Heterointegration Multifunktionaler Systeme - Additive Manufacturing – AVT der Zukunft?

Tag der Fakultät EuI, SAET, 30.09.2016

K.Bock , IAVT

Outline

Introduction

AM Methods at present

Examples of AM in packaging until now

Need of AM in future electronics

Conclusions

This presentation is for teaching purpose only,
Source of some pictures are refered unspecific, since based on internet search, if you are the owner, please contact us, we will set a proper reference or delete the picture immediately

TECHNISCHE UNIVERSITÄT DRESDEN

Introduction Society Grand Challenges
➔ Key Impact to Electronics Packaging

Energy and Resources

Environment and Climate

Energy Efficiency

Increase of efficiency in the use of regenerative and fossile energy sources, reduction of emissions

Ageing society

Health

AAL & Health

Reduction of costs, improvement in therapy and tolerability

Mobility

Urbanization

Mobility

Improvement in convenience and security

Knowledge Society

Living and Working

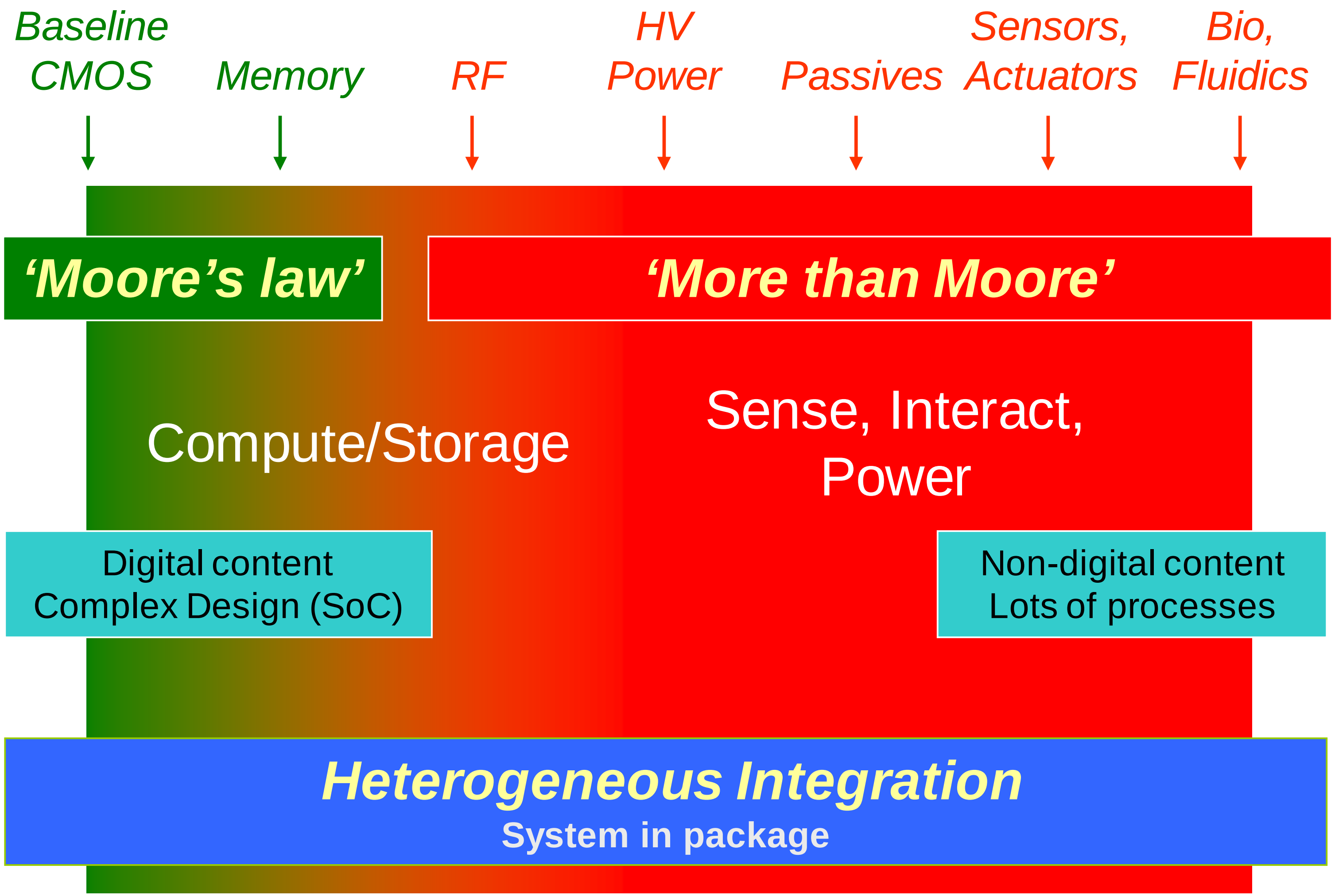
Smart Living

Miniaturisation and mobile use

Source pictures Fraunhofer

Heterointegration

System Integration - Scope and functionality



Source: EPOSS

Challenges by IoT und Ind. 4.0 → SFB HAEC, ESF ATTO3D

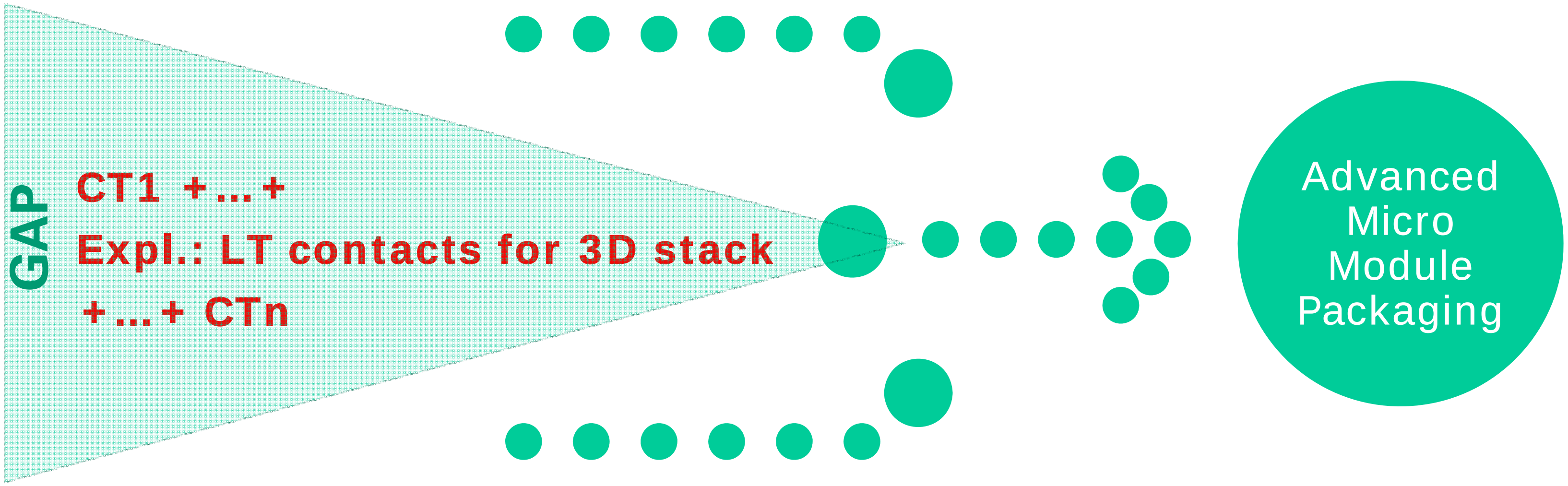
- High performance reconfigurable network, wire, fiber and wireless
