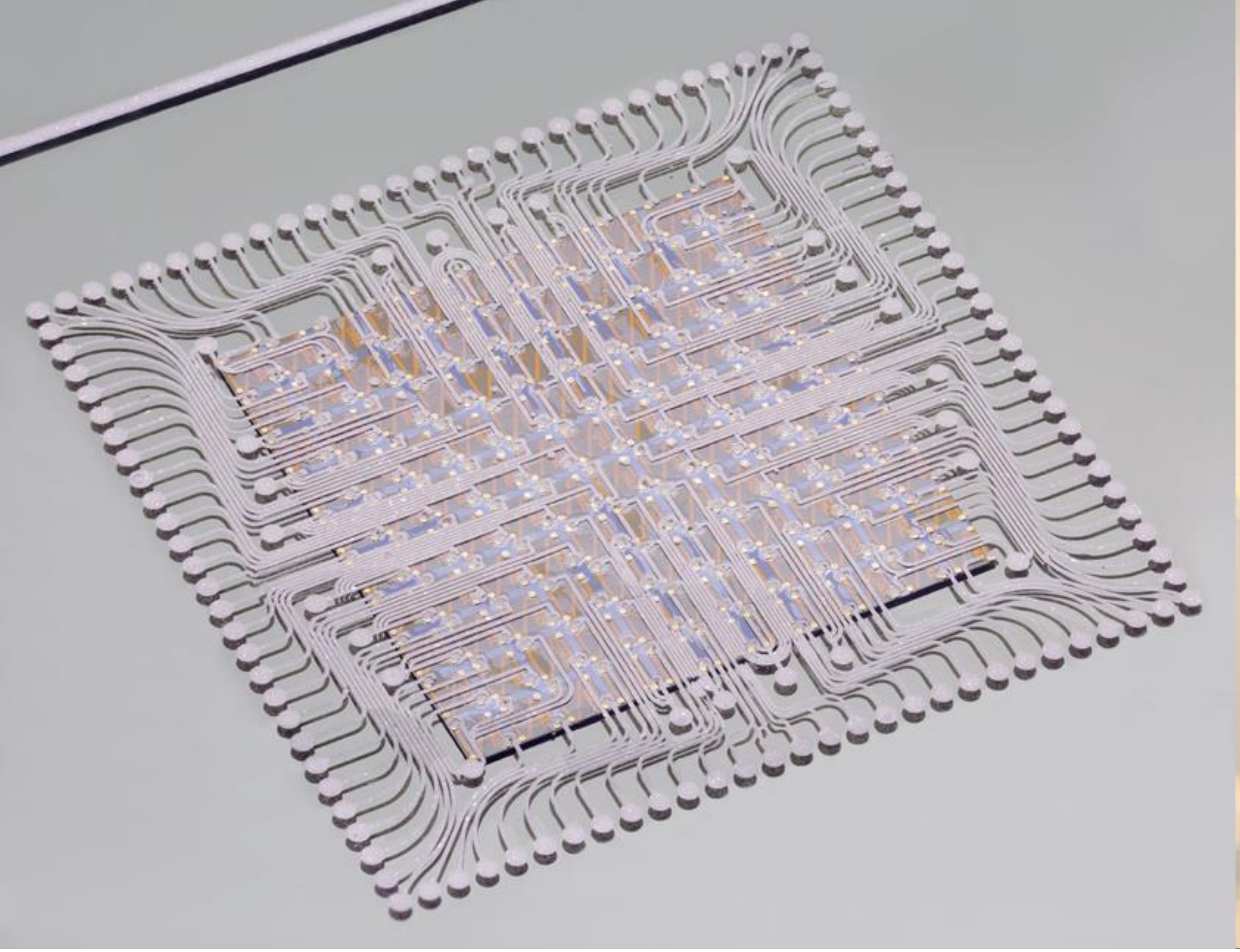
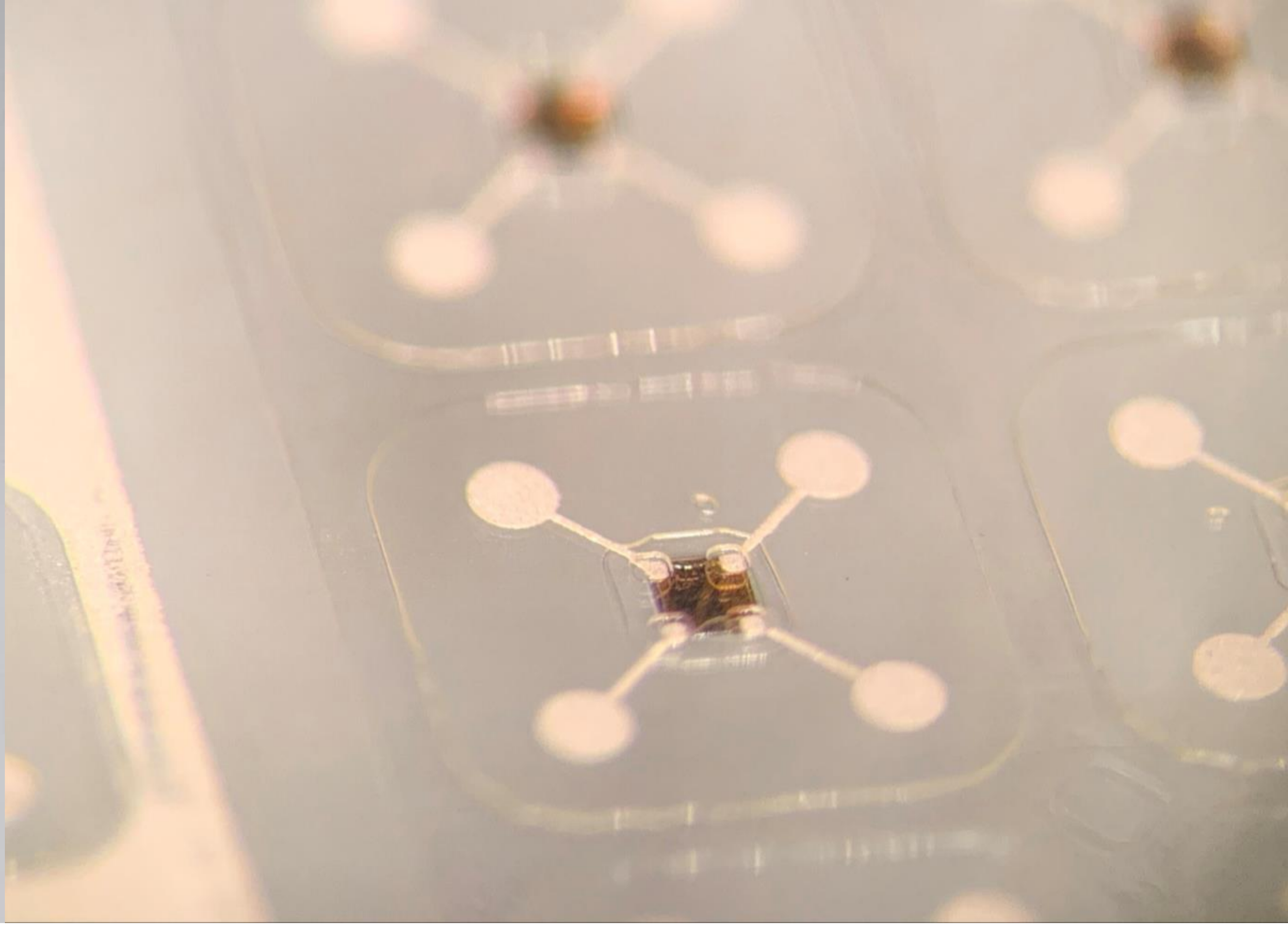
Prof. Dr.-Ing. Jörg Franke

Institute for Factory Automation and Production Systems

Friedrich-Alexander University Erlangen-Nuremberg

FAU
Friedrich-Alexander-Universität
Technische Fakultät

THANK YOU

Advancements in Functional Printing

3D Printed Chip Packaging

2022-09-21 | Dr.ir. Ashok Sridhar | Business Development

Holst Centre
powered by imec & TNO

An Introduction to Holst Centre

Holst Centre

- ✓ Started in 2006 on initiation from Philips Research, named after Gilles Holst, first director of Philips Research
- ✓ Located at the High Tech Campus in the heart of Brainport area, home of Dutch high tech industry
- ✓ Aimed at fostering and orchestrating innovation with and between companies

Holst Centre fundamentals

Holst Centre
powered by imec & TNO

- Managed and run by 2 reputed R&D institutes: TNO and imec
  - TNO: biggest Dutch R&D organisation focused on applied research aimed at improving societal welfare coupled to economic growth
  - Imec: famous Belgian R&D institute aimed at advancing chip technology

TNO innovation for life

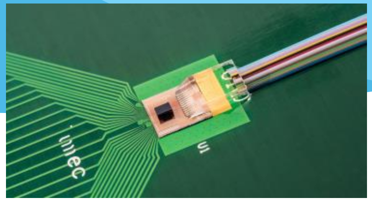
- Thin film, printed and flexible electronics
- Energy storage

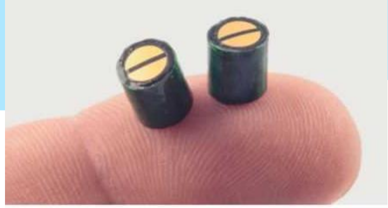
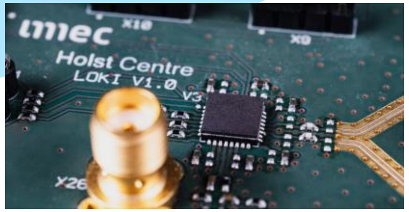
- Health care technology
- Integrated photonics

imec

- Low-power wireless communication
- Edge AI



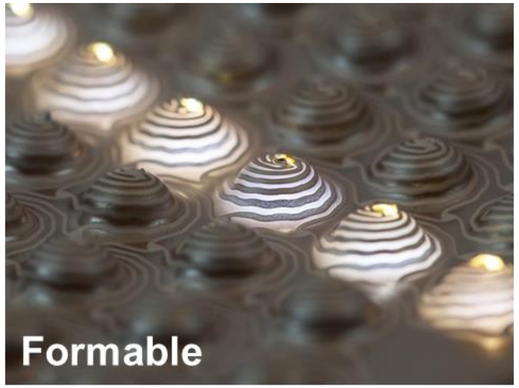


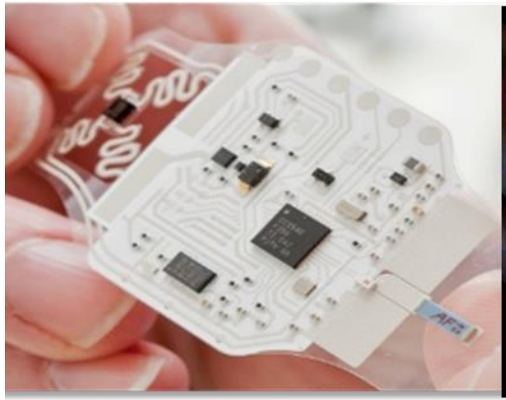
Expertise of Holst Centre

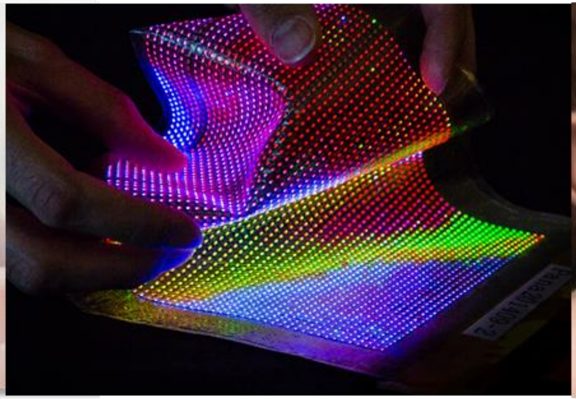
Holst Centre
powered by imec & TNO

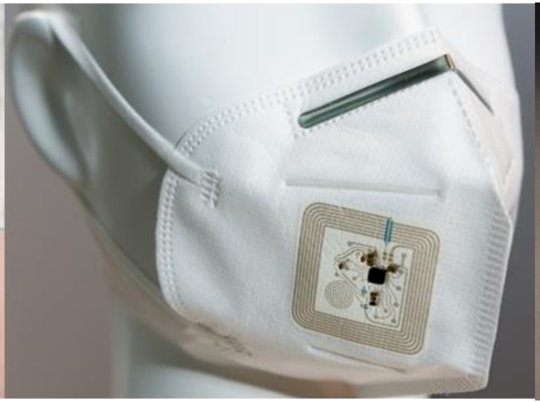
New form factors and design freedom by printing…



…and enabling new applications by combining with traditional components!







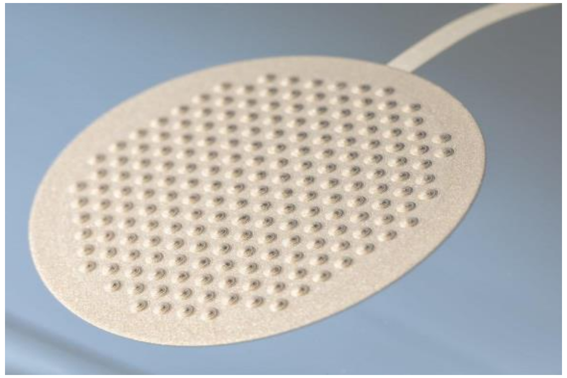
R&D orchestrator

Holst Centre
powered by imec & TNO

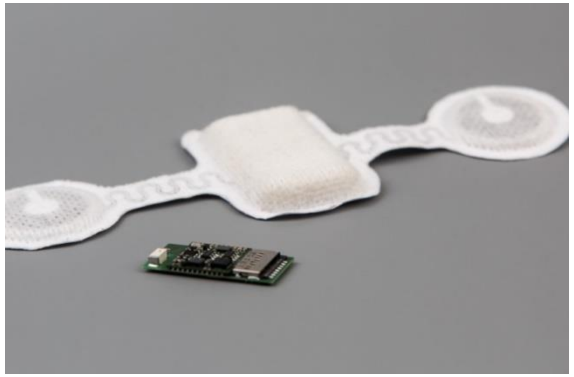
- One-stop shop approach
- From application requirements to full system design and material + equipment development
- Organizing and executing complex and disruptive innovations with and along the value chain

Technology → Components → Systems → Applications & Data analytics

Materials, equipment, processes => pilot line



Electrodes, sensors, electronic components

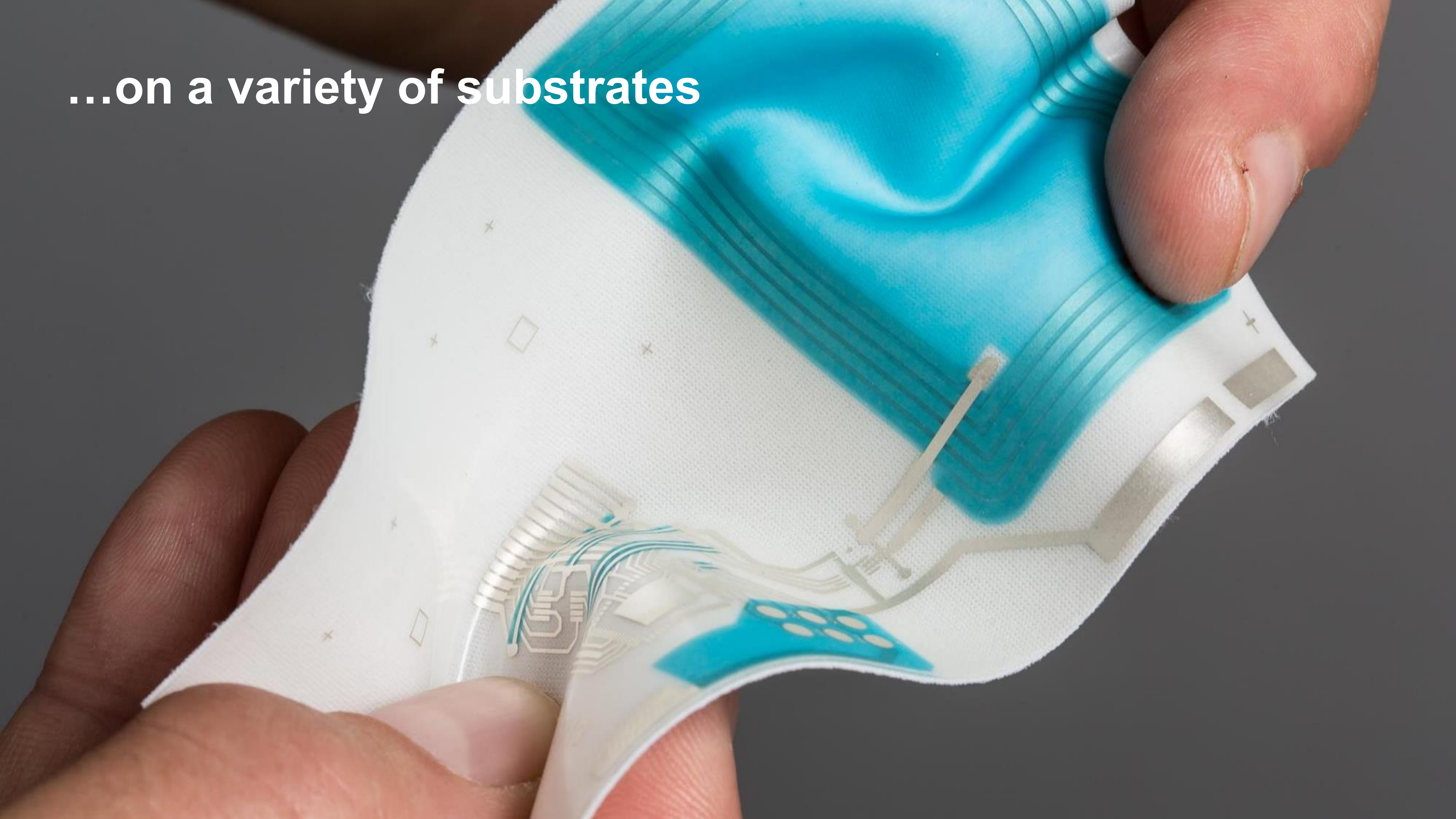


Health patch, IoT devices, optical switch

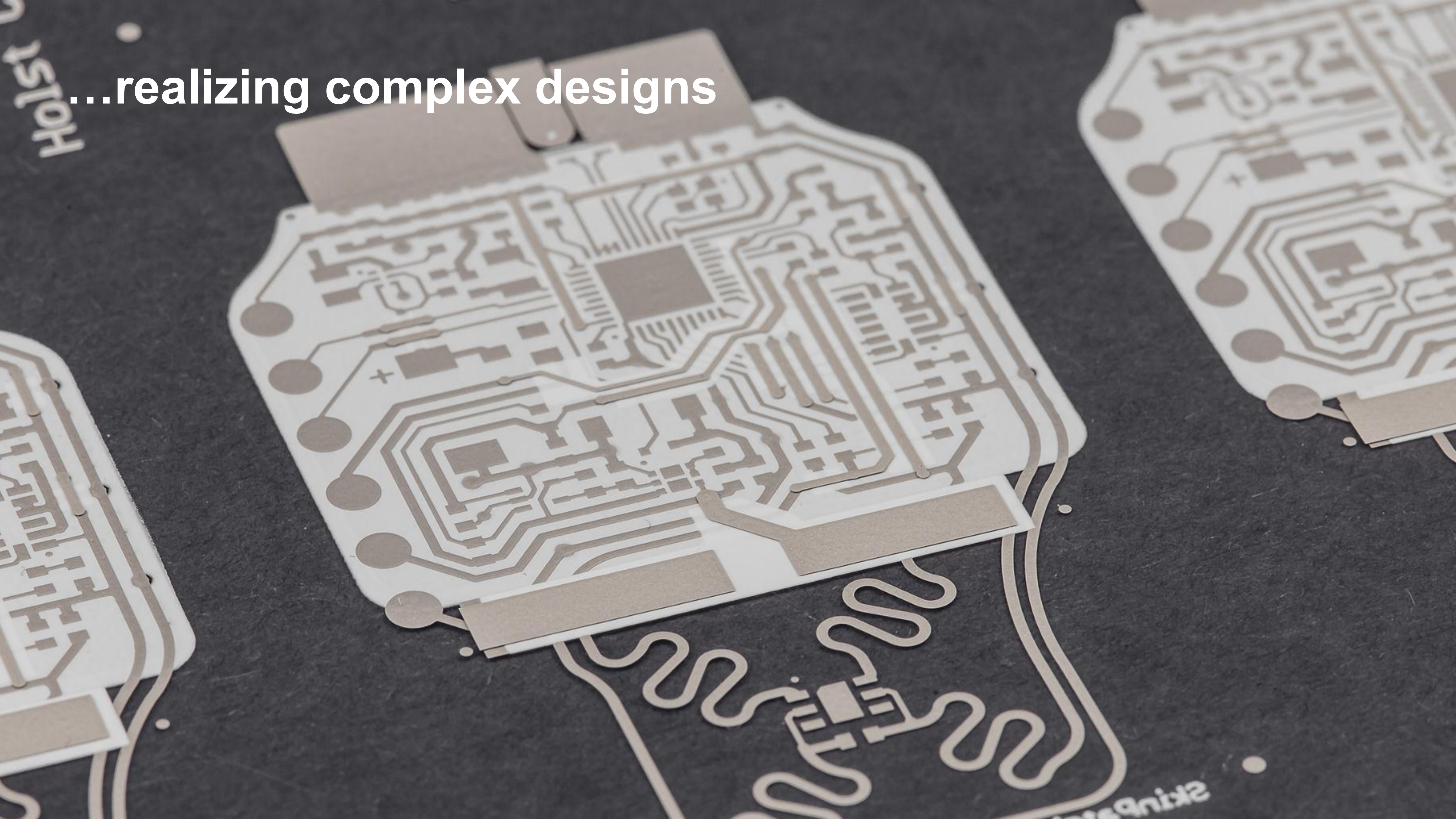
(Clinical) trials, data analysis, algorithms

Smart use of PRINTING…

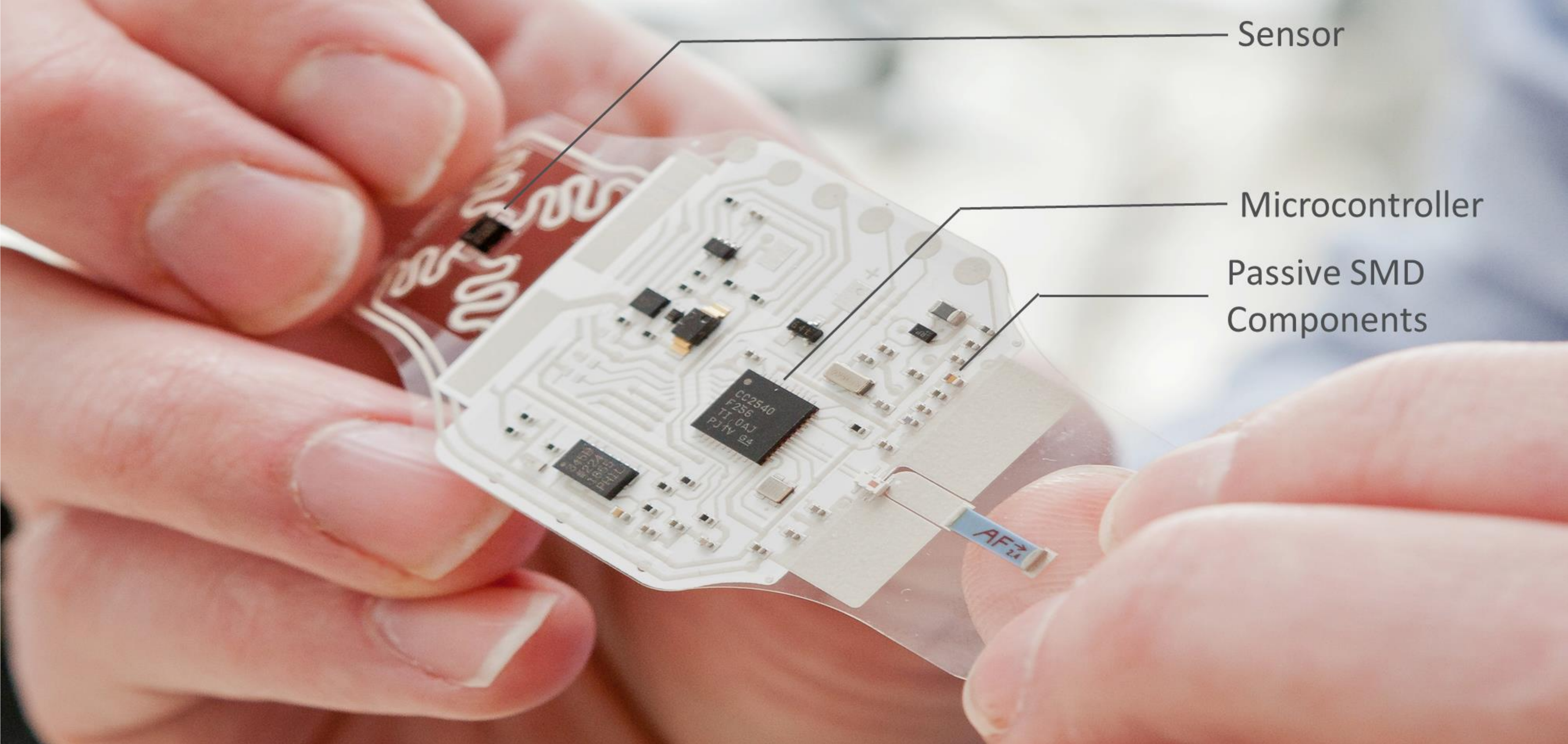
…on a variety of substrates



…realizing complex designs



…adding components in a smart way



What’s next in printing and integration?

Market drivers

- **Finer resolution**
- **Higher throughput**
- **Greater degree of integration**
- **Mass customization**
- **Sustainability**

…of course, it goes without saying that these drivers cannot be compromised at a product level:

- Cost
- Quality
- Reliability

Market drivers: µLED display

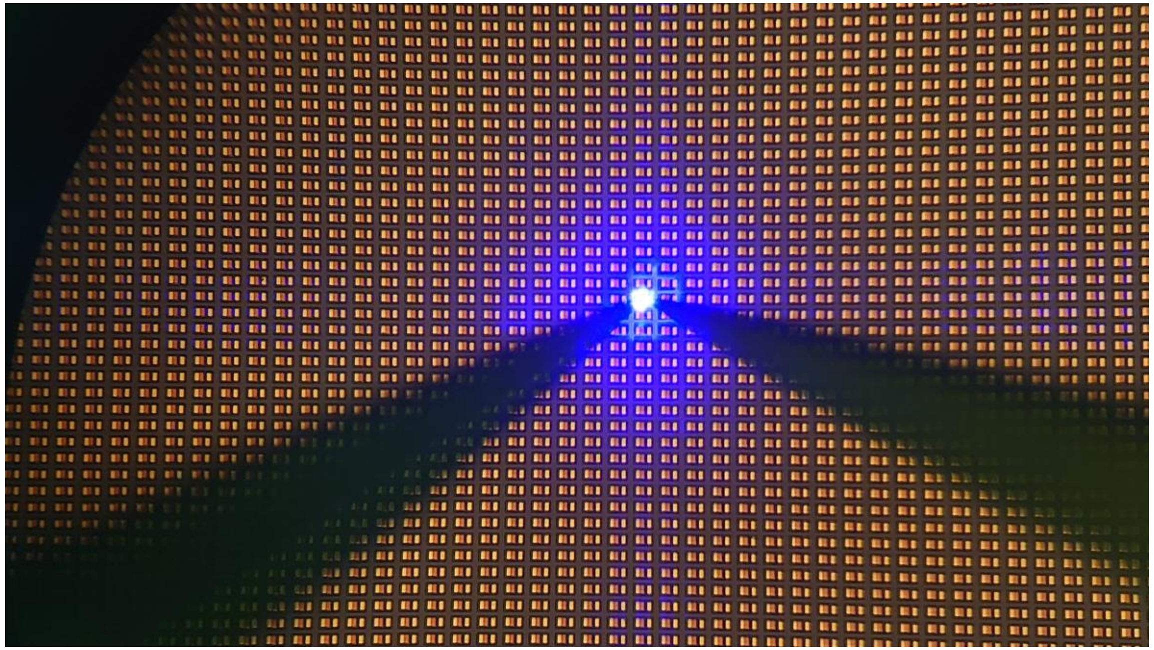
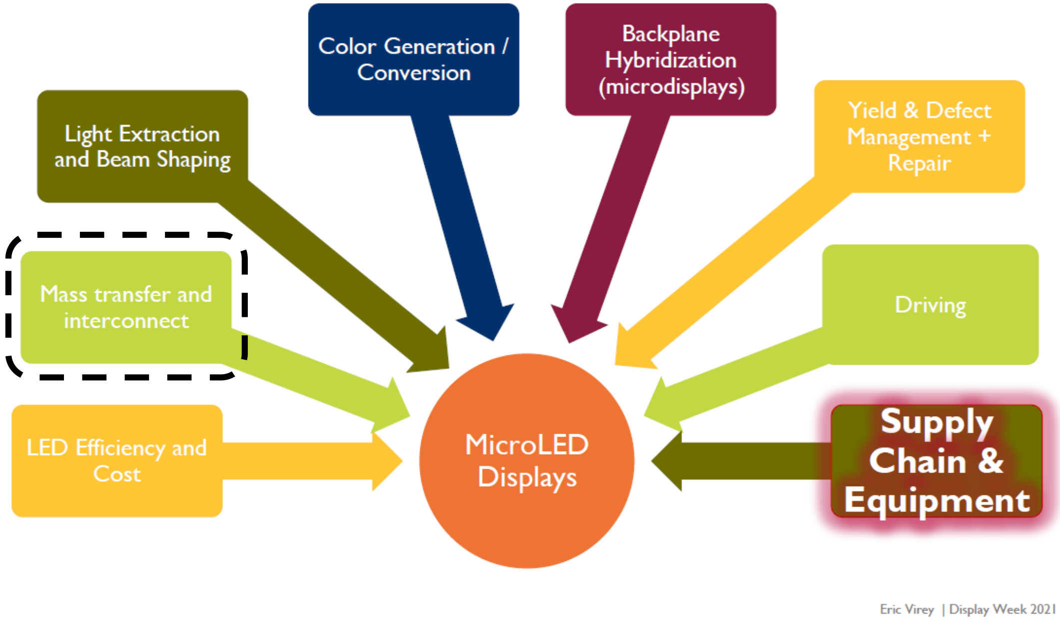


Image: Shin-Etsu

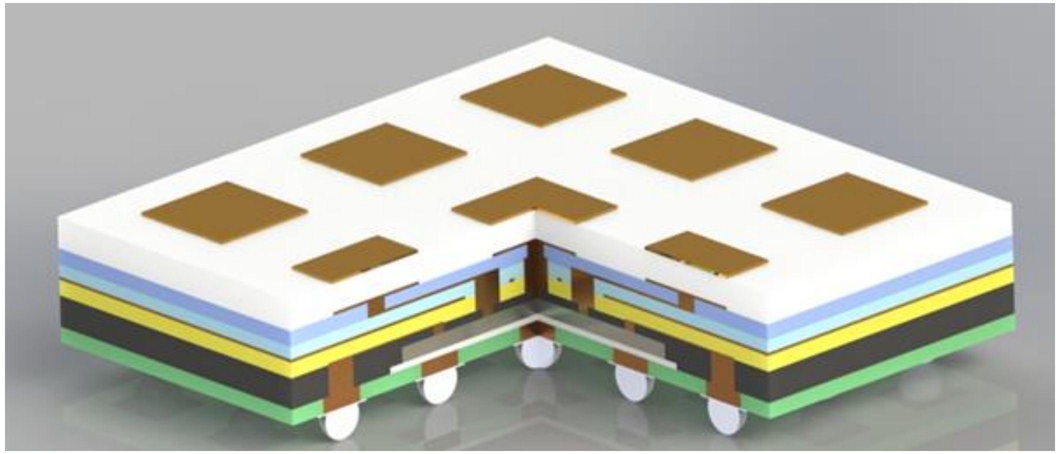


Market drivers: Chip integration

- Antenna-in-package (AiP)
- Stressless chip packaging
- Optical devices
- Organ-on-chip devices
- …

CITC

Chip Integration
Technology Center



Market drivers: Chip packaging

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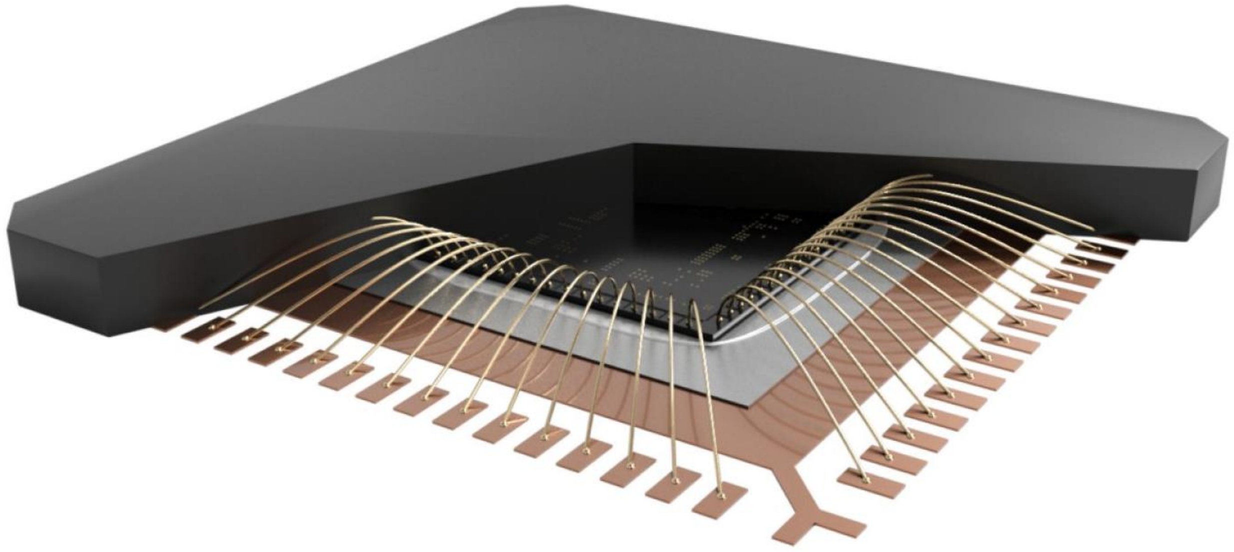
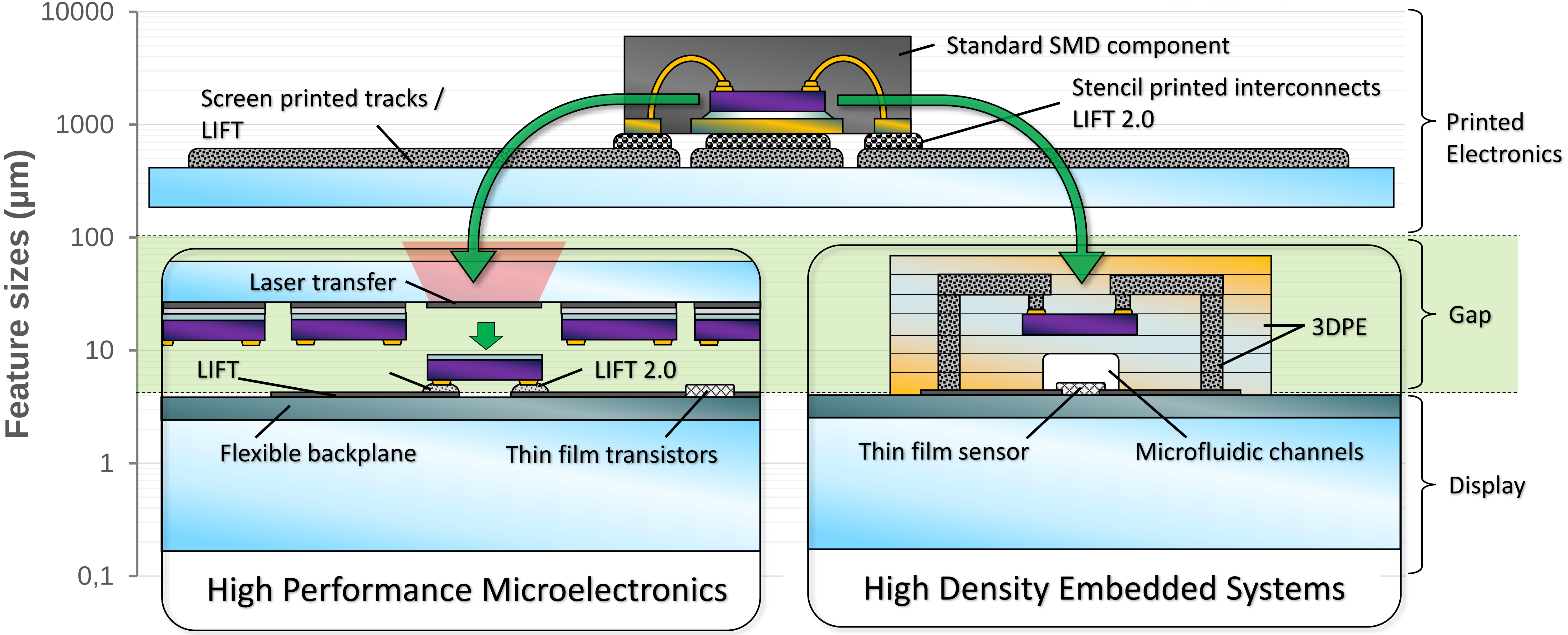


Image: CITC, Henkel

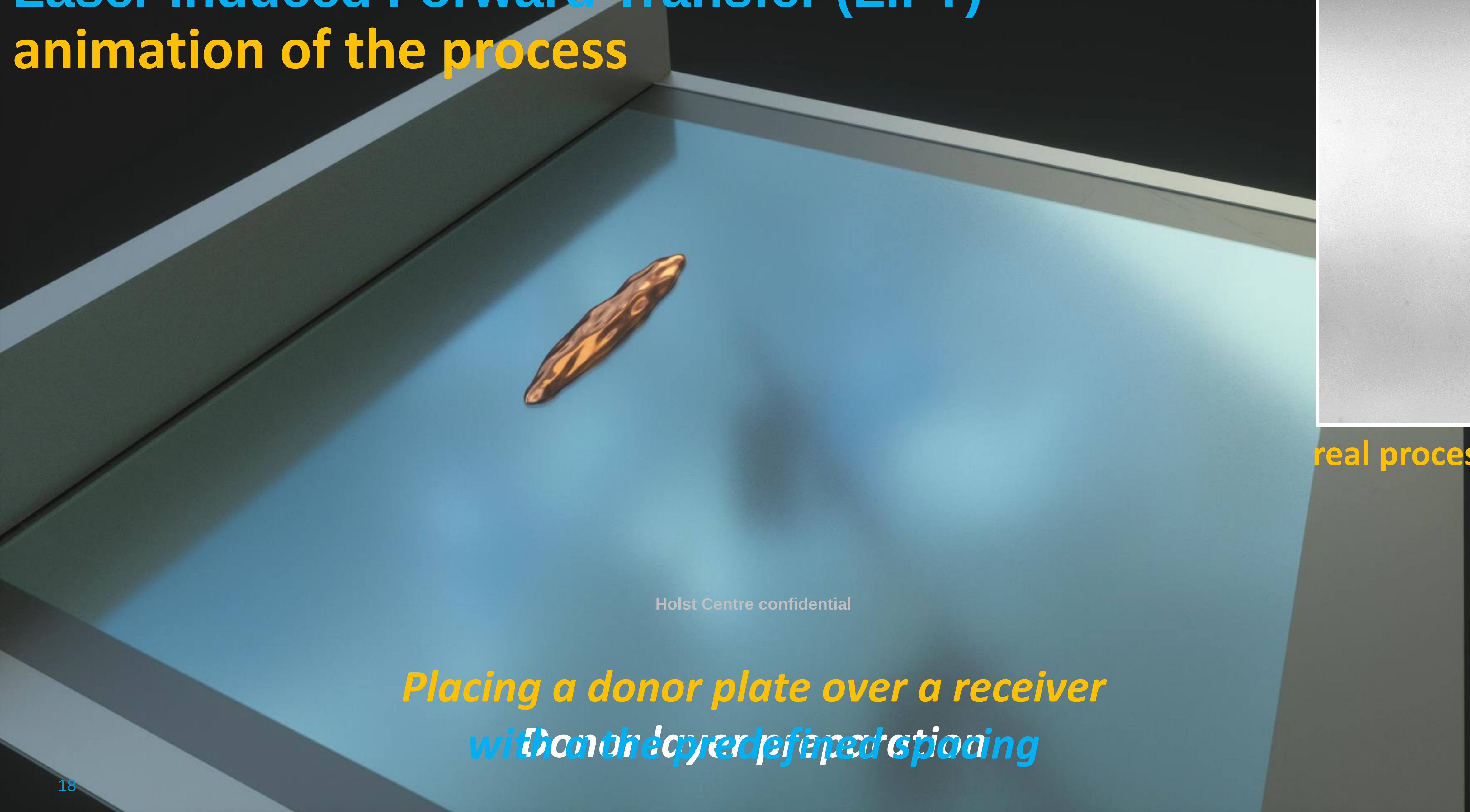
Bridging the gap...

