FED
Fachverband für Design,
Leiterplatten- & Elektronikfertigung

FED Arbeitskreis
3D
Elektronik

SEMIKRON
innovation + service

Disruptiver Ansatz additiv hergestellter Schaltungsträger

(Additive Herstellungsprozesse; Beispiel Inkjet)

FED & VDE/VDI SAET, 2021-12-08
M. Schleicher SEMIKRON Elektronik GmbH & Co. KG

Agenda

1. Introduction
2. Market overview
3. Soldermask
4. Functional fluid (Ag)
5. AME (PCB) & AM
6. Design & Data format

SEMIKRON innovation+service

Brief introduction

Fachverband für Design,
Leiterplatten- & Elektronikfertigung

Michael Schleicher R&D IPM & Systems PCB Design Semikron Elektronik GmbH & Co KG DKE K 682, IEC TC91, IPC	SEMIKRON Elektronik GmbH & Co KG One of the worldwide leading Power Modul manufacturer. Founded: 1951 Employee: ~ 3.000 Turnaround: ~ 540 Mio (2021)	FED e.V. & Arbeitskreis 3D-Elektronik German PCB Designers Council; education and qualification along the value chain of electronics located: Germany founded: 1992 members: ~ 700

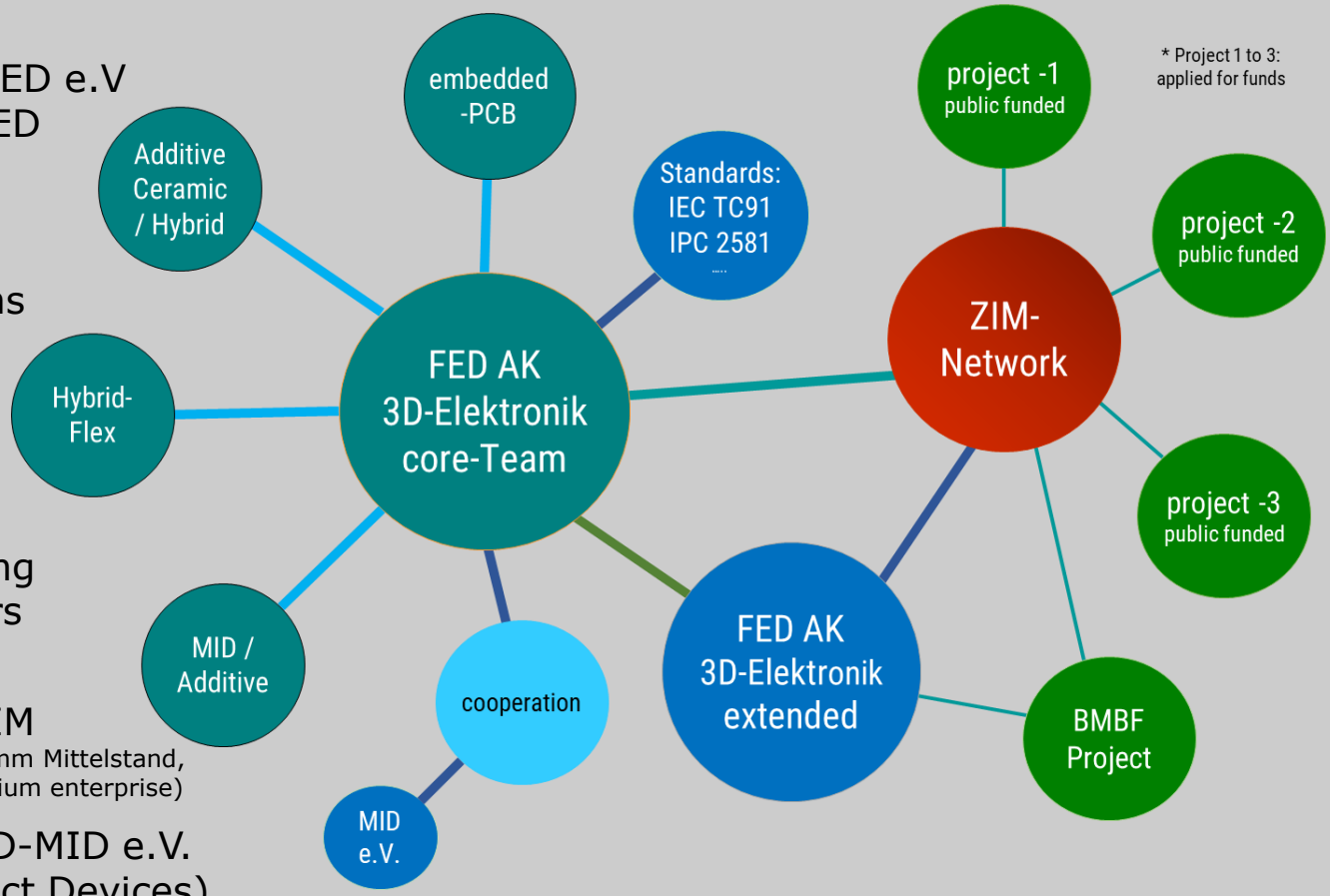
Brief introduction
FED Arbeitskreis 3D-Elektronik, Organization & structure

1. Core- & Extended Team

- FED e.V. Member
- Strong relation to FED e.V (few members of FED advisory board)
- Privat companies
- Research institutions

2. Networking

- Industrial networking within FED-Members
- Gouvernement funded Network: ZIM
  (Zentrales Innovationsprogramm Mittelstand, public funded for small & medium enterprise)
- Cooperation with 3D-MID e.V. (Molded Interconnect Devices)

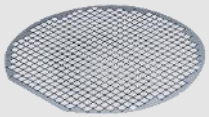


Source: FED Arbeitskreis 3D-Elektronik

Brief introduction
Semikron, Product Range

DISCRETES
1 A ... 6000 A
50 V ... 3600 V



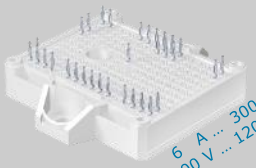


Diodes/Thyristors/Chips

POWER MODULES

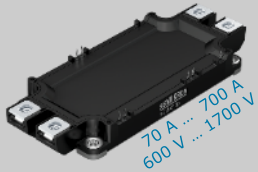
2 A ... 600 A
600 V ... 1700 V

MiniSKiiP®



6 A ... 300 A
100 V ... 1200 V

SEMITOP®

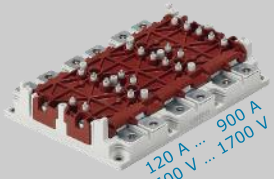


70 A ... 700 A
600 V ... 1700 V

SEMiX®

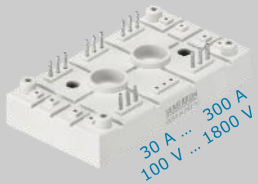
10 A ... 2000 A
50 V ... 1700 V

SEMITRANS®



120 A ... 900 A
600 V ... 1700 V

SKiM®



30 A ... 300 A
100 V ... 1800 V

SEMIPONT®

20 A ... 2000 A
50 V ... 2400 V

SEMIPACK®

560 A ... 3800 A
1400 V ... 1800 V

SEMiSTART®

IPMs

500 A ... 3000 A
1200 V ... 1700 V

SKiiP®

STACKS
1 A ... 6000 A
50 V ... 3600 V

1800 A ... 3600 A
1200 V ... 1700 V

Water-cooled IGBT
SEMISTACK® RE

Air-cooled IGBT
SEMIKUBE®

Diode/ Thyristor
SEMISTACK® CLASSIC

Customised
Applications

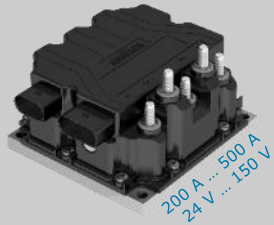
IGBT DRIVERS

SKYPER®/SKHI

SYSTEMS

120 A ... 300 A
100 V ... 1200 V

SKAI® 2 HV



200 A ... 500 A
24 V ... 150 V

SKAI® 3 LV

Source: SEMIKRON Elektronik GmbH & Co. KG

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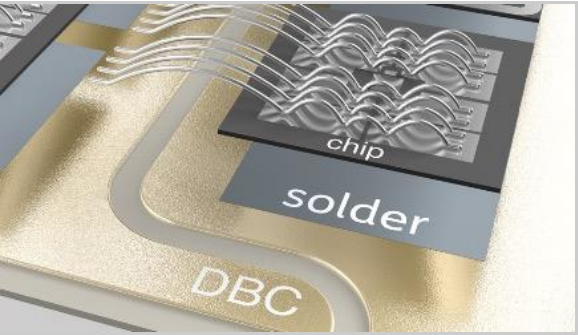
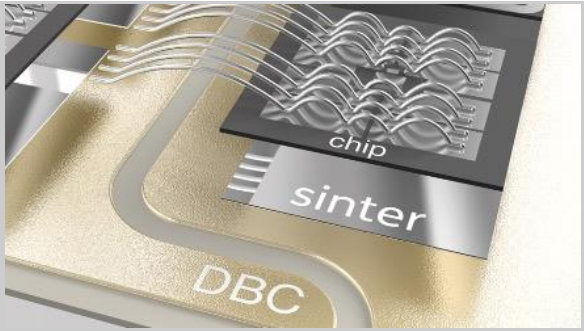
Brief introduction
Semikron, Basic Module Technologies