- Reconfigurable phased array Base stations, 70GHz? (5G; 3-5 J),
- Mobile Data transfer rates 1 Gb/s (today), 10 Gb/s (3-5 J), 100 Gb/s (10 J)
- Wireless interconnected multiple functions between things and humans, tactile internet delays approx. 1-10 ms can be mission critical
- High-performance mobile transmitter / receiver modules in things, machines and humans, HF, Bandwidth, Power, Compatibility…
- Miniaturization, 3D Integration, Chip stacking, Interposer (Si, glass, polymer…)
- „Trillion(s of) Sensors“

Packaging Challenges by IoT und Ind. 4.0 ➔ Heterointegration and AM

- **Multi-functionality,** many sensors, different environments
- **In-line enabled electronics**, integrateable in mechanical parts
- Resource-optimized, fast (**self-assembly**), high-volume and low-cost production, environmentally compatible (**Bio**) and recyclable, **flexible, organic and large area electronics (FOLAE), manufacturing(R2R)**
- **Open form-factor**, lightweight, conformable , **New Material and Process-Co-Integration, additive digital Manufacturing, 3D printing for electronics packaging**
- **Reliability** under difficult conditions ➔ **Rest lifetime prediction and structural health SHM or condition monitoring CM**
- **Reconfiguration, Redundancy and self-repairing systems** in use
- **Highest performance for RF and power at lowest power consumption, extremely miniaturized and 3D integrated… ?**