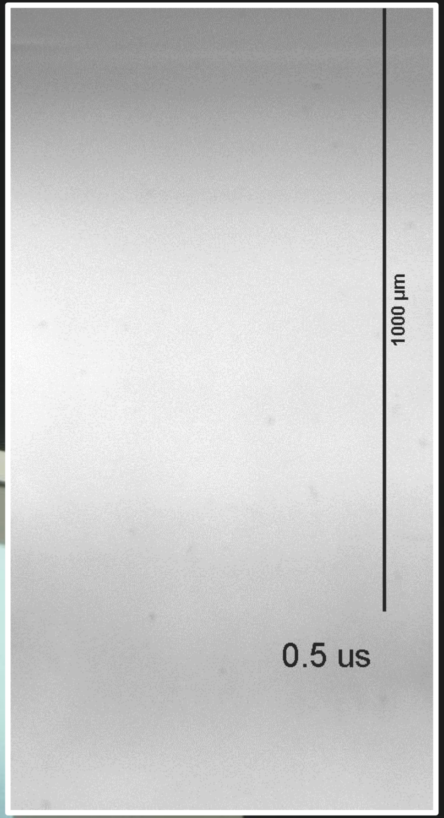
New printing technologies to bridge the gap



Laser Induced Forward Transfer (LIFT)

animation of the process





real process video

Holst Centre confidential

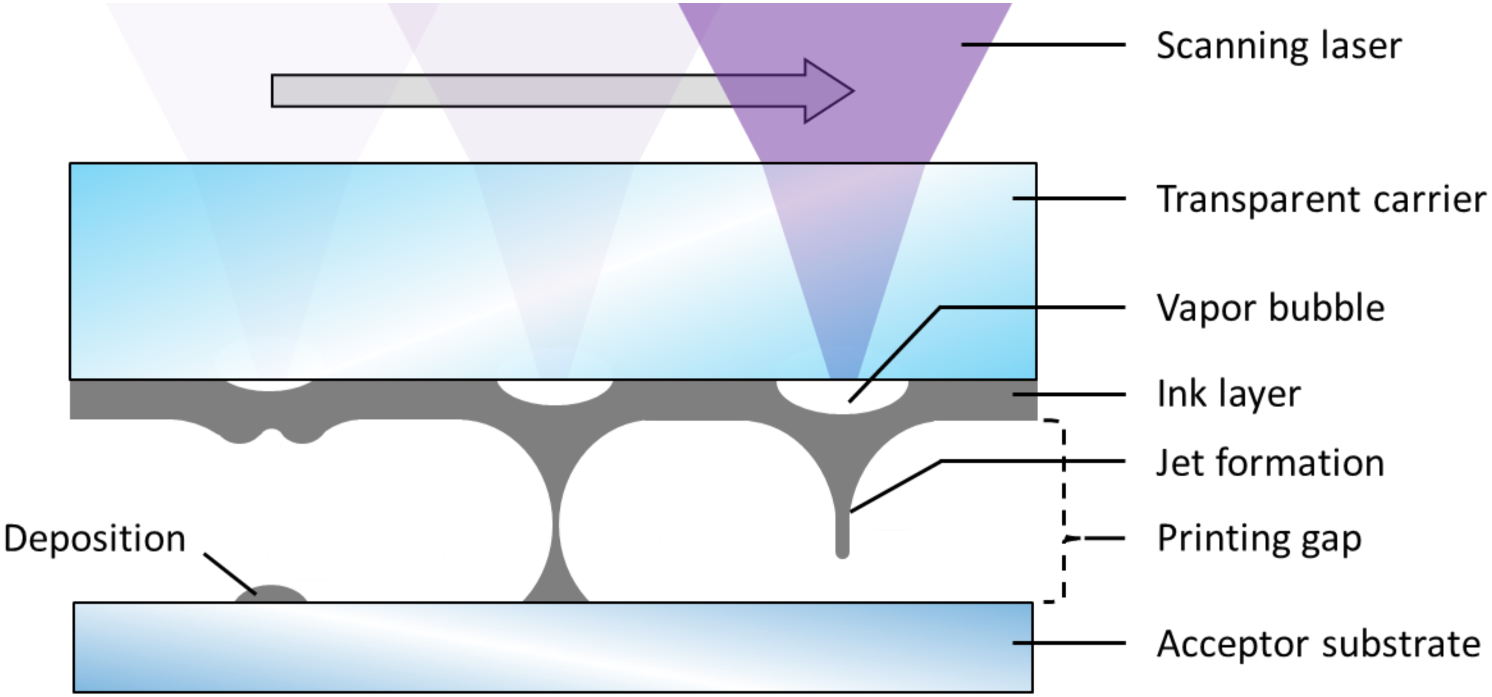
Placing a donor plate over a receiver

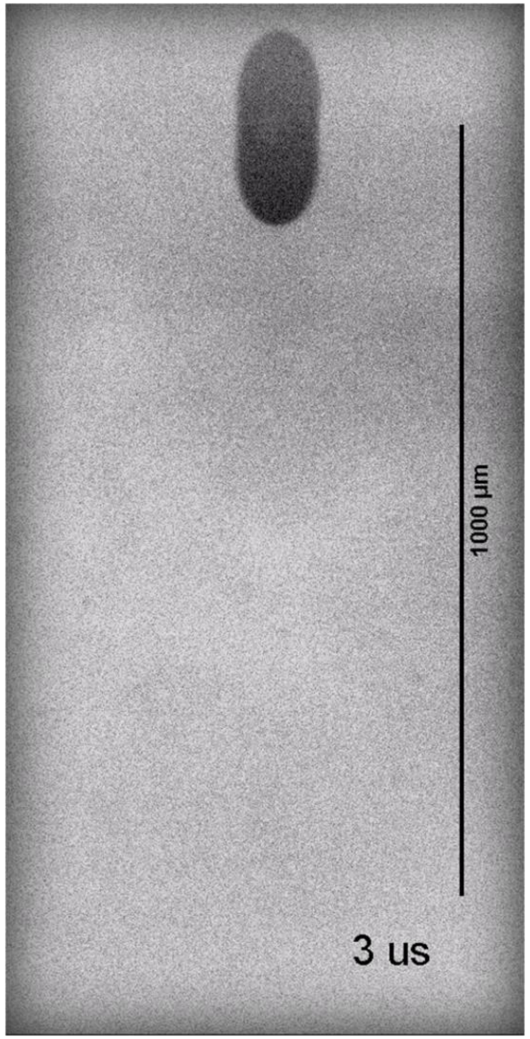
with a the predefined spacing

Donor layer preparation

Working principle: LIFT 1.0.

- A laser pulse rapidly heats the ink at the ink/carrier interface
- A vapor bubble expands and ink layer forms a jet
- The jet touches the acceptor substrate and leaves a deposition

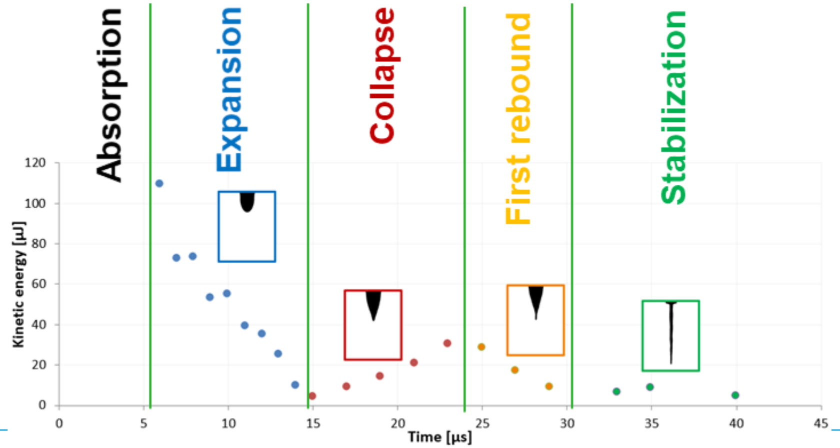


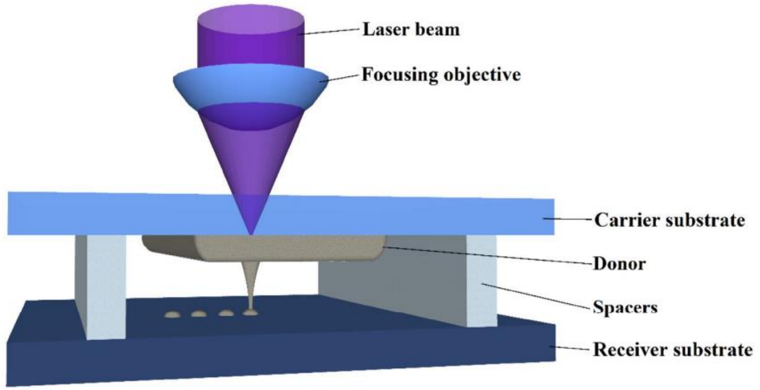


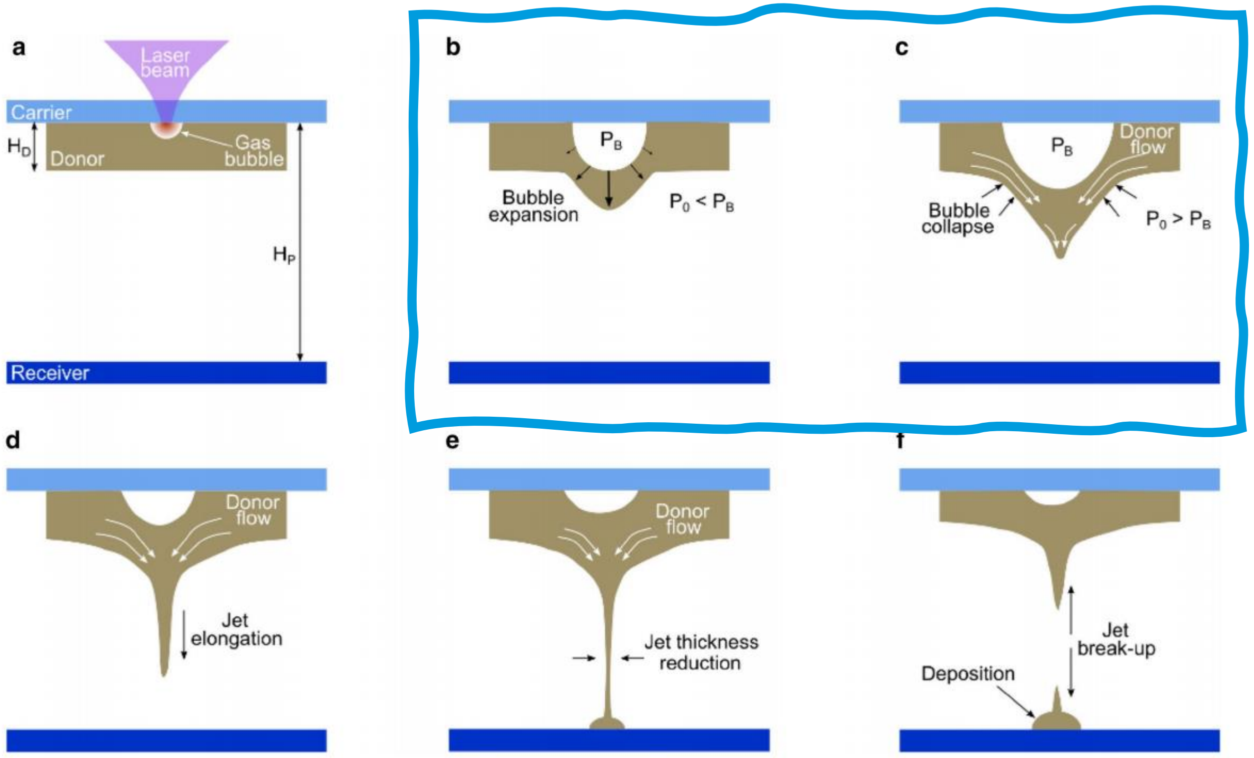
Phases of LIFT process

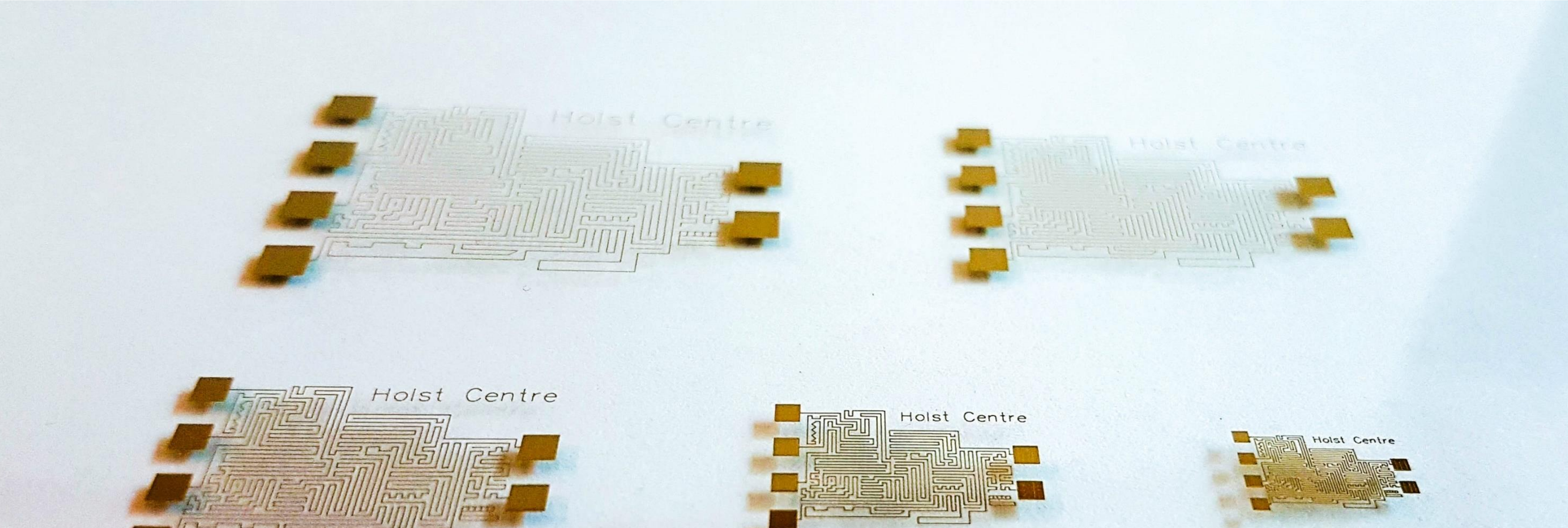
re

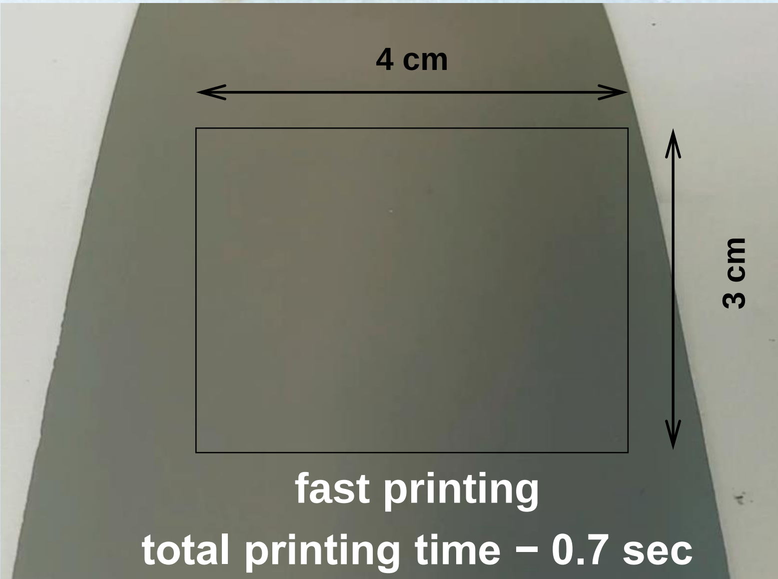
- Initial gas bubble and Ps depends on laser parameters, material absorption properties and material composition
- Donor flow and jet elongation depends on material rheology (viscosity, thixotropy, recovery time, particle size)









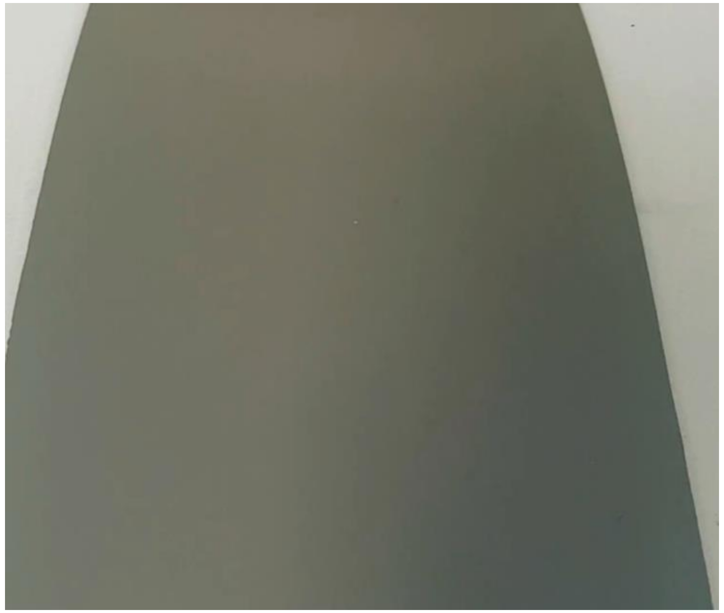


Ultrafast printing of conductive structures

printing speed 2.8m/s

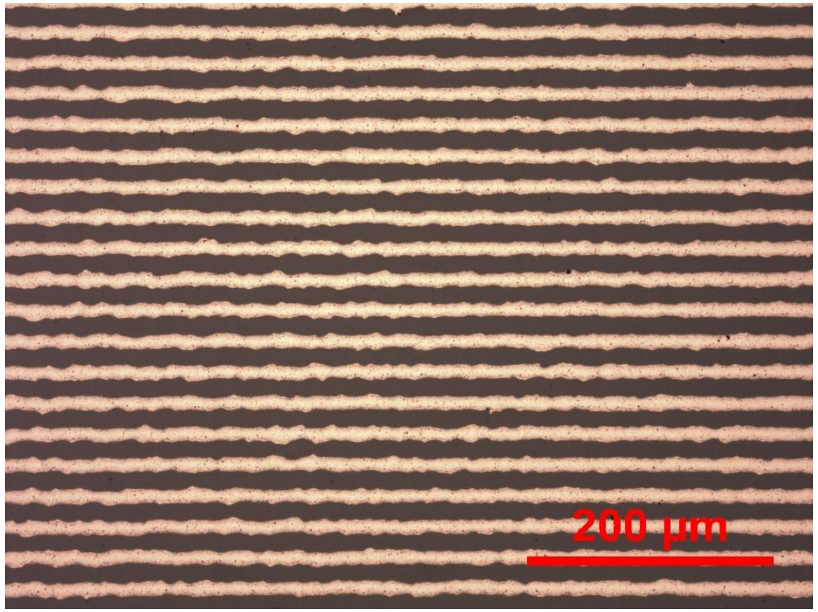
Uniqueness of LIFT 1.0.

- **Fast processing** The printing speed is only limited by the coating process
- **Non-contact** Printing on non-planar surfaces
- **High resolution** Feature sizes down to 15 µm are possible



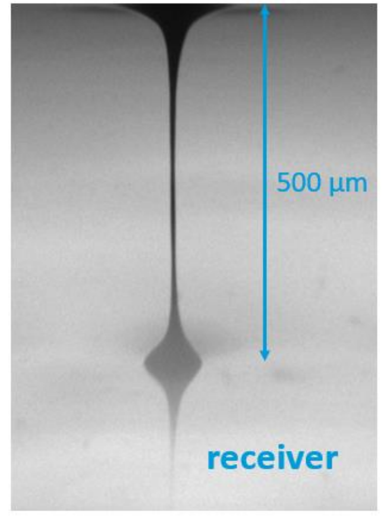
Fast processing

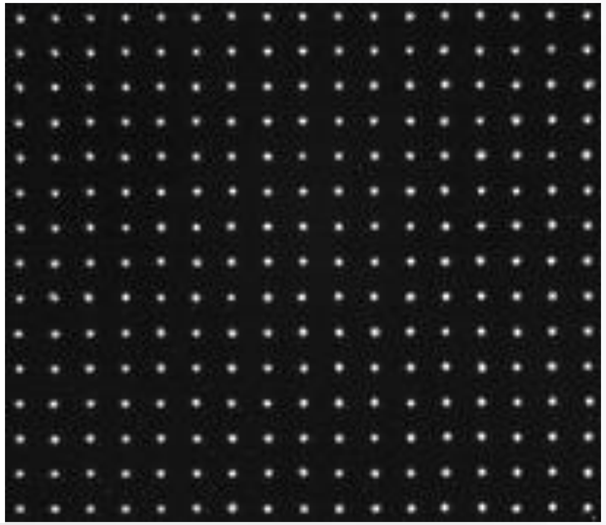
Printing on non-planar surfaces



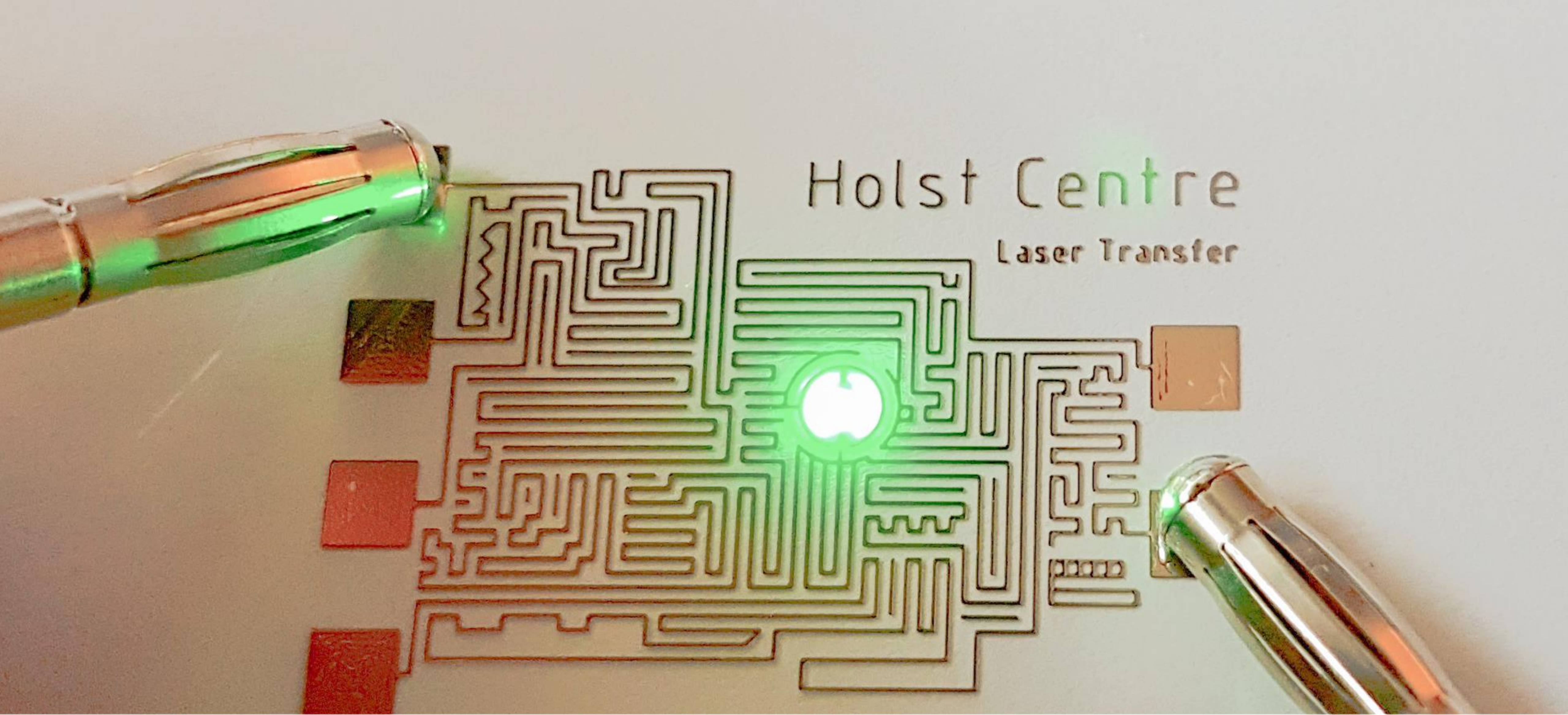
High resolution features

Printing interconnect materials





- printing of a **conductive adhesives**
- **>10k dots** (200 µm size, **0.5 mm spacing**), printed in **less than 1 second**
- (…. thereby beating any other jetting technology)
- using the laser system based on budget pulsed laser

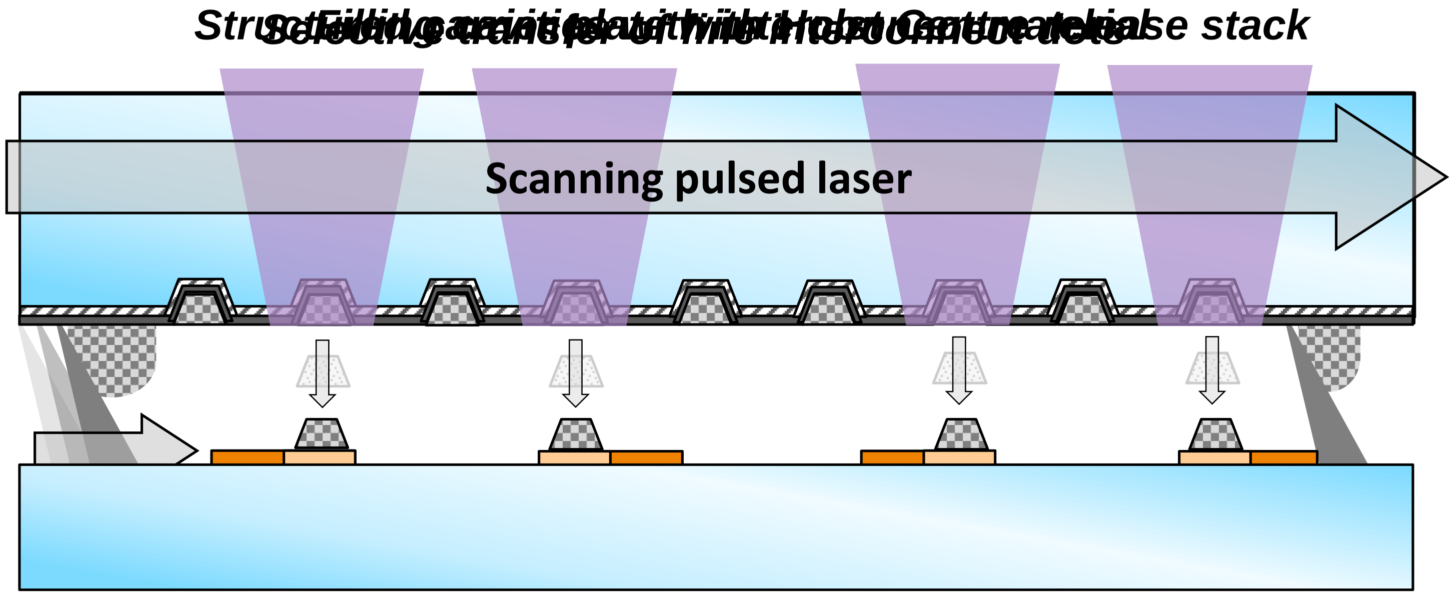


Functional demonstrator on PEN

- 160µm conductive tracks
- ICA Bondpads
- 0402 component picoLED

Volume-controlled laser printing: LIFT 2.0.

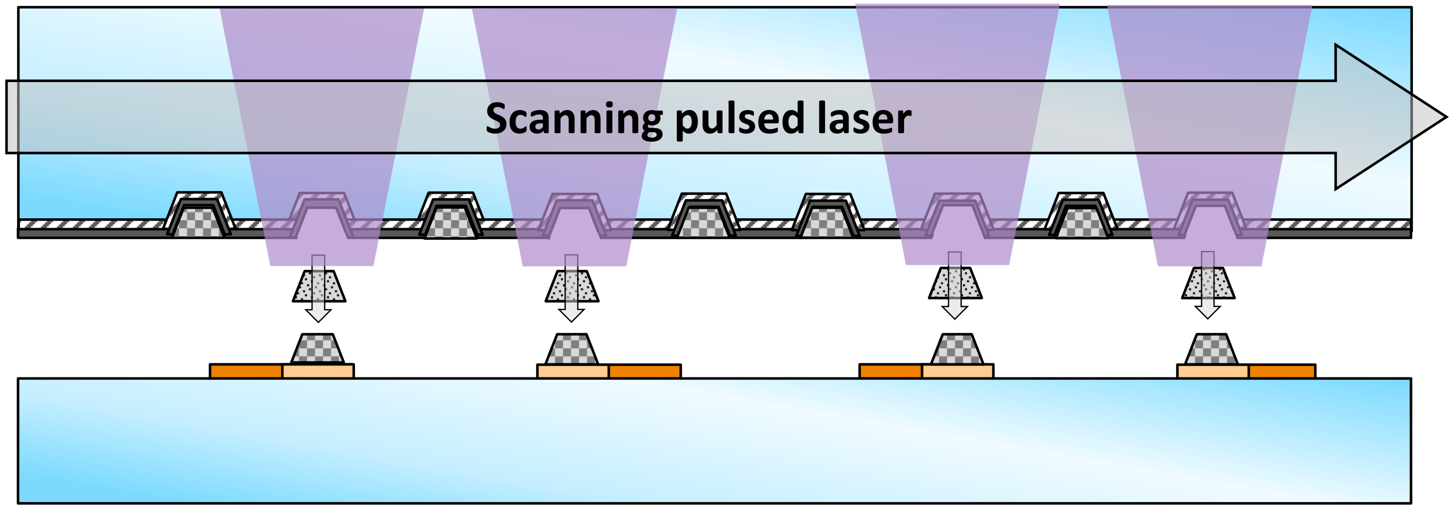
- Laser printing technology enabling ultra-fast printing of interconnects
- Laser pulse accurately accelerates pre-defined patterns towards substrate
- Additive manufacturing with high material efficiency



Volume-controlled laser printing: LIFT 2.0.

- Laser printing technology enabling ultra-fast printing of interconnects
- Laser pulse accurately accelerates pre-defined patterns towards substrate
- Additive manufacturing with high material efficiency

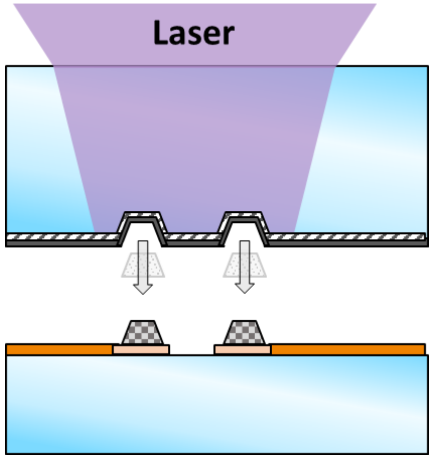
Selective transfer of fine interconnect dots

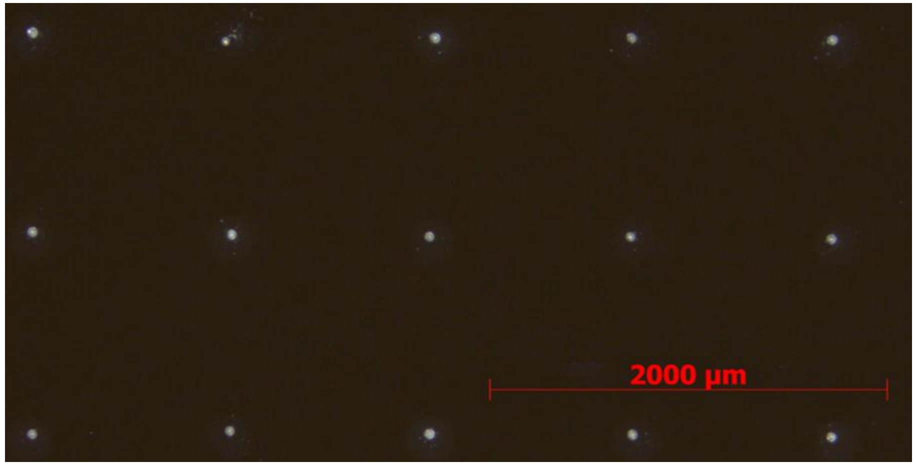


Heat flux control is crucial

Laser printing of solder paste from cavities

with Holst Centre release stack

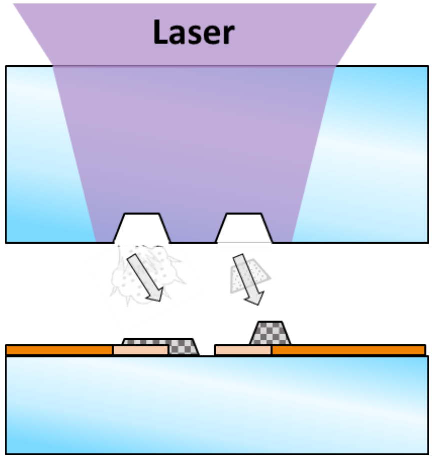


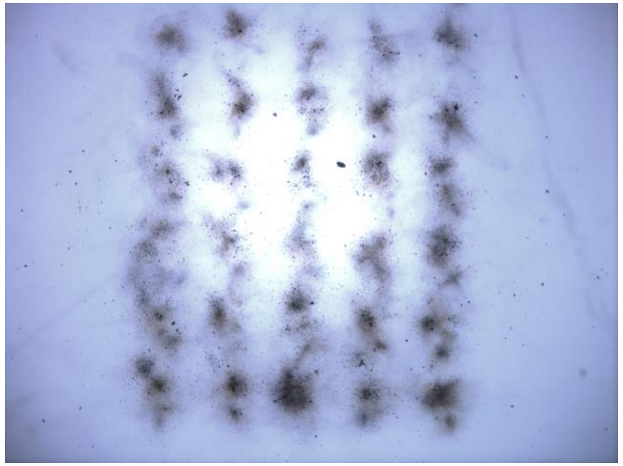


clean fine dots of solder paste

Laser printing of solder paste from cavities

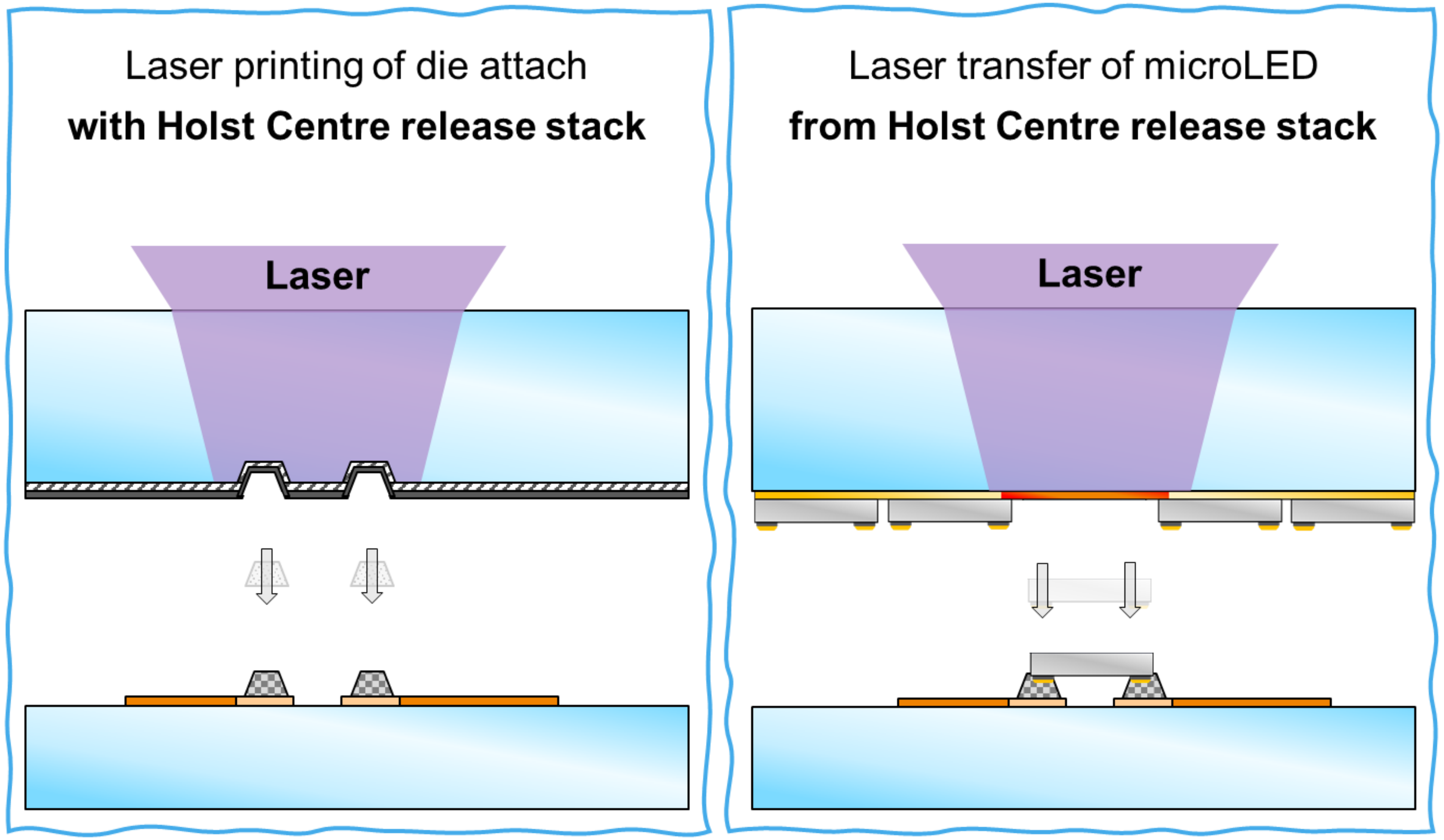
without Holst Centre release stack





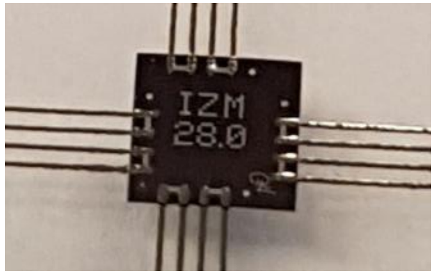
dust spray of solder balls

High throughput assembly of µLEDs

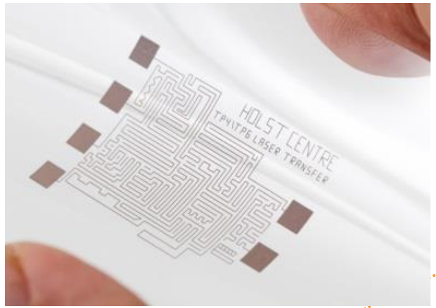


LIFT as a “one-stop-shop”

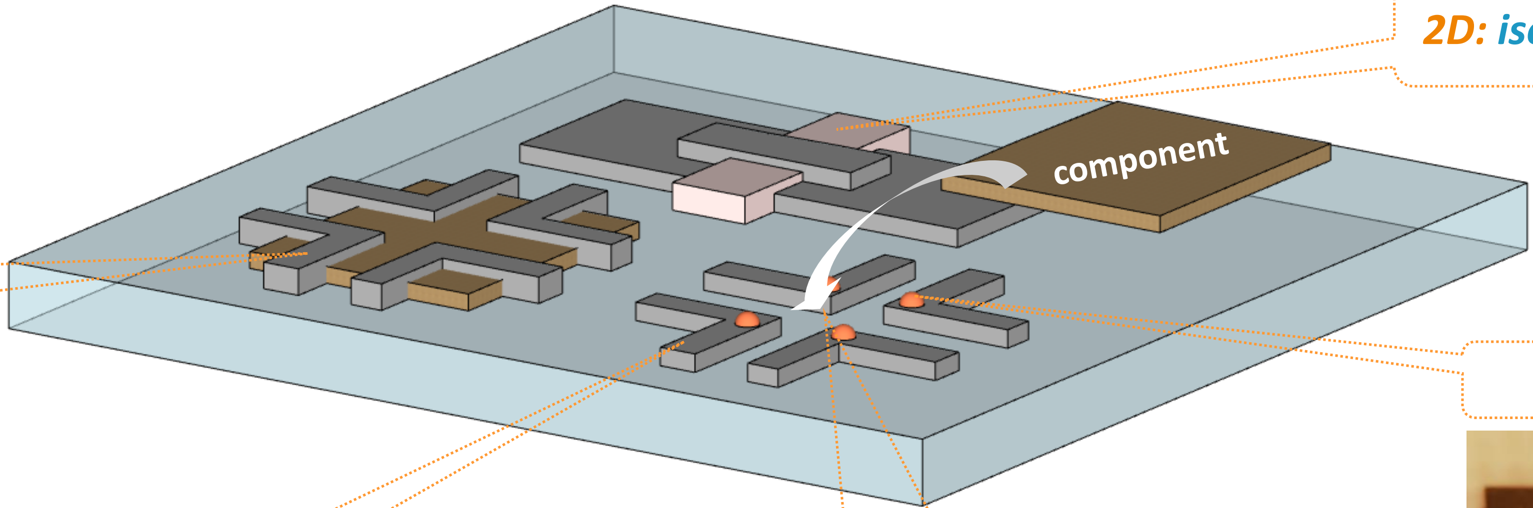
Holst Centre
powered by imec & TNO



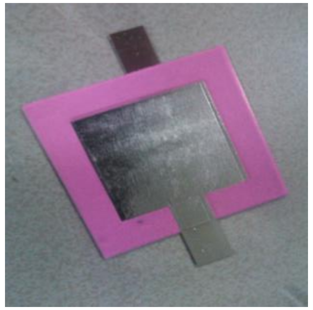
Face-up integration (2.5 printing)



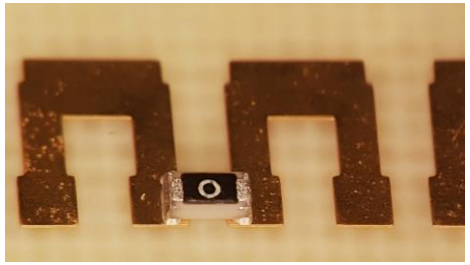
2D: conductive circuit (silver/copper paste)