Solder

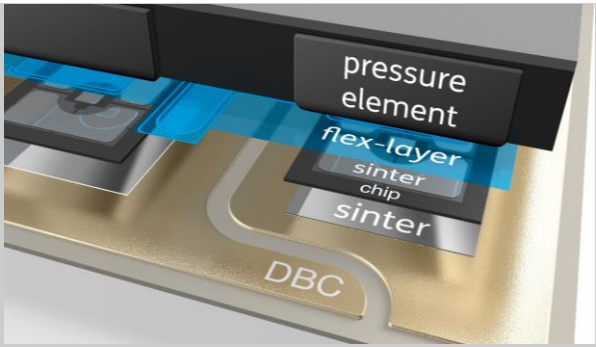


Single Sided Sintering

Die Attach

Bonding: Al, AlCu, Cu

Double Sided Sintering



Direct Pressed Die

Die Connection

Source: SEMIKRON Elektronik GmbH & Co. KG

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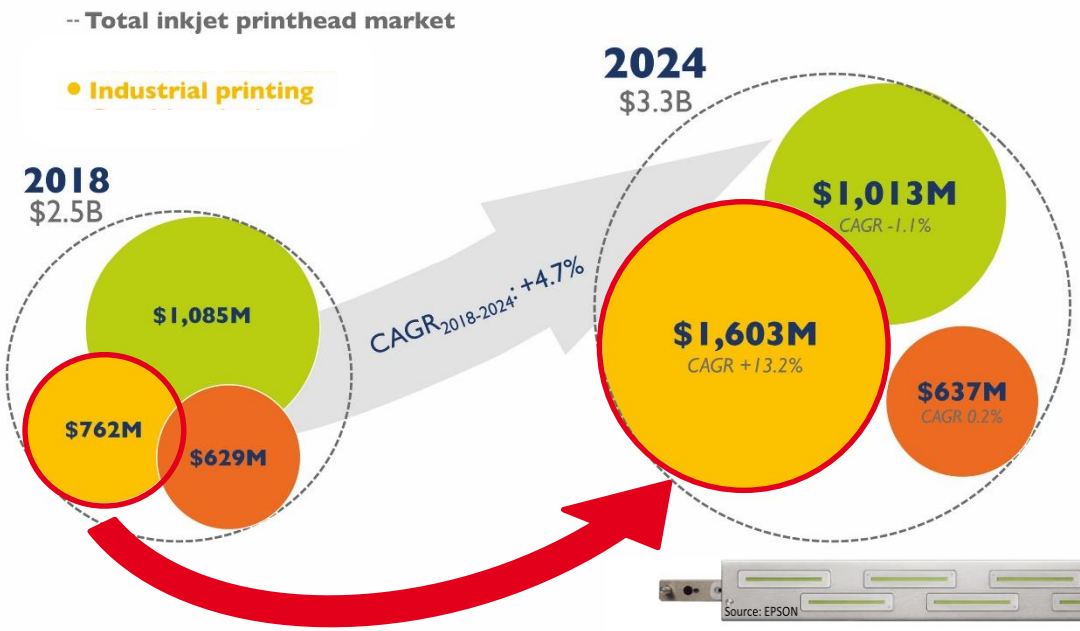
Additive manufacturing
Inkjet Technologies market dynamics

Inkjet printhead main market dynamics: 2018 - 2024 forecast

(Source: Inkjet Printheads: Dispensing Technologies & Market Landscape 2019, Yole Développement, 2019)



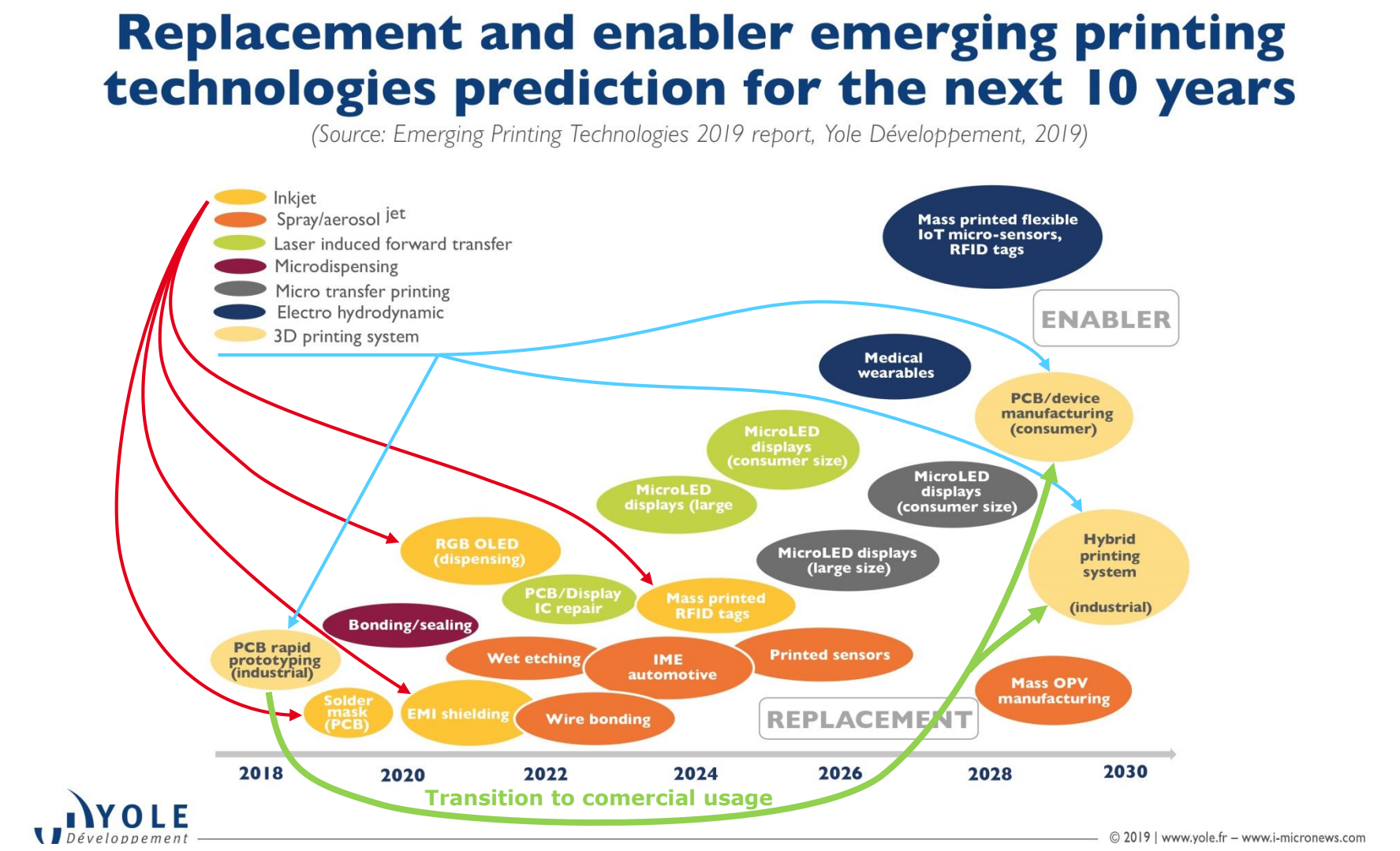
Inkjet-printhead arrays for huge areas

SurePress L-6034 11-chip 33 cm linehead

in 6 years 210 %

Source: YOLE Developpment, HP, EPSON

Additive manufacturing
Technologie predictions 2019 … 2029



Source: YOLE Developpment, M. Schleicher

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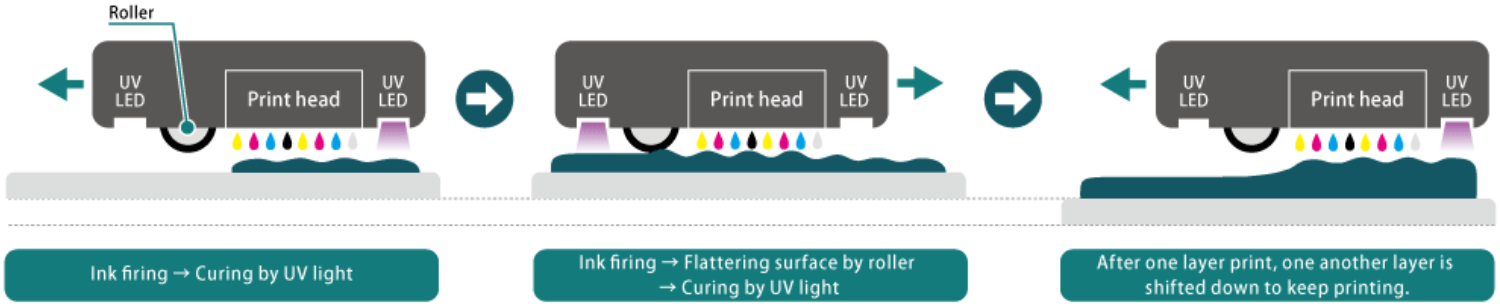
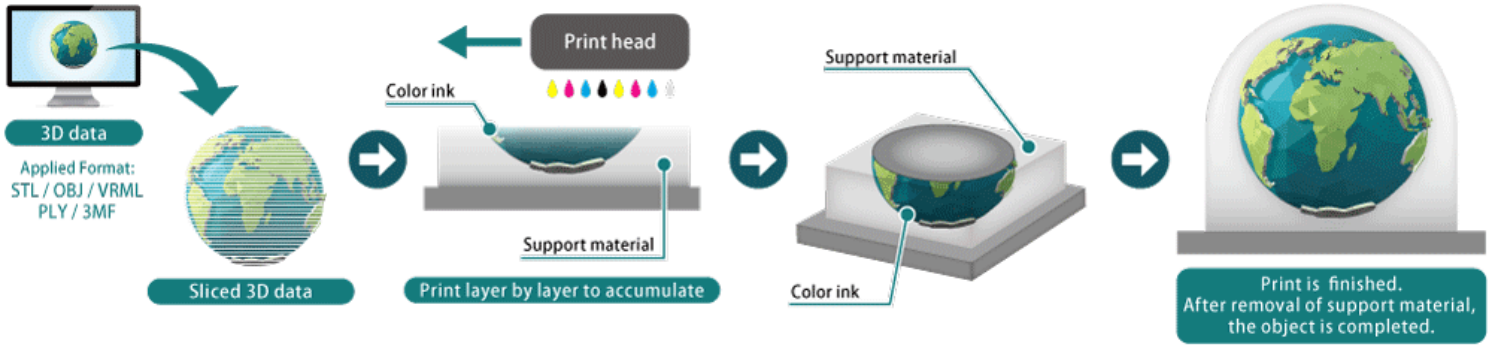
Additive Manufacturing (AM)
Principle of curable Inkjet printing (UV-curing)