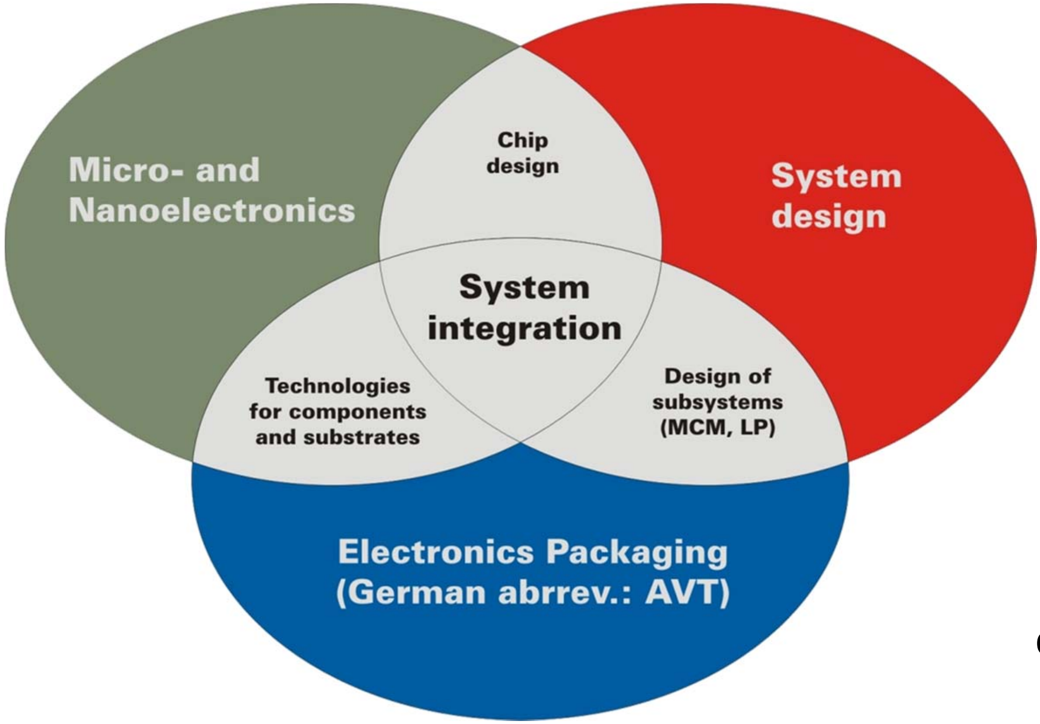
Between Conventional Microelectronic (ME) Fabrication Methods and ME Packaging we lack suitable Core Technologies (CT) (Packaging Gap)

Conventional ME Fabrication Methods

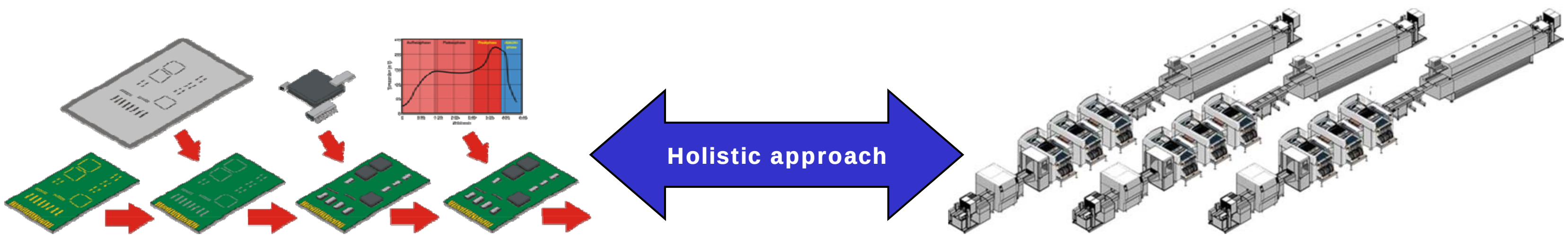


STOA ME packaging methods

AIM: Holistic Approach ➔ From wafer to package (application) on optimized process and equipment chain



Procedures, processes and technologies to assemble electronic components and microtechnical modules