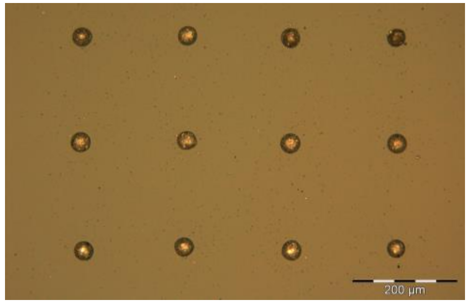


2D: isolation

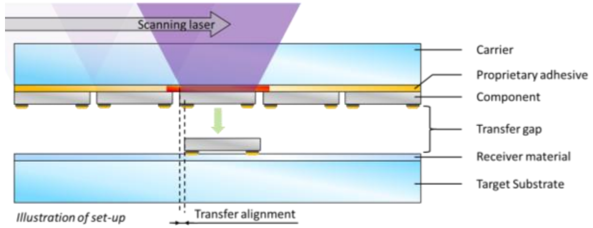


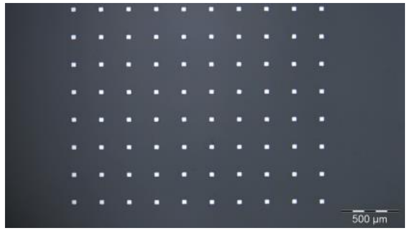
interconnects





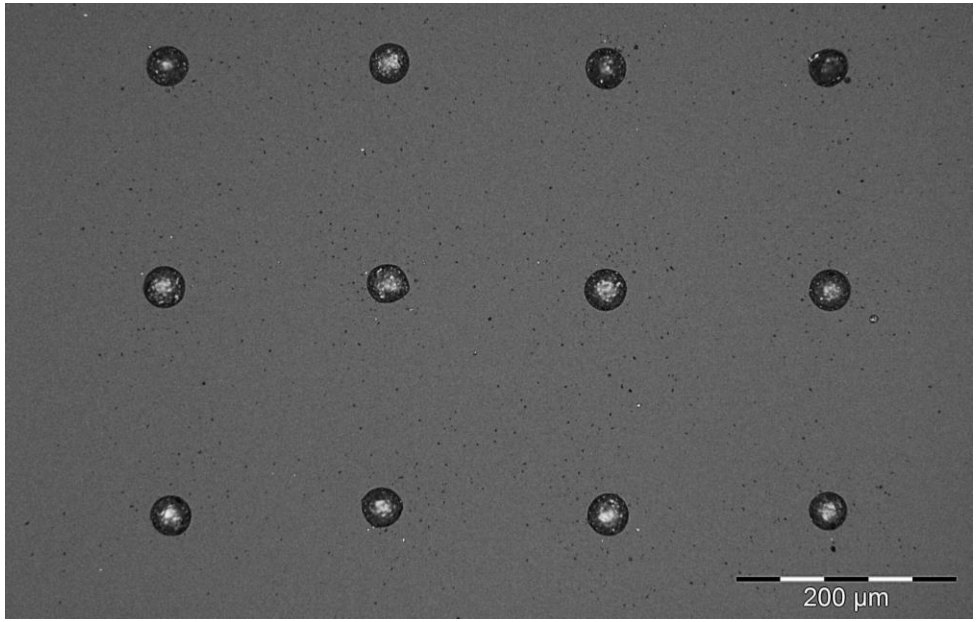
Laser Die Transfer: mini/µLED





Fine interconnect printing

35 µm dots of **conductive adhesive**

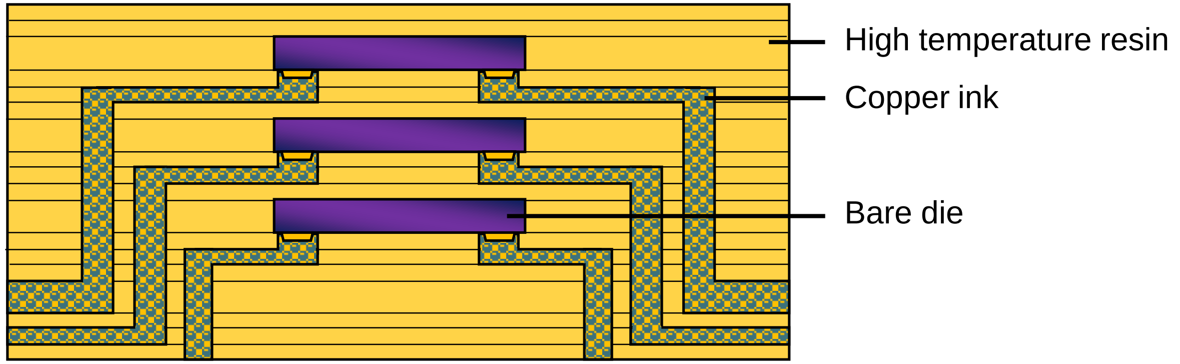


40 µm dots of **solder paste**

From 2.5D to 3D…

Increased IC Density enables 3D printed chip package

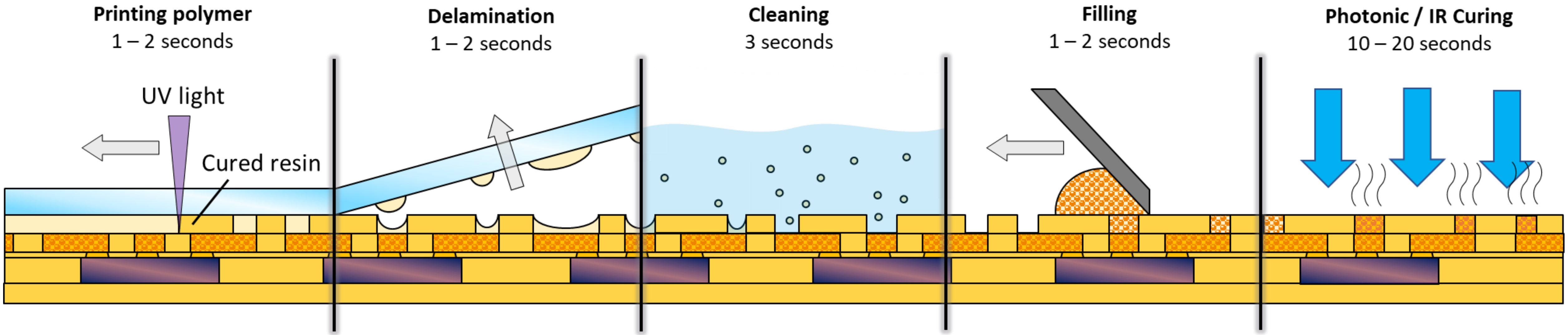
- Printing < 30 µm conductive traces will be interesting for chip packaging applications
- High throughputs at low costs are required to be competitive
- Printing conductive tracks with a single nozzle system is not an option
- Only stereolithography can achieve high resolution features at high throughputs



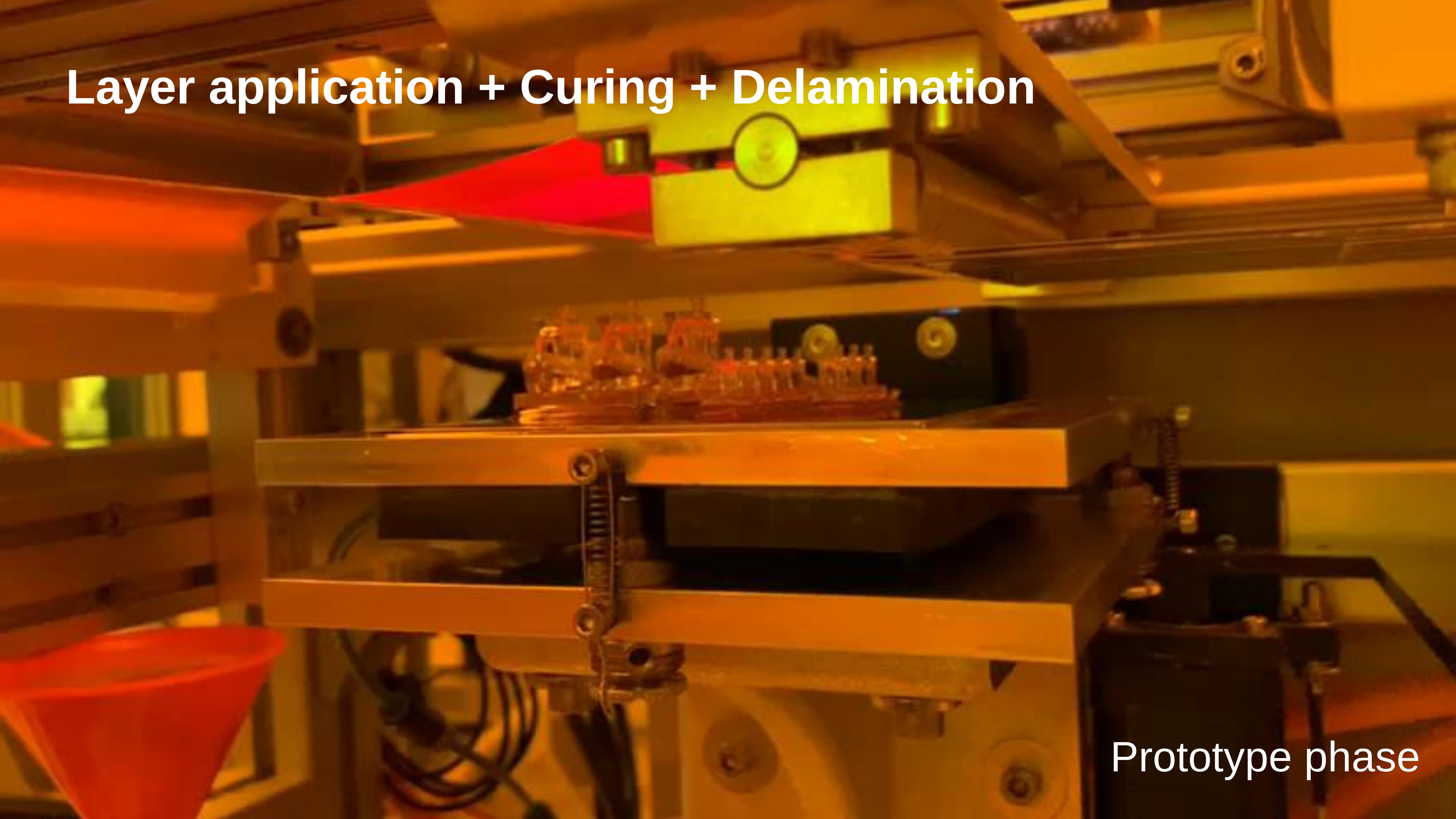
Embedding bare die components
Requires **< 30 µm** features

Stereolithography + Filling (3D-ALE)

- New lamination/delamination method produces mirror-like surface with groove structures
- Grooves are filled with highly loaded inks at speeds of up to 100 mm/second
- Throughput increased by 100 times: 30 seconds per layer
- Resolution increased by 10 times: ≤ 20 µm line/spacing



Layer application + Curing + Delamination



Groove filling tool

- Patented pumping tool used for groove filling
- Allows the use of high solid content inks

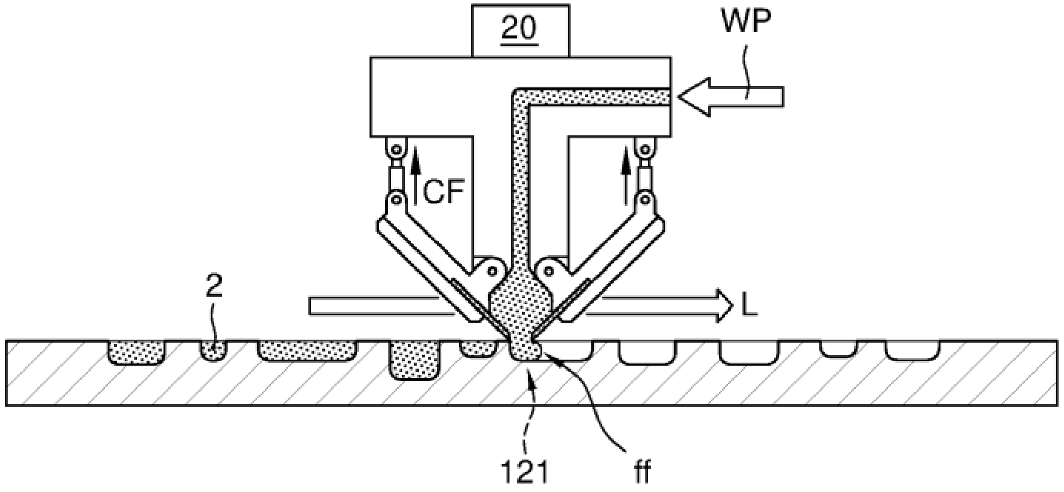
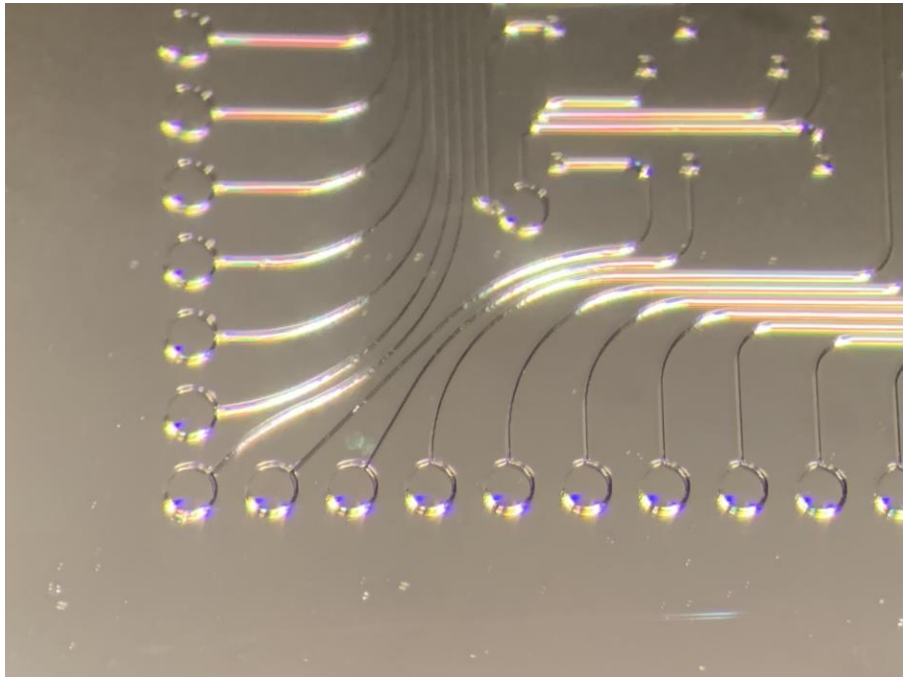
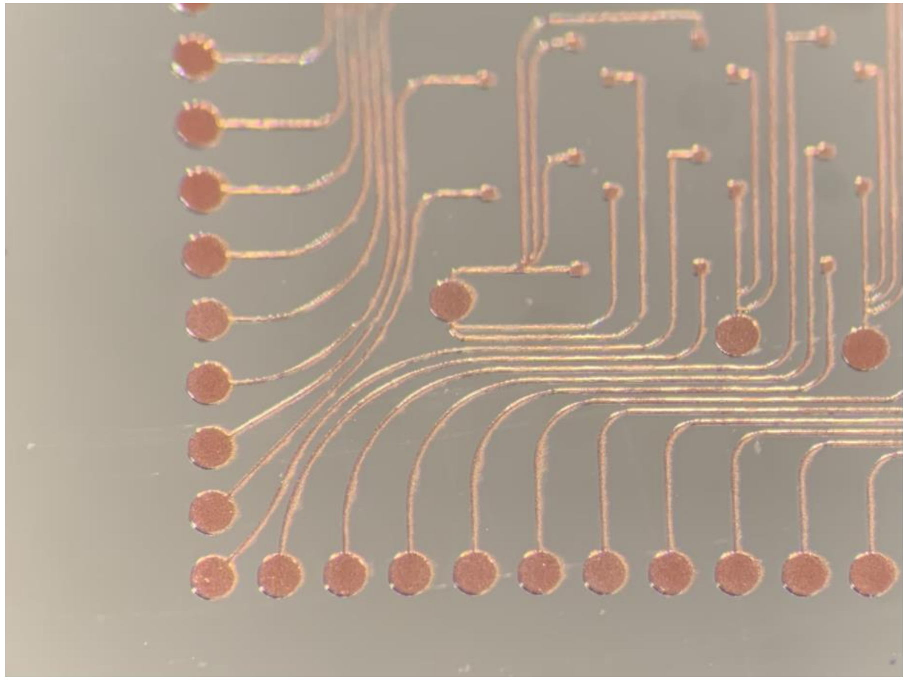


FIG. 2B



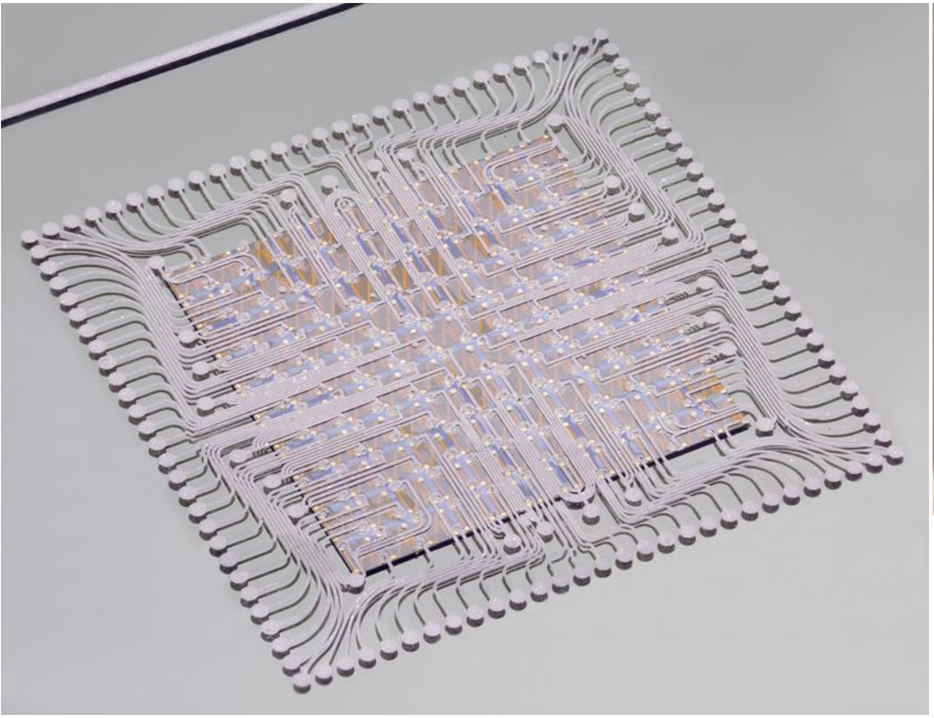
Cleaned grooves: 10 µm wide,15 µm deep



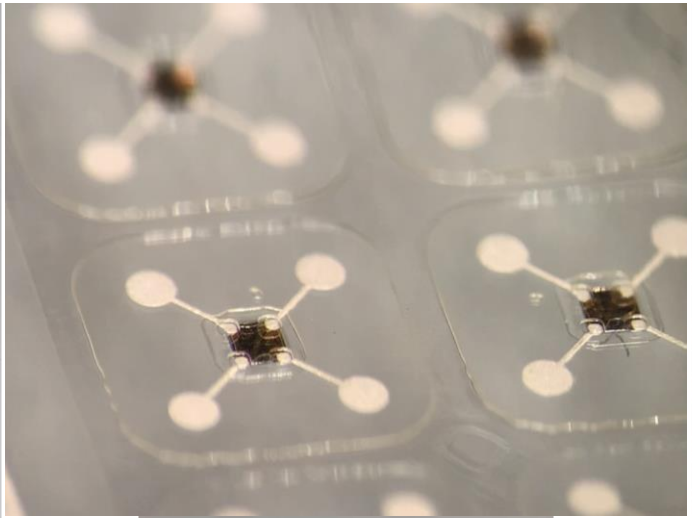
Filled grooves with Cu nanopaste

Stereolithography + Filling: Results

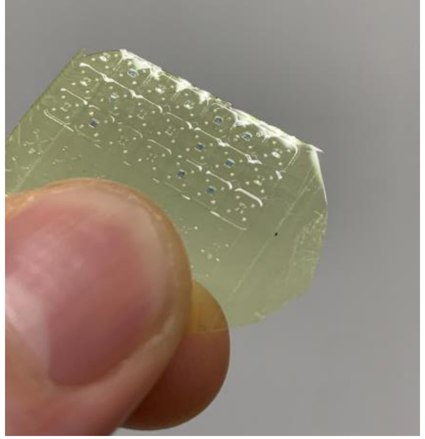
Clean filling of high aspect ratio grooves with silver micron flake paste

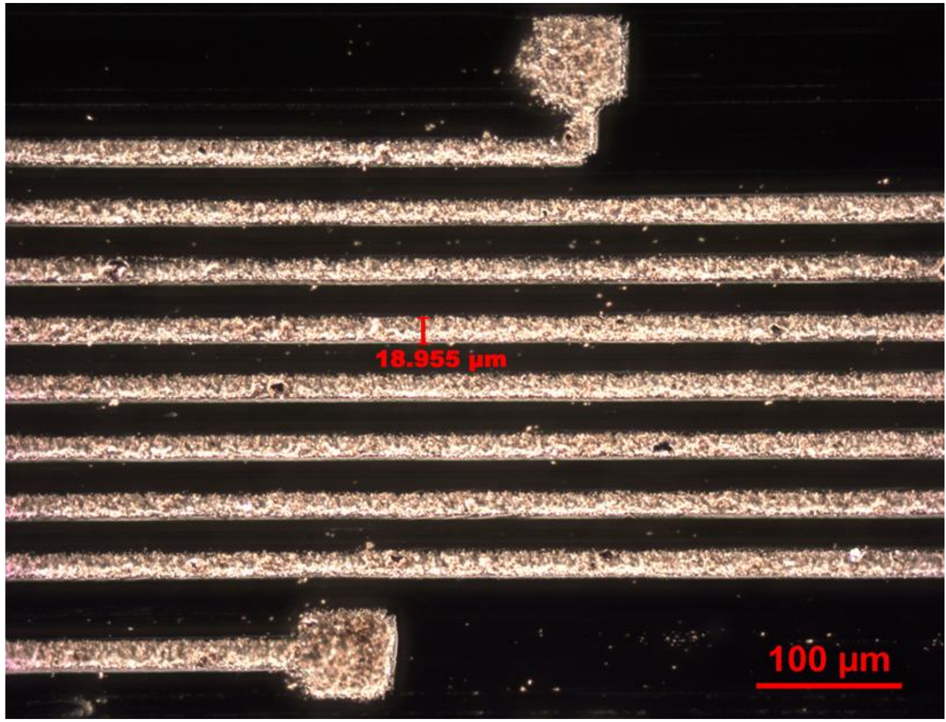


Fan-out structure with 220 interconnects



Stressless chip packaging





20 µm line/spacing, after filling and curing

Summary and outlook

- Holst Centre is actively developing technologies such as Volume-Controlled Laser Printing (LIFT 2.0.) and 3D-ALE, which are promising for chip integration and packaging
- Together with its sister institute CITC, Holst Centre is developing application-specific technologies with industrial partners in healthcare, IoT, 5G and microLED domains
- Broader range of materials and improvements in electrical and thermal performance of material are key to the success of these technologies
- Holst Centre looks forward to learning more about your experiences and requirements, and is open to collaborating with you.

ashok.sridhar@tno.nl

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HYB MAN

Printing technology comparison

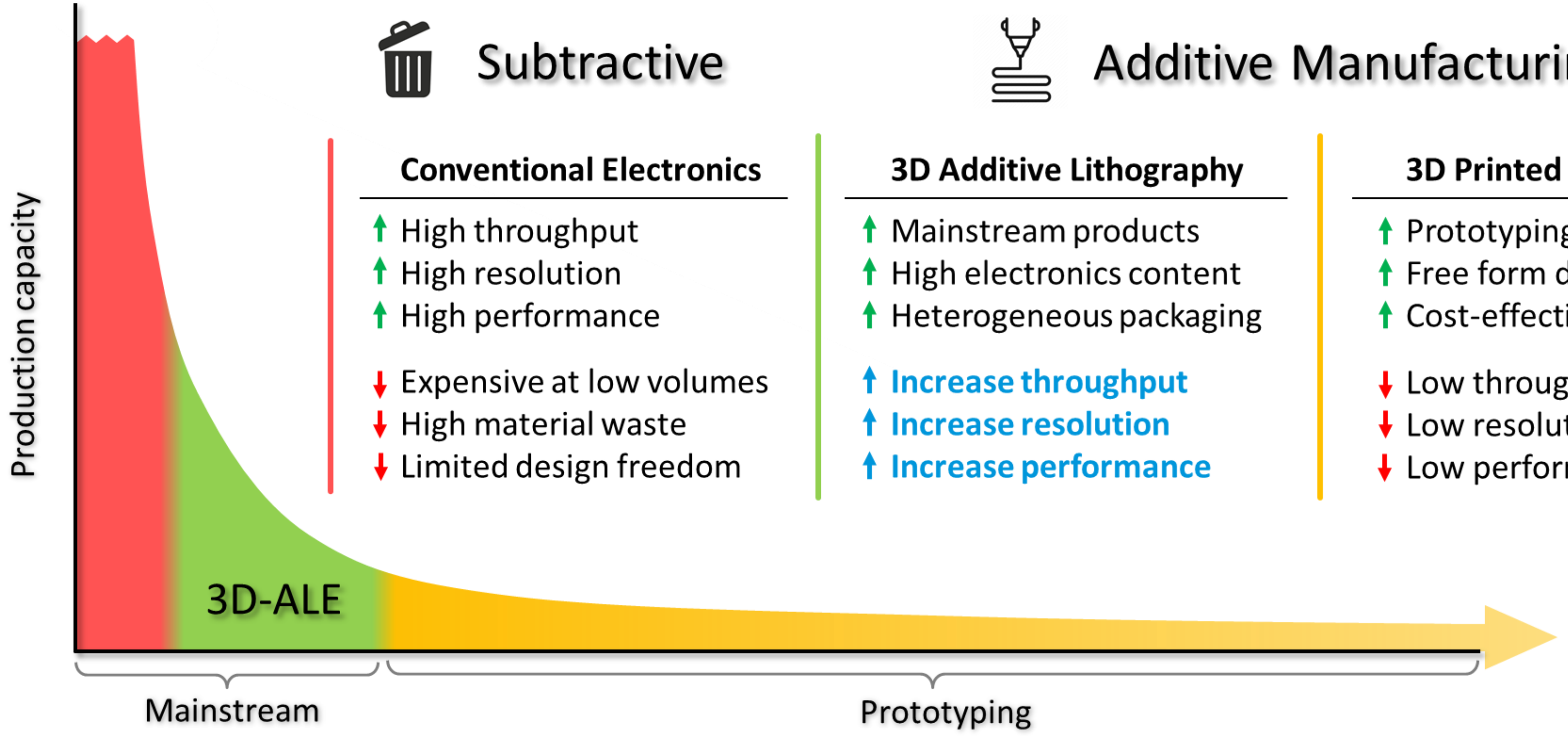
Holst Centre
powered by imec & TNO

Throughput limits current 3D printing technologies from becoming mainstream

Structural		Conductive: Inkjet	Conductive: Dispensing	Conductive: Electroplating	Conductive: LIFT	Conductive: Filling (New)
		Performance ↕	Performance ↕	Performance ↑	Performance ↑	Performance ↑
Inkjet	Resolution ↕	Throughput ↓ Thermal curing of solvent rich inks				
Dispensing	Resolution ↓		Throughput ↓ Printing with a single nozzle			
SLA	Resolution ↑		Throughput ↓ Cleaning and curing steps	Throughput ↓ Additional steps outside of printer	Throughput ↑ Parallel printing / Digital process	Throughput ↑ Parallel filling of grooves structures

Available at Holst Centre (shaded cells: SLA × Dispensing, Electroplating, LIFT, Filling)

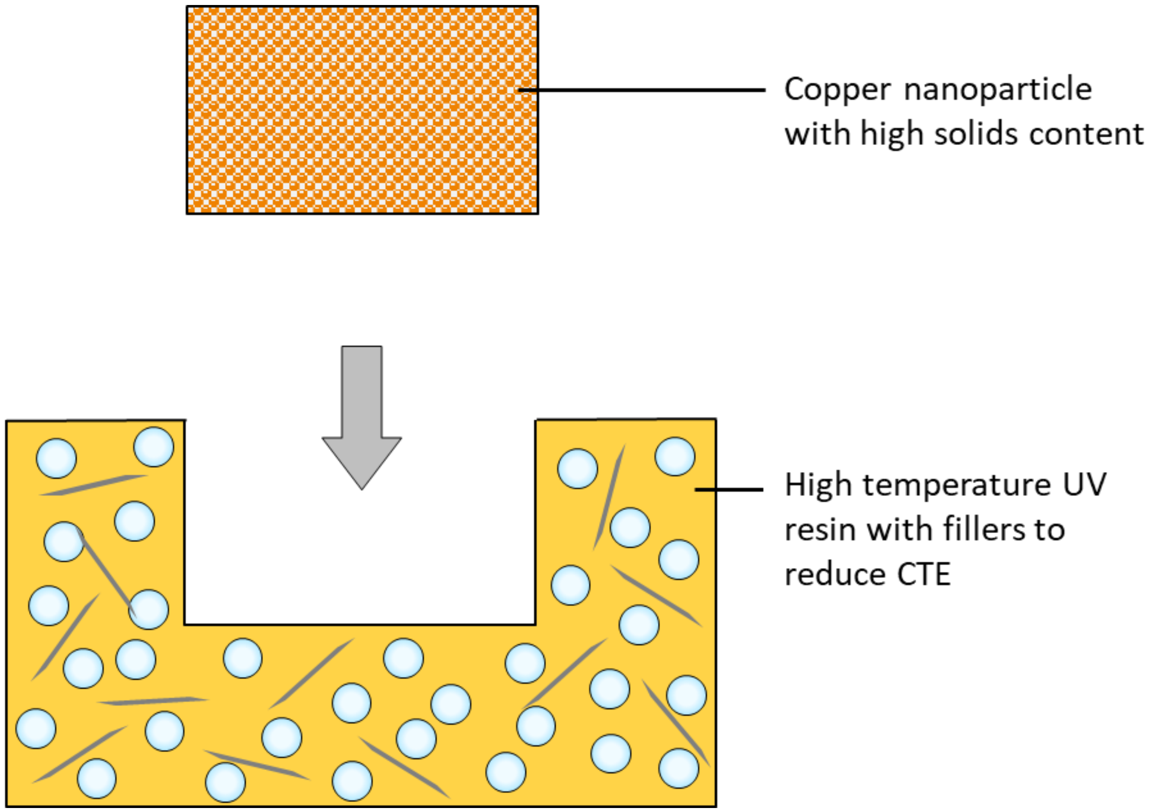
Where 3D-ALE fits in…



Materials for 3D-ALE

- **High performance conductors**
  - Electrical conductivity: ≥ 50% bulk Cu
  - Thermal conductivity: ≥ 100 W/mK
  - Viscosity range: **10 to 10,000 Pa·s**

- **High performance UV resins**
  - Thermal expansion coefficient: < 20 ppm/K
  - High temperature resistance: > 200°C
  - Viscosity range: **1 to 100 Pa·s**



Hahn Schickard

Visions to Products

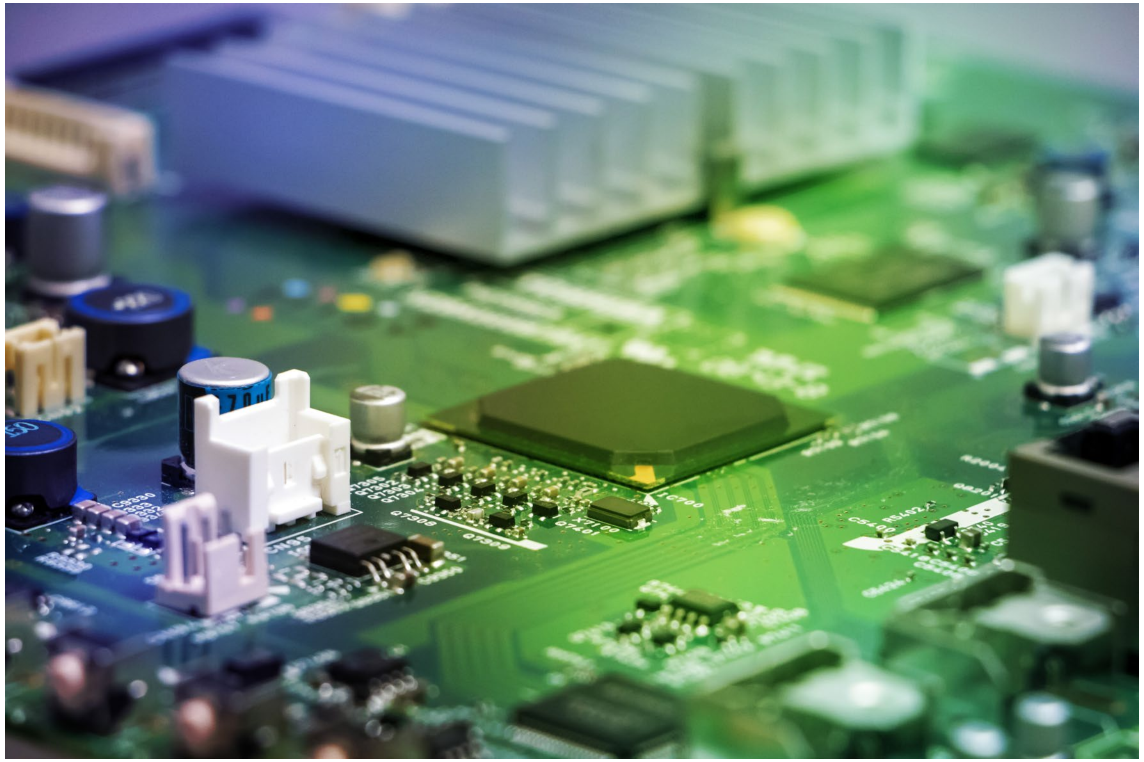
MID Workshop and MID Summit
21.09.2022

Contacting inkjet-printed silver structures and SMD

Jonas Jäger

Hahn-Schickard
Stuttgart, Germany

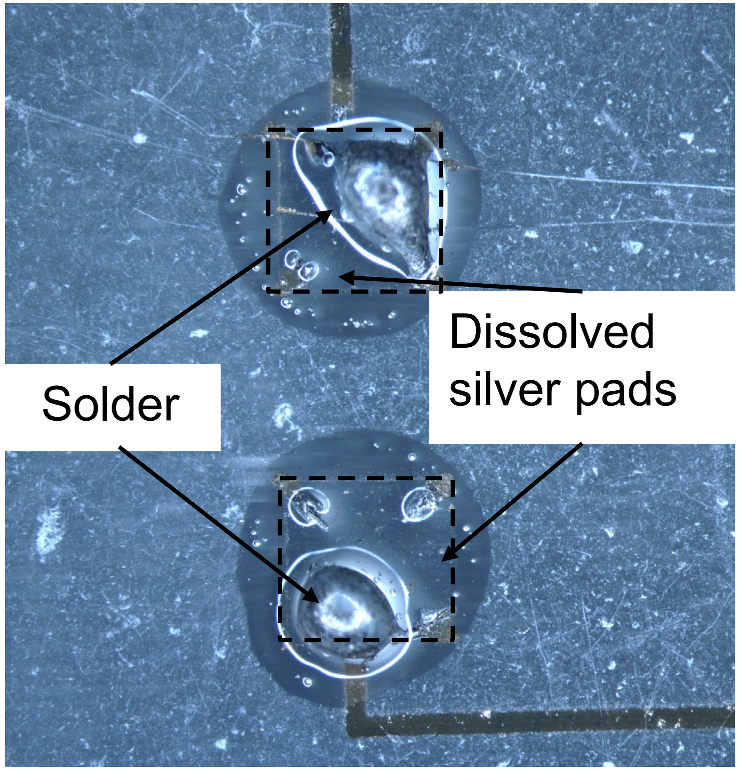
Motivation: Why do we need electrical connections on printed electronics?



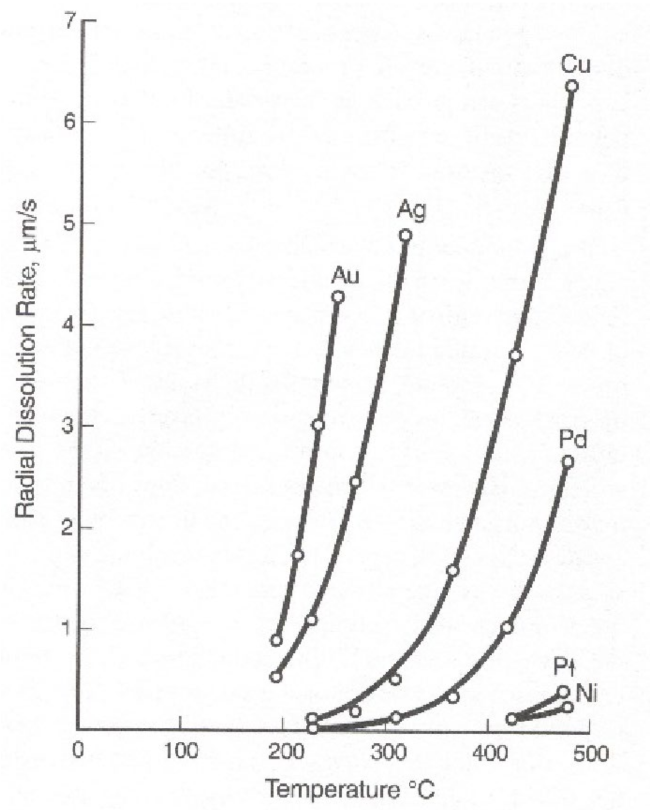
Digital printing technologies: Great value (3D, huge variety of substrates, ressource-friendly), …

… but often not useful without connection to MCU, battery, sensors or other electronic components

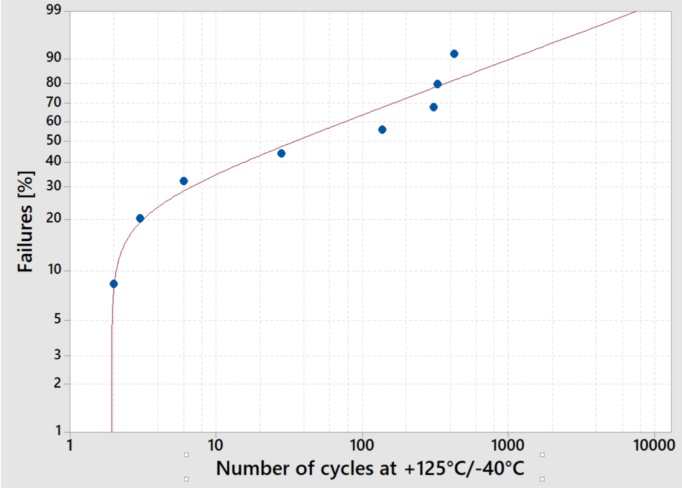
Why is contacting of digitally printed electronics difficult?

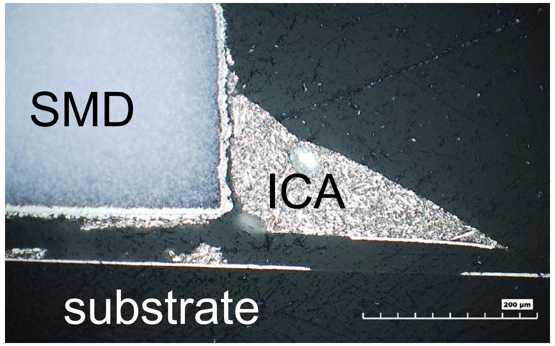


Dissolution of thin printed silver structures in SnAgCu solder



Dissolution rate of metals in SnPb solder [W.G. Bader „Dissolution of Au, Ag, Pd, Pt, Cu and Ni in a molten tin-lead solder“]

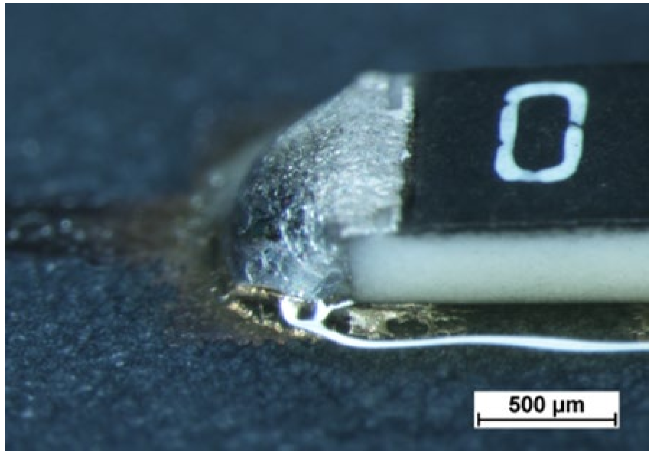


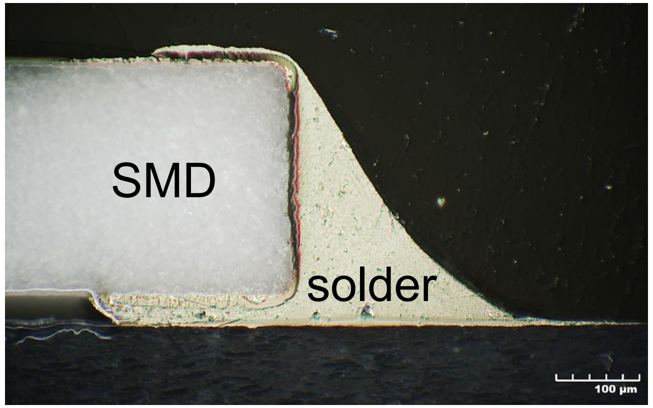


Low reliability of ICA connections between SMD and printed structures

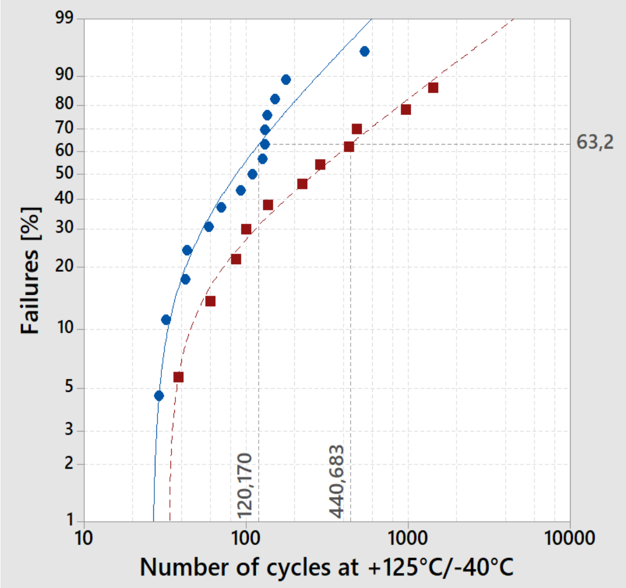
What did we do to solve the existing problems?