Processing on flat and even surfaces (Paper, Glas, Textile)

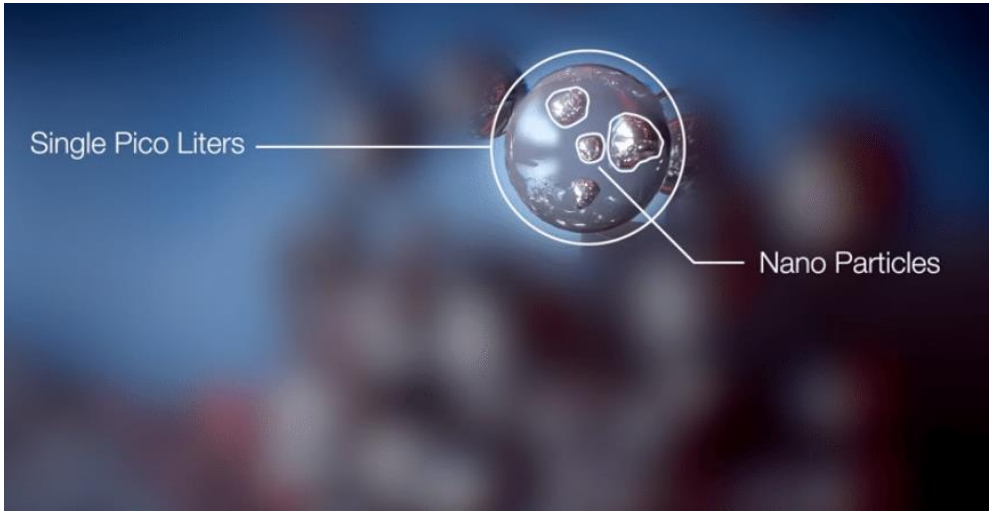


3D-Structure by using vertical movable Printheads or Workspace

Source: Mimaki Engineering CO., LTD.

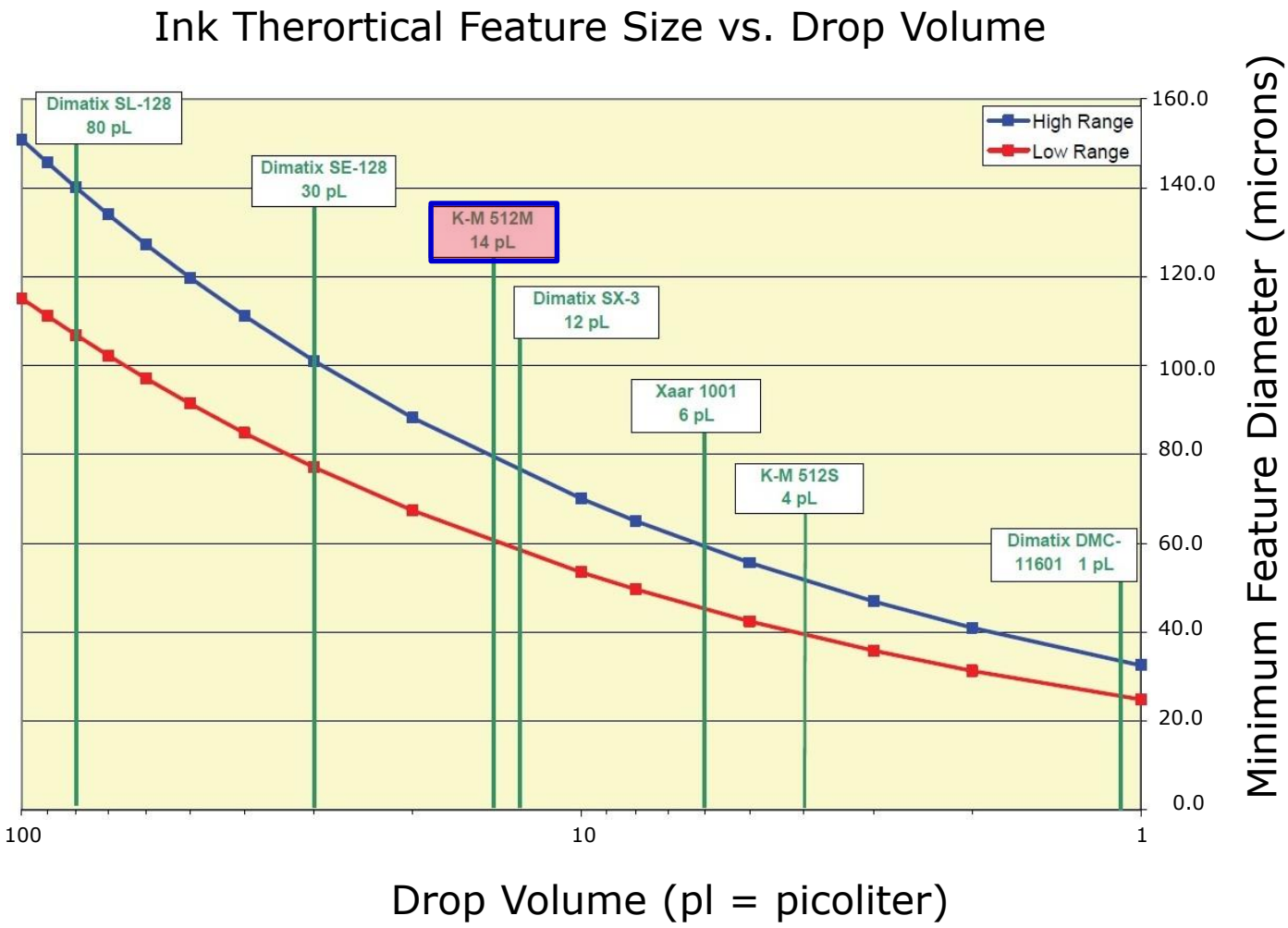
Additive Manufacturing (AM)
Correlation of „drop-size“, „nozzle pitch“ and „solution“

Drop Size: 6 pl → 2 pl
Nozzle Pitch: 45 µm → 20 µm



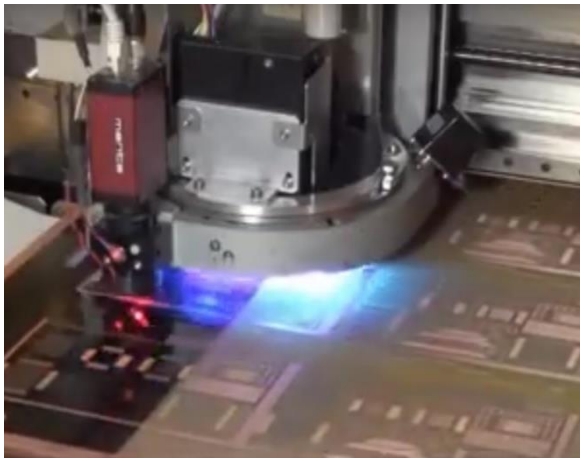
Source: VCE Solutions: Epson XJET (nano-particle ink); www.3dprintingindustry.com

Additive Manufacturing (AM)
Comparing comercial available Inkjet Printheads

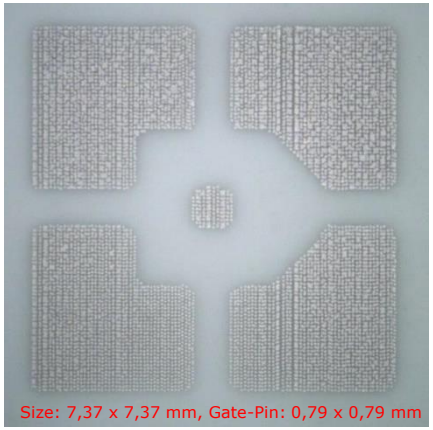


Source: B. Amos, T. Suttner Dow Electronic Materials, IPC-APEX EXPO 2019, San Diego; FujiFilm (Online)

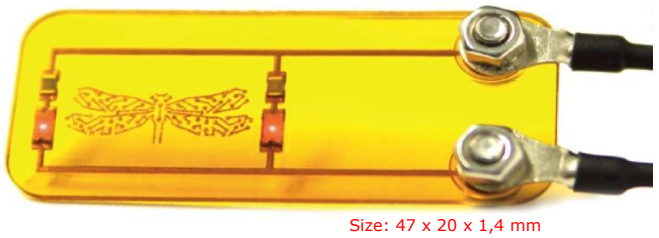
AM via Inkjet substrates and auxiliary material for electronics
Three representatives: Soldermask, Functional fluid and Substrate



Example No 1: Soldermaks



Example No 2: deposited Ag-functoinal fluid



Example No 3: PCB with embedded devices
Additivley-manufactured Circuit Boards (ACBs)

Since e few years Inkjet-Printing of soldermask is comercial available.

The printprocess, by depostition of a thin laquer film on the surface, is verry fast, up to 10 sec per PCB manufacturing panel [3].

A new approach to apply auxiliary material for the manufacturing process by using Inkjet printing method seems promising.

The process and new developed Functional fluid is in a *very early* stage.

To create a complete PCB within one printing process is one of the dreams of R&D designer and engineers.

2012 the "first generation" of machines for Additive Manufacturing for Electronics was launched by Nano Dimension.