Fields of activity of the Electronics Packaging Lab

Bio-compatible electronics packaging

Thick-film technology

Microstructure characterization

Micro interconnection technologies

Modelling, simulation, optimization of processes

Assembling technologies

Quality assurance in electronics

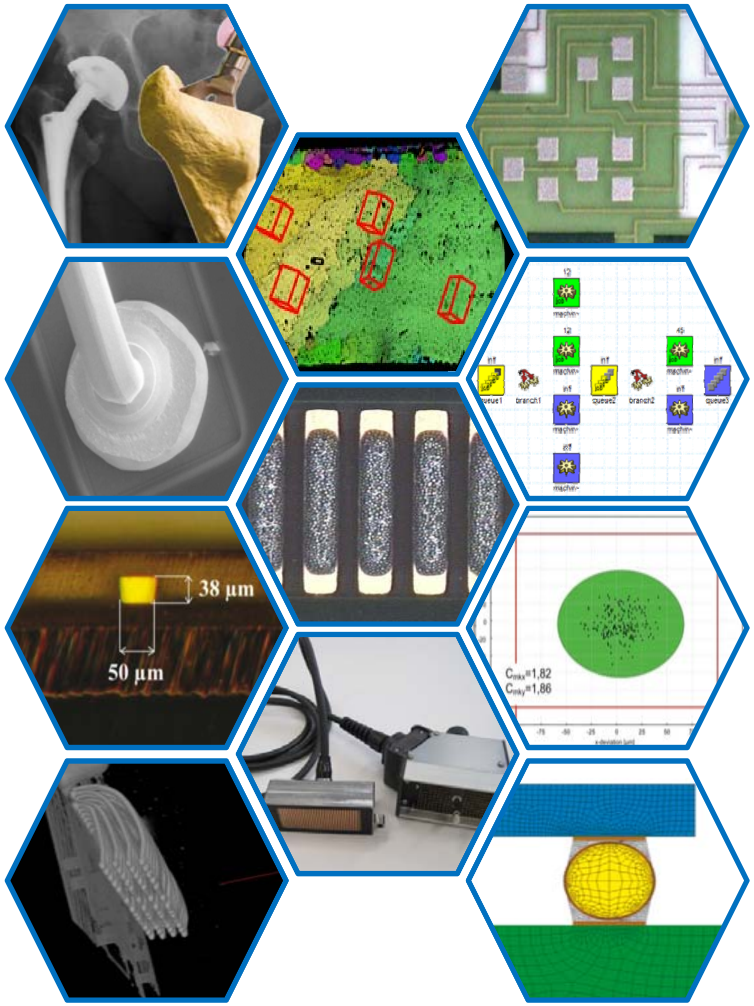
Sensors for NDT and SHM

Non-destructive inspection

Board Level Reliability

Photonic Packaging

→ **SFB HAEC and ESF Atto3D**



Present Status of AM or 3D Technologies

Type	Technologies	Materials
Extrusion	Fused deposition modeling (FDM) or Fused filament fabrication (FFF)	Thermoplastics, eutectic metals, edible materials, Rubbers, Modeling clay, Plasticine, Metal clay (including Precious Metal Clay)
	Robocasting or Direct Ink Writing (DIW)	Ceramic materials, Metal alloy, cermet, metal matrix composite, ceramic matrix composite
Light polymerized	Stereolithography (SLA)	Photopolymer
	Digital Light Processing (DLP)	Photopolymer
Powder Bed	Powder bed and inkjet head 3D printing (3DP)	Almost any metal alloy, powdered polymers, Plaster
	Electron-beam melting (EBM)	Almost any metal alloy including Titanium alloys
	Selective laser melting (SLM)	Titanium alloys, Cobalt Chrome alloys, Stainless Steel, Aluminium
	Selective heat sintering (SHS)[44]	Thermoplastic powder
	Selective laser sintering (SLS)	Thermoplastics, metal powders, ceramic powders
	Direct metal laser sintering (DMLS)	Almost any metal alloy
Laminated	Laminated object manufacturing (LOM)	Paper, metal foil, plastic film
Powder Fed	Directed Energy Deposition	Almost any metal alloy
Wire	Electron beam freeform fabrication (EBF³)	Almost any metal alloy

Source: internet unspecific

|3DP| ZPrinter 3D-Druck

Schichtweise Verfestigung eines Pulverwerkstoffs durch Aufdruck eines flüssigen Binders. Prinzip Tintenstrahldrucken.

- Vollfarbig
- Sehr schnell
- Sehr produktiv
- Niedrige Materialfolgekosten
- Niedrige Instandhaltungskosten
- Einfach zu bedienen
- Stützmaterial wird recycelt
- Erste Funktionsprüfung, Variantenerprobung, Formfindung, Kommunikation, Präsentation, Design, Entwicklung, Marketing, Vertrieb, Anschauungsmodelle

3DP | ZPrinter 3D-Druck

Source: internet unspecific

|MJP| MultiJetPrinting

MJM| MultiJet Modeling

Aufdruck von flüssigem Photopolymer über Piezzodruckkopf und Aushärtung durch UV-Belichtung. Prinzip MultiJet Verfahren.

- Multi-Material fähig
- Präzise Funktionsbauteile
- Gute Maßhaltigkeit
- Sehr hohe Kantenschärfe
- Sehr hohe Detailauflösung
- Funktionsprüfung, Design, Entwicklung, Engineering, Designmodelle, Urmodelle für Duplizierungsverfahren, z.B. Vakuumguss, Komplexe Bauteile, Mikro- und Kleinteile
- Sehr feine Schichtdicken