Process development: Inkjet, soldering, adhesive bonding, semi-sintering

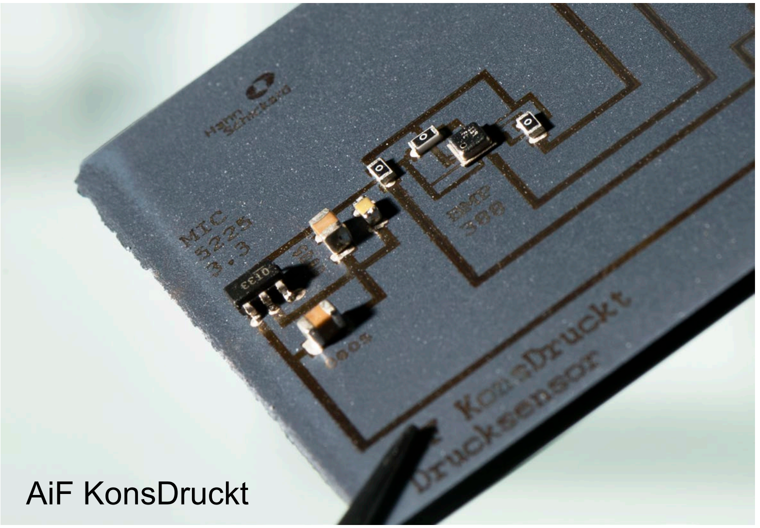




Reliability testing:
Thermal shock, damp heat

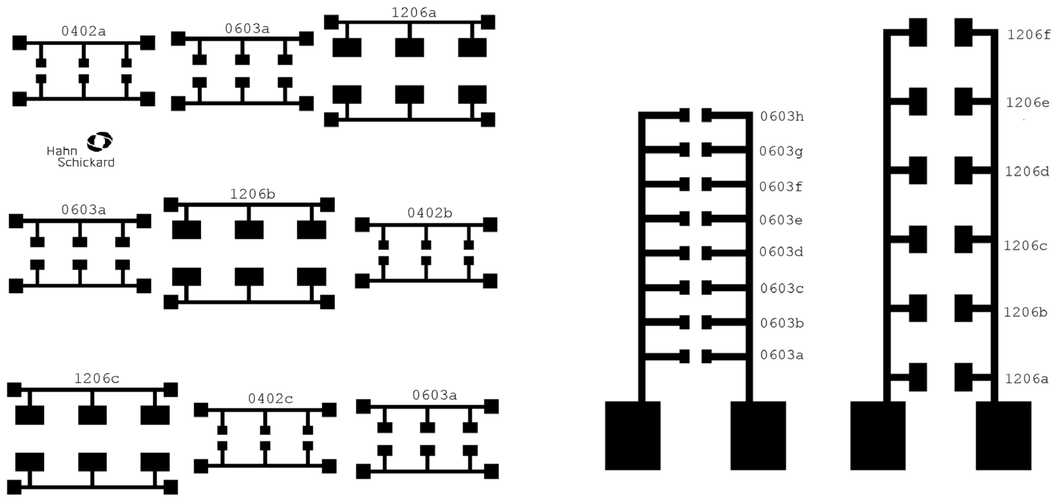


Reliable connections on digitally printed structures for advanced applications



Inkjet-printing and SMD assembly

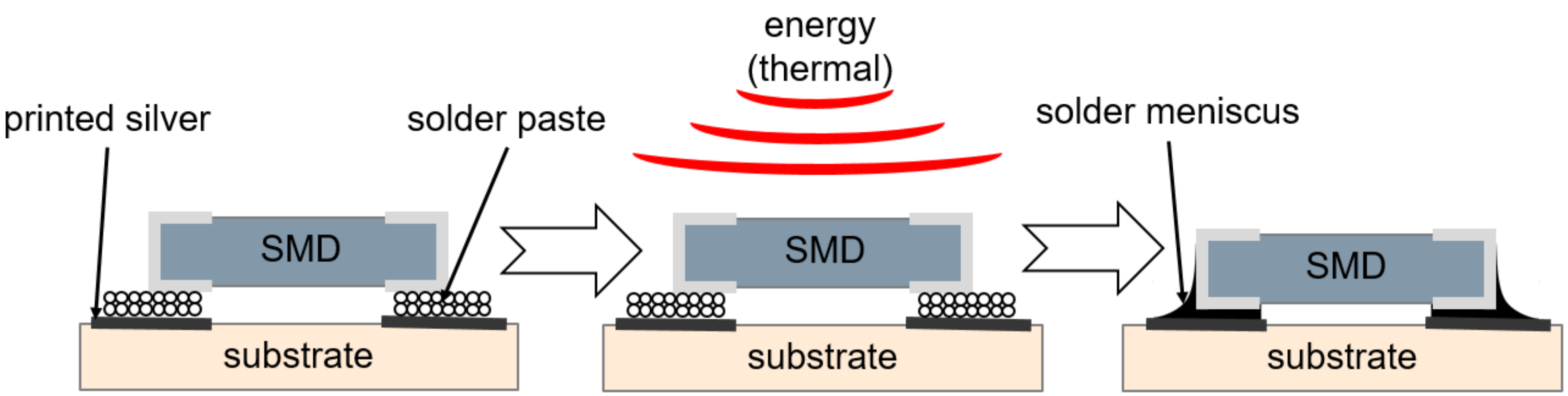
- **Inkjet-printer: Dimatix Materials Printer 2850**
- **Pre-treatment of substrate: atmospheric plasma (depending on substrate)**
- **Silver nanoparticle ink (30 wt.-% metal)**
- **Thermal curing: 200 °C**
- **SMD sizes:**
  - 0402 (1 mm x 0.5 mm)
  - 0603 (1.6 mm x 0.8 mm)
  - 1206 (2 mm x 1.25 mm)



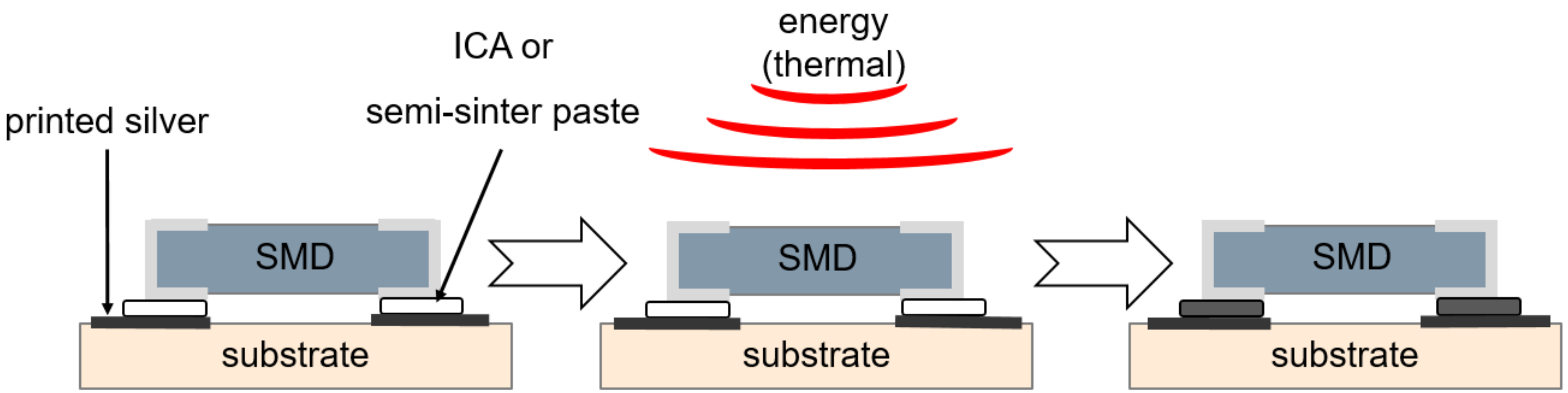
Layouts for printing parallel connections: standard layout (left), layout for 4-wire-measurement (right).

Surface Mount Technologies

- **Soldering**



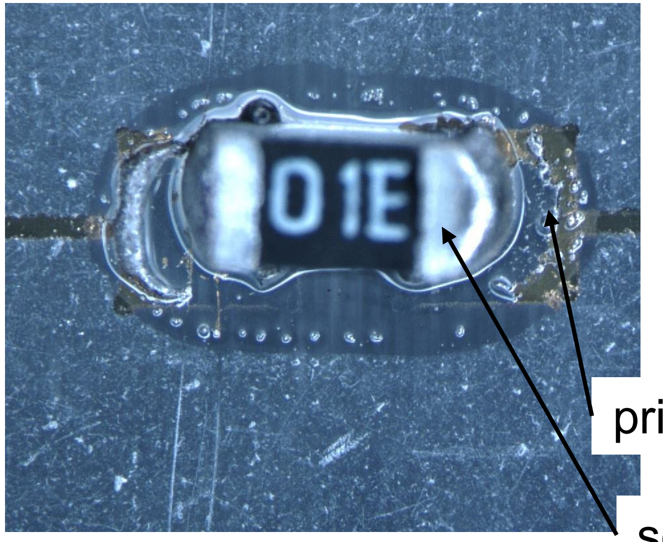
- **Adhesive bonding (Isotropic Conductive Adhesive), Semi-Sintering**



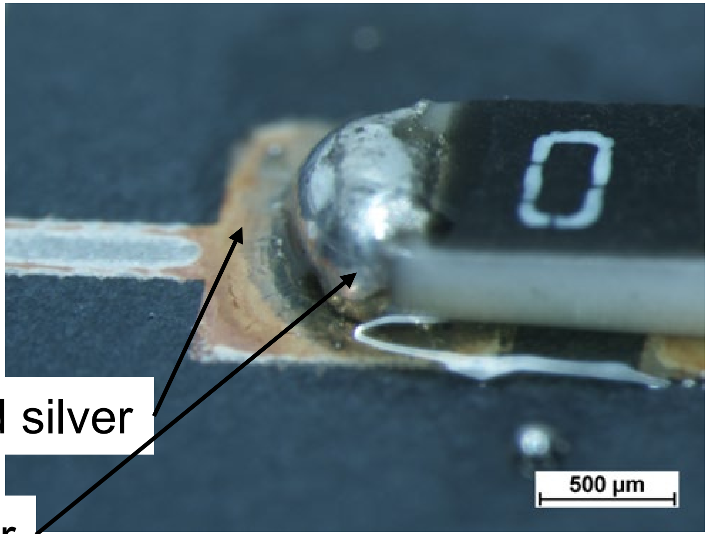
Soldering

Hahn Schickard

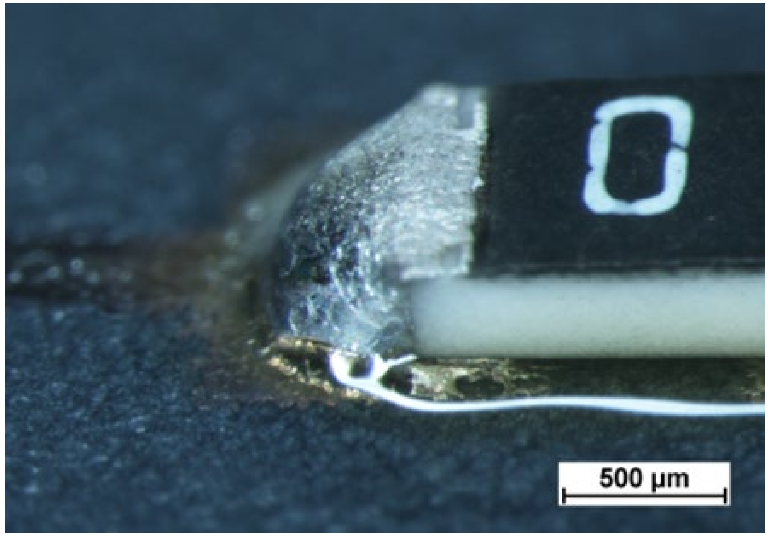
SnAgCu, high temperature



SnBi, low temperature, low Ag layer thickness



SnBi, homogeneously printed structures > 5 µm



Complete dissolution of printed silver structures in SAC solder. High temperature, high dissolution.

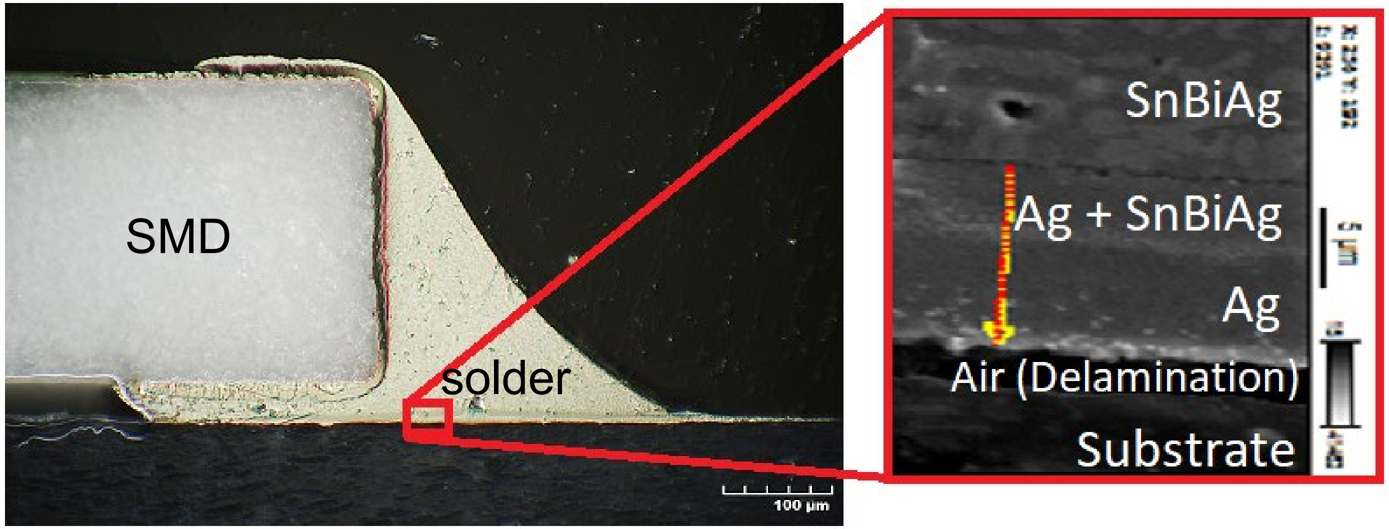
⇨

Lower melting SnBi solder. Partly dissolution of printed silver structures at 155 °C for 5 min. Poor wetting of SnBi solder.

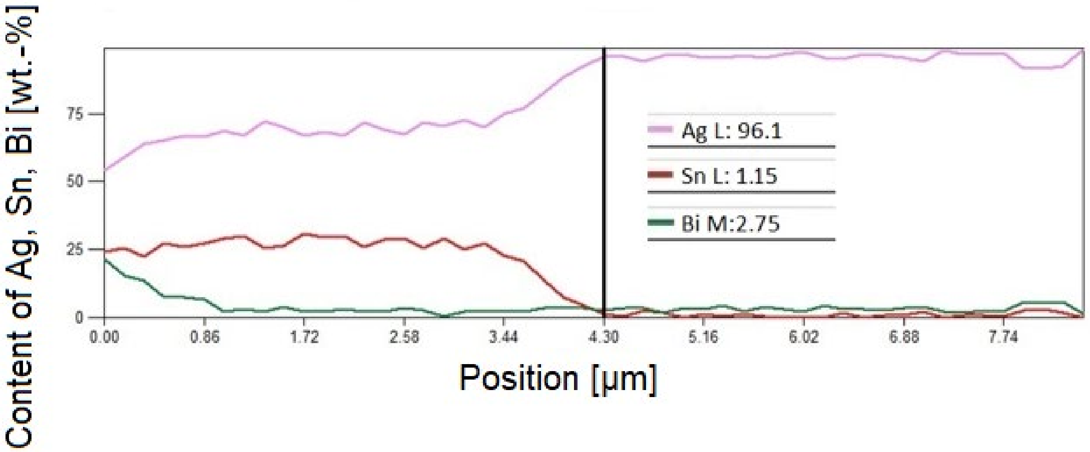
⇨

Homogeneously printed silver structures, thickness > 5 µm. No dissolution and good wetting of SnBi solder.

Soldering



- **Thickness of intermetallic phase: 5 µm**
- **Soldering peak temperature: 155°C**
- **Substrates: LCP, PA6T, PA66**



Soldering on 10 µm thick inkjet-printed silver structures. SEM and EDX analysis

Soldering: Reliability

- 1206 SMD, SnBiAg solder, thermal shock (+ 125 °C, - 40 °C)
  - PA6T, PA66 (CTE 98, 70 ppm/K): Infantile failures
  - LCP perpendicular to flow direction (CTE 24-35 ppm/K): Low lifetime (441 cycles)
  - LCP parallel to flow direction CTE (9-17 ppm/K): High lifetime (> 2000 cycles)

  Good results! ☺

→ **Low coefficient of thermal expansion (CTE) of substrate benefits reliability**

- 0603 SMD, SnBiAg solder, thermal shock
  - LCP perpendicular to flow direction (CTE 24-35 ppm/K): High lifetime (> 3500 cycles)

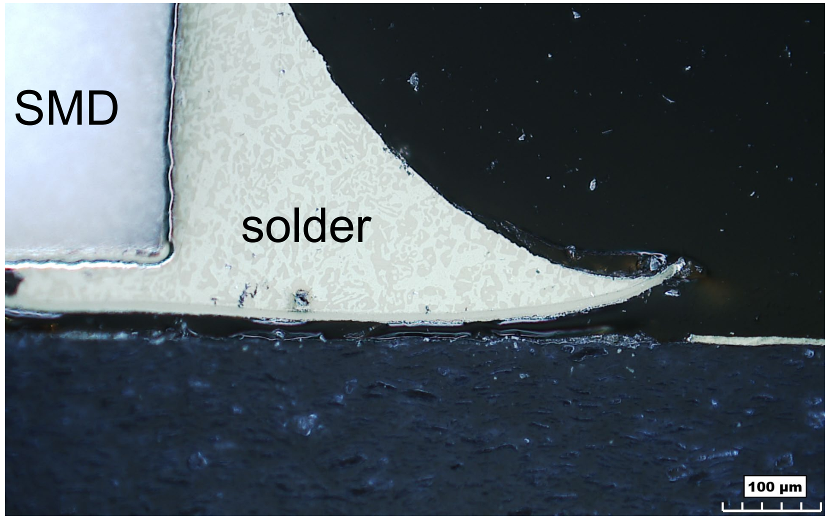
  Good results! ☺

→ **Small SMD size benefits reliability**

Soldering: Reliability

- Failure mechanisms after thermal shock:

  Delamination between printed structure and substrate

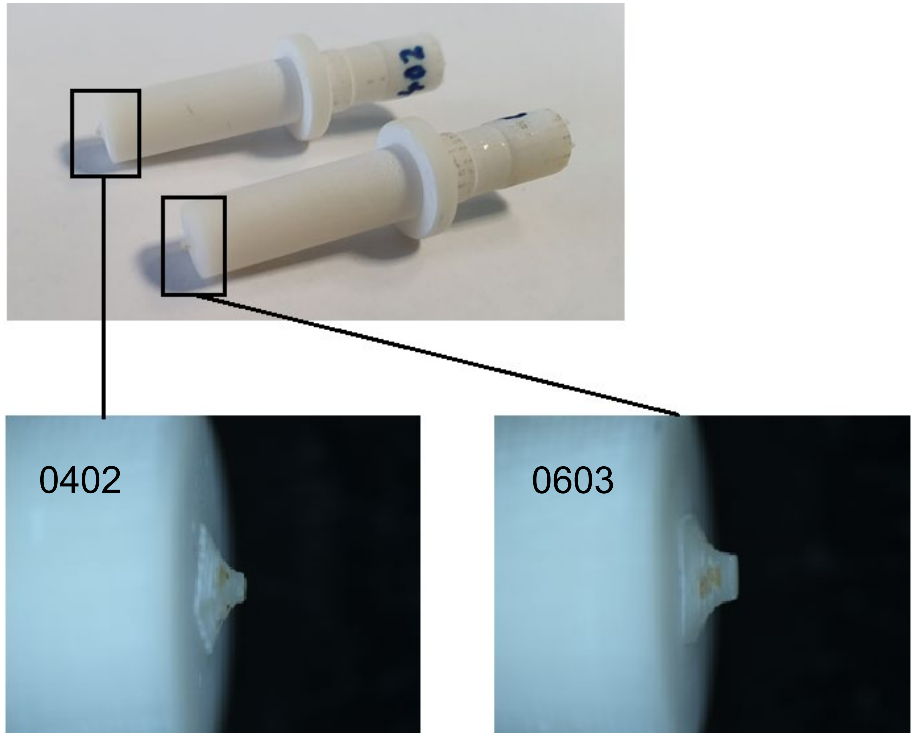


Delamination of solder joint of 1206 SMD after thermal shock [IGF report 20337N]

- Damp heat test, SnBiAg solder, 0402, 0603, 1206:
  - 0 % failures after 1000 h at 85 °C, 85 % r.h.
  - **Good results!** ☺

Isotropic Conductive Adhesive

- Two different silver-based epoxy ICA
- Dispensing or stamping
- Curing at 80 °C to 150 °C for 5 min to 120 min
- Substrates: LCP, PC
- Printed structures: No special properties needed (thickness, homogeneity)



Additively manufactured stamps

Isotropic Conductive Adhesive: Reliability

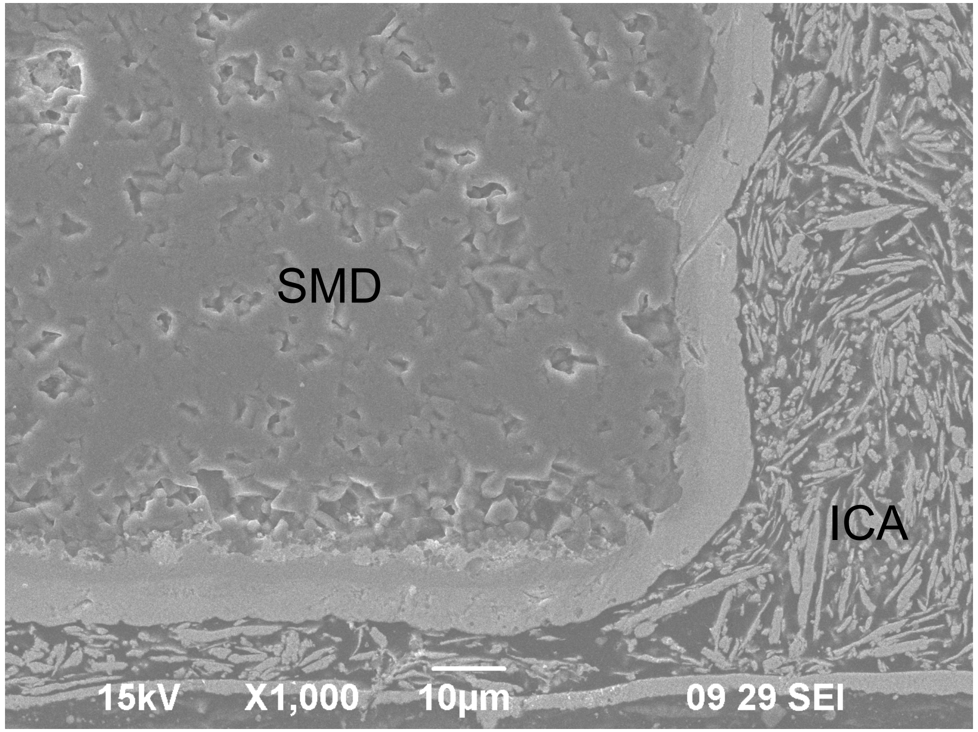
- Thermal shock 0603 and 1206 SMD on LCP (24-35 ppm/K) at + 125 °C / - 40 °C: lifetime > 3500 cycles

  Good results! ☺

- Delamination starts between SMD and ICA

- Only 1.1 % SMD (0402, 0603, 1206) on LCP failed after 1000 h at 85 °C, 85 % r.h. **Good results!** ☺

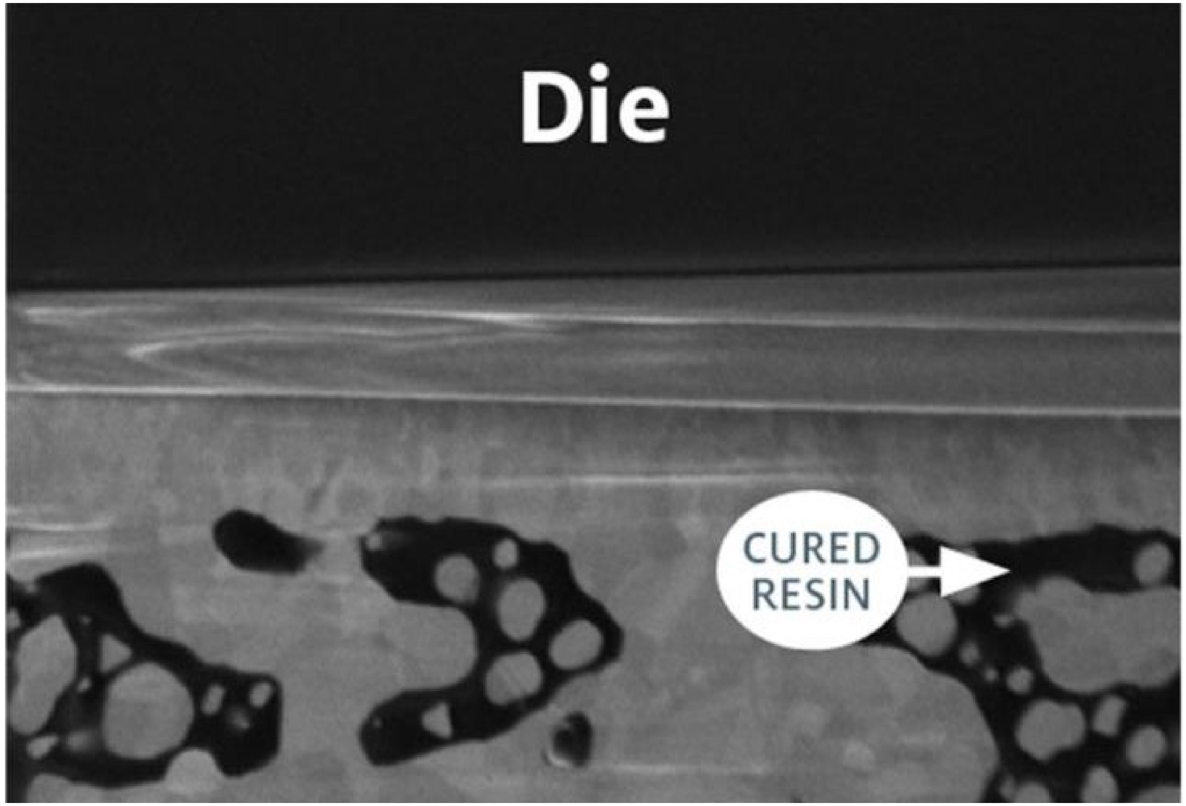
- 60 % SMD (0402, 0603, 1206) on PC failed after 1000 h at 85 °C, 85 % r.h.



SMD mounted with ICA on LCP after 3500 cycles thermal shock.

Semi-Sintering

- Paste / resin highly loaded with silver filler (→high electrical and thermal conductivity)
- Dispensing and stamping
- Curing at 175 °C - 200 °C for 1 h
- Substrates: LCP, PI
- Printed structures: No special properties needed (thickness, homogeneity)

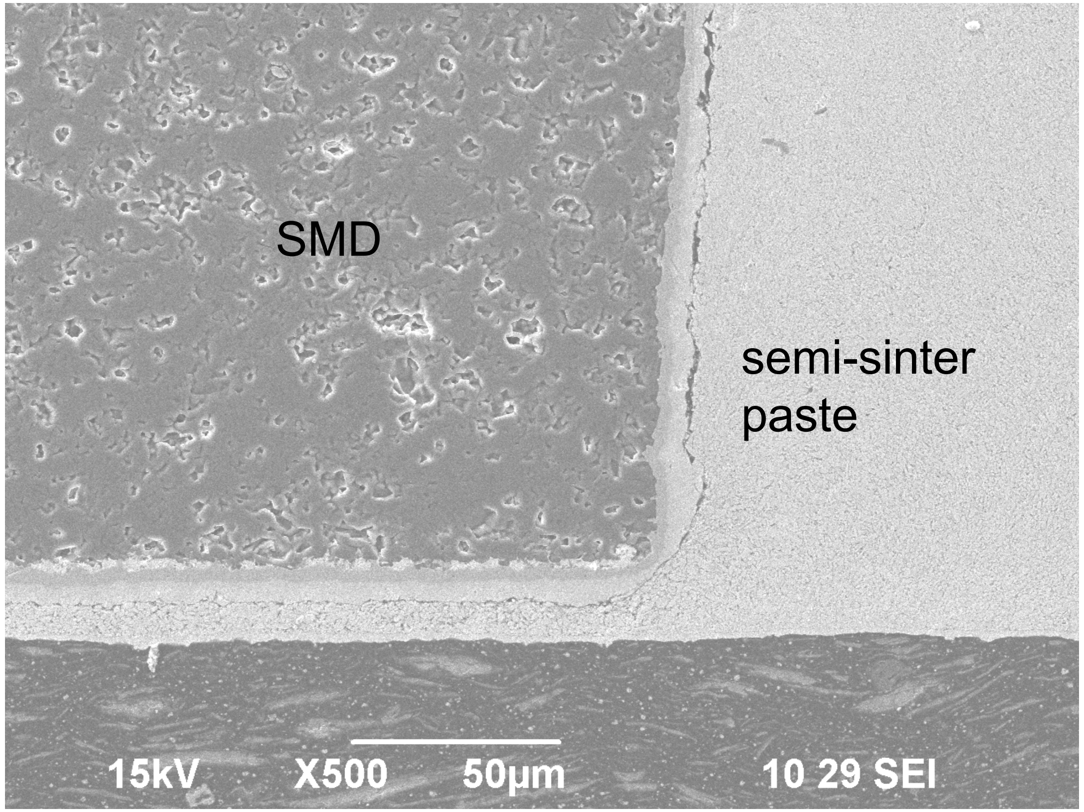


Semi-sintering [www.henkel-adhesives.com]

Semi-Sintering: Reliability

- 1206 SMD on LCP and PI at + 125 °C / - 40 °C: lifetime > 3500 cycles. **Good results!** ☺

- Delamination starts between SMD and paste

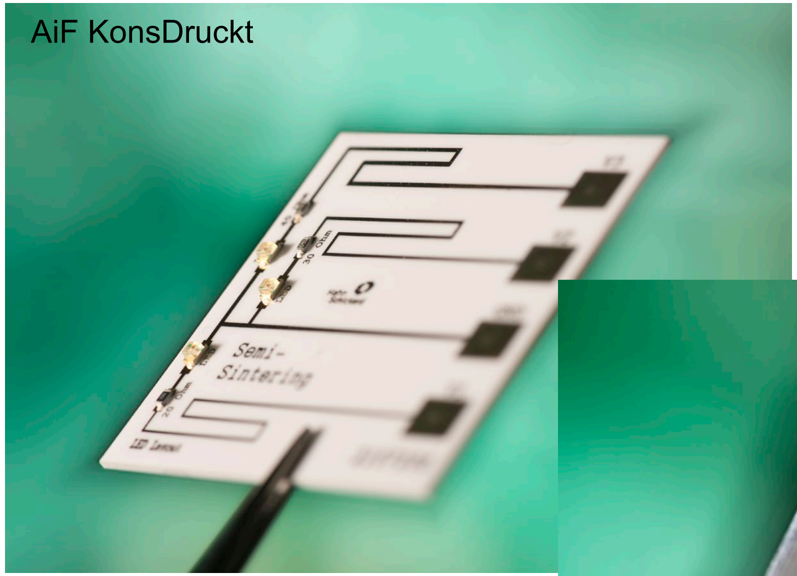


Starting delamination between semi-sinter paste and SMD after thermal shock.

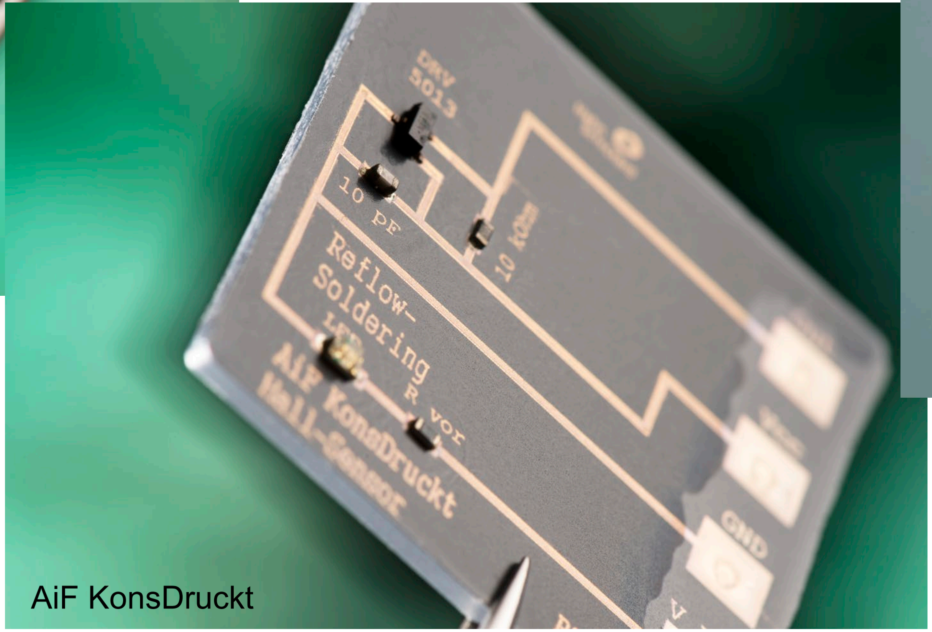
Conclusion

- **SMD assembly by soldering, ICA bonding and semi-sintering sucessfully demonstrated on inkjet-printed silver structures**
- **Electrical connections between inkjet-printed silver structures and 0603 SMD on LCP substrates can withstand**
  - 3500 cycles at + 125 °C / - 40 °C
  - 1000 h at 85 °C / 85 % r.h.
- **ICA and semi-sintering are good alternatives to soldering**
- **Selection of materials is crucial**

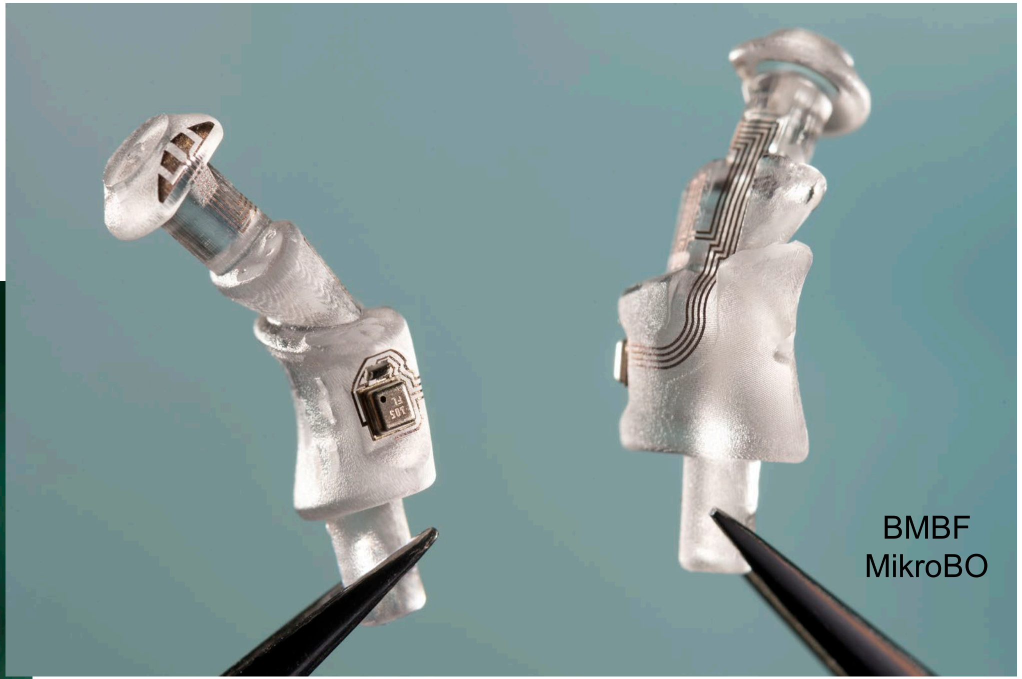
Conclusion



AiF KonsDruckt



AiF KonsDruckt



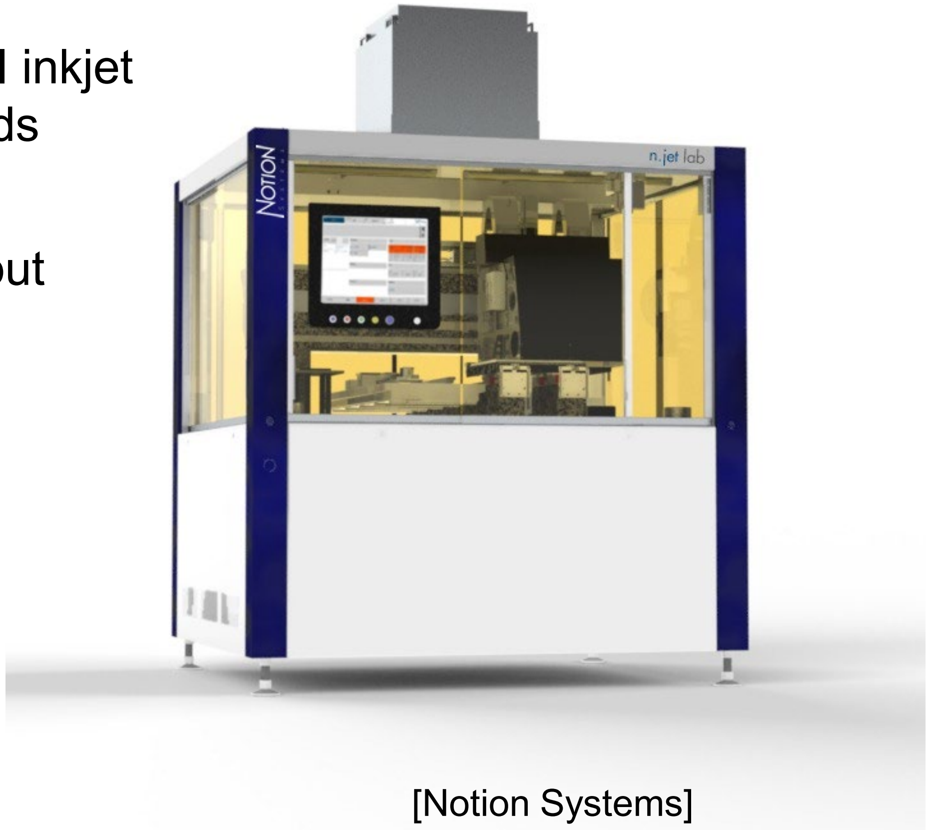
BMBF
MikroBO

New products with digitally printed electronics can be designed and manufactured

Reliable connections between SMD and digitally printed conductive structures are feasible

Outlook: New digital printing technologies at Hahn-Schickard shortly available

- Multiple industrial inkjet printheads
- High throughput



[Notion Systems]

[Neotech AMT]

- Multiple printing technologies
- FFF, pellet extruder and plasma included
- Curing, dispensing and pick and place included