Source: TAIYO INK MFG. Co. LTD., Semikron Elektronik GmbH & Co KG, Nano Dimension

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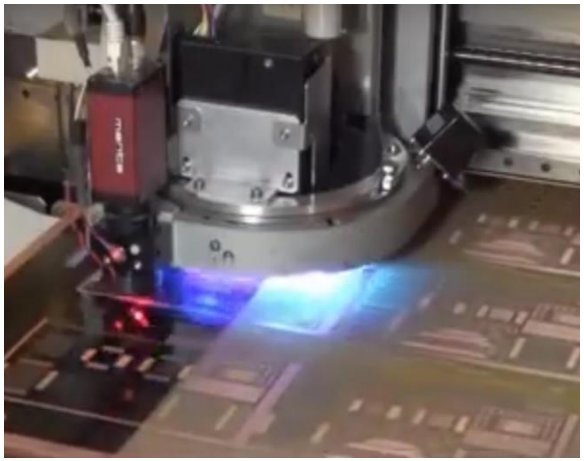
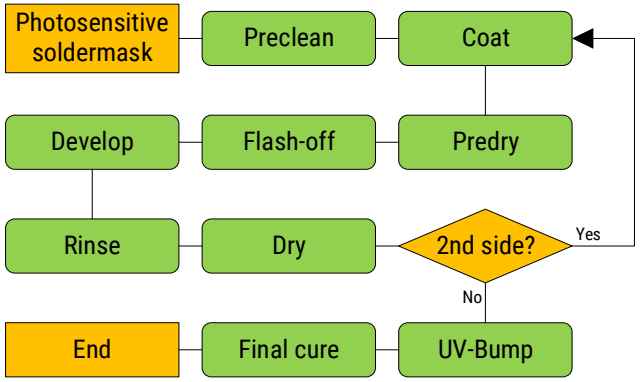
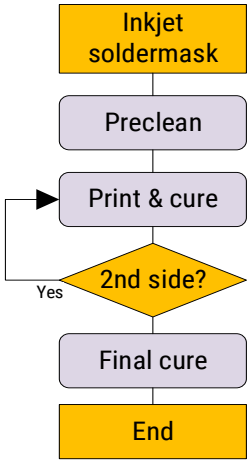
Soldermask Ink-Jet Printing
Additive process



InkJet Soldermask Application within curing



Processflow of a typical curtain coating proces.



Processflow of a Inkjet soldermask proces.

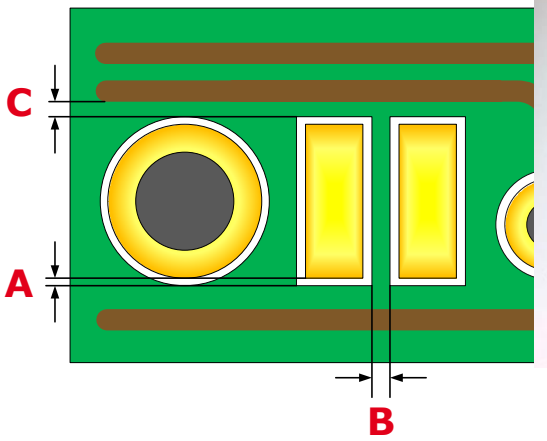
- only needed material will be applied on the PCB
- cured by using UV light
- print multiple solder mask layer

- no additional development and rinse process needed
- no additional waste will be generated
- no topics on wastewater treatment

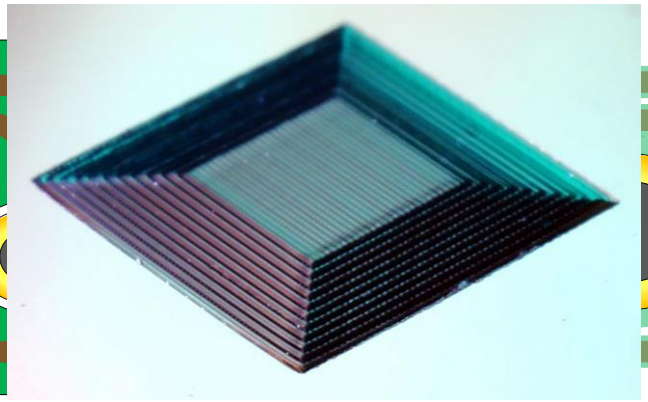
- reduced process steps
- reduced footprint in fab
- reduced residues and ionic contamination

Source: Würth Elektronik GmbH & Co KG. (FED-Conference 2019), TAIYO INK MFG. Co. LTD. Semikron Elektronik GmbH & Co KG)

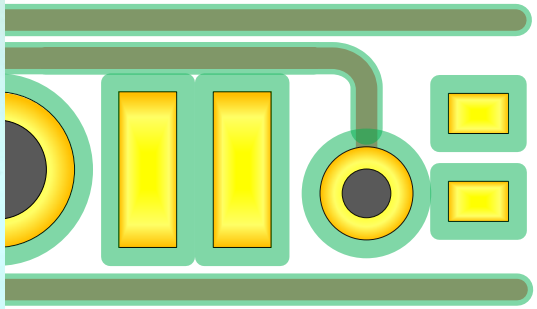
Soldermask for PCB's:
Comparing: Curtain Coating & Inkjet-processing



All unused areas were covered by soldermask



Pyramid structure, length: 4,5 mm,
Source: Electra Polymers Ltd.



Optional soldermask covers minimal unused copper areas

The values of minimum spacing "curtain" Soldermask process (typical values):

A) Arround Pins:	50 µm
B) Between 2 Pins (min line):	100 µm
C) To next copper (covered):	100 µm
D) Thickness on copper edge:	> 5 µm
E) Soldermask thickness:	5 … 100 µm

Source: Semikron Elektronik GmbH & Co KG, TAIYO INK MFG. Co. LTD.

The values of minimum spacing "Inkjet" Soldermask process (typical values):

A) Arround Pins:	down to 0 µm
B) Between 2 Pins (min line):	40 µm*
C) To next copper (covered):	up to 5 µm*
D) Thickness on copper tracs:	> 5 µm*
E) Soldermask thickness:	5 … 100 µm*

* Depending on the actual comercial available printheads

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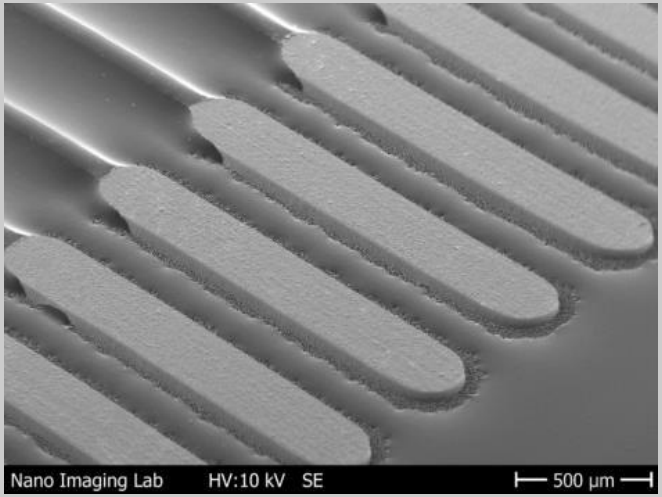
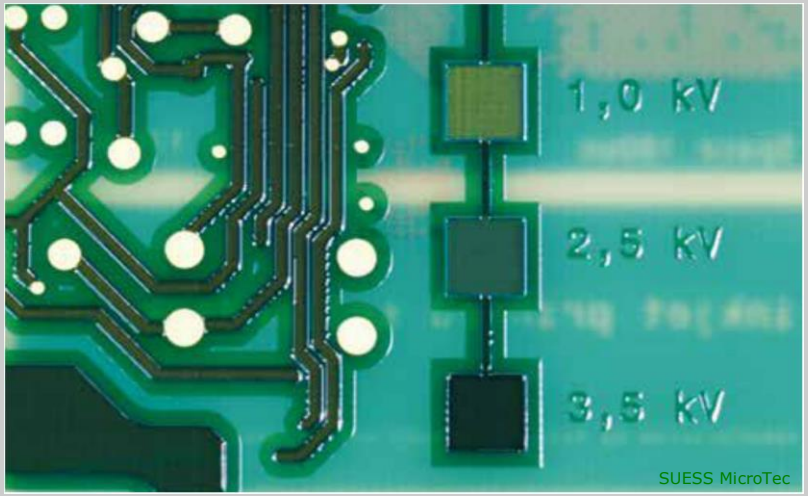
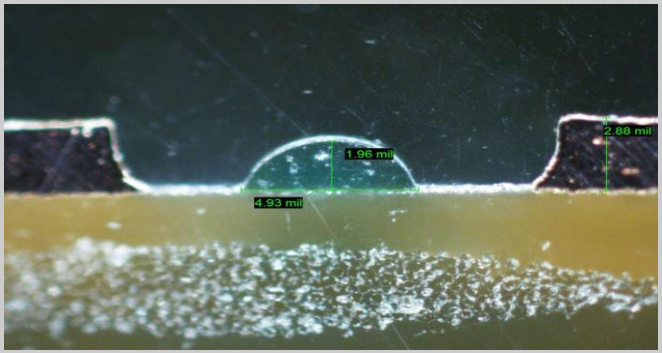
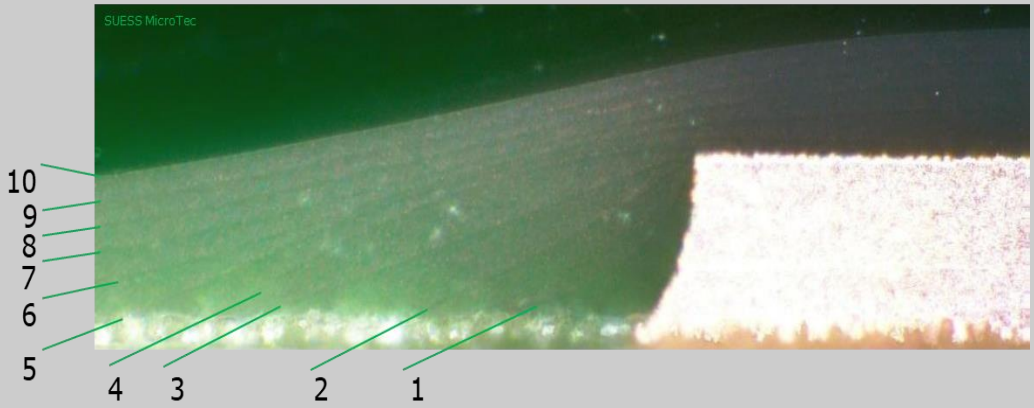
Soldermask Ink-Jet Printing Examples