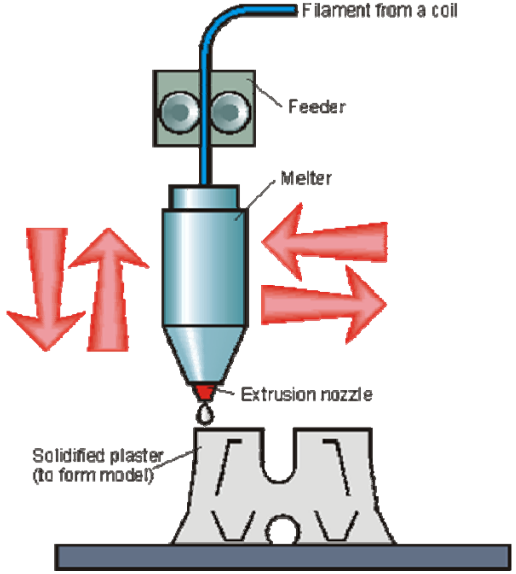
MJM | MultiJet 3D-Druck

Source: internet unspecific

|FDM| Fused Deposit Modeling

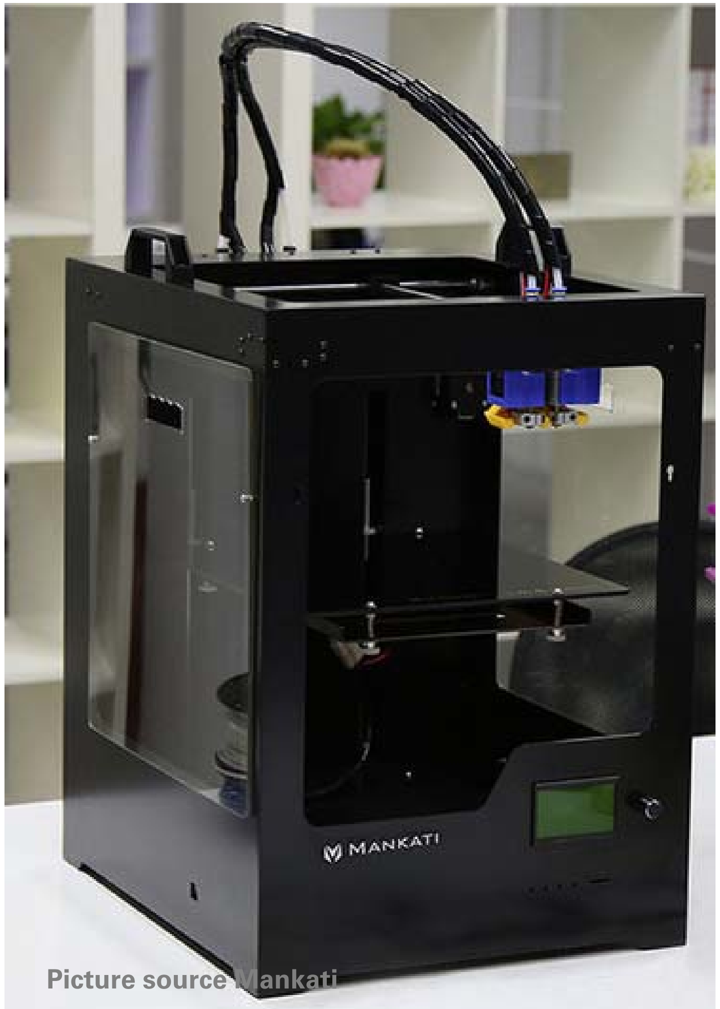
Ablegen eines abgeschmolzenen Kunststoffdrahtes per xy Düse. Verfestigung über Abkühlung. „Strangablageverfahren". Prinzip Fused Deposition Verfahren.

- Strangextrusion
- Studentenbausätze
- Engineering, Entwicklung, Funktionsüberprüfungen
- Niedrige Geschindigkeit trotz grober Schichten (Strang ca. 0,2mm)
- Hohe Betriebskosten (Baumaterial + Verschnitt an Supportmaterial)

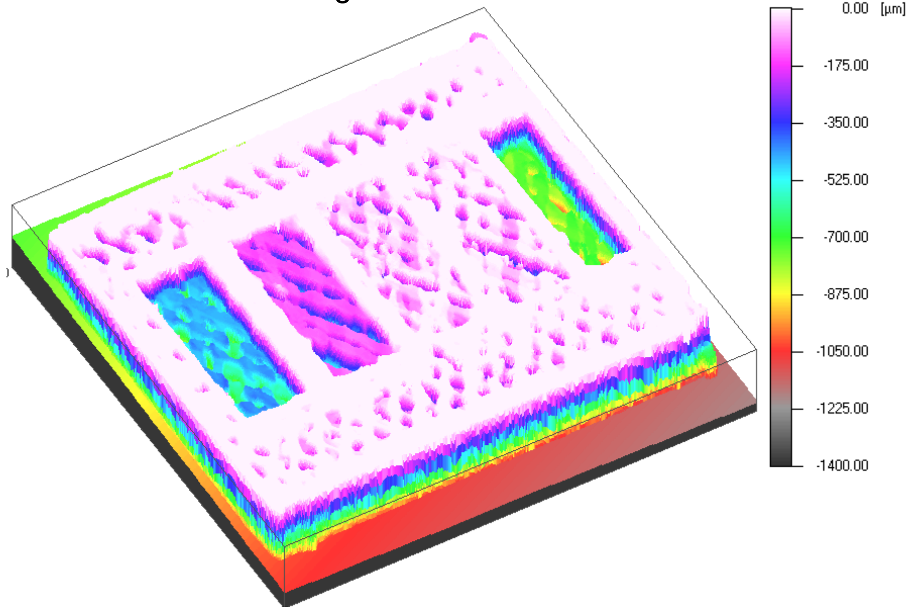


Picture Source: internet unspecific

Fused Deposition Modeling (FDM)