Hahn Schickard

Jonas Jäger
✉ Jonas.Jaeger@Hahn-Schickard.de
☎ +49 711 685 84789

www.hahn-schickard.de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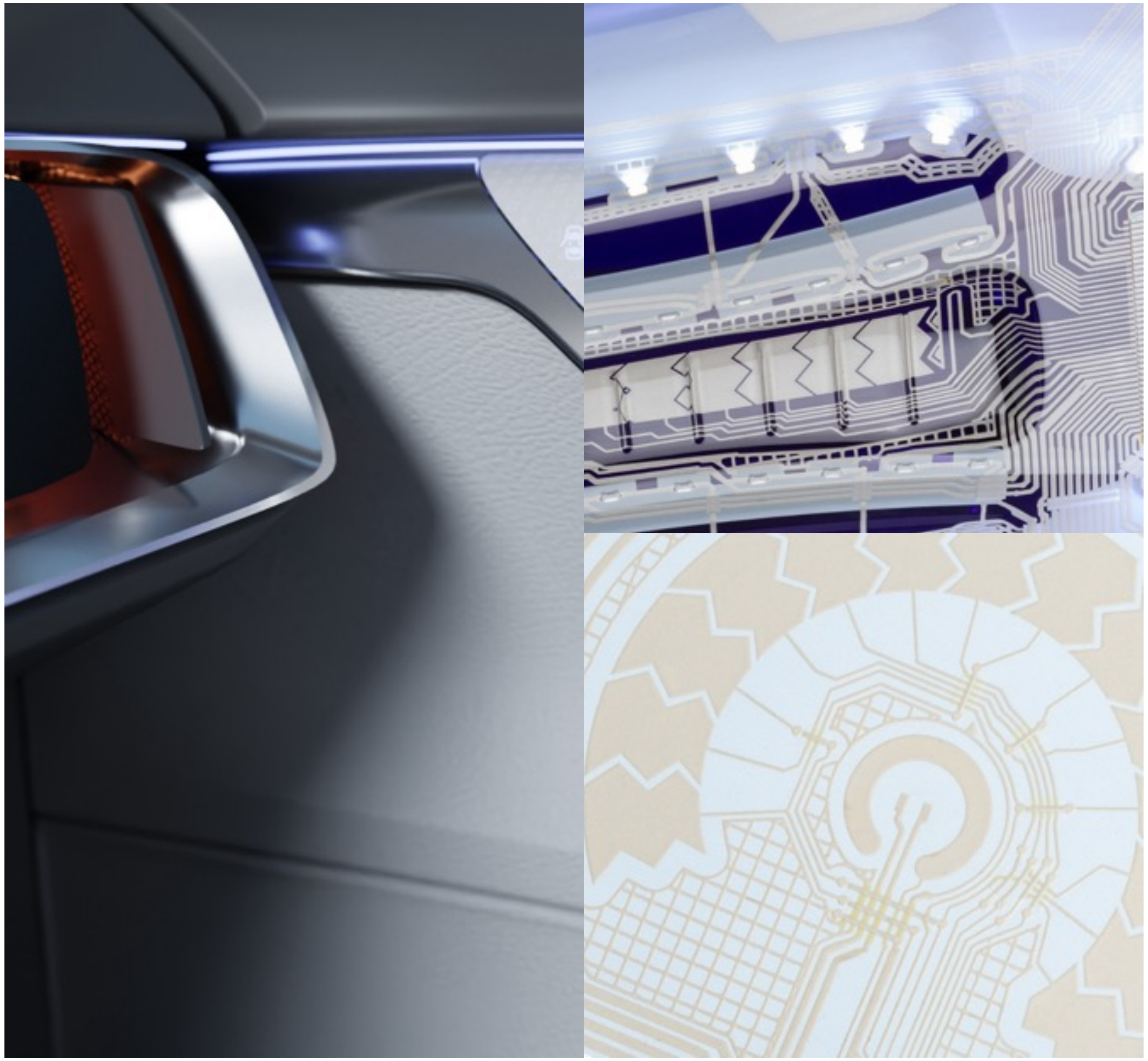


This is TactoTek®

We develop, validate and commercialize injection-molded structural electronics (IMSE®) – technology that transforms the way electronics are designed and built

40+ global patent families, 120+ granted patents

HQ in Oulu, Finland

Offices in USA, Germany, Japan and South Korea

Head count 100

ISO9001 certified


We want to make technology invisible and seamlessly integrated. We’re here to disrupt hardware – turning conventional structures into smart, natural and interactive surfaces.
TACTOTEK

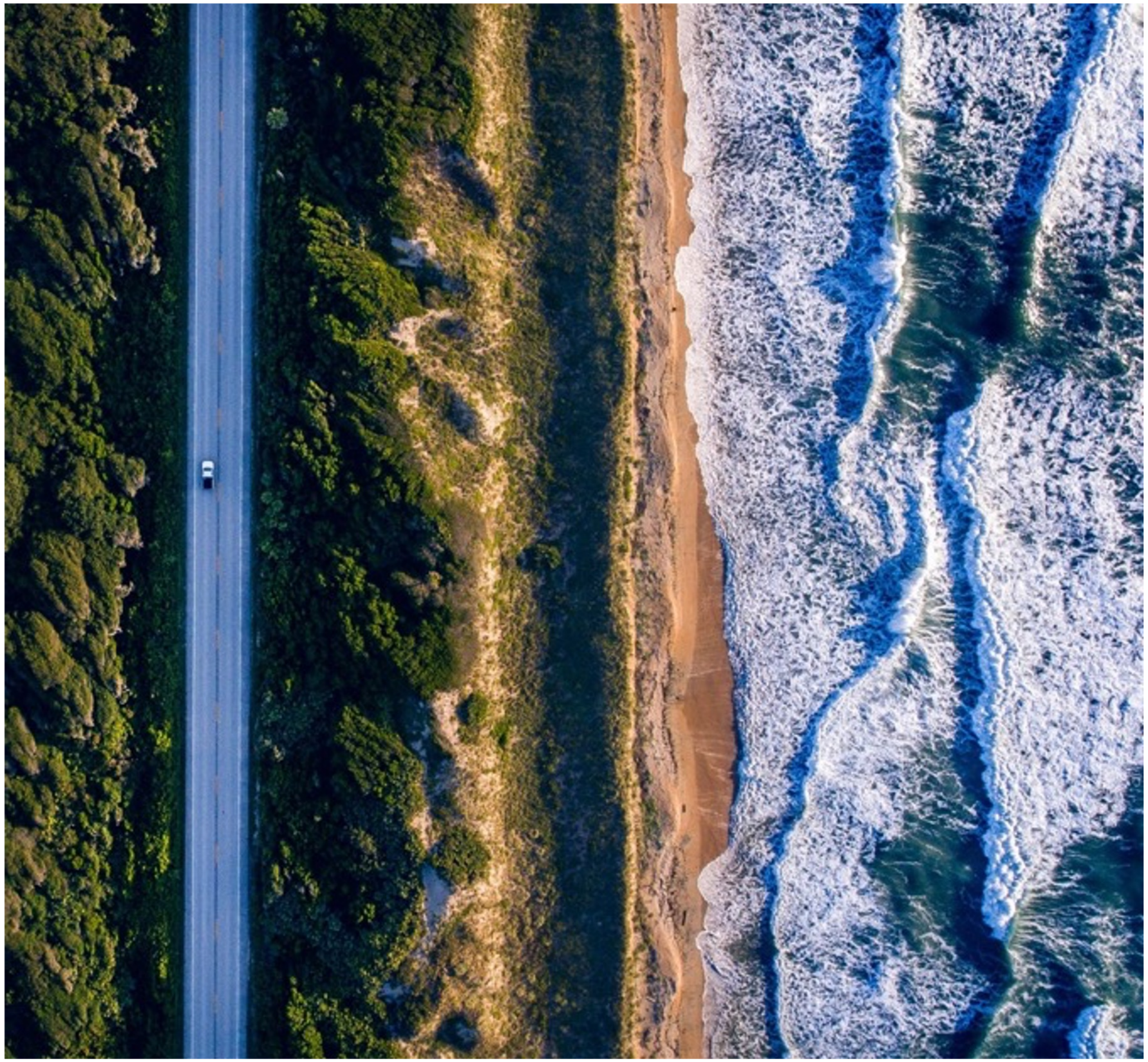
Market trends driving change

Interconnected human-machine interfaces appear all around us

Consumers expect intuitive and consistent user interfaces

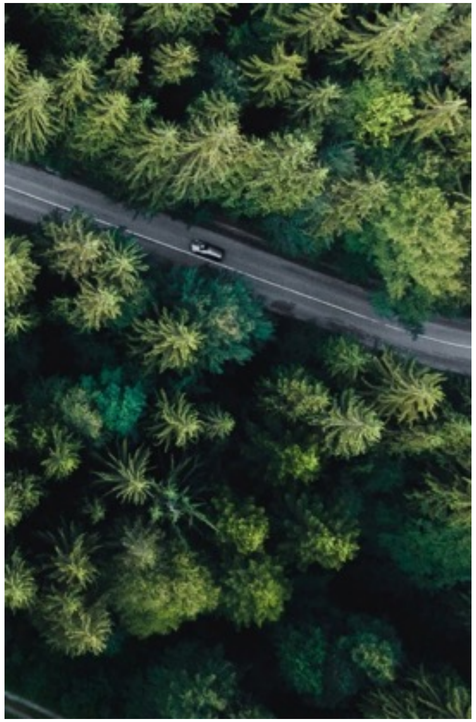
Use of illumination for providing function and styling to surfaces is increasing

Regulatory initiatives require minimizing waste and material usage, and maximizing recycling



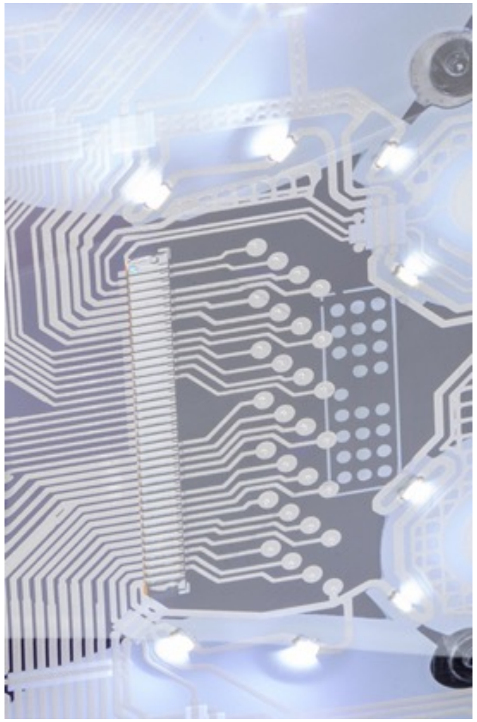
TACTOTEK

Transforming how smart surfaces are made



Reduced emissions

Brand differentiation



Efficiency with simplicity

Delighting user experiences

Innovative design that leads to brand differentiation

Ultra-thin, lightweight structures with encapsulated electronics liberate design and save space

Seamless forms with genuine 3D designs

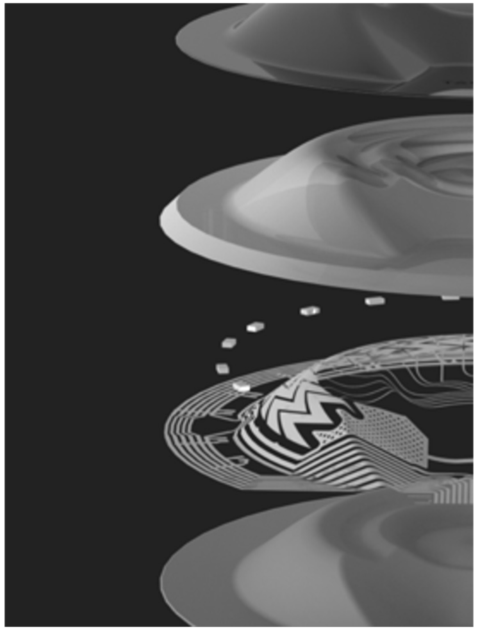
Design freedom for intuitive HMI, UX, and UI designs

Innovative and diverse illumination opportunities

Fast product update and variant management opportunities for decoration and functions

Reduce greenhouse gas emissions by 60%

Carbon neutral manufacturing
80% less tools needed



90% less toxic waste

Sustainable materials
Plastics use reduced by 70%

100% recyclable

A smarter, more efficient approach to making electronics

Well-known materials and production processes used in an innovative way

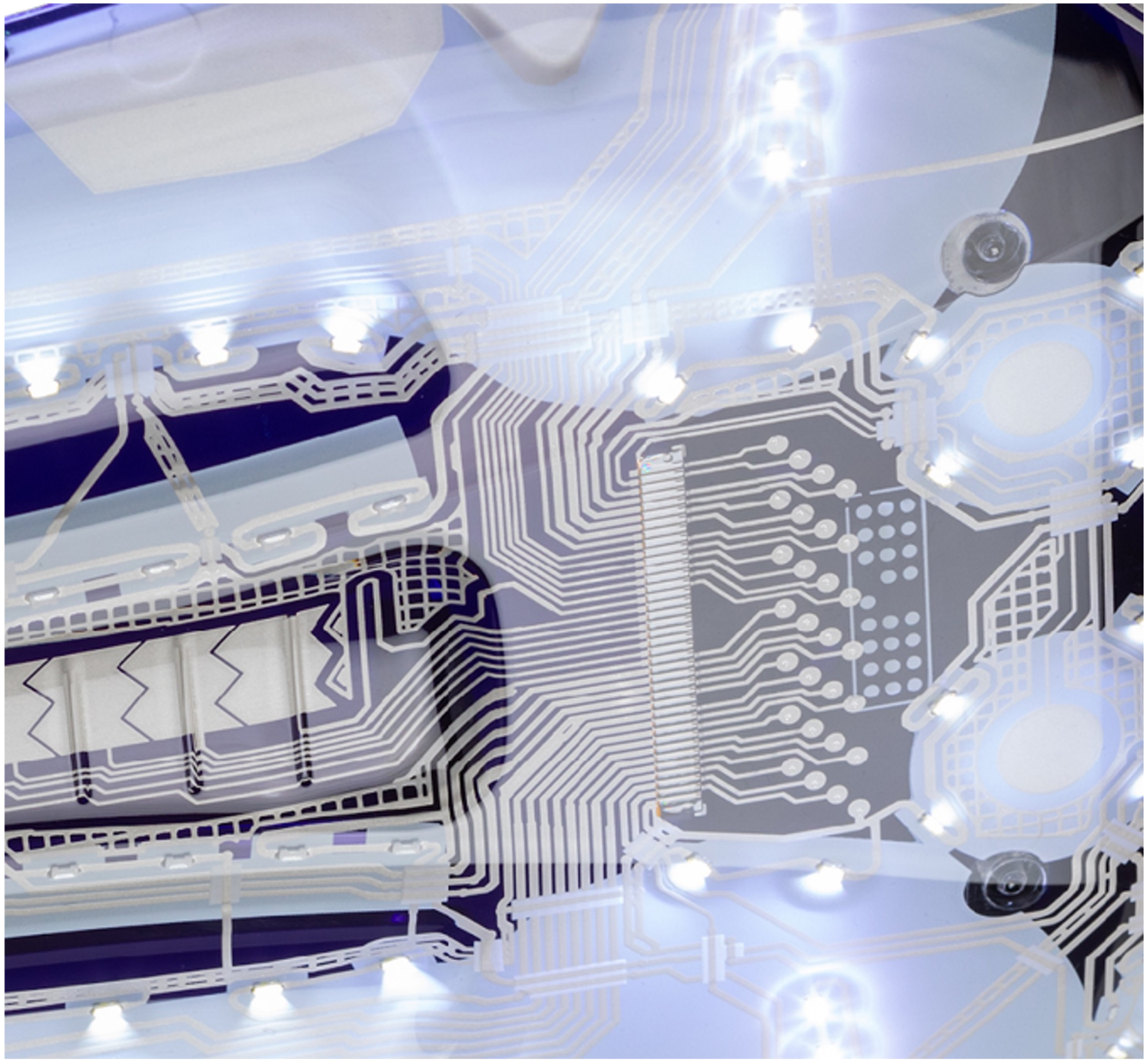
Simulation-based design processes

Electronics and components molded within the surface structure, full-size circuit board eliminated

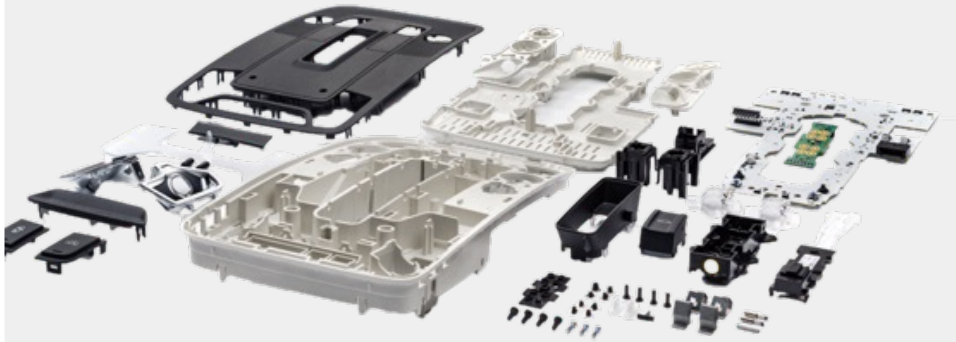
Reliability & durability increased due to capsulated structure

Up to 90% thinner parts

Up to 80% less weight

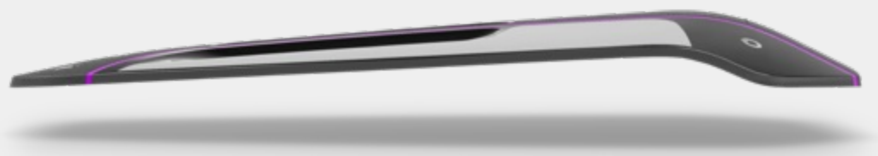


Comparing IMSE® with conventional



Conventional Electronics

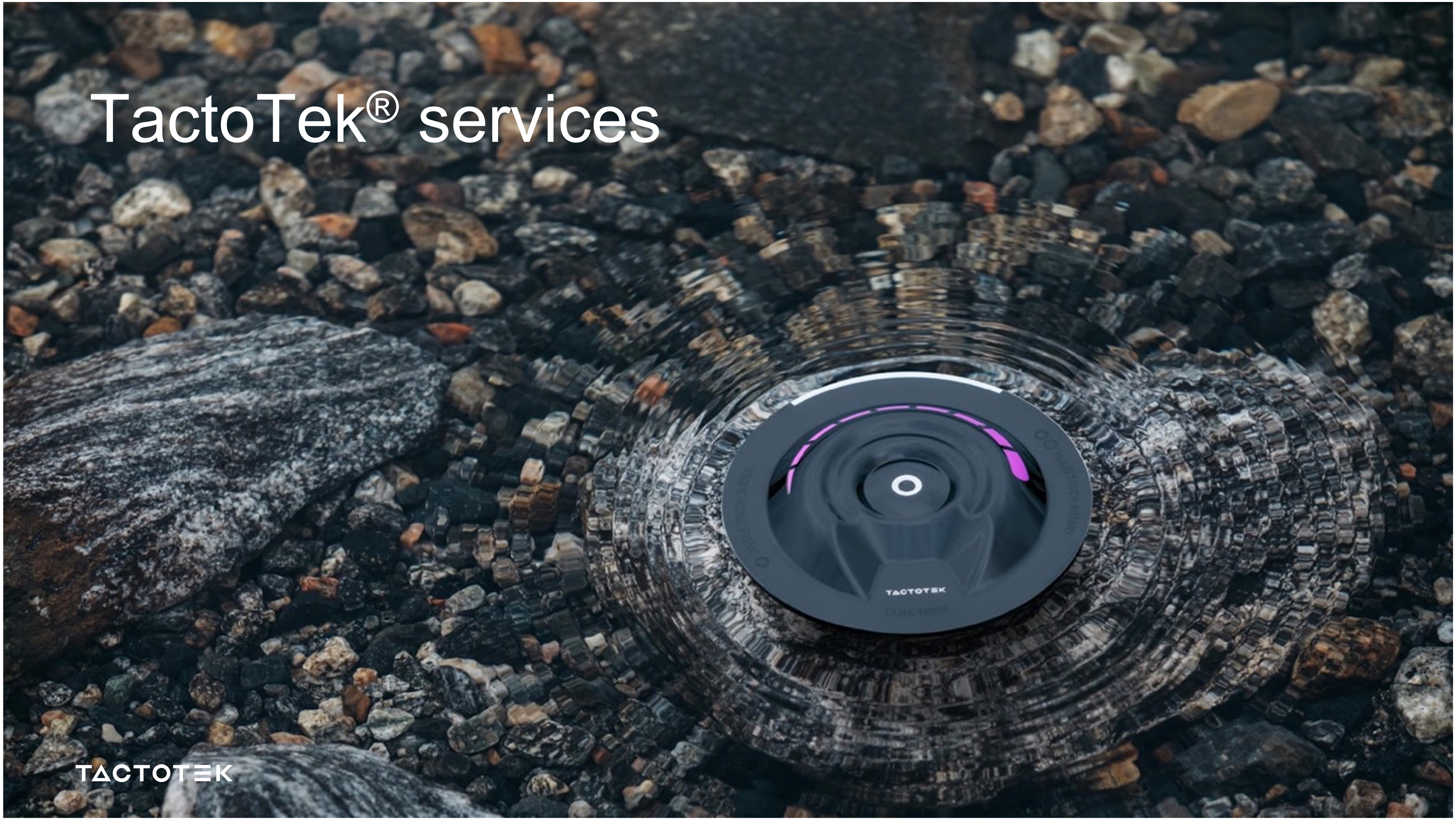
64 parts + PCBA
Costly assembly
45mm assembly depth
470 grams



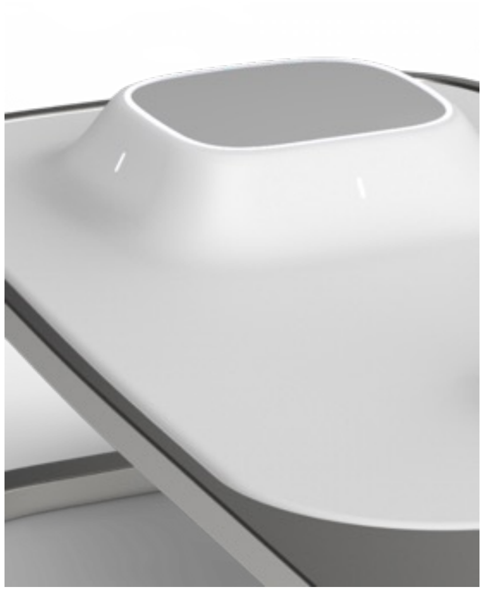
IMSE Smart Molded Structure

One molded part + small PCBA
Fewer parts to design, less tooling, less inventory, minimal assembly
3 mm molded material thickness, **90% less**
200 grams, **57% less**
Co2eq **60% less**

TactoTek® services

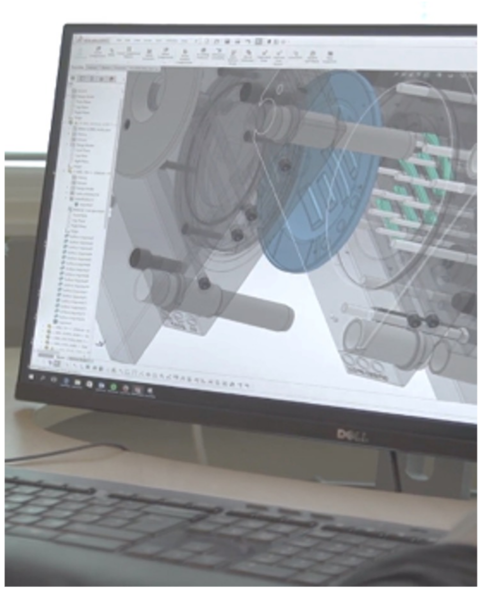


How we operate



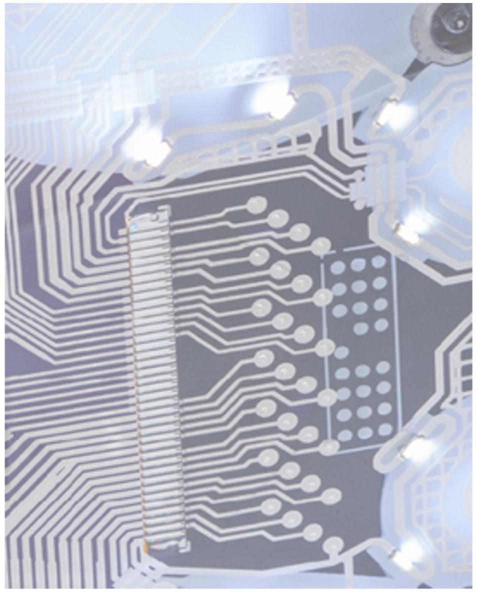
TactoTek® Design & Prototyping services

Your design vision, TactoTek's IMSE® engineering to bring it to life. We will also manufacture your IMSE prototypes.



IMSE Designer® License

Enables you to master IMSE design



IMSE Builder® License

Become a certified IMSE part manufacturer and mass produce IMSE parts

TactoTek® Manufacturing

TactoTek manufactures your IMSE parts

Introducing IMSE® technology

Revolutionary way to create smart surfaces

IMSE® enables creating a single-piece, seamless part that integrates electronics within the surface

Design enablers for a next generation of UX

AESTHETICS

Surface materials
Surface finishing
Passive haptics

TOUCH

Touch button
Linear slider
Rotary slider
Multi touch control

SENSE

Proximity
Ambient light sensor
Infrared

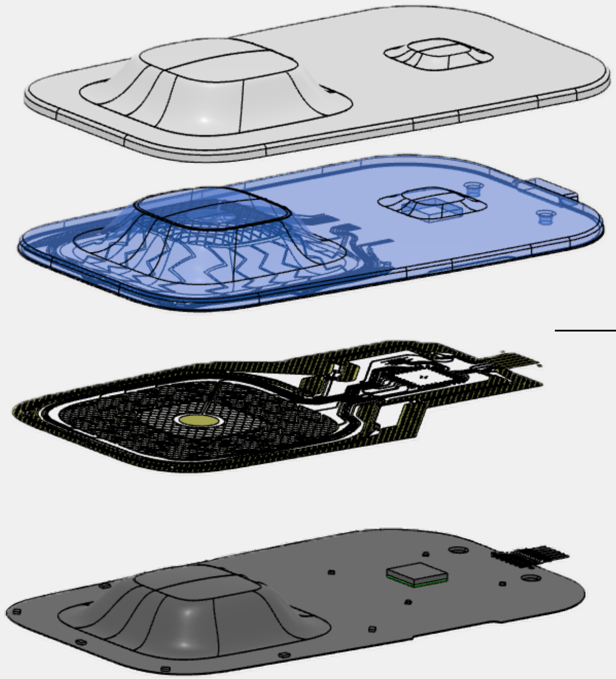
ILLUMINATE

Button/icon backlight
Indicator light
Large area illumination (LAI)
Light line (static/dynamic)

CONNECT

Wi-Fi
BT
NFC

IMSE® creates a smart, thin, seamless surface structure



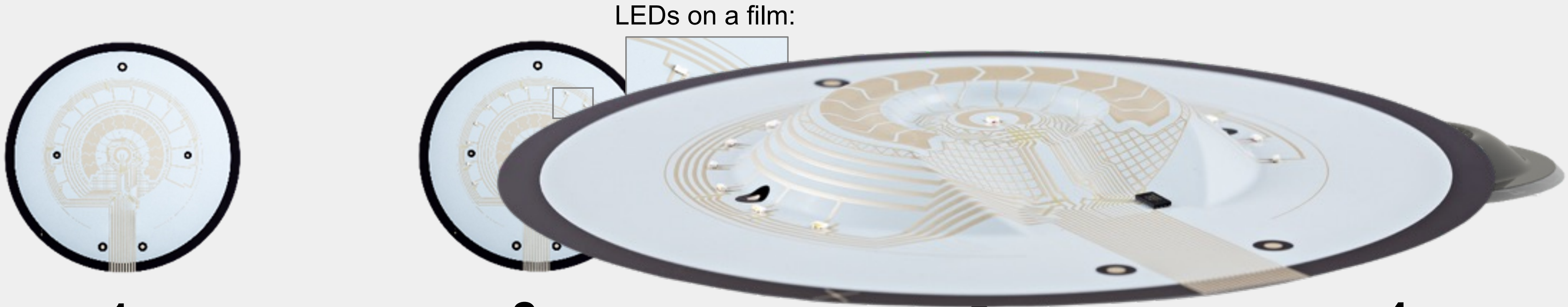
Decorative surface
FIM film or natural materials
Decorative inks

Plastic resin
PC

Electronics
Conductive inks
Dielectric inks
SMT electronics
- LEDs
- IMSE SiP

Functional surface
FIM film

Manufacturing process overview



1.
Print decoration and electronics

2.
Mount components on **flat** film

3.
Form 3D shape **with** components

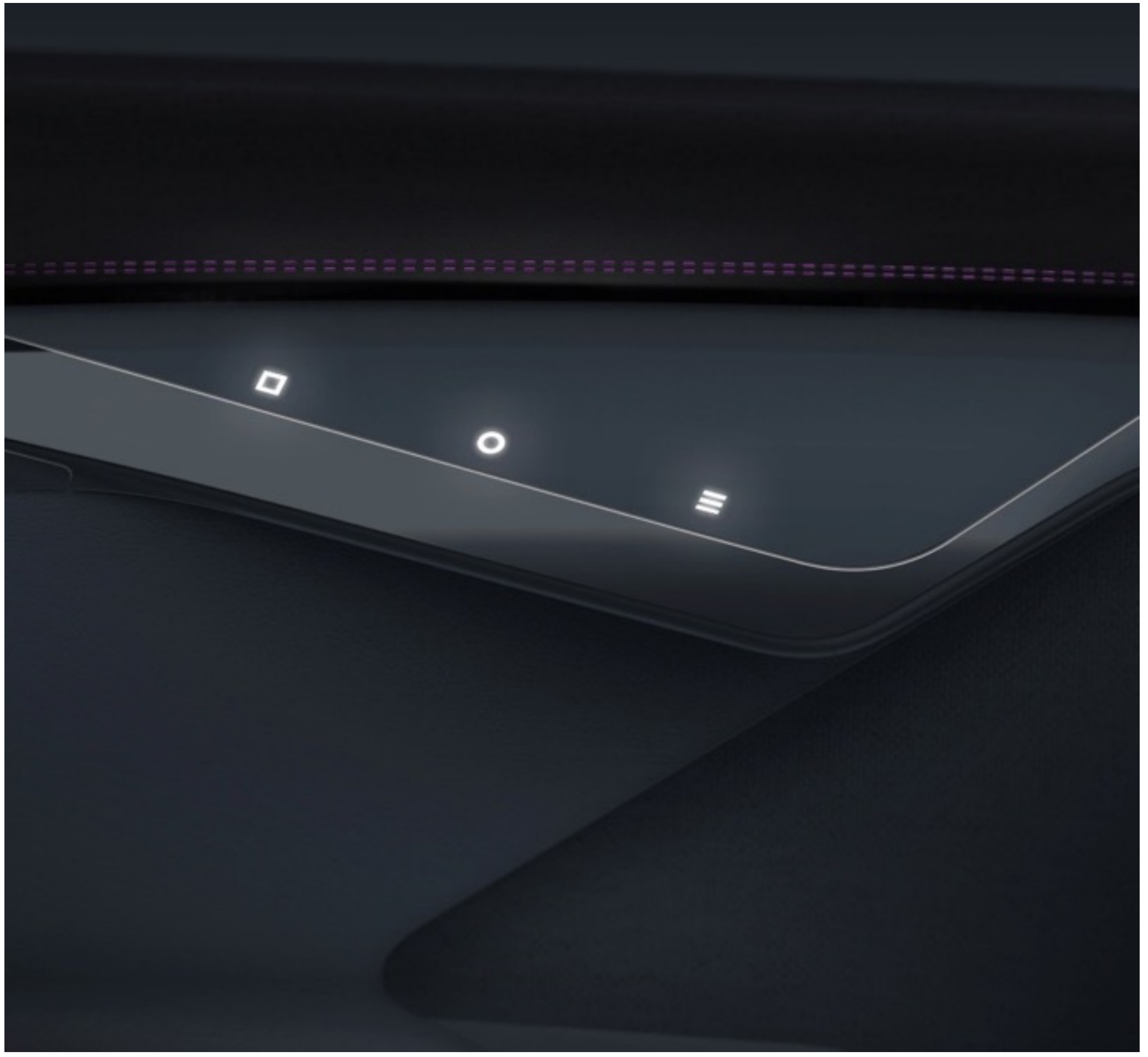
4.
Injection mold final single, seamless part


The future of car interior design
TACTOTEK

IMSE® Door Trim concept

Light, “floating” structure combining illumination and touch controls

- Multitude of surface and ambient illumination possibilities
- Large area illumination (LAI) for styling and indication of functions
- Graphical and functional variants with a single tool set



Origo Steering Wheel

Origo Steering Wheel HMI brings mobile device user experience to driving, enhancing safety, design and usability

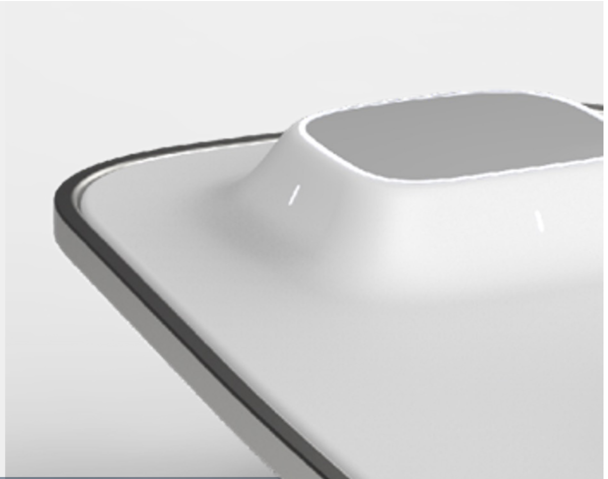
- 3D touch sensors and illumination integrated in the steering wheel
- Multiple mechanical controls replaced
- IMSE® part thickness 4 mm
- Winner of CES Innovation award and German Design Award

RIGHTWARE siili_auto
TACTOTEK CANATU

TactoTek® Mesa IMSE® Controller

Elegant, intuitive touch control interface

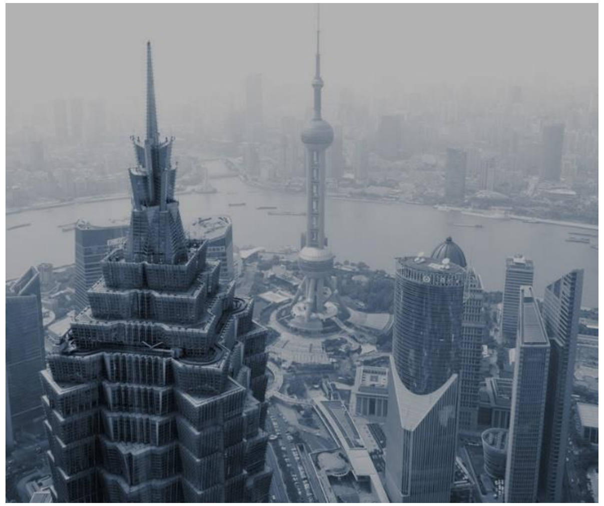
- Capacitive touch controls – buttons and sliders
- Software configurable gesture facets
- Lighting system for the HMI (top side)
- Ambient illumination for decorative or informative purposes (bottom side)
- IMSE SiP – sophisticated system electronics, integrated inside the IMSE part

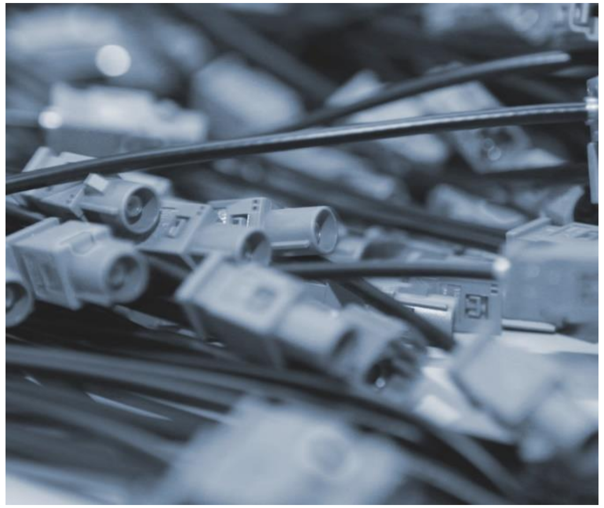


Join the revolution

GEELY
CEVT
SUUNTO MOVESENSE
SHEPHERD
PassiveBolt
FORVIA
LS Automotive
MARQUARDT
ALPSALPINE
fischer AUTOMOTIVE SYSTEMS
novem
CLAYENS NP
Techniplas Making the Connected World
KYOCERA
BÖLA LEADING IN FILM-DECORATION
zollner
NAGASE
CORNES Technologies
PHIARO
LIGHTWORKS PASSION FOR LIGHT
infineon
Melexis INSPIRED ENGINEERING
ams OSRAM
covestro
3M


TACTOTEK
Discover a step change in design and innovation
Smarter surfaces for a smarter future
How 3D structural electronics will change the way we design, create and experience the future





IMS CONNECTOR SYSTEMS

Retrofit Sensor Technology – MID Summit & MID Workshop, Sept. 21-22nd 2022, Böblingen – Germany

Peter Peetz / CEO

AGENDA

1. Products by IMS Connector Systems - Design-In Partner for Real time Data Exchange

2. Data-based Innovation Process
ends with Demonstrator –
supported by Hahn-Schickard Digi Pro

3. Value add for Customer

4. Q & A

1. PRODUCTS BY IMS CONNECTOR SYSTEMS - DESIGN-IN PARTNER FOR REAL TIME DATA EXCHANGE

IMS CONNECTOR SYSTEMS

With tradition and experience.