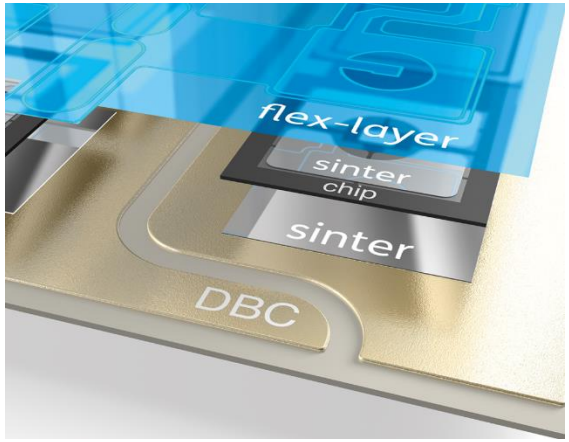


(Width: 4.93 mil = 125,2 µm, heigth1.96 mil = 49,78 µm)

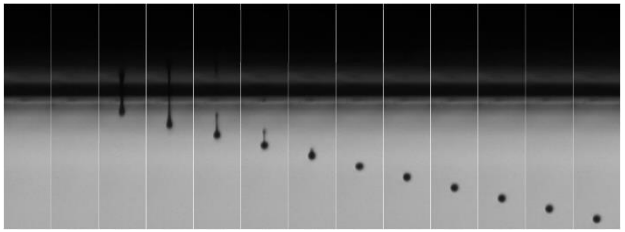


Source: Würth Elektronik GmbH & Co KG. (FED-Conference 2019), TAIYO INK MFG. Co. LTD. (EIPC-Conference 2020), Suess MicroTec (2021)

Silver Sintering
Applying the functional fluid (Ag) with an Inkjet process

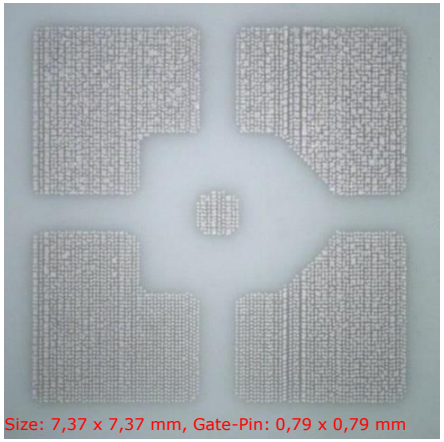


Double side sintered bare die chip



From 0µs to 120 µs

„Drop on Demand" of functional fluid (Ag)



Deposited functoinal fluid (Ag)

SEMIKRON established the Ag-sinter process in 2007

Bare dies were assembled by pressing with a defined force & temperature

Void free technology

Optimization by using "drop on demand": Inkjet (digital printing process)

Apply a precise volume of functional fluid (Ag-Ink)

Contact-free application on uneven surfaces (assembled)

Precision of the deposition depend on e.g.:

- DPI of nozzles
- Ink (e.g. viscosity)
- speed (printhead)

Ongoing investigations at Semikron

Source: SEMIKRON Elektronik GmbH & Co. KG

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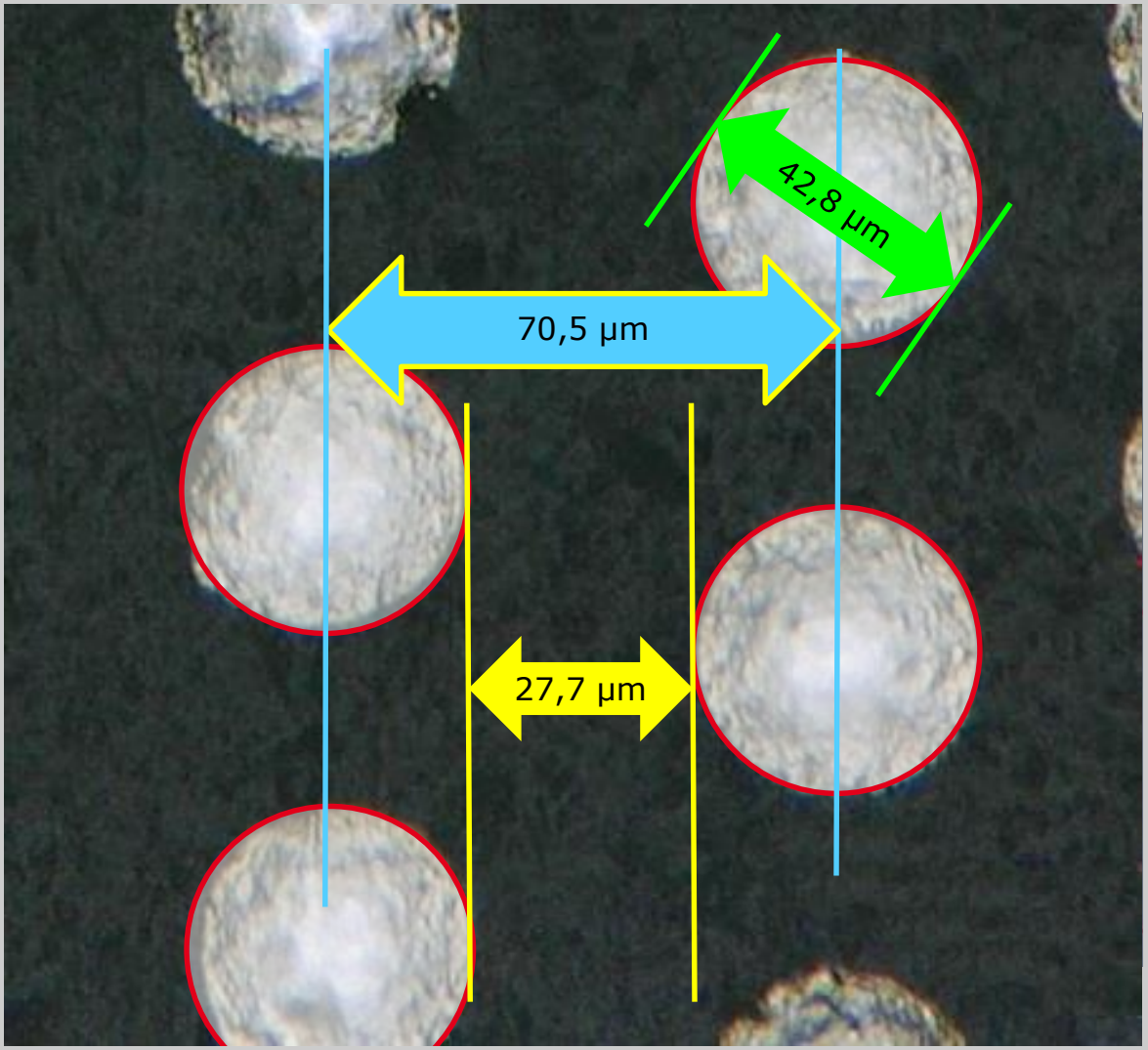
Silver Sintering
Applying the functional fluid (Ag) with an Inkjet process

1. Printed image:

- Semikron Teststructure
- Substrate: PTFE-Foil
- Funktional fluid (Ag)
- Solution: 360 dpi

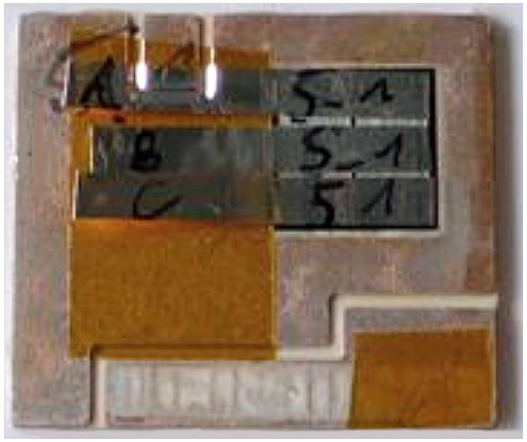
2. Measurement:

- Diameter: 42,80 µm (± 1,08 µm)
- Pitch: 70,50 µm
- Spacing: 27,70 µm

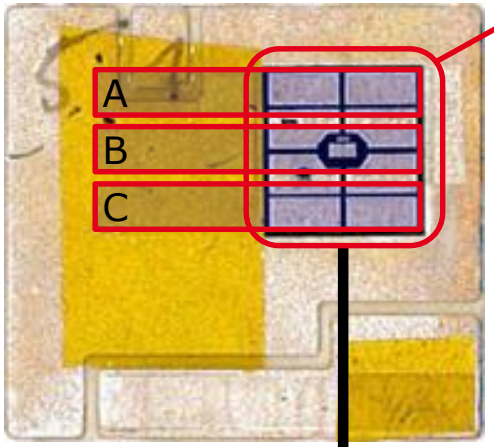


Source: Semikron Elektronik GmbH & Co KG

Silver Sintering
Adhesive strength

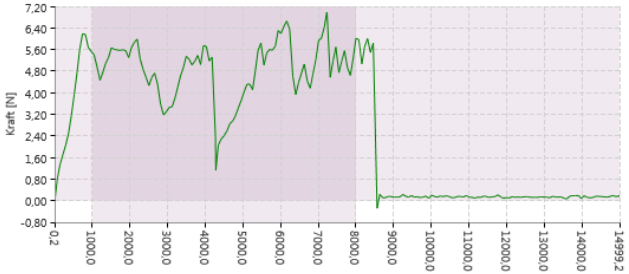


Double side sintered bare die chip



sinterable area
(TOP-surface of a bare die IGBT-chip)