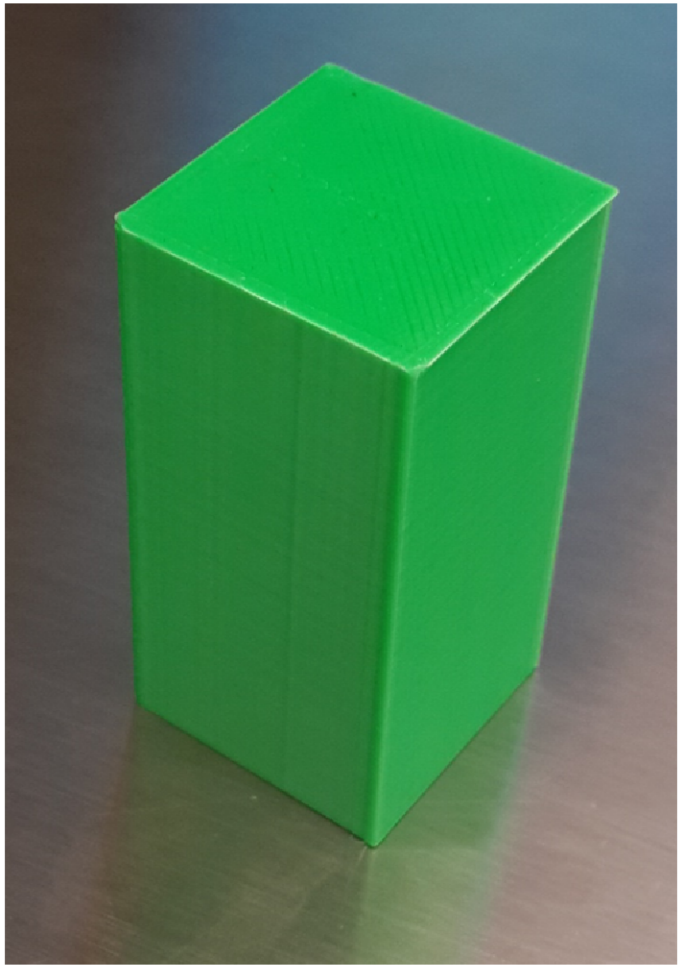
Druckversuch von
Hohlräumen/Einbettungsstrukturen...

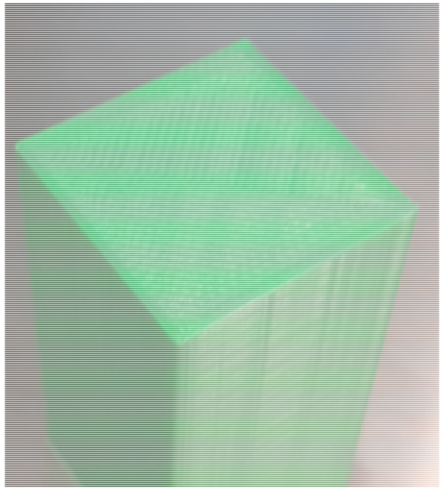


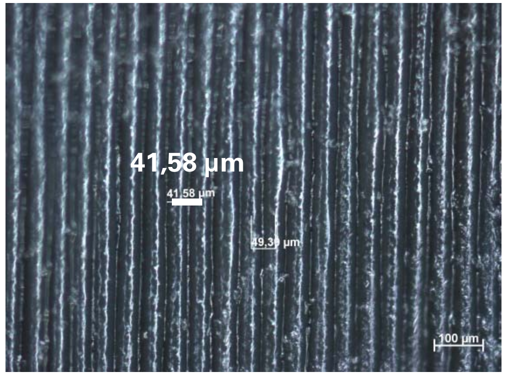
Mankati Fullscale XT PLUS

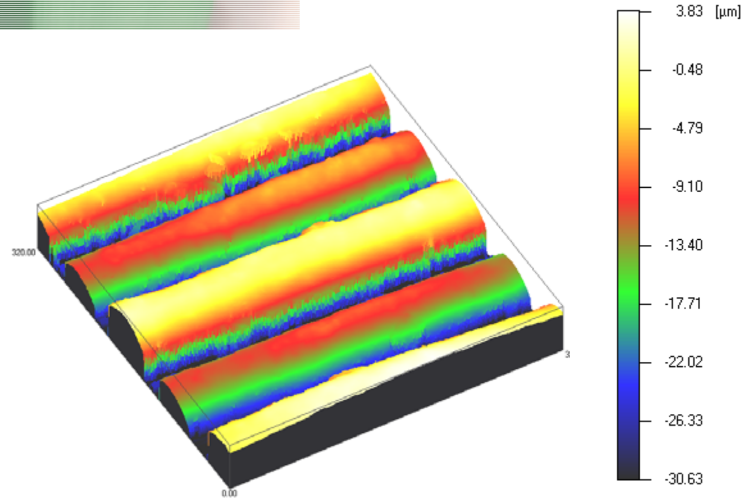
X-Y-Z (250 x 250 x 300) mm
Z-Auflösung (50µm) 100 µm
Picture source Mankati