1863

Foundation of the family business by Johann Morat

1972

Production of the first RF connector systems and cable assemblies

1989

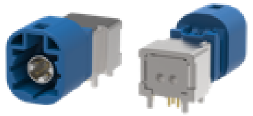
Telecommunications: Manufacturing of components for cell phones

2002

Automotive: Manufacturing of SMBA connector systems according to FAKRA standard

2011

Automotive: Development of High Speed Data HSD®



2015

Telecommunications: Development of 4.3-10

2017

Automotive: Development of MCA

2019

Telecommunication: License agreement for the production of NEX10®

2020

Industrial: Development of SmartMod

» Cooperation with Aptiv + Lear Corp. + Turck

2020

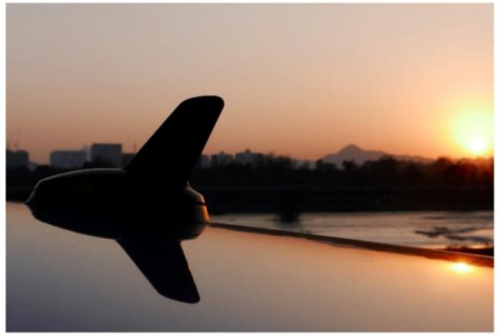
Automotive: Development of HTP

IMS CONNECTOR SYSTEMS

1. PRODUCT PORTOFOLIO IMS CONNECTOR SYSTEMS - AUTONOMOUS DRIVING – 5G SYSTEMS – ... SOLUTIONS AVAILABLE

HIGH-GRADE ANTENNA TECHNOLOGY

RADIO UNITS, SMALL CELLS DEVICES



SMART ANTENNAS

AUTONOMOUS DRIVING

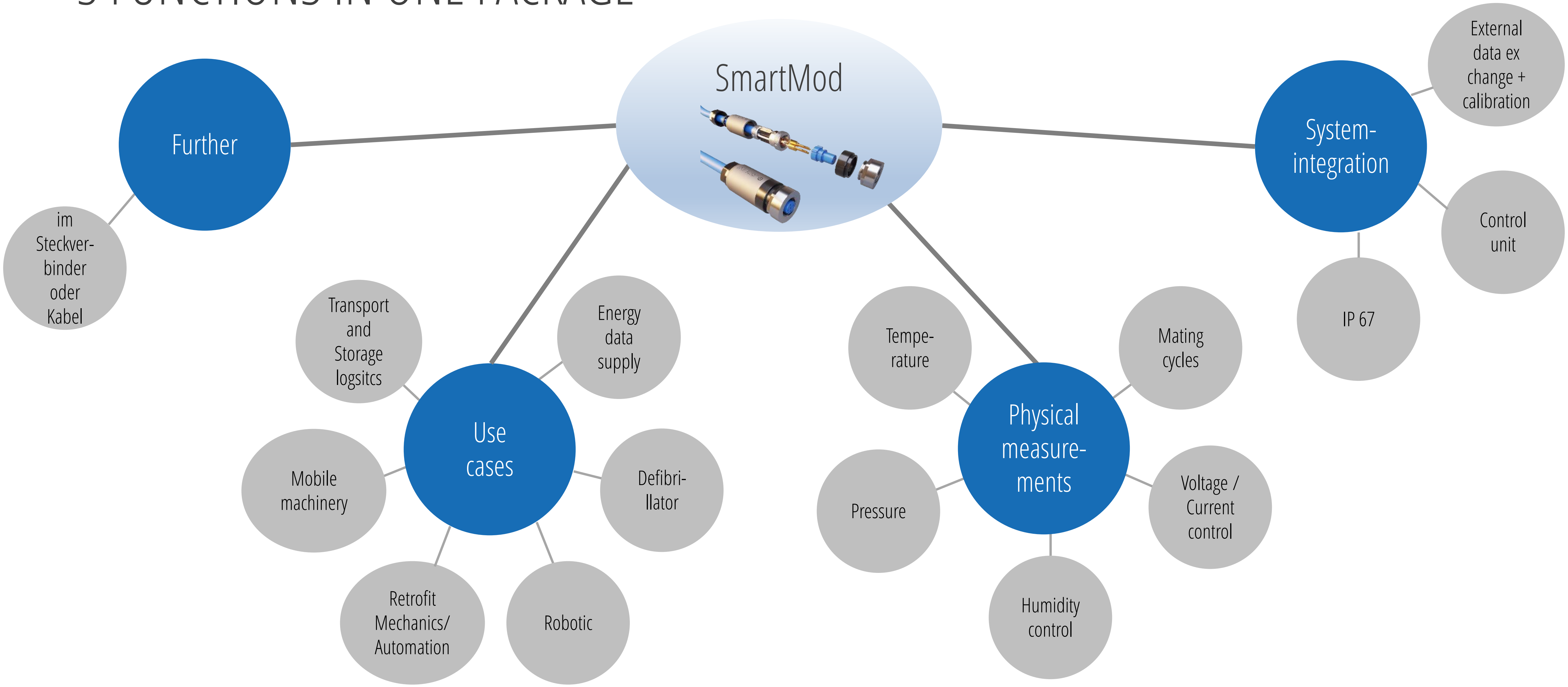
2. DATA-BASED INNOVATIONSPROCESS – VALUE CHAIN POSITION AS DEVELOPMENT PARTNER

IMS CONNECTOR SYSTEMS

1 … 4	Commodity Business (high volume >1 Mio. pcs./month, hugh compedition, CM is target)
1 … 4	Design-In / Technical Sales Concept (Requirement spec. is starting point)

→ **Value add position from IMS CS**

2. DATA-BASED INNOVATIONSPROCESS - 3 FUNCTIONS IN ONE PACKAGE

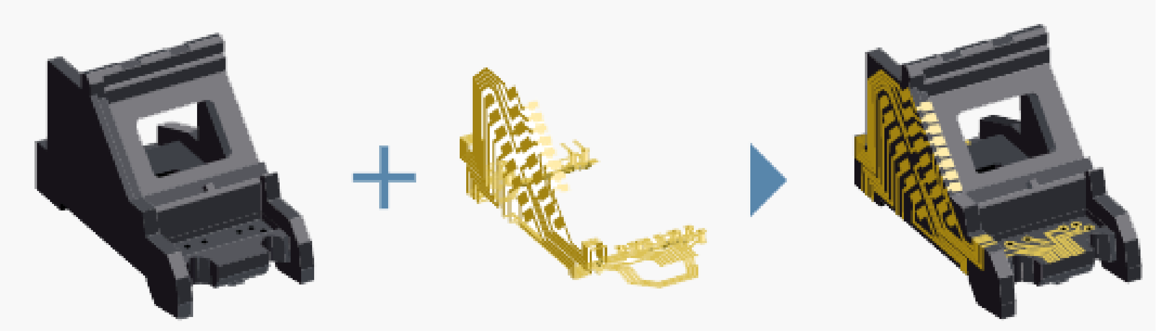


2. DATA-BASED INNOVATIONSPROCESS – EARLY VALUE ADD CHECKING FOR CUSTOMER AND INCREASED MARKET VALUE FROM START OF DEVELOMENT

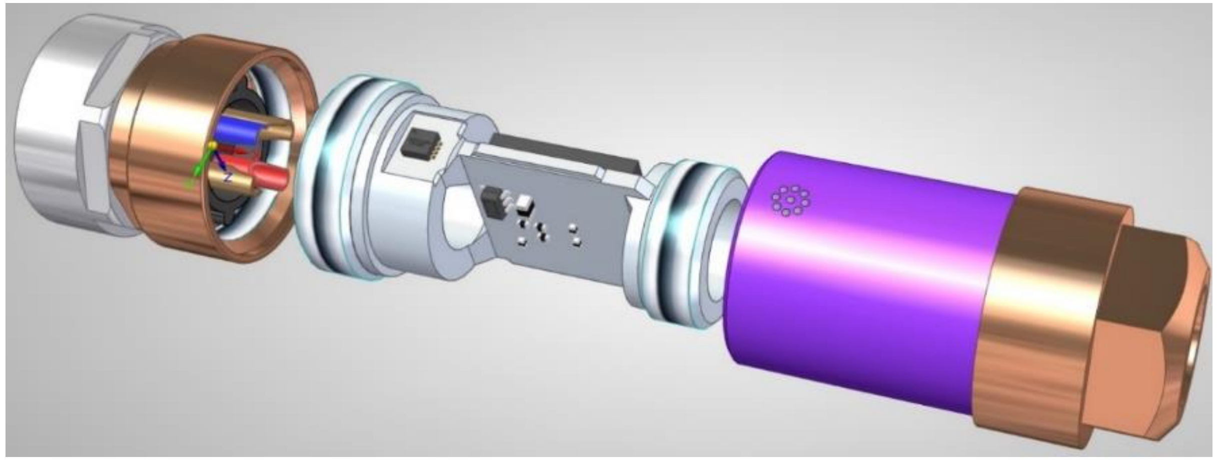
CONNECTOR SYSTEMS

Industrie Standard Connector called smart mod

- 3D MID (Molded Interconnect Devices)
- Molded circuit (Technologieinnovation)
- M8/M12 Standard Industrial
- Molding device was designed by Hahn-Schickard
- Sensoric element – humidity, Temperature and pressure used
- Data transfer via µ-Controller and active electronic components
- Value by demonstrator: Risk and Solutions as soon as possible before development starts.



https://www.panasonic-electric-works.com/at/miptec-eine-mid-technologie-von-panasonic.htm

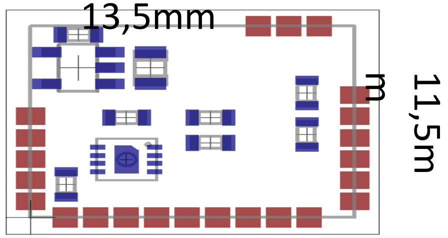


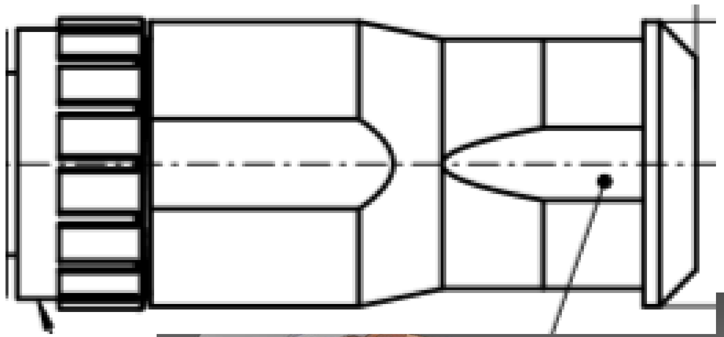
https://www.elektroniknet.de/design-elektronik/elekromechanik/m12-fuer-alle-faelle-89123.html

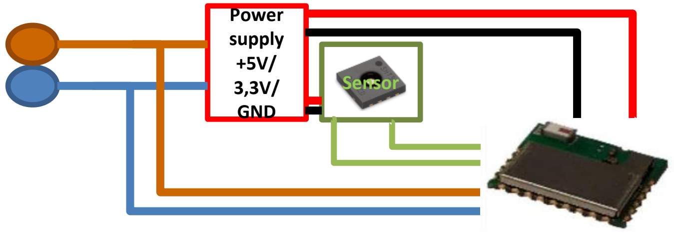
Hahn Schickard

2. Data-based Innovation Process – Demonstrator was produced by Hahn-Schickard / Project DigiPro

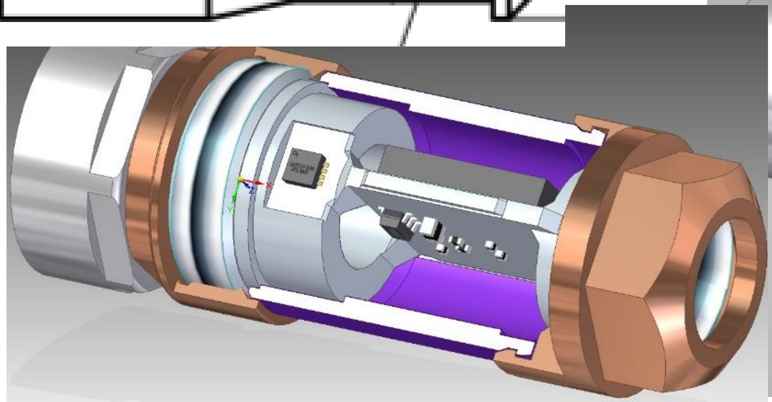
- SMART Connector M12 Bluetooth Proj.Nr.:11539
    - **Start was January 2020 with Partner Hahn Schickardt**
        - The construction of the chasis was finished in the last week of January
        - Target is to get a 3D MID Prototype includes sensoric and wireles communication via bluetooth till the end of june.
        - 30.06.20 public presentation of „DigiPro“ and „SMART Connector“

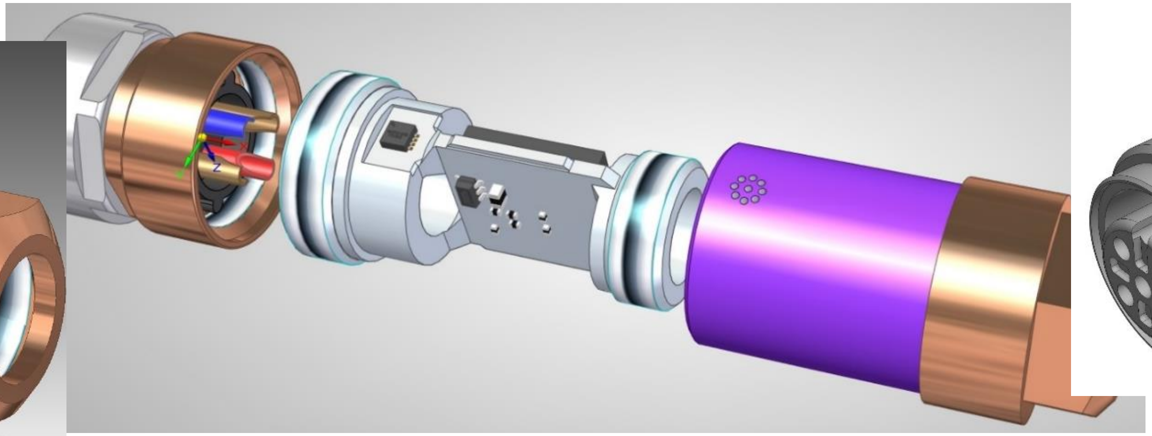


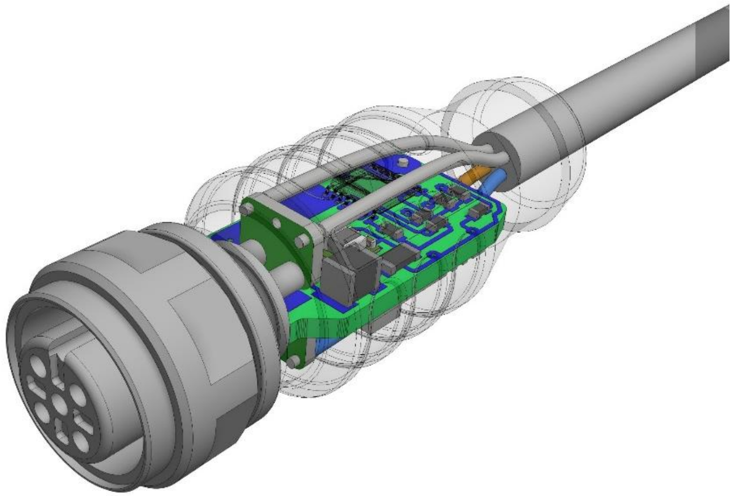




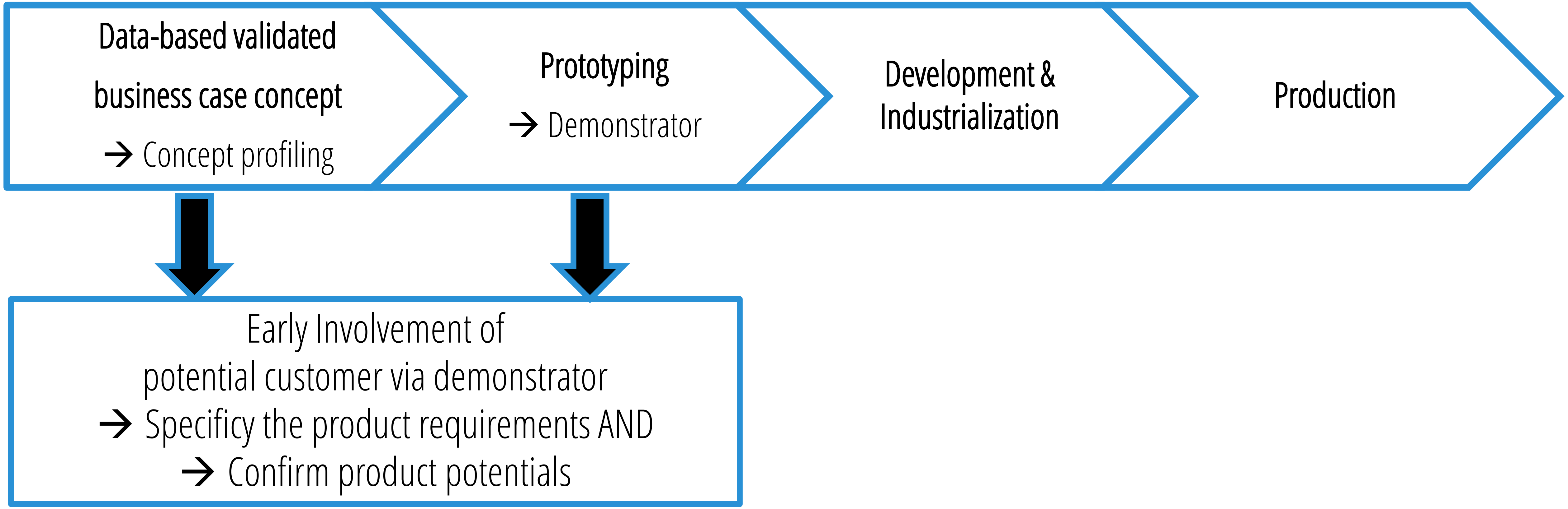
Bluetooth Modul
ST BlueNRG-M2





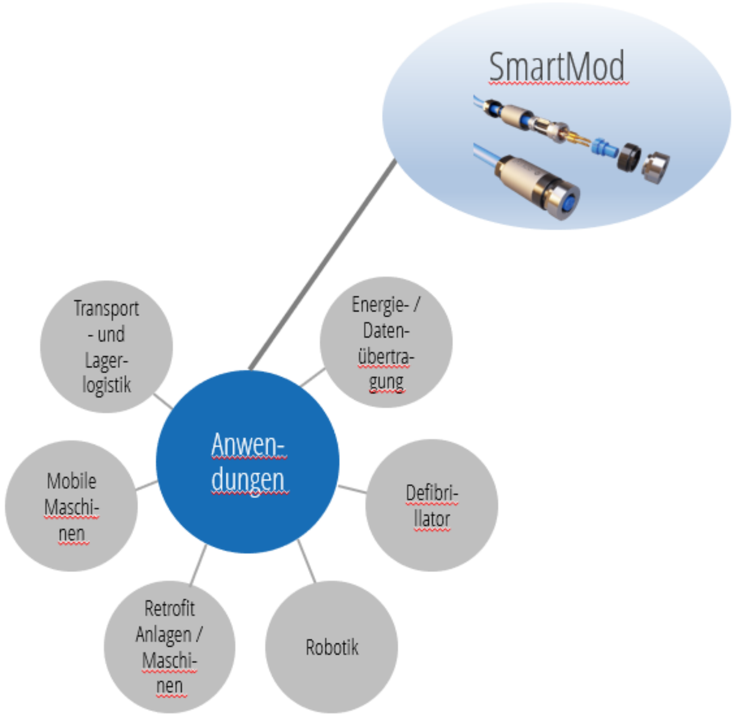


3. VALUE ADD FOR CUSTOMER – FACTBASED VALIDATION + DEMONSTRATOR TO CLOSE PROCESS



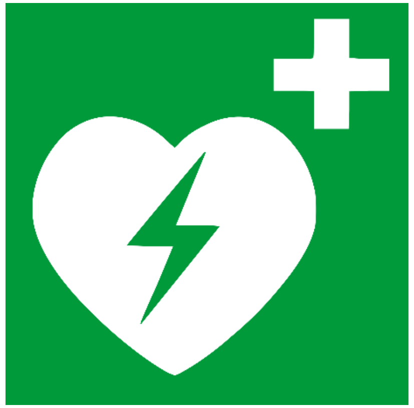
3. VALUE ADD FOR CUSTOMERS - SEVERAL POSSIBILITIES

IMS CONNECTOR SYSTEMS

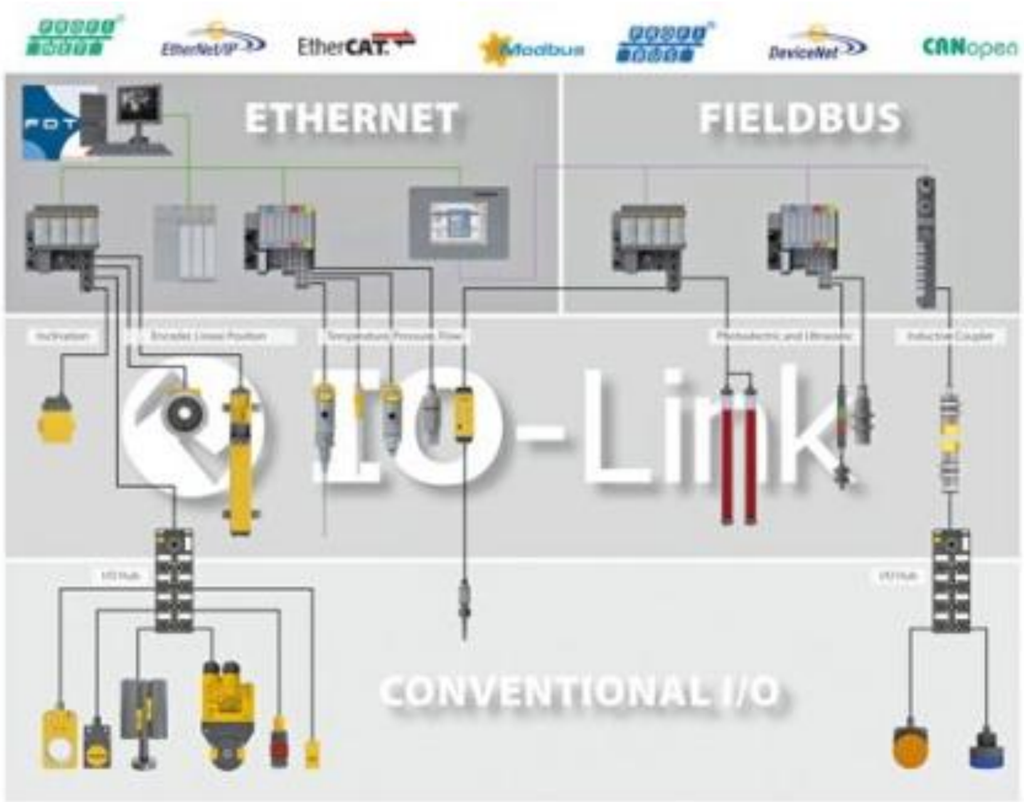


-> Examples for Product Use:
Predictive Maintenance/Retrofit – high availability due to significantly reduced risk of failure

- Voltage monitoring for passengers and freight elevator
- Voltage monitoring and logging of environmental parameters at public AED
- Contineous logging of the voltage parameters (freely adjustable) for robots
- Complete monitoring of the network in the area of transport and warehouse logistics
- Energy and data transmittion systems in the crane area

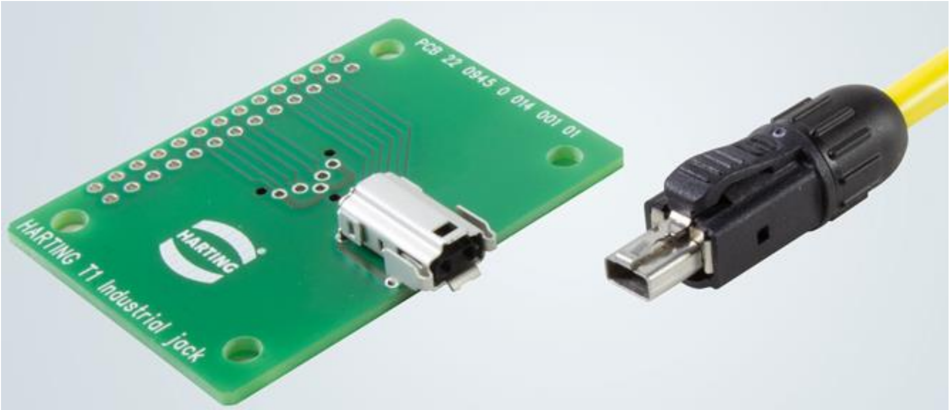

3. VALUE ADD FOR CUSTOMERS -
HIDDEN FUNCTION VIA SMART CONNECTOR



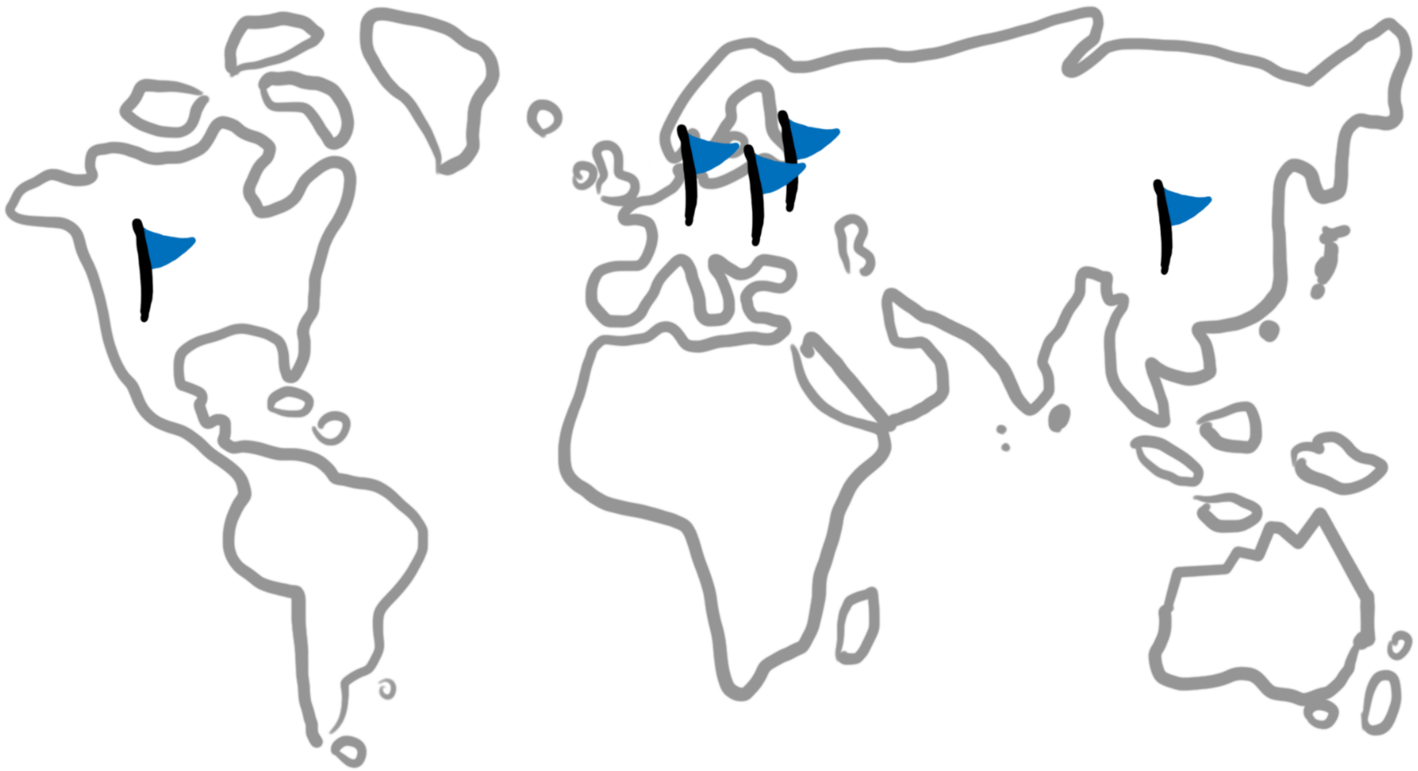
https://www.turck.de/de/iolinkpassivverteiler-verdrahten-auspuffproduktion-4017.php

SPE

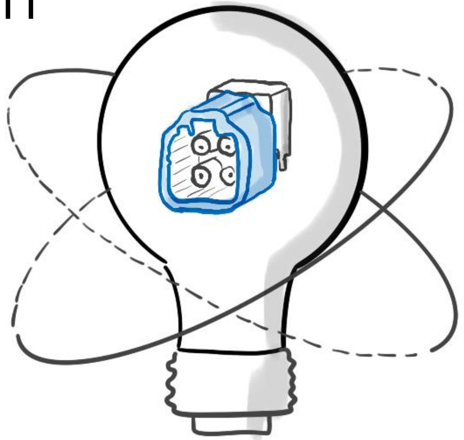
SINGLE PAIR ETHERNET -
ENABLER FÜR IIOT



https://www.harting.com/DE/de/single-pair-ethernet



Thank you very much



Q & A

Contact:

Peter Peetz / CEO
IMS Connector Systems GmbH
Obere Hauptstrasse 30
D – 79843 Löffingen

Email. ppeetz@imscs.com
Phone. +49 7654 901-130

Rapid Prototyping of MID by Stereolithographic Printing

22. September 2022

Dr. Hendrik Mohrmann

CONTAG today

PCB Production

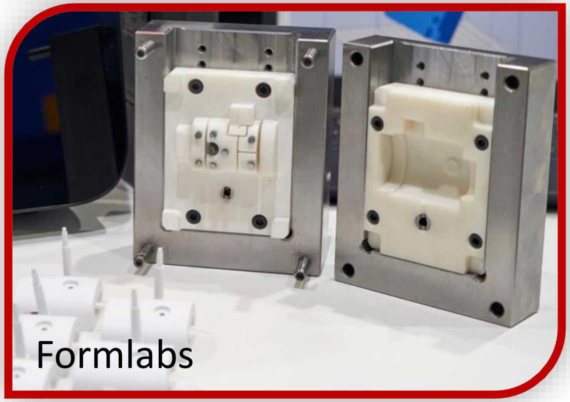
- Automotive, medical, communication, aviation, lighting,…
- Prototypes, small series and series
- Express-Delivery in 4h, Multilayer in 14h
- Newest Materials and Technologies
- Line/Space <25µm, Micro-Vias (Ø 40µm), Laser Drilling, HF-Materials, Rigid-Flex, IMS
- (Rigid-) Stretchable PCBs

3D-MID

- Member of 3D-MID e.V. since 2016
- Customer Orders of 3D-printed MID since 2019
- R&D projects involving MID

Motivation: Prototyping 3D-MID

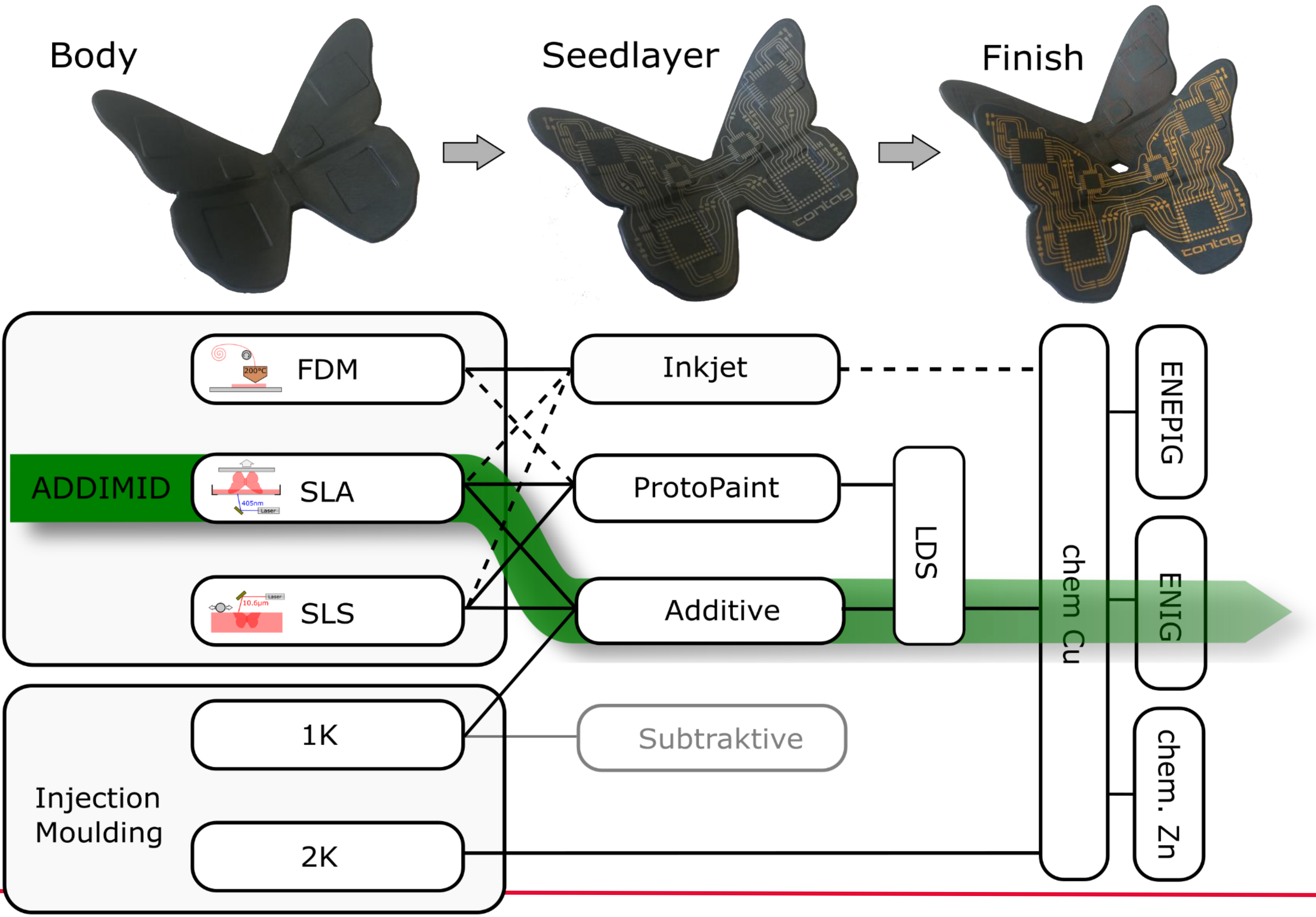
- **Injection Moulding problematic in product development**
  - Expensive tooling
  - Long iteration cycles



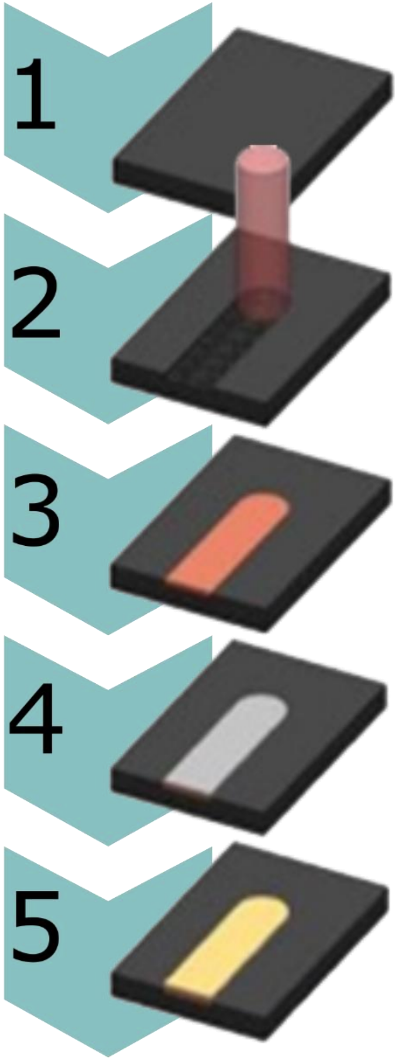
- **LPKF-Protopaint**
  - High material versatility
  - Assembly by conductive glue
- **3D-printed mould**
  - Close to serial production
  - HT-material for mould

→ Additive manufacturing of LDS-approved materials

Production Strategies of 3D-MID



Process Chain



Production of Body
3D-printed LDS-resin

Laser Direct Structuring
metal seeds on rough surface

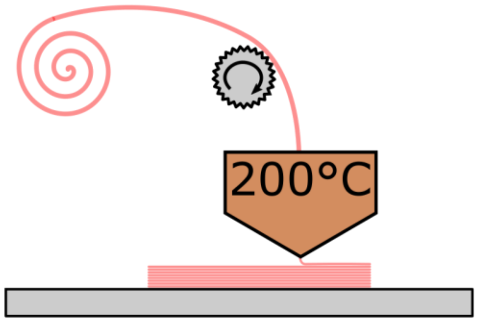
Chem Cu
8-12µm

Electroless Ni
5µm

Immersion Au
>50nm

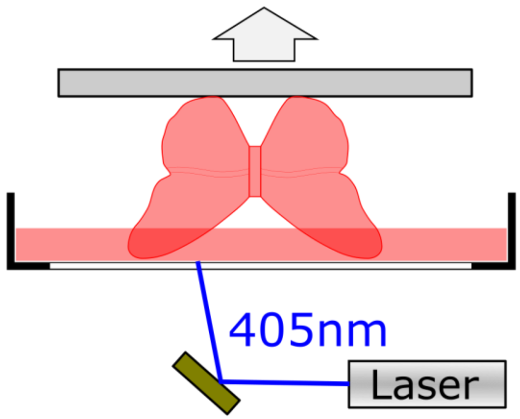
Rapid Prototyping

Fused deposition modeling



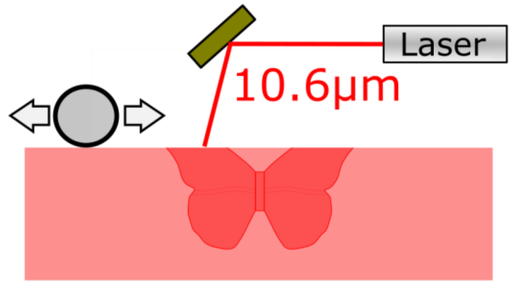
- PLA , ABS, PEEK, Ultem, Polysulfon
- Thermoplastics
- Resolution >100µm
- Structured surface
- Anisotropic

Stereolithography



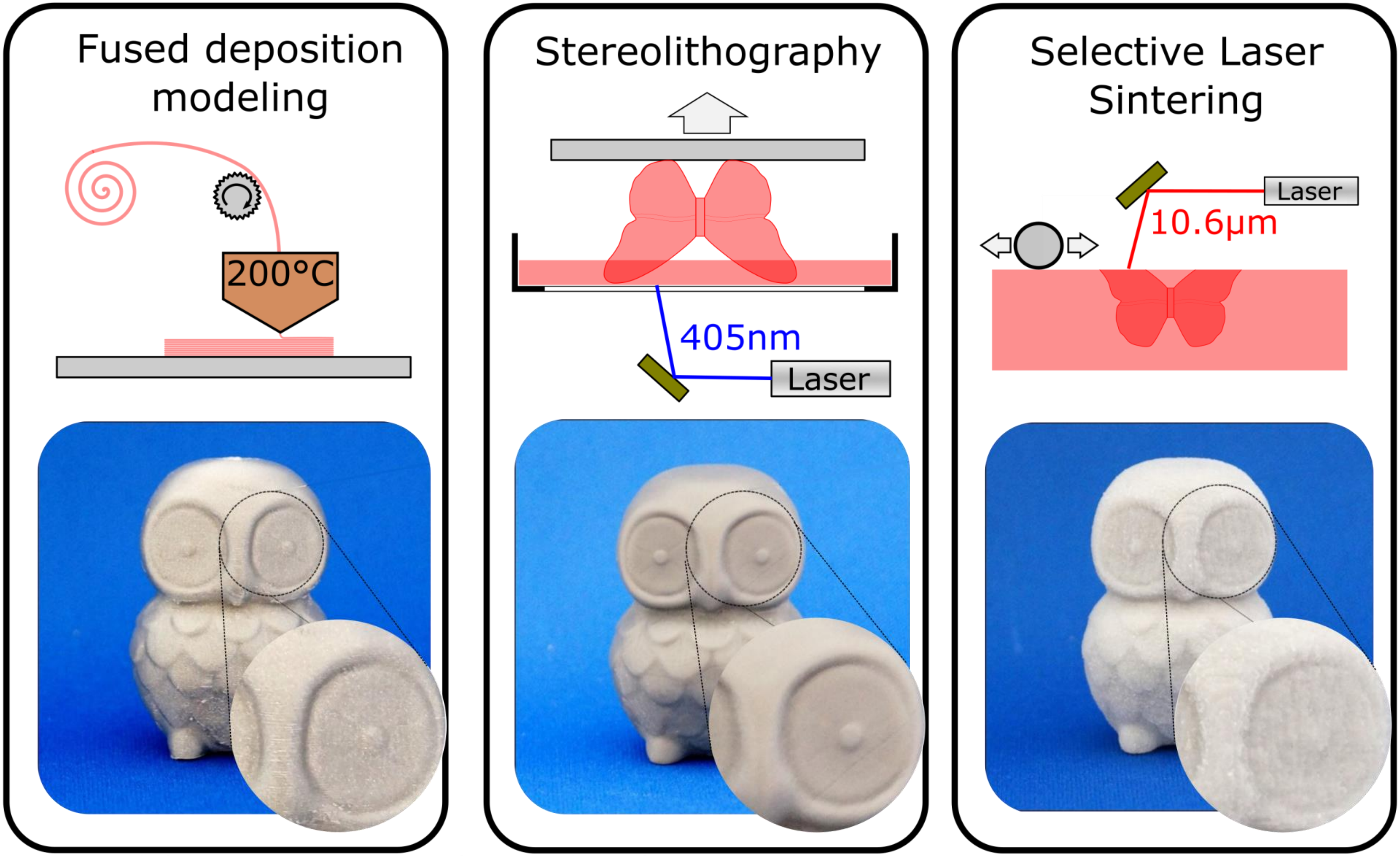
- UV-curing Thermosetting
- Mainly acrylic
- Thermally stable to 250°C
- Resolution >25µm
- Highest surface quality

Selective Laser Sintering



- Mostly Nylon
- Thermoplastics
- Thermally stable to 160°C
- Resolution >25µm
- Porous surface

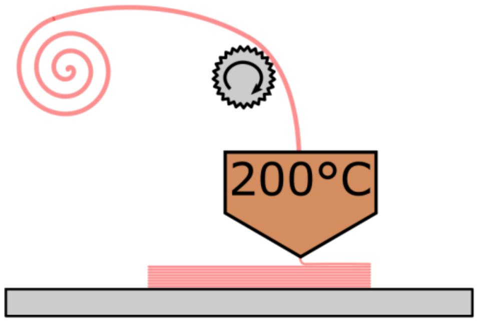
Rapid Prototyping



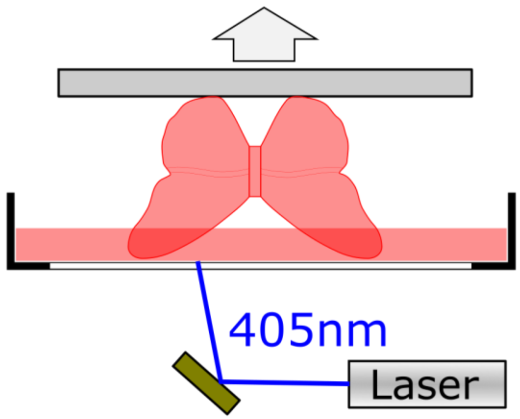
https://3faktur.com/en/the-surface-quality-of-3d-printed-parts/#1495634773127-9db76804-b69c