Analysis of the joint with peeling strips

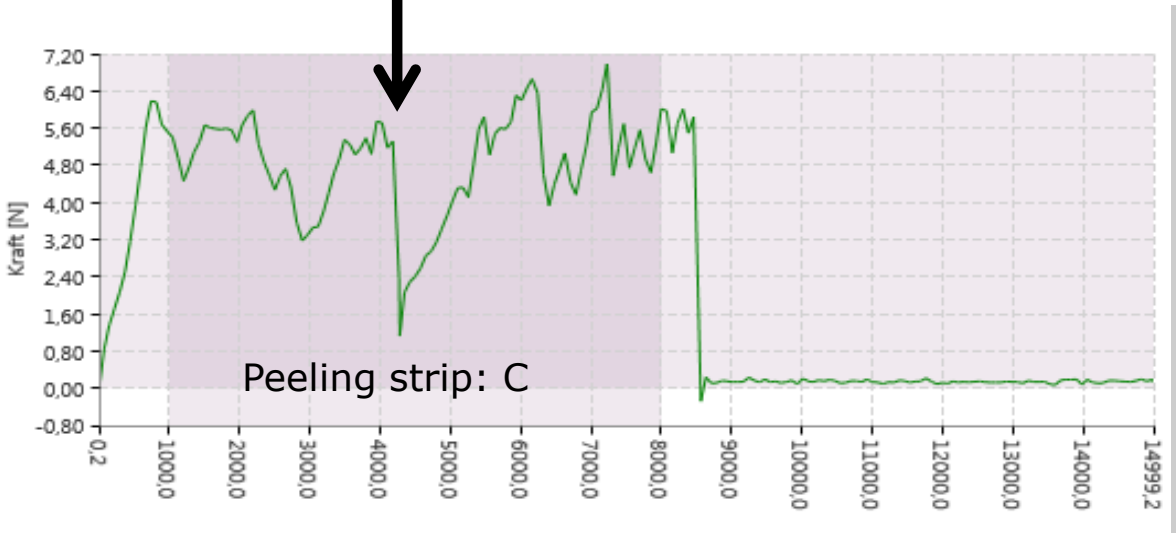


Peeling strip C: Diagram of adhesion

To sinter from both sides it is necessary to apply the functional fluid (Ag) on the TOP side of the IGBT-chip.

Three areas for a peeling strength test were applied.

On every area a silver metal strip were sintered.



Source: Semikron Elektronik GmbH & Co KG

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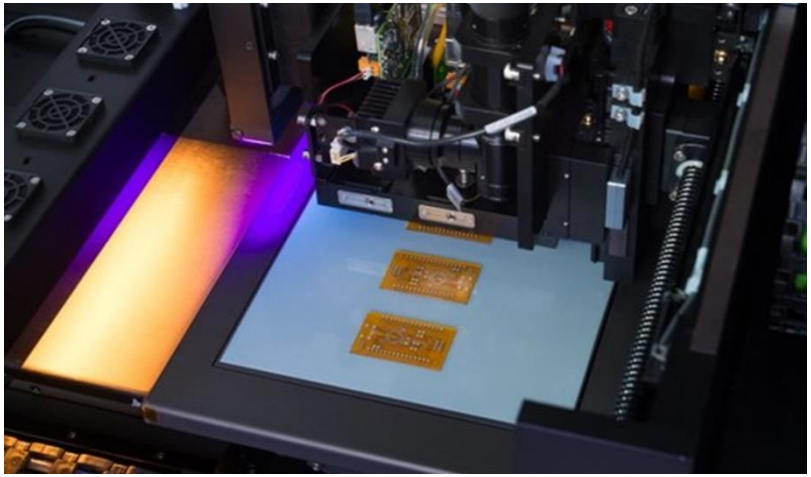
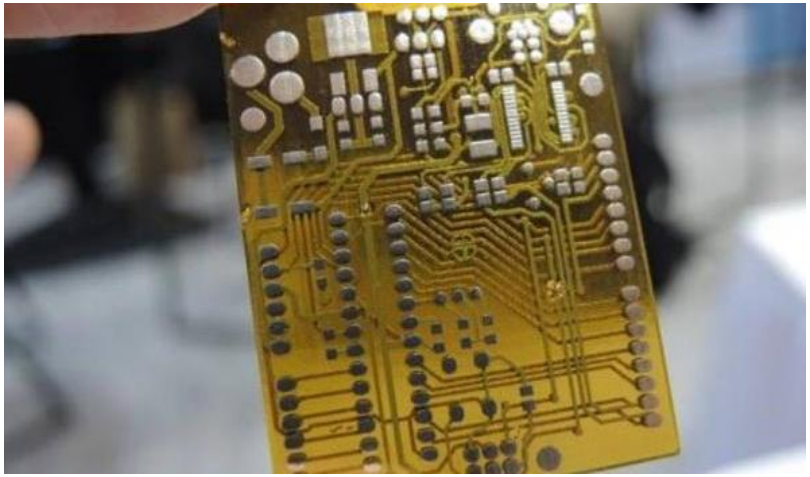
Additively **M**anufactured **E**lectronics (AME)



Printing Process, functional fluids (dielectricum, Ag) and UV-curing



Example of an AME

Nano Dimensioin was founded in 2012

They own the IP's
- conductive fluid
- and non conductive fluid

The first Dragonfly was launched in 2015

acquired Essemtec Group (Swiss)
for assembly and dispensing of auxilery material, for electronic components

Design options:

- max. dimensions 160 x 160 mm
- max. height (released): 3 mm

- min. Layer thickness 17 µm
- min. dielectric thickness: 25 µm

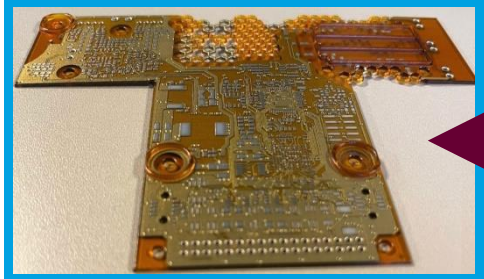
- solder mask thickness (typ): 50 µm

- line / spacing: 70 / 100 µm

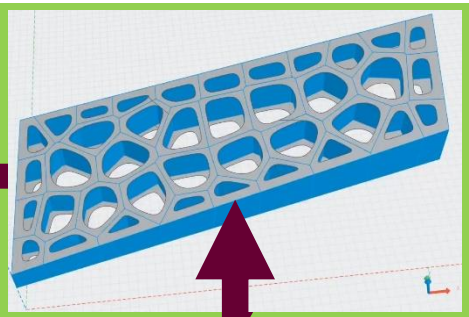
Source: www.3Dprintingmedia.network, www.eenewseurope.com

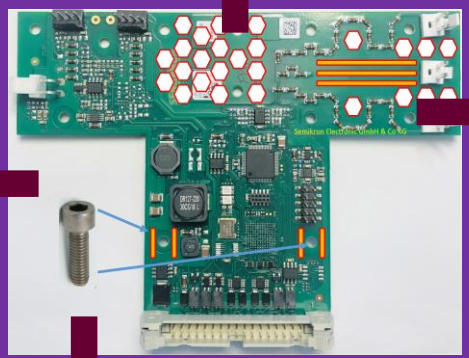
AME application
Features to improve the current PCB design