FDM Resolution









|SLS| Selektives Laser Sintern

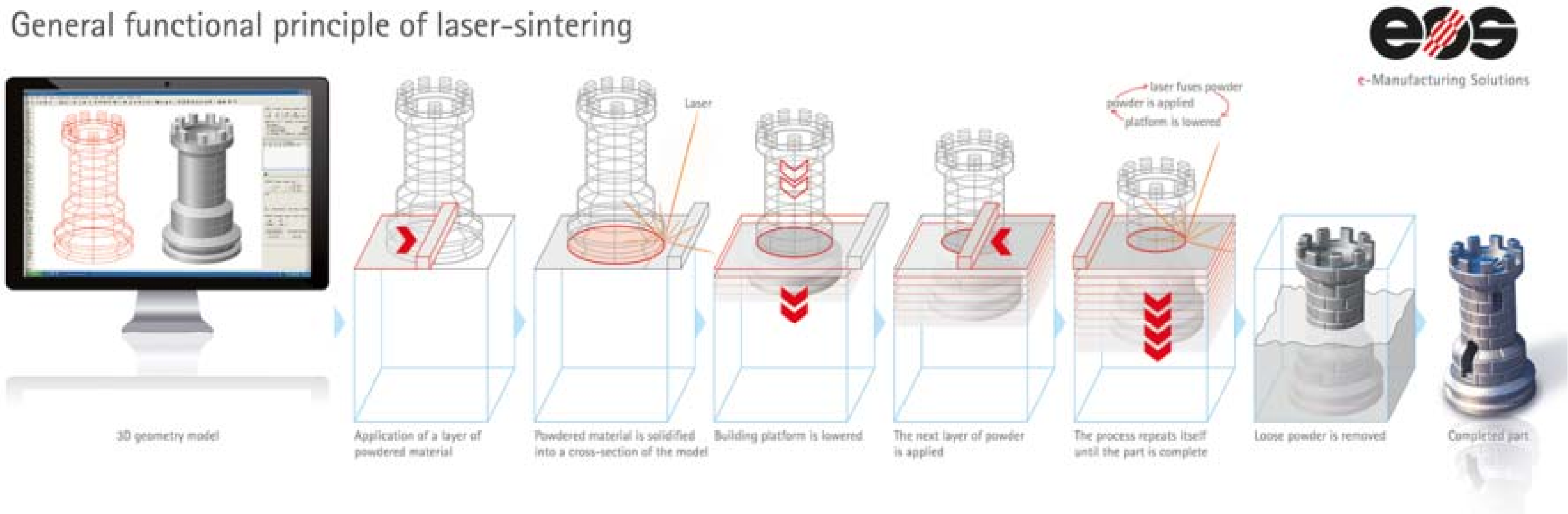
Selektives Verschmelzen von Kunsstoffpulver (Metallpulver)

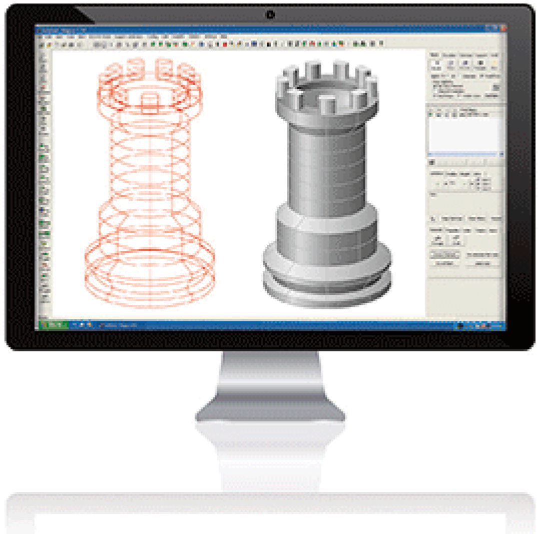
- Prototypen mit höchsten mechanischen Materialeigenschaften
- Einsetzbar für die Fertigung von Serienbauteilen
- Funktionsprototypen
- Funktionsprüfung
- Hohe Investitionskosten
- Hohe Betriebskosten
- Know How intensiv
- Benötigt spezielle Werkstatteinrichtungen