Rapid Prototyping

Fused deposition modeling



Stereolithography



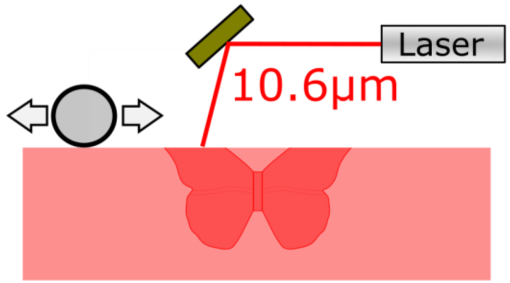
Hahn Schickard

bLz Bayerisches Laserzentrum

Fraunhofer IEM

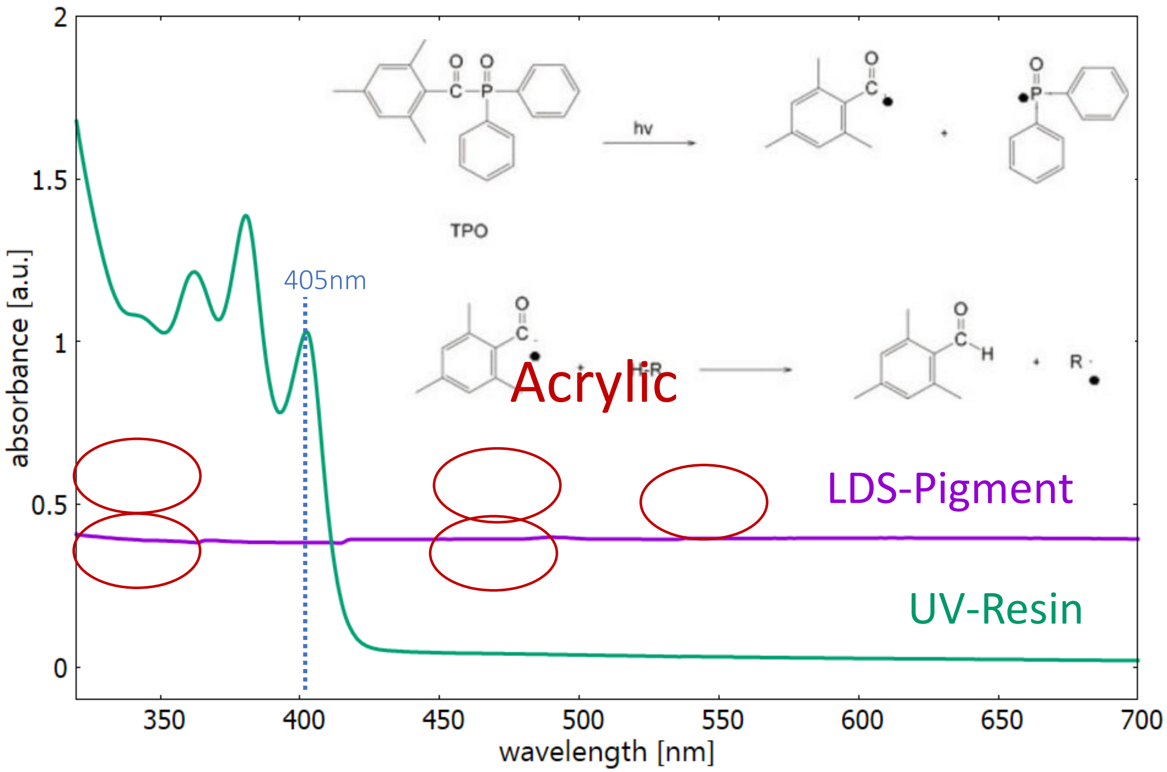
contag

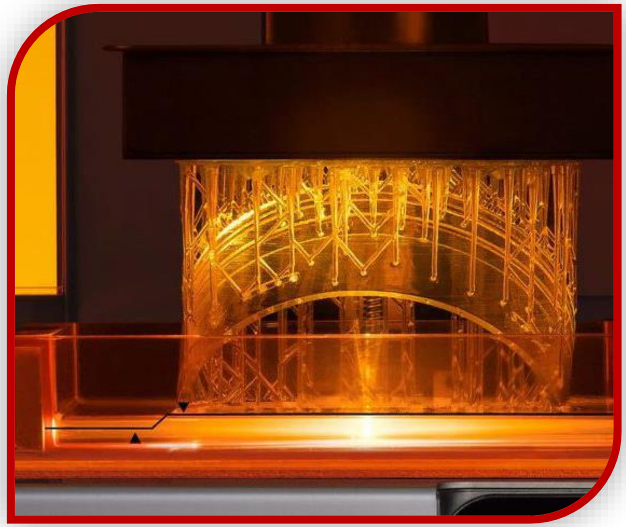
Selective Laser Sintering



UV-curing Resins

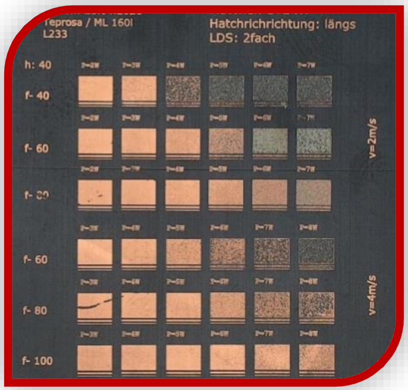
Free-Radical Polymerization



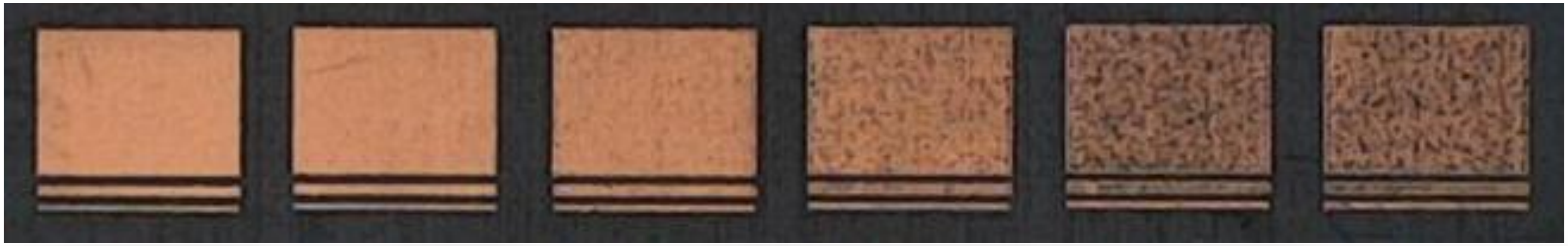


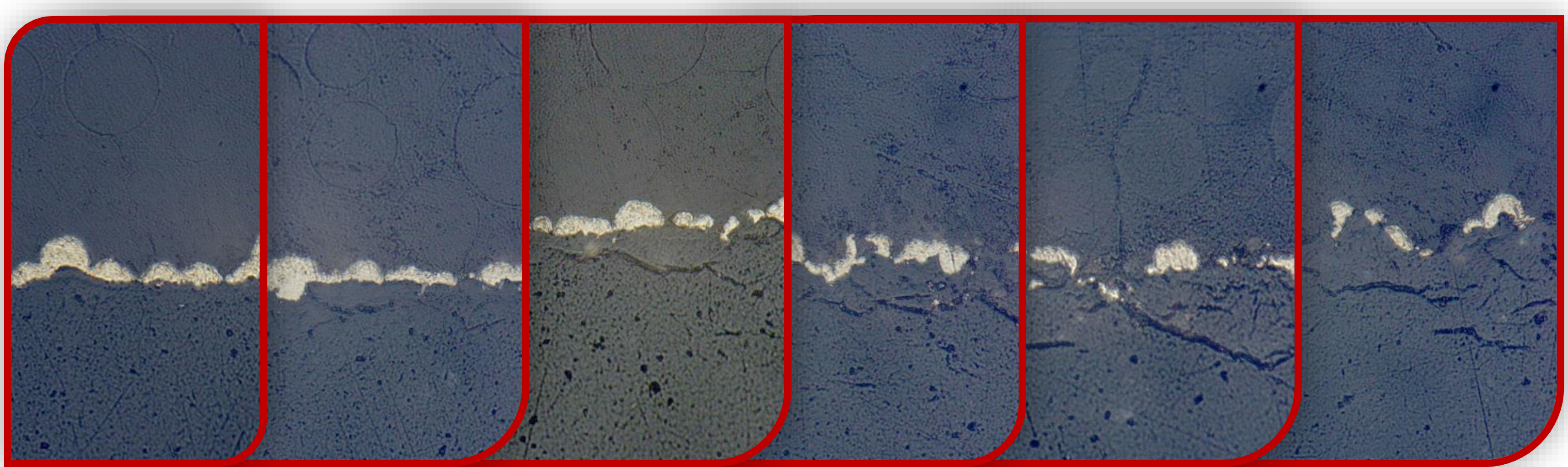
	SLA (Form3)	DLP (Prusa SL1S)	LPKF 160i	unit
Light Source	CW-Laserdiode	LED-Array	Nd:YAG	
Power density	$\sim 10^{6}$	2,2	$\sim 10^{15}$	mW/cm^2
Resolution	25	50	80	µm
Exposure ($40 mJ/cm^2$)	$2 \cdot 10^{-5}$	9	-	s

Laser Direct Structuring



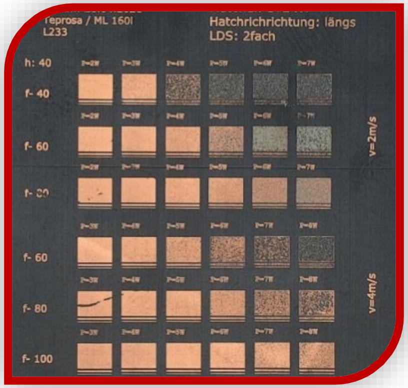
Frequency	40 kHz
Hatch	40µm
Scanning Speed	2m/s



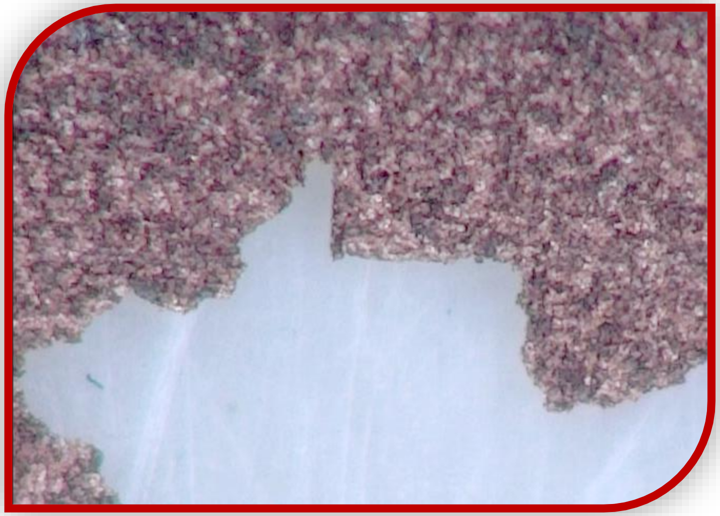


2W 3W 4W 5W 6W 7W

Laser Direct Structuring

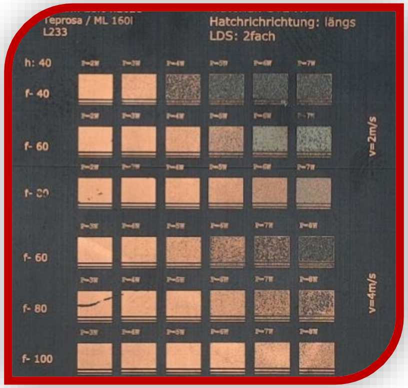


Frequency	40 kHz
Hatch	40µm
Scanning Speed	2m/s



- High Power leads to cracks below surface
- Best results for low Power and high Frequency
- ps-Pulses for higher reliability (?)

Laser Direct Structuring

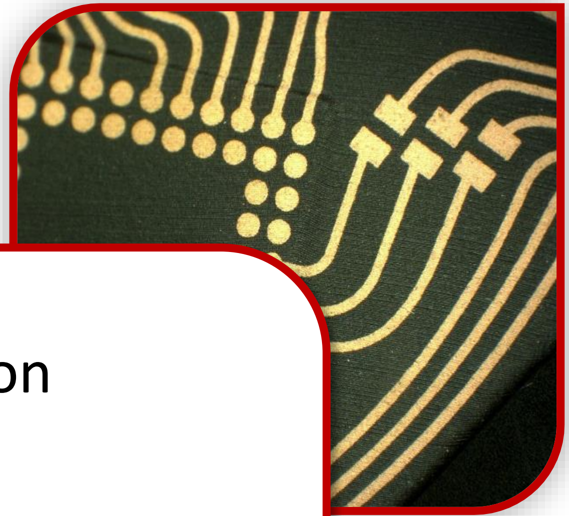


Cross Section LCP


Cross Section SLA

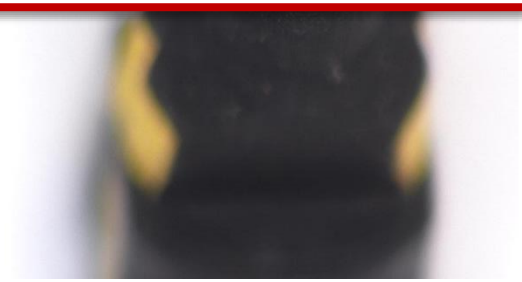
- Reliable LDS-parameter
- Chemical Cu-buildup up to 50µm

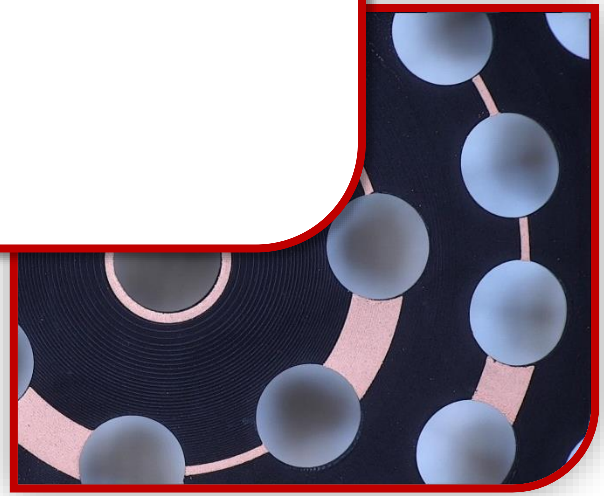
Material Properties



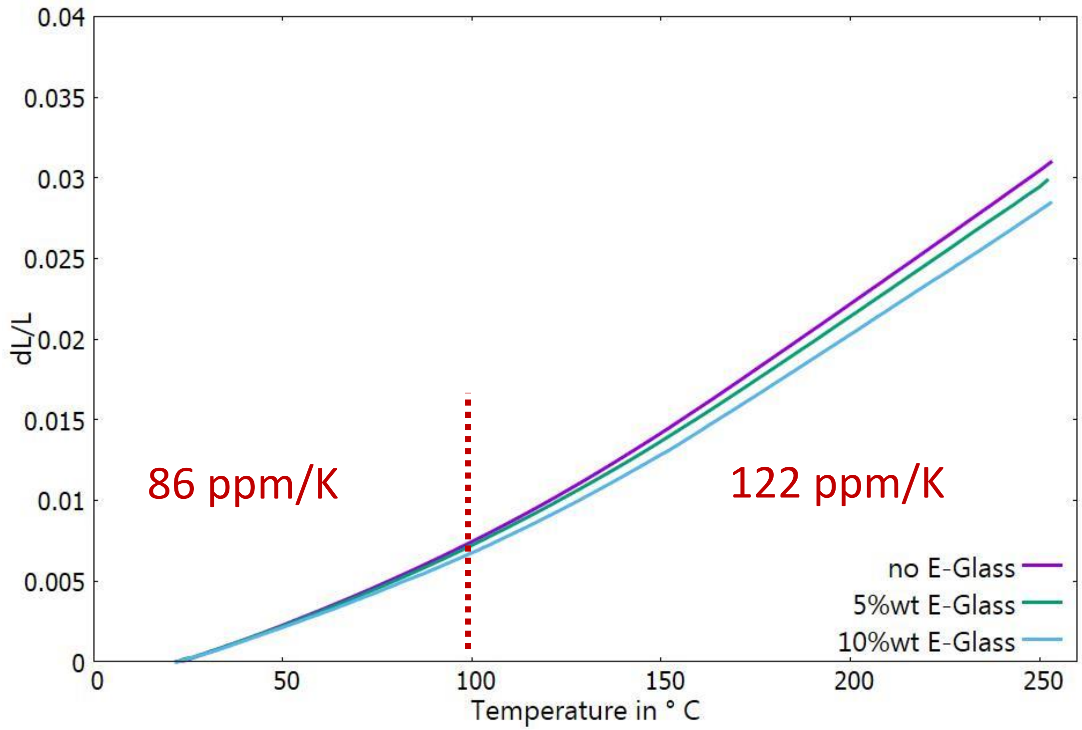
Moul

- Coefficient of Thermal Expansion
- Assembly: Thermal stability
- Dielectric properties

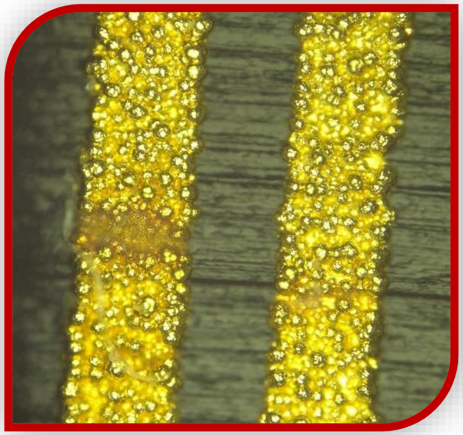


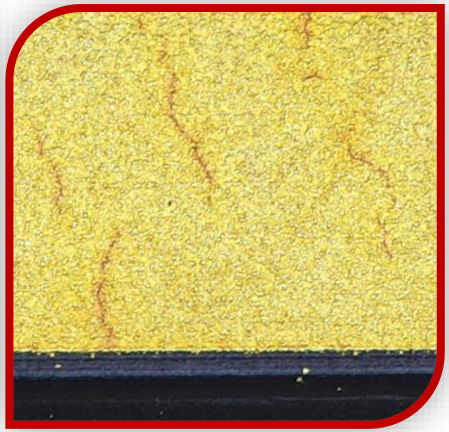


Thermal Expansion



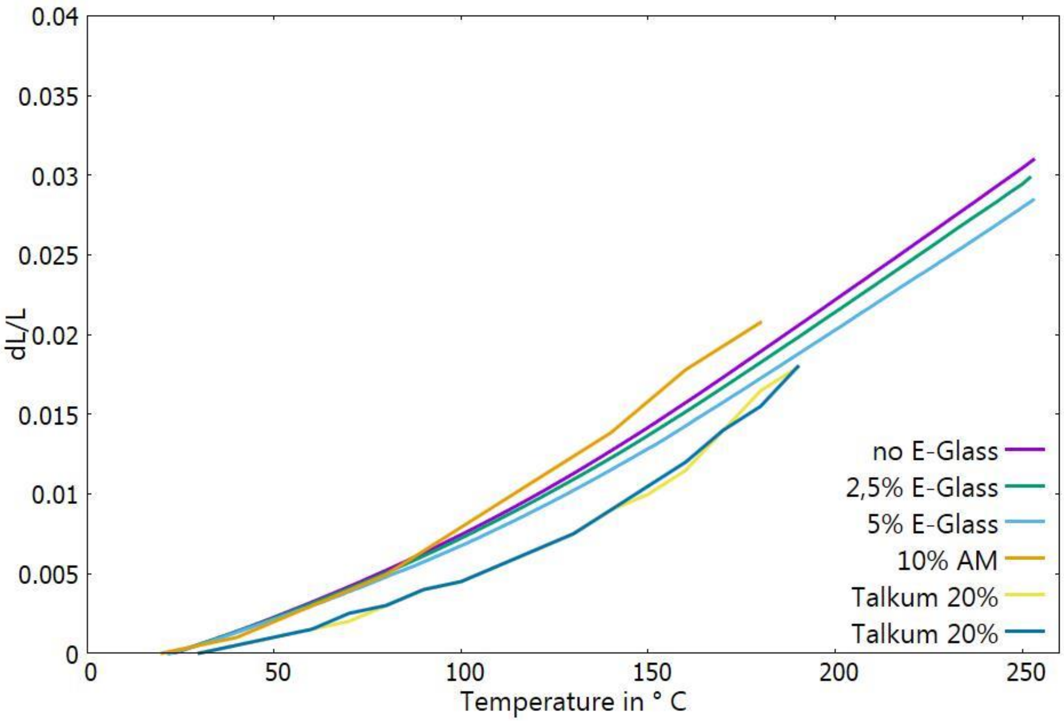
- CTE=122 ppm/K (RT-250°C, sTMA)
- CTE isotropic
- Reduction of CTE through
  - high filler content
  - change to different resin system





Thermal Expansion

	1	2	3	4	5	6	7
	Vol.-%	Vol.-%	Vol.-%	Vol.-%	Vol.-%	Vol.-%	Vol.-%
Epoxidharz	45,00	45,00	45,00	45,00	45,00	45,00	45,00
Glasperlen	38,00	15,00					
Glasfaser	7,00	30,00					
LDS Additiv	1,50	1,50	1,50	1,50	1,50	1,50	1,50
Talkum	8,50	8,50	26,75	8,50	8,50	17,00	17,00
Wollastonit			26,75		45,00	36,50	
Aluminiumoxid				45,00			36,50



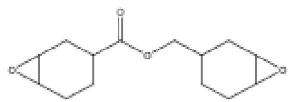
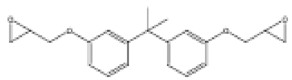
[Rudin et.al., 2014, MID-Forum im Rahmen der SMT]

Raschig Epoxidur:
CTE= 16-18ppm/K (50-180°C)

- 20% wt Talkum:
  75ppm/K (30-130°C)
  173 ppm/K (130-190°C)
- 24% wt E-Glass not printable

Thermal Expansion

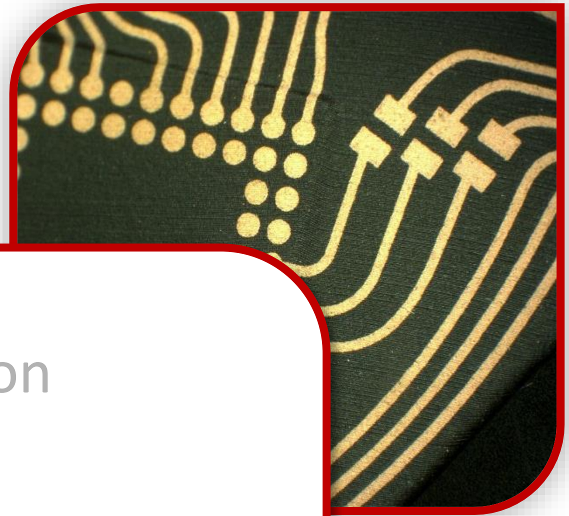
	Material	Heat Deflection Temperature [°C]	Elongation at Break	Tensile Modulus [GPa]	CTE (0-150°C) [ppm/K]
SLA	Formlabs Tough 1500	52	51%	1,5	97
SLA	Formlabs HighTemp	238	2,4%	2,9	74
SLA	PlastCure Rigid 10 500	120-125	1-2%	7,7-8,2	‚Low CTE‘
SLA	Druckwege Type D	260	2,5%	2,45	-
SLA	Rogers Radix	76,7	2,3%	2,7	123 (50-250°C)
IM	Pocan DP 7140 LDS	>255		12	36/56
IM	Vectra E 840i LDS	>260	3%	10	12/27
PCB	Rogers 4350B	>280 (T_g)	-	19,65	11-14 (X/Y), 46 (Z)
PCB	Panasonic R1755-M	150 (T_g)			13-15 (X/Y), 40/240 (Z)

Ionic	Epoxides	3,4-Epoxycyclohexylmethyl-3′,4′-epoxycyclohexane carboxylate		Low shrinkage and chemical and thermal resistance	Fragility and low toughness
Ionic	Epoxides	Diclycidylether derivative of bisphenol A (ADE)		Low shrinkage and chemical and thermal resistance	Fragility and low toughness

We need low-CTE UV-curing Resin!

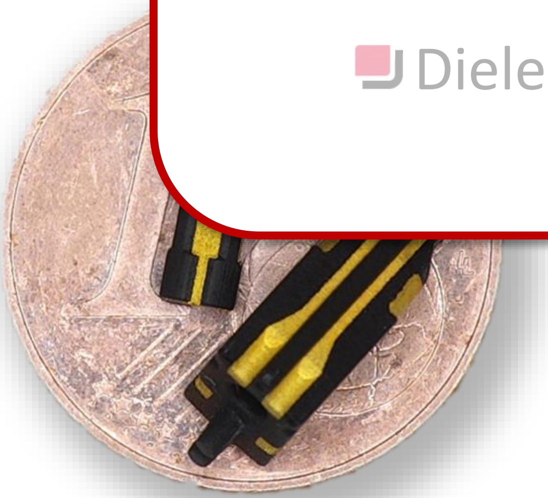
[Adv. Mater. Technol. 2019, 1800618]

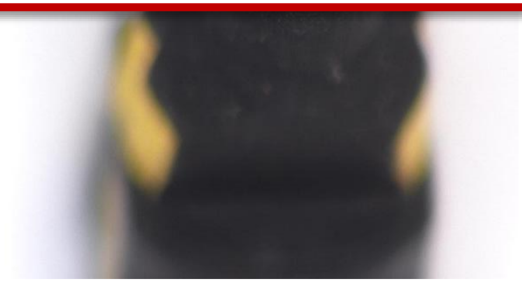
Material Properties

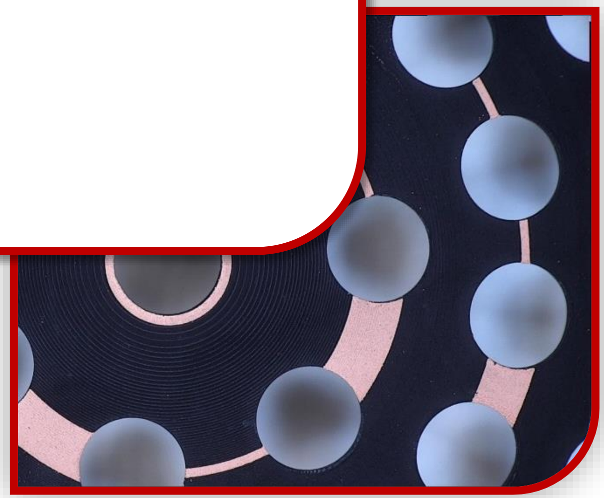


Moul

- Coefficient of Thermal Expansion
- Assembly: Thermal stability
- Dielectric properties

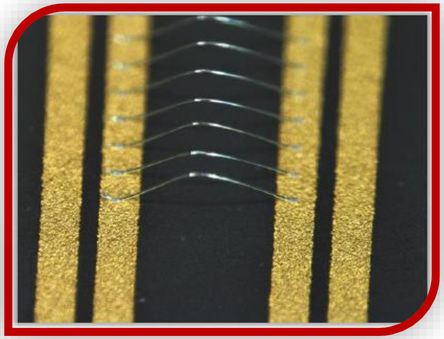




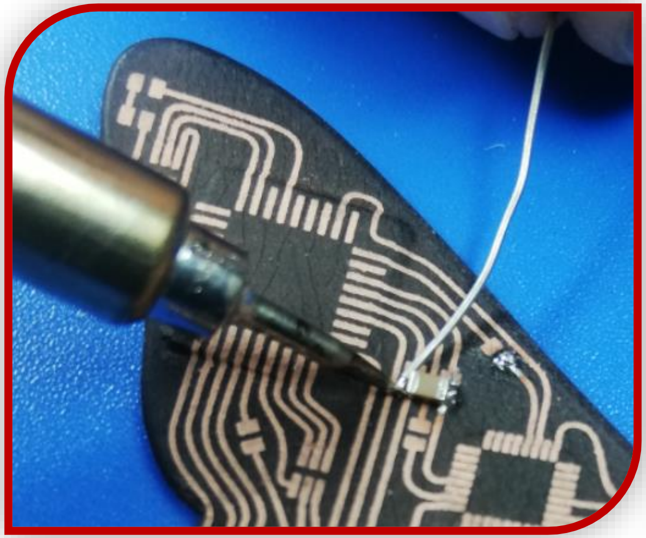


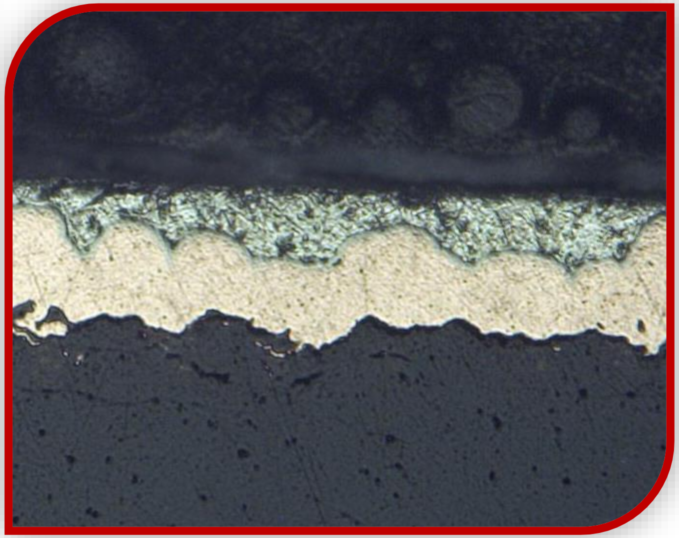
Assembly

- Hand soldering with standard solder possible
- Reflow successfully tested for small parts
- Al-wire bonding currently testing, proven by others



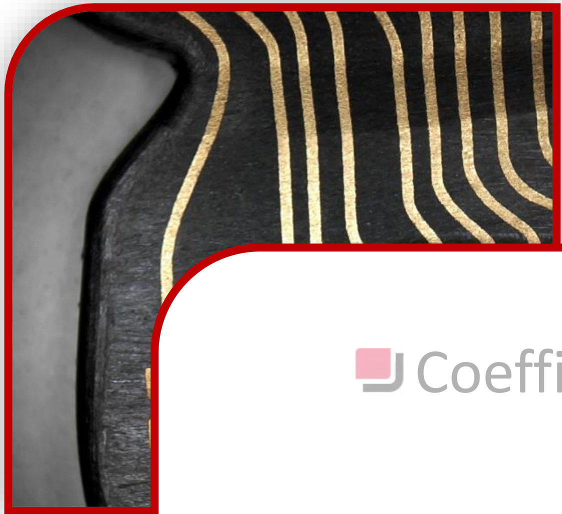
[Müller et.al.,(2018),13th International Congress MID]

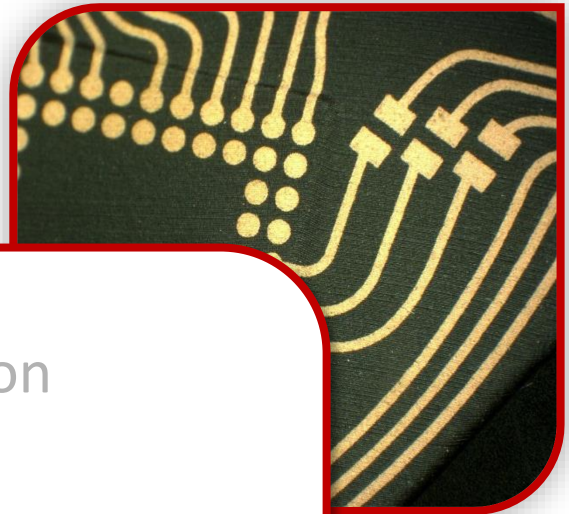




	T in °C	LCP/PEEK	SLA-HT	FDM-HT	ProtoPaint®
Wire Glue	Room	✓	✓	✓	✓
Bi58Sn42	165	✓	✓	✓	✓
Sn63Pb37	220	✓	✓	✓	✗
Sn95,5Ag3,8Cu0,7	280	✓	✓	✗	✗

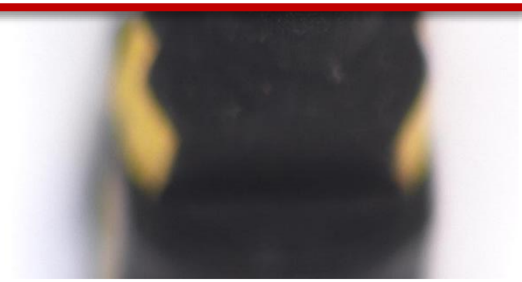
Material Properties

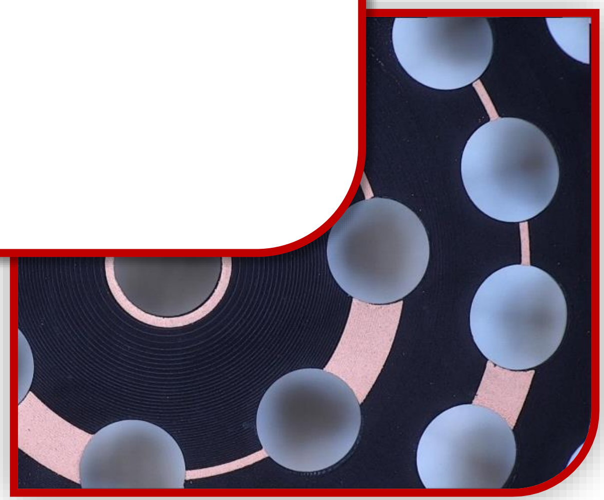




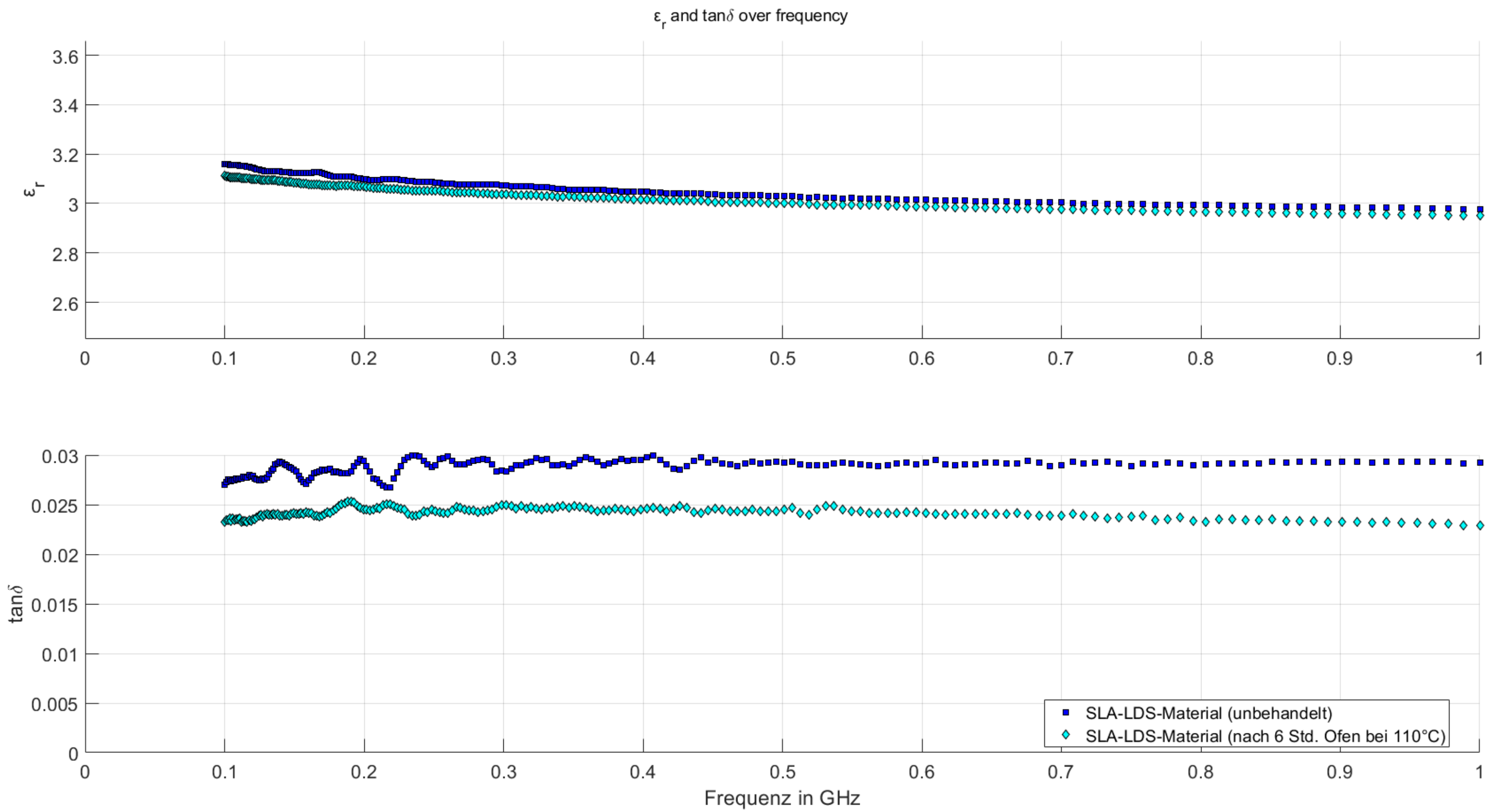
Moul

- Coefficient of Thermal Expansion
- Assembly: Thermal stability
- Dielectric properties





Dielectric Properties



FR4 (Panasonic 1755M)
D_K= 4.6
D_f= 0,014

SLA-LDS Resin
D_K= 2,9
D_f= 0,023

[Universität Hannover, blabla]

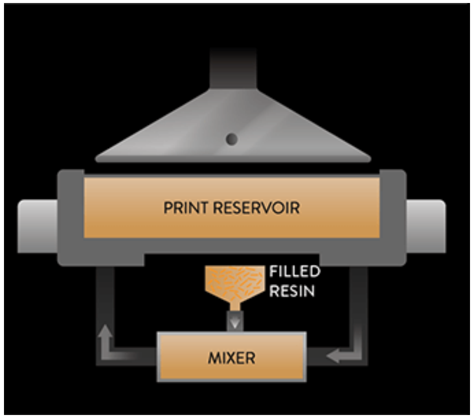
Low Loss Material: Rogers Radix

Data Sheet

Radix™ Printable Dielectric

Properties	Typical Values [1]	Direction	Units	Test Conditions		Test Method
Electrical Properties						
Dielectric Constant	2.8	Z	-	23°C @ 50% RH	10 GHz	IPC-TM-650 2.5.5.5
	2.8	Z	-	23°C @ 50% RH	24 GHz	IPC-TM-650 2.5.5.5
Dissipation Factor	0.0043	Z	-	23°C @ 50% RH	10 GHz	IPC-TM-650 2.5.5.5
	0.0046	Z	-	23°C @ 50% RH	24 GHz	IPC-TM-650 2.5.5.5
Thermal Properties						
Decomposition Temperature (Td)	313	-	°C	2hrs @ 105°C	5% Weight Loss	IPC TM-650 2.4.24.6
Coefficient of Thermal Expansion	76, 75	XY, Z	ppm/°C	-	-50°C to 50°C	IPC TM-650 2.4.41
Coefficient of Thermal Expansion	123, 120	XY, Z	ppm/°C	-	50°C to 250°C	IPC TM-650 2.4.41

[www.rogerscorp.com/advanced-electronics-solutions/radix-printable-dielectric]

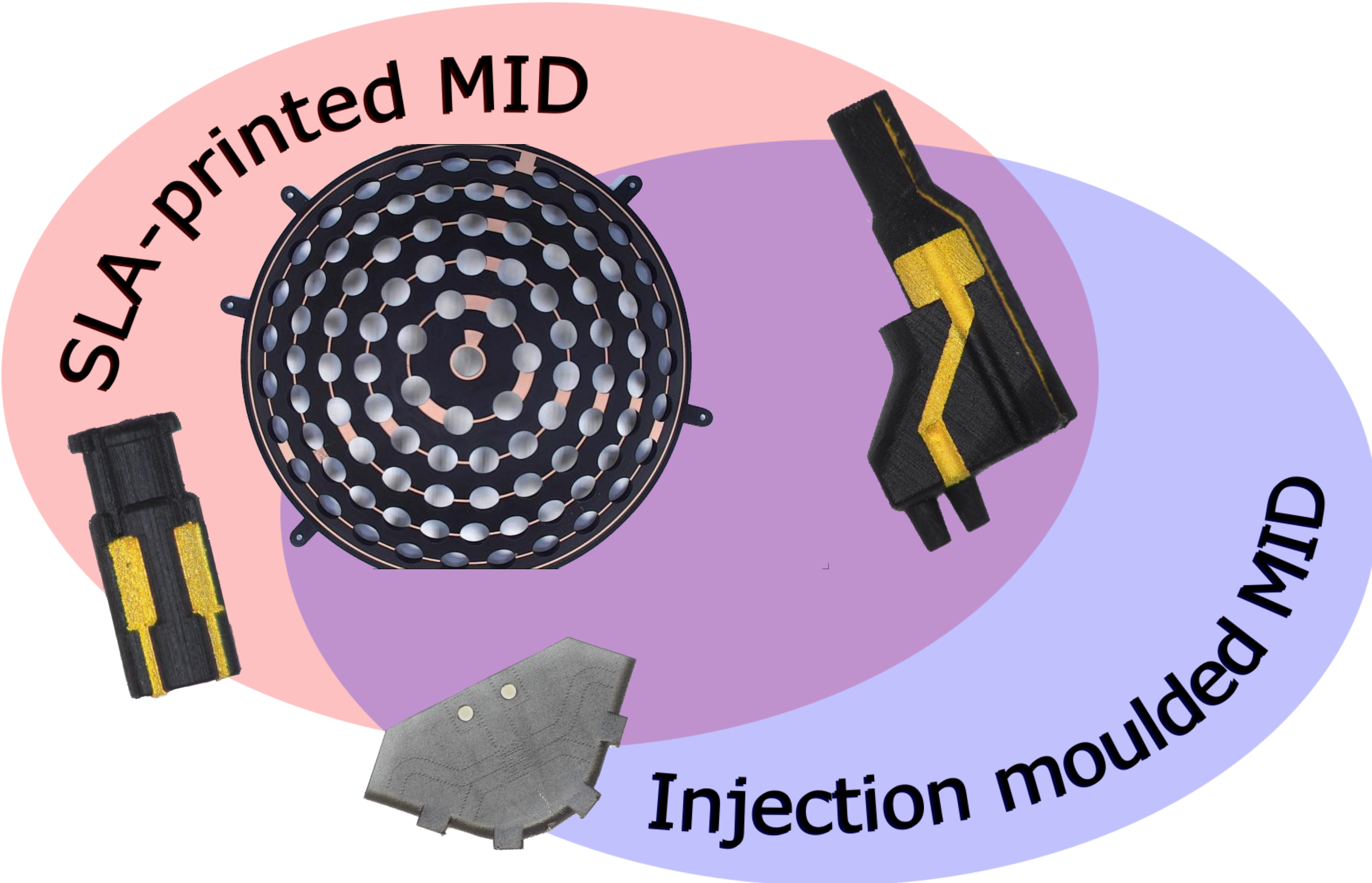


Continuous Kinetic Mixing™

- Highly filled material possible by continous mixing
- Reduction of CTE requires additional filler

Conclusion

- SLA-printing complements injeciton moulding not only in prototyping
- Fast iteration cycles through 3D-printing



- We need low-CTE UV-curing Resin!
- High filler content in SLA/DLP possible by active mixing

Wir beflügeln Leiterplatten.