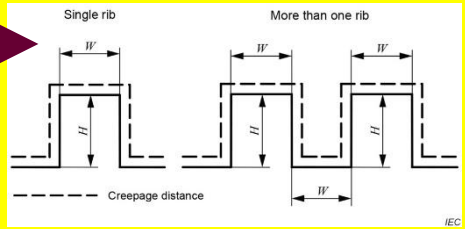
AME-Demonstrator



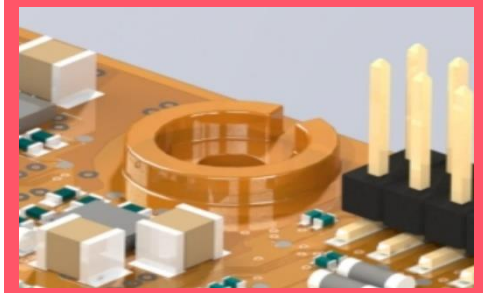
1st Redesign of Sensor-PCB

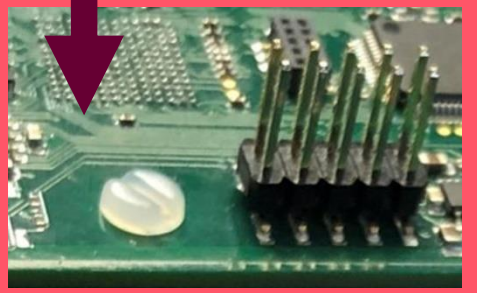


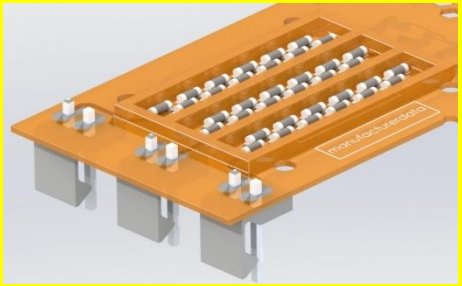




Creepage distance regarding
IEC 60664-3:2020







Source: SEMIKRON Elektronik GmbH & Co. KG

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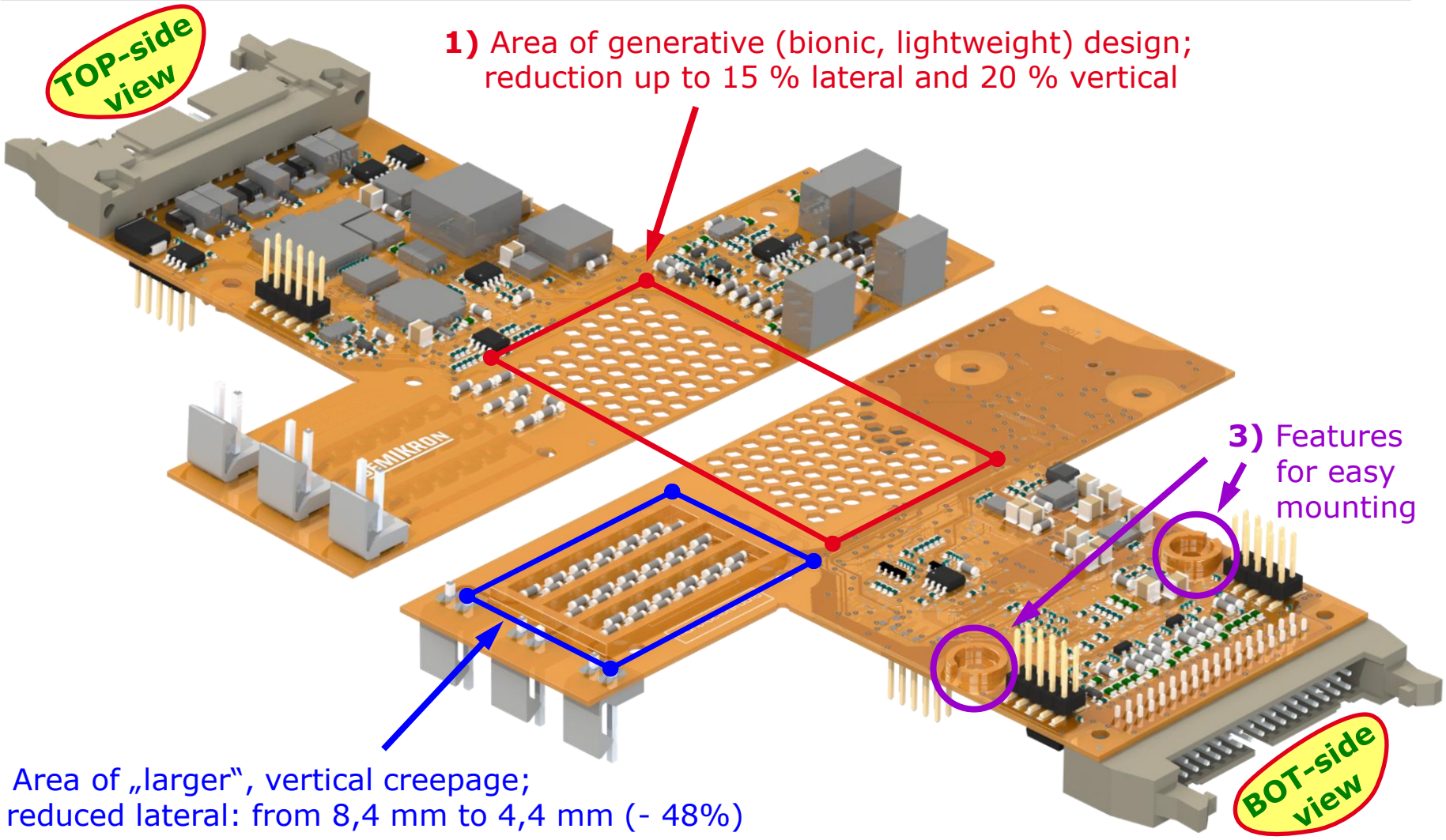
AME application
Overview of the design



Source: SEMIKRON Elektronik GmbH & Co. KG

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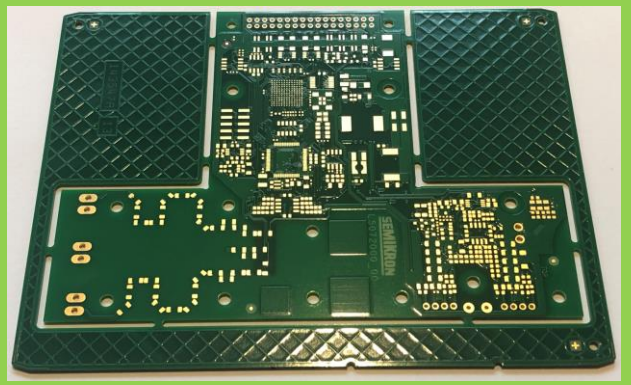
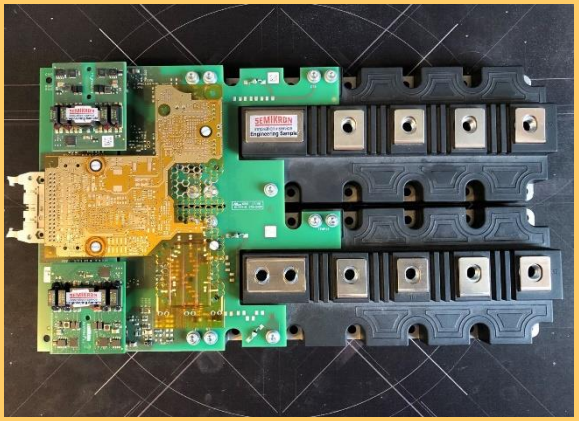
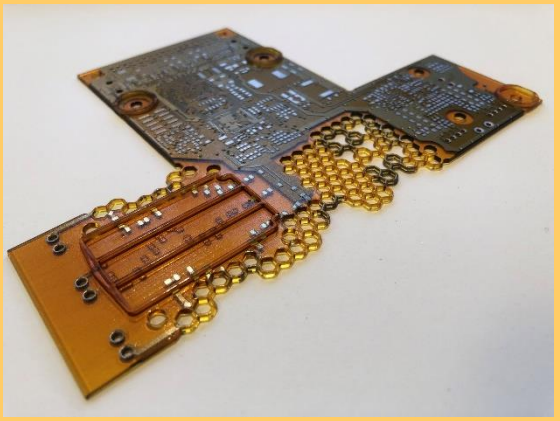
PCB-version // AME application
Overview



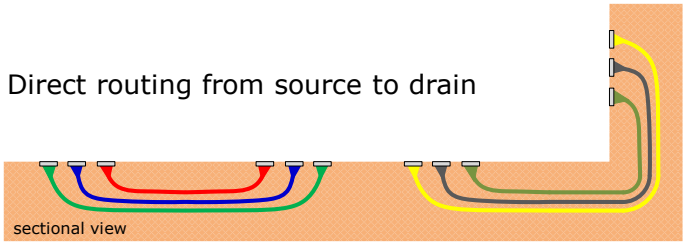




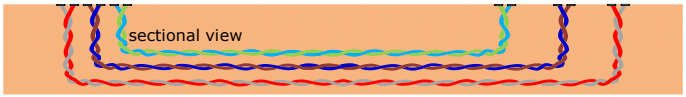
Source: SEMIKRON Elektronik GmbH & Co. KG

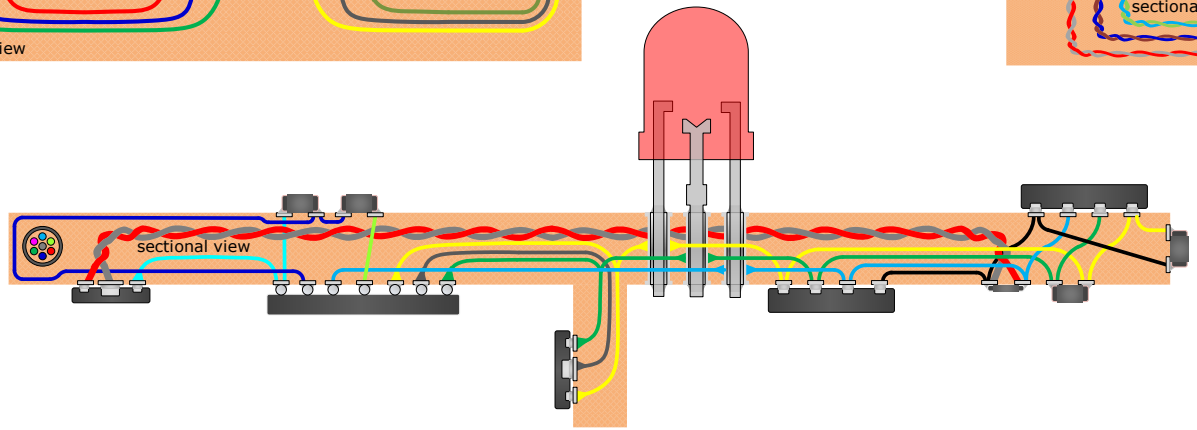
Future prospects
Possible and required AME layout solutions → disruptive approach

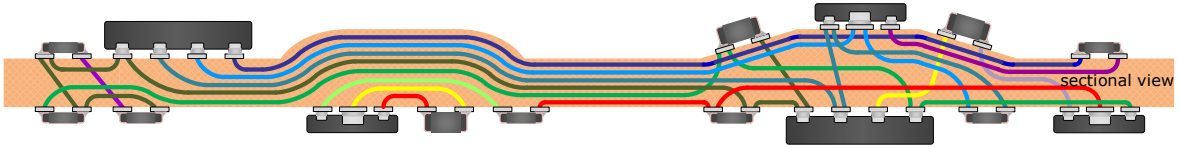
Direct routing from source to drain



Twisted pair routing (without vias)