CONTAG AG
Päwesiner Weg 30
13581 Berlin

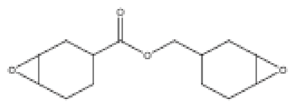
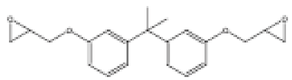
www.contag.de

Dr. Hendrik Mohrmann
Technologie

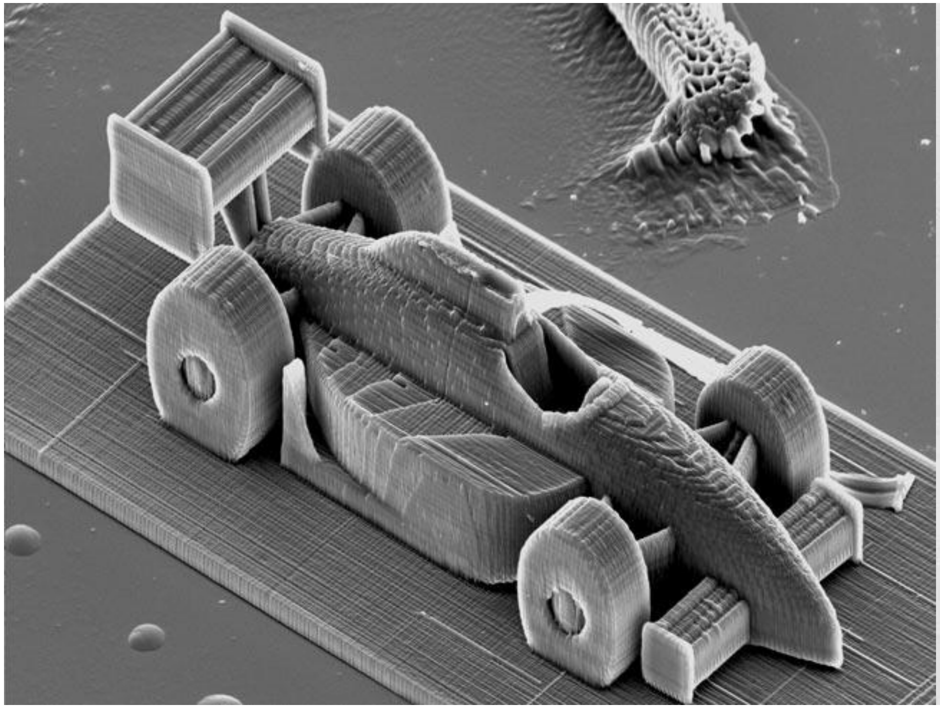
hendrik.mohrmann@contag.de
+49 30 350 788-521

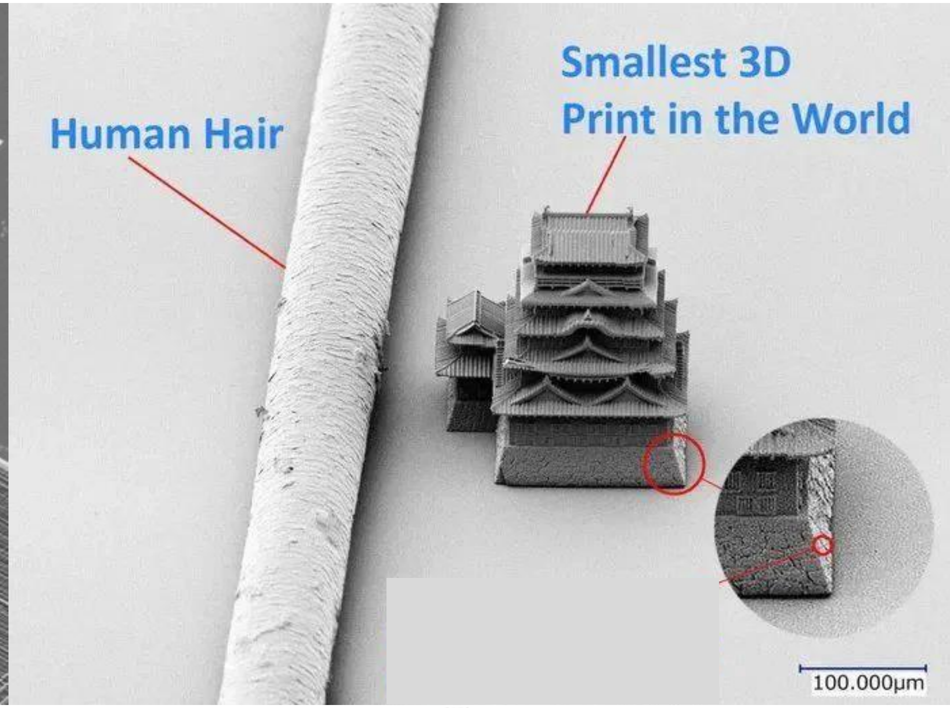
State-of-the-Art and Future Challenges of UV Curable Polymer-Based Smart Materials for Printing Technologies

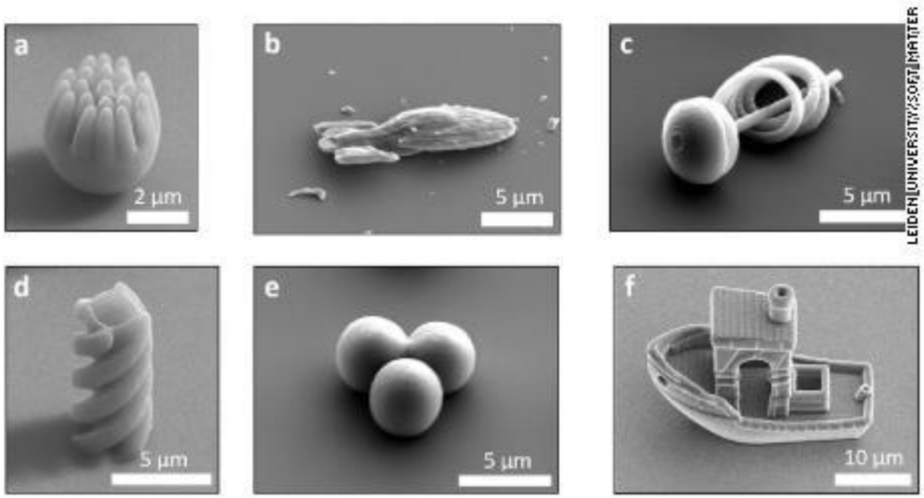
*Cristian Mendes-Felipe, Juliana Oliveira, Ikerne Etxebarria, José Luis Vilas-Vilela, and Senentxu Lanceros-Mendez**

Ionic	Epoxides	3,4-Epoxycyclohexylmethyl-3′,4′-epoxycyclohexane carboxylate		Low shrinkage and chemical and thermal resistance	Fragility and low toughness
Ionic	Epoxides	Diclycidylether derivative of bisphenol A (ADE)		Low shrinkage and chemical and thermal resistance	Fragility and low toughness

Epoxides are another type of monomers employed in cationic photopolymerization due to their high mechanical properties, relatively low shrinkage, and chemical and thermal resistance. Nevertheless, epoxy matrix suffers from fragility and low toughness. 3,4-Epoxycyclohexylmethyl-3′,4′-epoxycyclohexane carboxylate and diclycidylether derivative of bisphenol A (ADE) are some examples[49,50] shown in Table 2.




Human Hair
Smallest 3D
Print in the World
100.000µm


a
2 µm
b
5 µm
c
5 µm
d
5 µm
e
5 µm
f
10 µm
LEIDEN UNIVERSITY/SOFT MATTER

Visions to Products - MID and Beyond

Functionalized Otoplastic (MikroBO)

Böblingen | 22. September 2022

•• audifon – The only hearing aid manufacturer in Germany

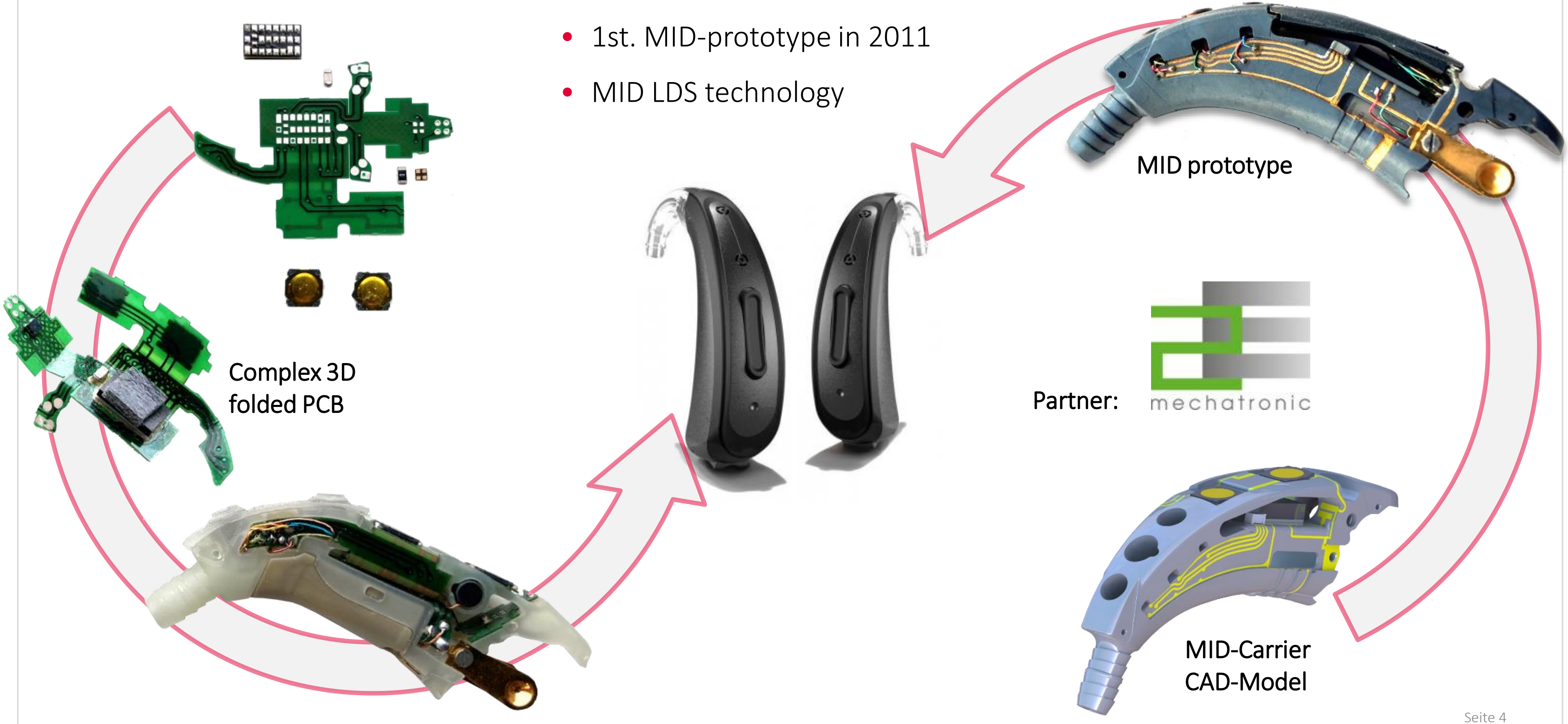
•• Family owned business with full value chain.

audifon hearing systems

KIND DAS GANZE LEBEN HÖREN

•• audifons history in 3D MID – a fully working MID Hearing Aid prototype

- 1st. MID-prototype in 2011
- MID LDS technology



•• Functionalized Otoplastic – Miniaturizing the system to fit into the ear canal

Microelectronic for continuous, non-invasive blood pressure measurement in the ear canal

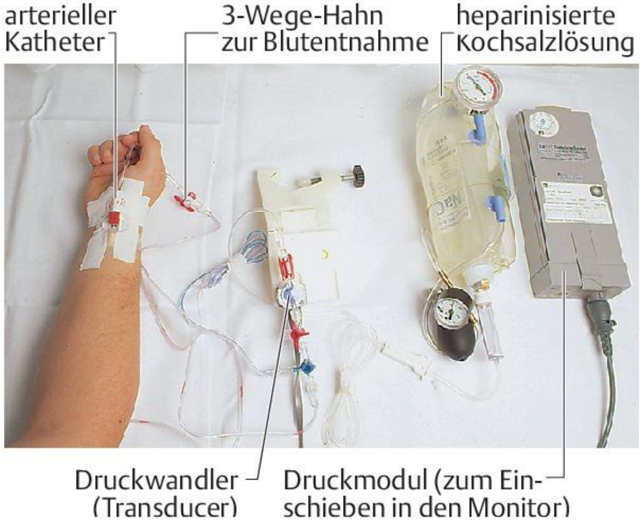
2018 - 2021

Bundesministerium für Bildung und Forschung

VDI | VDE | IT

•• Current BPM methods are not stress-free and not suitable for long-term continuos measurements

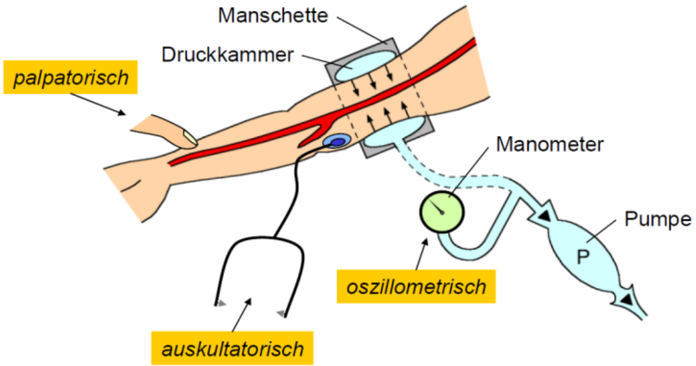
invasive



Source: http://www.medizin-kompakt.de/invasive-blutdruckmessung

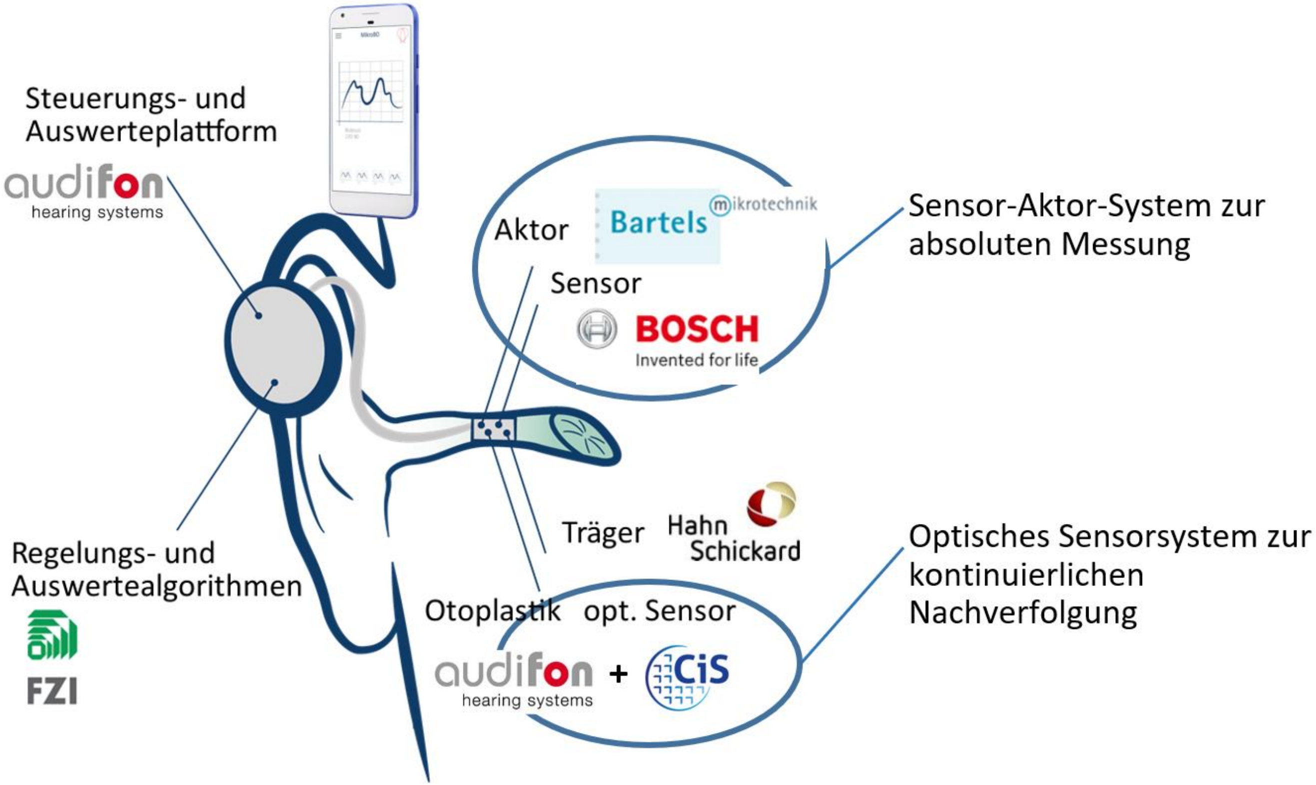
Non-invasive

Sphygmomanometry



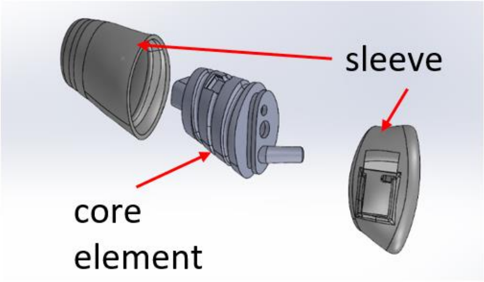
Source: Dissertation von Hans Peter Boll

•• The solution combines two methods: absolute and relative BPM



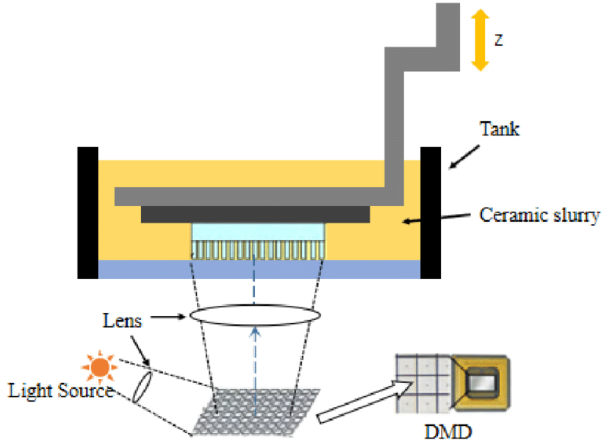
•• The in-ear unit (otoplastic) integrates all functions except data processing

- Ergonomic shape fits ~80% off all ears
- Sensor-Actor-System:
  - Pressure sensor
  - Interfaces for a micro pump
  - Inflatable sleeve / balloon like function
  - Air canals
- Optical system: PPG sensor
- In-ear unit too small for PCB or cable wiring
- **Goal: Ink printed conducting paths**

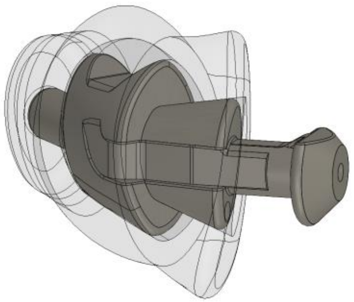


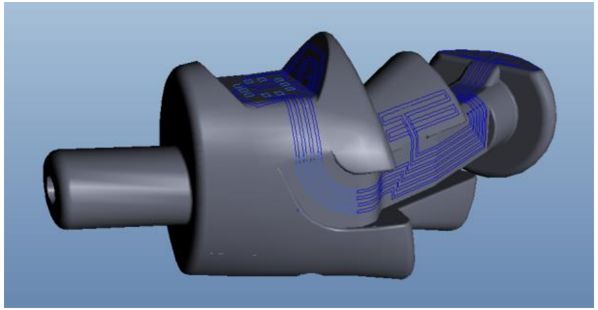
Design on experiments

- Use of hearing industry standards
  - DLP process / machine
  - Proven biocomp. DLP materials used for ear moulds
- Surface to be designed for Aerosol / Ink Jet process
- audifon: mechanical design work, DLP prototypes
- Hahn Schickard: ink selection, Aerosol Jet printing, soldering



Source: https://www.researchgate.net/figure/The-working-principles-of-DLP_fig1_337573876

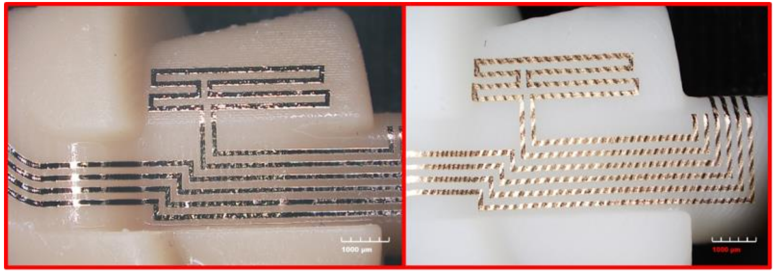




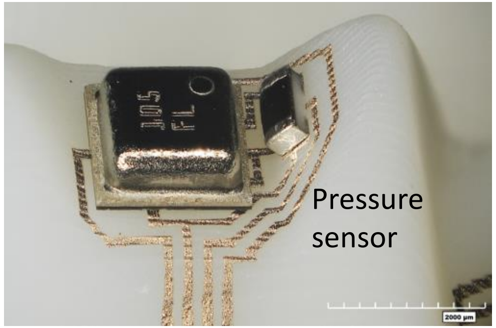
Inlay with ramps suitable for Aersosol Jetting

Successful in-ear demonstrator

- Experiments: different materials, inks, solder pastes, process parameters
- MID application at Hahn Schickard with an electronic circuit and components
- Automated 3D mounting
- Successful test of functional prototype of an MID Otoplastic with pressure sensor



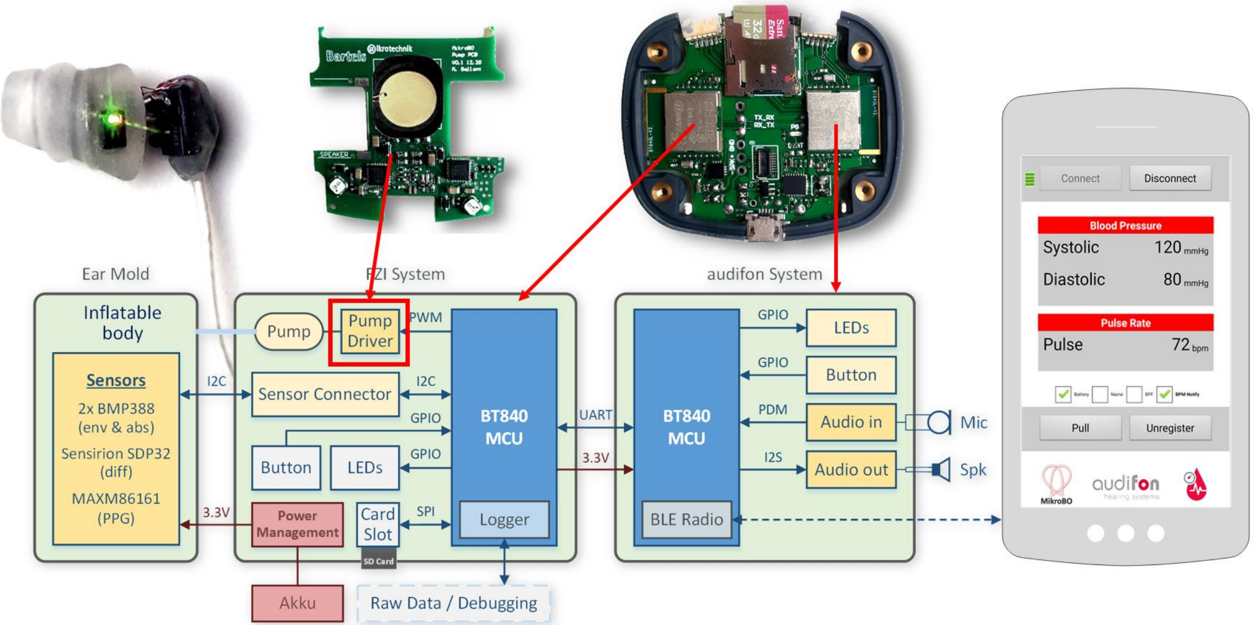
Dreve Fototec DLP A | PLASTCure Rigid 10500



Photos: Hahn Schickard

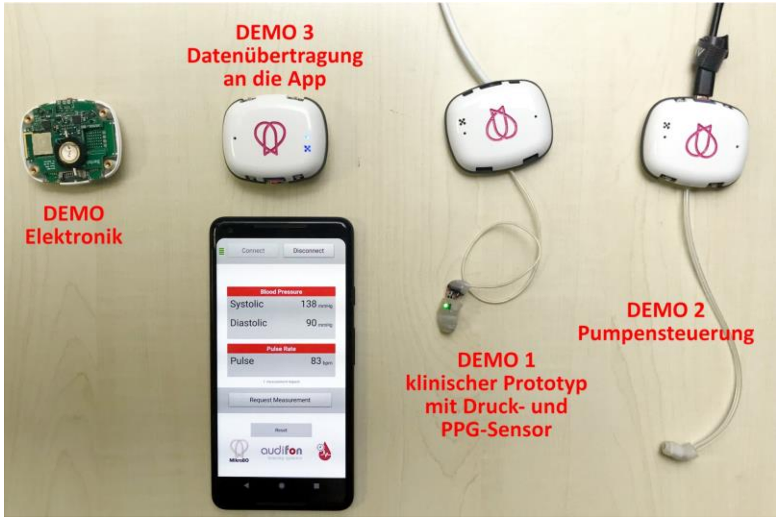
•• Integration into the MikroBo system

- Data logging & processing unit
- Actor (micro pump) driver & control unit
- Bluetooth communication
- Audio processing
- Android App



•• Clinical study – comparative invasive measurements

- Positive ethics vote (according to §15 of the professional code of the Medical Association)
- Simultaneous measurement via the cardiac catheter located in the aorta with 39 patients (2019 and 2021)



Thank you for your attention!

Contact:

hartmut.richter@audifon.com

michael.brandl@audifon.com

PAD PRINTING ELECTRONICS

ENABLING THE FUTURE OF 3D CONNECTED SURFACES

AAD VAN DER SPUIJ, BÖBLINGEN, SEPTEMBER 2022

Henkel

INTRODUCTION

AAD VAN DER SPUIJ

BUSINESS DEVELOPMENT MANAGER EIMEA
Printed Electronics

+31-6 534 85 779

aad.vanderspuij@henkel.com

in

HENKEL ADHESIVES TECHNOLOGIES | PRINTED ELECTRONICS | NEW BUSINESS ACCELERATOR

HENKEL – WHO ARE WE?

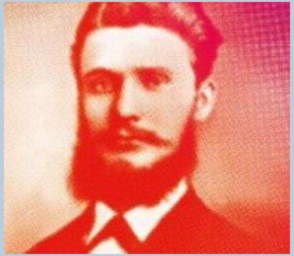
THREE BUSINESS UNITS

ADHESIVE TECHNOLOGIES
BEAUTY CARE
LAUNDRY & HOME CARE

WE ARE ACTIVE IN
78
COUNTRIES

WE EMPLOY MORE THAN
52,000
PEOPLE WORLDWIDE FROM
120 NATIONALITIES

SALES
€20.1 BN



MORE THAN
143 YEARS SUCCESS
WITH BRANDS AND
TECHNOLOGIES

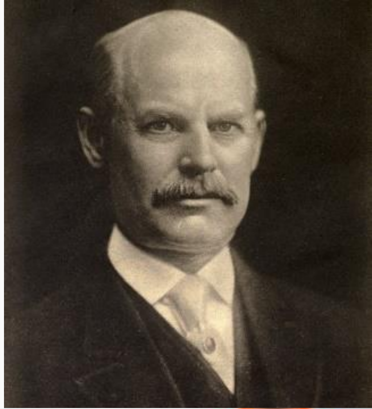
LEADING IN
SUSTAINABILITY
+56%
RESOURCE EFFICIENCY

AROUND
2,000
SOCIAL PROJECTS
SUPPORTED

AROUND
36%
WOMEN IN
MANAGEMENT

INTRODUCTION TO PRINTED ELECTRONICS

A Bit of History



- Edward Goodrich Acheson was the inventor of synthetic graphite which is a lubricant, release agent & conductive material
- Graphite based products were used for metal forming, lubrication and conductivity
- Acheson Colloids developed to a small multinational, became part of ICI in **1998**
- In **2008** Acheson Colloids became part of Henkel, through National Starch Adhesives business
- Printed Electronics product range from Henkel originate from Acheson Colloids

INTRODUCTION TO PRINTED ELECTRONICS

Henkel Loctite Printed Electronics Product Range

STANDARD INK PORTFOLIO

CONDUCTIVE INKS

Conductive inks filled with silver or carbon for circuit, switch, and antenna printing

RESISTIVE INKS

Based on blends of silver, carbon and non-conductive pigments to adjust resistance levels for printed resistors, potentiometers, and heating elements

DIELECTRIC INKS

For printing dielectric layers, conformal coatings, and encapsulations

FUNCTIONAL INK PORTFOLIO

ELECTRODE INKS

Based on silver/silver chloride for biosensors, ECG electrodes, and transdermal drug delivery

PTC INKS

Based on carbon for self-regulating heating elements

EMI SHIELDING PAINTS

Processed by spray-coating or brushing

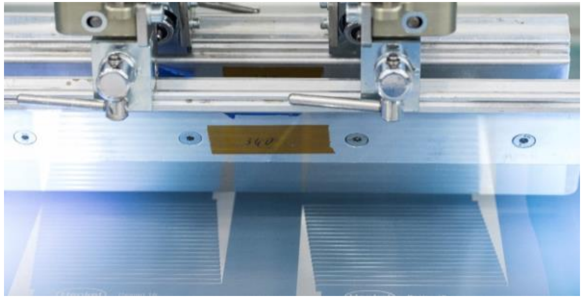
INTRODUCTION TO PRINTED ELECTRONICS

From Material to Full Solution

Materials → **Processes** → **Device / Sensor**

Functional Inks

- Silver filled inks
- Carbon filled inks
- Dielectric inks
- …



Printing

Application of ink on flexible substrate using:

- Screen printing (> 95%)
- **Other printing techniques (< 5%)**

Flexible Electronic Device

- Touch foil interfaces
- Smart surfaces (heating and antenna
- Electrodes and (bio) Sensors
- …

COMBINED TRENDS
CONNECTIVITY & 3D ELECTRONICS

Connectivity

- Increasing demand for new electronic solutions
- enabling IoT, smart living and mobility.

- **Internet of Everything (IoE)** is creating a network that connects people, things, processes and data

3D-Electronics

- Miniaturization & Integration
- Customization & Increased functionality
- Large range of processes

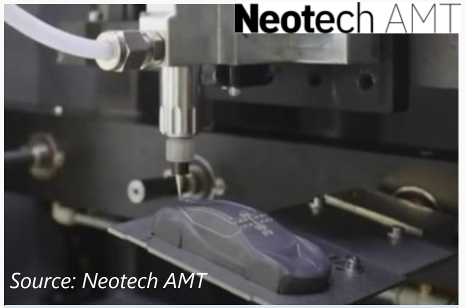
Source: Techblick

3D PRINTED ELECTRONICS

Some application technologies

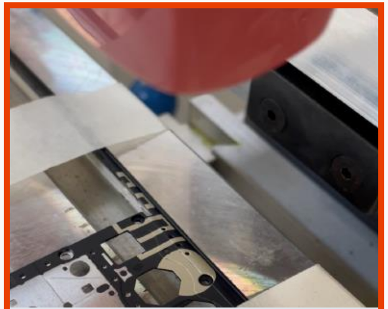
THERMOFORMED FOILS

- Conductive circuit screen printed in 2D foils,thermoformed and over- or back molded



VALVE JET DISPENSING

- Conductive circuit dispensed directy onto a 3D shaped surface



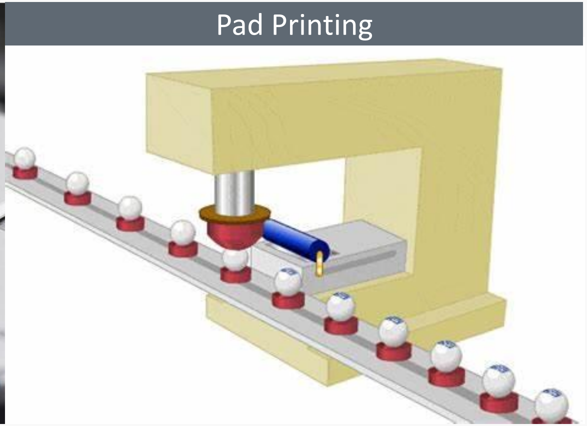
PAD PRINTING

- Conductive circuit transferred by silicone pads, directy onto a 3D shaped surface

PAD PRINTING PROCESS INTRODUCTION

History of Pad Printing

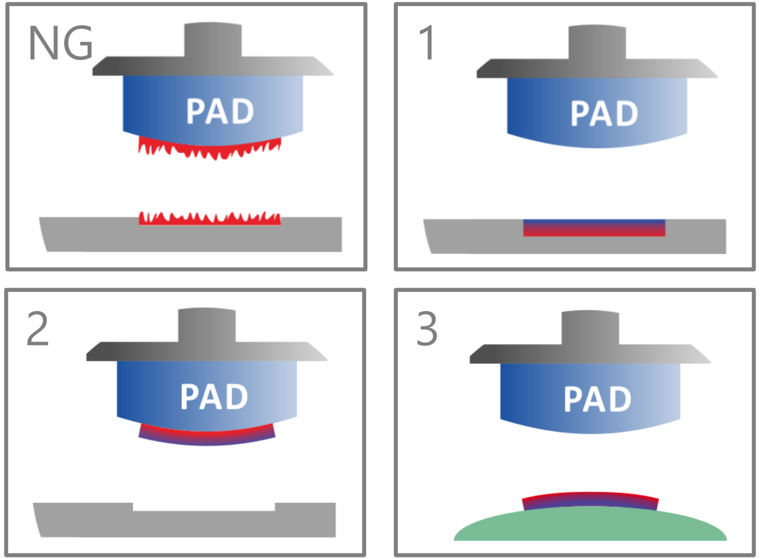
- Pad printing is the process of printing a 2D image into a 3D object. Its roots can be traced back more than 200 years. Originally, pad printing was done by hand.
- The Swiss watchmakers were the first to industrialize the pad printer to print watch dials following World War II (*source: https://screenprintsupply.com/*)
- Today Pad Printing is widely used for decorative designs

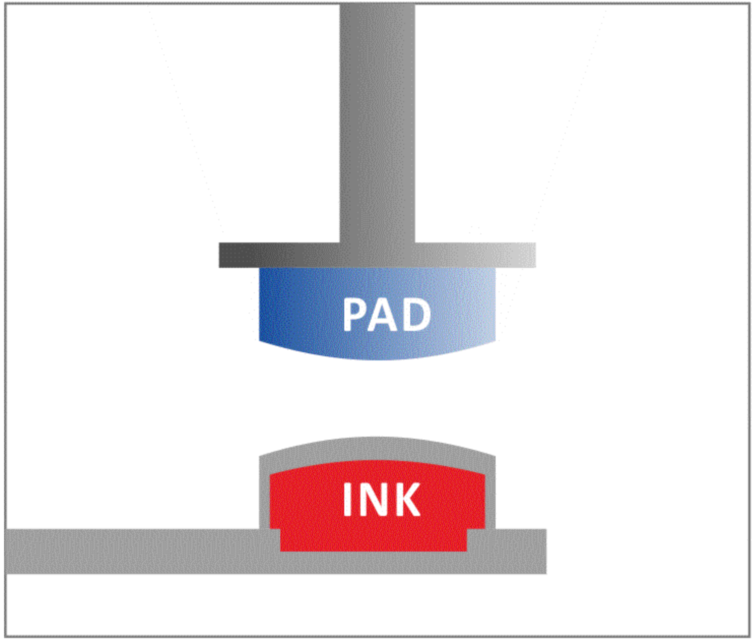


PAD-PRINTING OF HENKEL SILVER INKS

Key benefits of pad printing

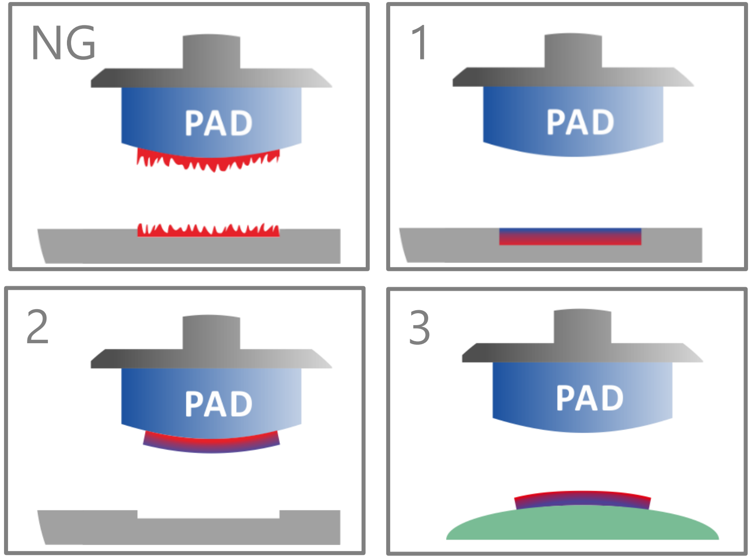
- Accuracy of dimension & thickness
- Multi-layer printable, adjustable thickness
- Fast processing
- Potential alternative to laser direct structuring (LDS)

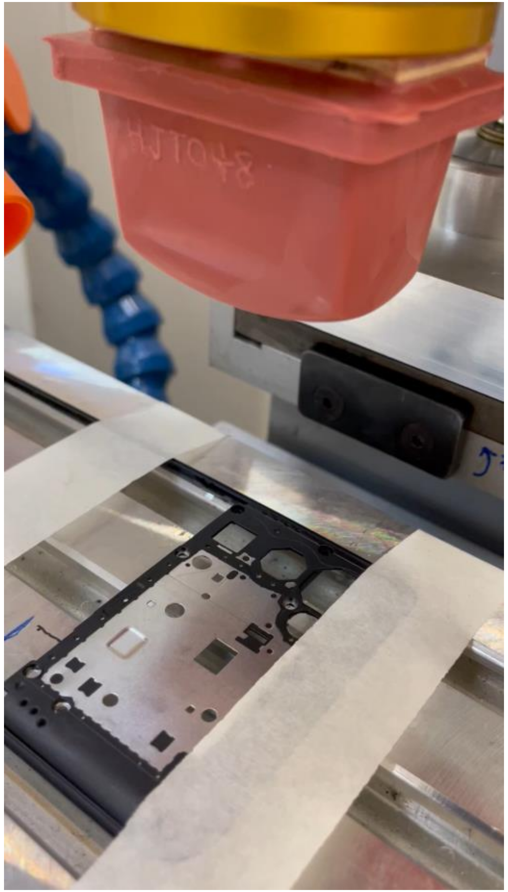




PAD-PRINTING OF HENKEL SILVER INKS

Process in motion

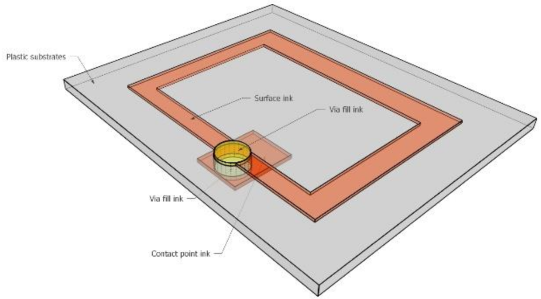


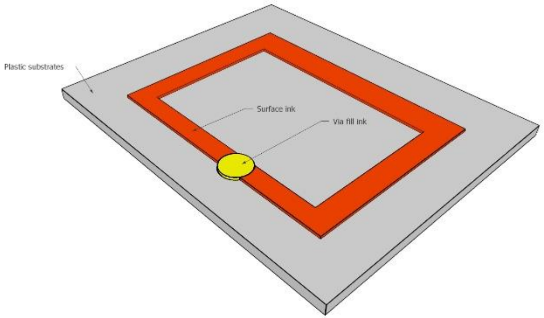


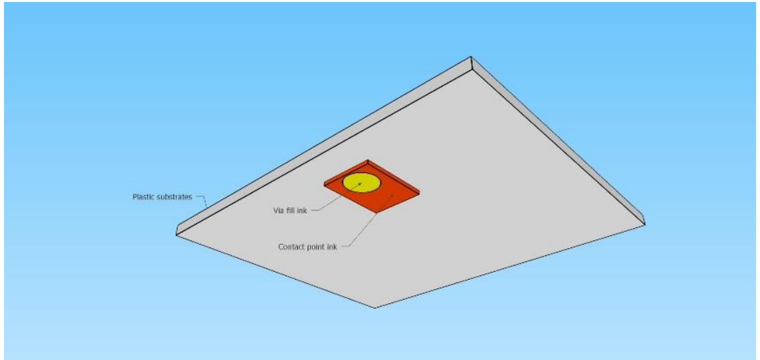
Henkel

THE STRUCTURE OF PRINTED ANTENNA

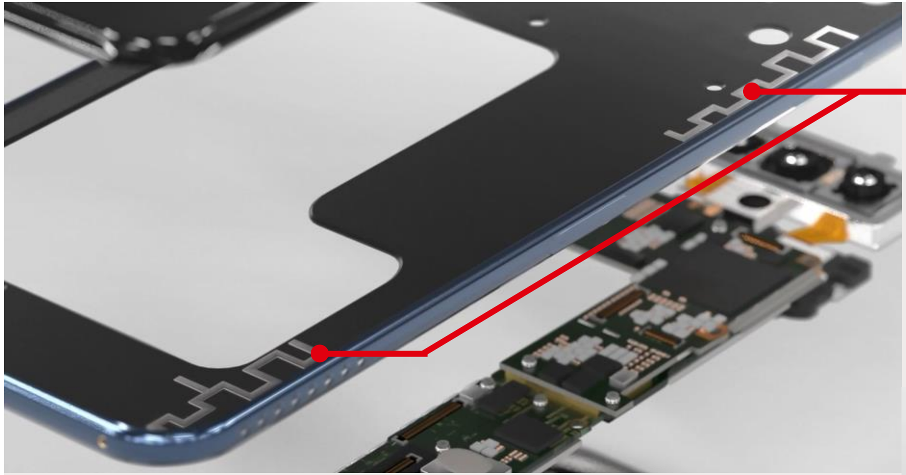
The concept; conductivity at surface, via fill and contacting







- Surface ink worked as antenna
- Via fill ink bring the signal inside
- Contact point ink connects with the on- board electronics of the smartphone



SURFACE INK, LOCTITE ECI 1203

- Very good conductivity, < 10 mOhm/sq/25µm
- Major functional circuit

CONTACT INK, LOCTITE ECI 1204

- Contact the internal pin or bump to form the interconnect circuit
- Very robust, with good abrasion resistance

HENKEL INKS & PRINTING PROCESS KEY BENEFITS

LOCTITE Conductive Ink

Electrical performance*

- Good conductivity: 10 mΩ/sq/25µm.
- Low temperature curing: 80°C
- Inks have curing agent which allow for cross-linking

Waste reduction

- Suited for additive manufacturing
- Removes the need for copper plating

Adhesive performance

- Withstand more than 2000 RCA abrasion tests
- Solvent free -> compatible for via fill
- Excellent fluidity for dispensing

Pad Printing

Versatile

- Fine line printing, down to 150 microns
- Excellent for curved surfaces and 3D shapes
- Compatible with wide range of substrates

Industrial production

- Consistent results for large print volumes
- Quick drying process
- Pads can be tailored to each application

*Values may change for each of the inks

THINK TOGETHER!

#innovate

- HENKEL DEVELOPED **PAD-PRINTING INK** SOLUTION FOR SMARTPHONE ANTENNAS AS AN **ALTERNATIVE TO LDS** AND FPC TYPES OF ANTENNAS.
- **LARGE PRODUCT PORTFOLIO** TO SUPPORT ANTENNA AND 3D ELECTRONICS APPLICATIONS

Connect with Us & Get Your Tailored Product Recommendation!

aad.vanderspuij@henkel.com
Business Development Manager EIMEA

QUESTIONS ?