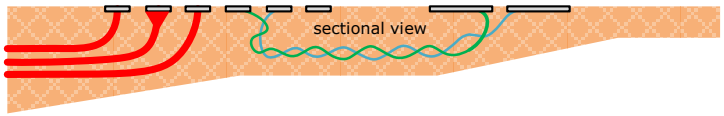






Design features:

- any layer (layerless) routing
- any angle routing
- any angle teardrops
- any angle holes / tubes
- vialess routing
- vertical fanout
- „real" twisted pair routing
- harness design option
- shielding (koax) routing
- 3D-trace-shape (optional)
- 3D shape (substrate)
- 3D shape routing
- 3D line/spacing (DRC)
- 3D push-back-routing (plow)



reduce thickness, 3D-shape, 3D-DRC or bionic design

Bus structures (shielding option), equal to harness design

Source: SEMIKRON Elektronik GmbH & Co. KG

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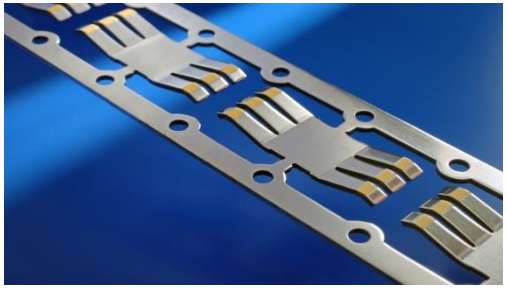
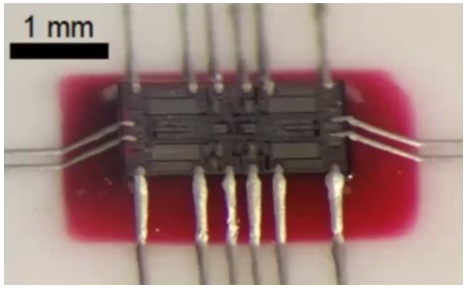
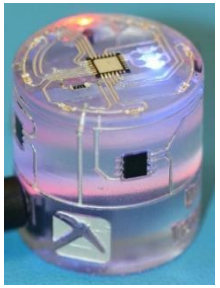
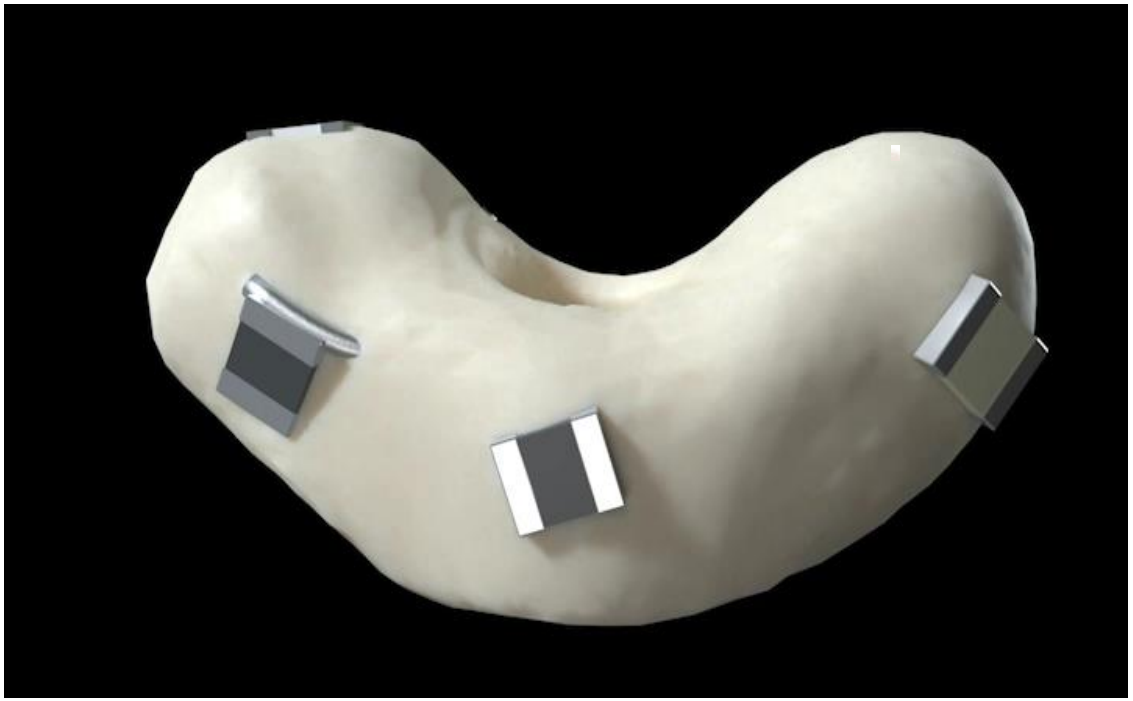
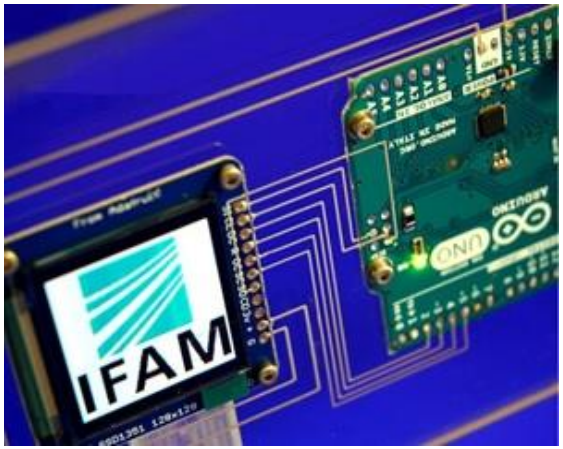
Future prospects
Possible „Additively Manufactured“ solutions (semi- & fulladditive)











Source: UTEP EM Lab, Semikron Elektronik GmbH & Co. KG, Video: UTEP EM Lab

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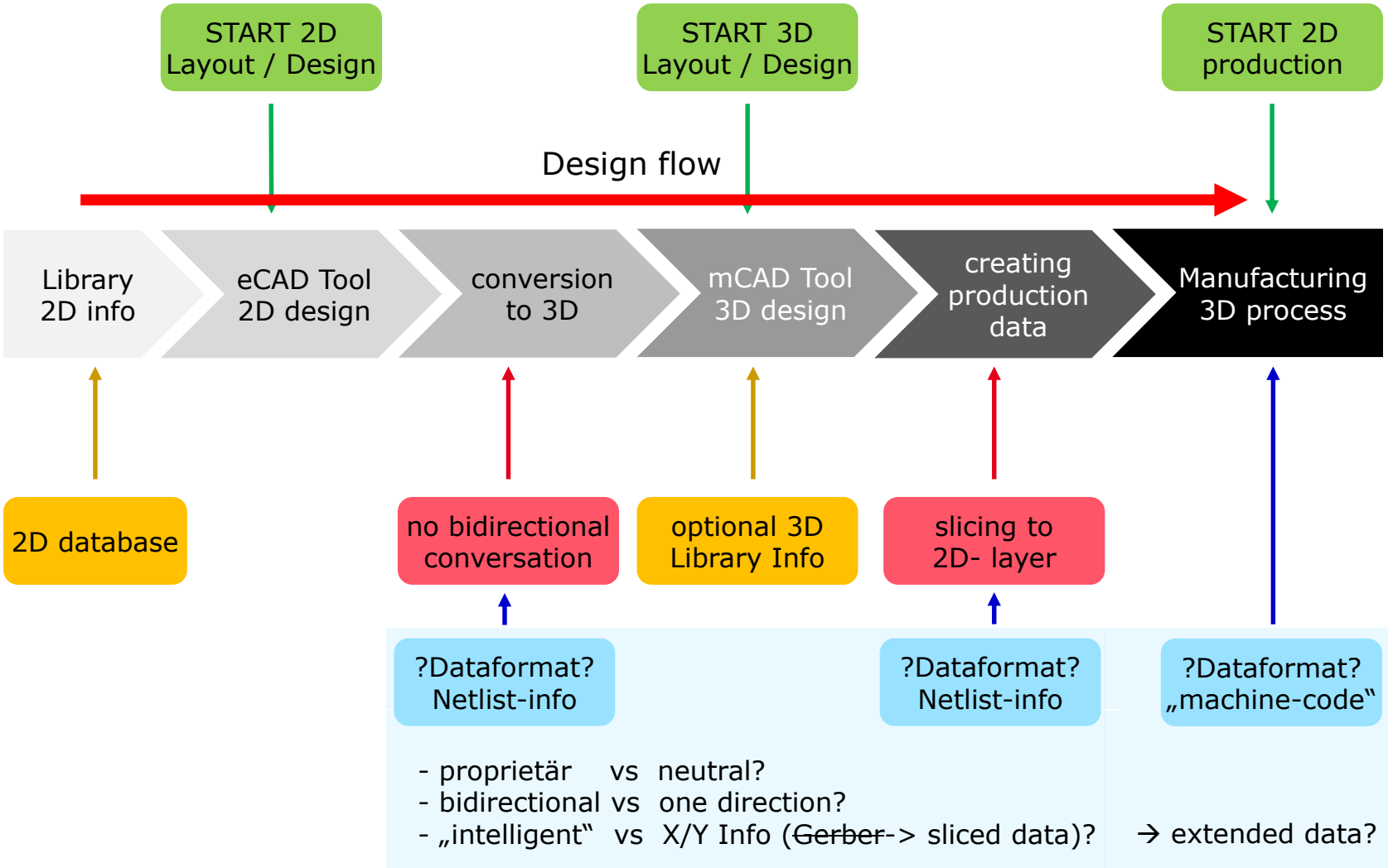
2D design, 3D design, Datatransfer, smart manufacturing



Source: Semikron Elektronik GmbH & Co KG

Contact

Vielen Dank für Ihre Aufmerksamkeit

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