SLS | Selektives Laser Sintern

Picture source unspecific internet

3D Laser Sintering





Jet turbine parts 3D Laser Sintered steel by GE

Resolution < 50µm, surface polishable, picture source GE

|SLA| Stereolithographie

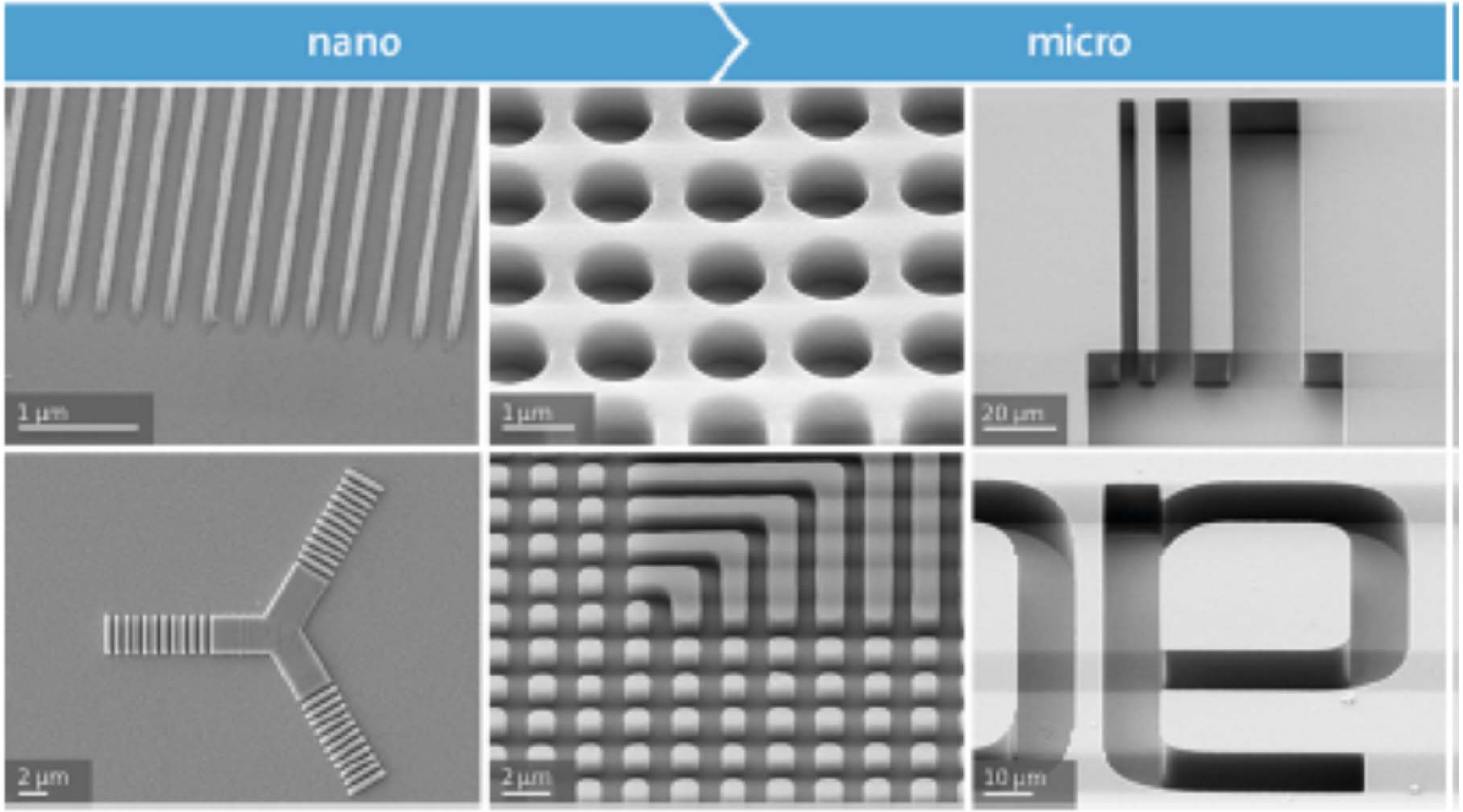
Vernetzen von flüssigem Photopolymer (Epoxidharze) durch UV Belichtung per Laser. Erstes kommerziell verfügbares Verfahren (1986 – USA; 1987 – Europa)

- Stereolithographie Verfahren
- Hoch präzise
- Maßhaltig
- Hohe Kantenschärfe
- Sehr hohe Detailauflösung
- Sehr gute Oberflächenqualitäten
- Engineering, Entwicklung, Urmodelle für Duplizierungsverfahren z.B. Vakuumguss,
- Hohe Investitions- und Betriebskosten
- begrenzte Werkstoffeigenschaften
- KnowHow intensiv
- Benötigt spezielle Werkstatteinrichtungen

SLA | Stereolithographie

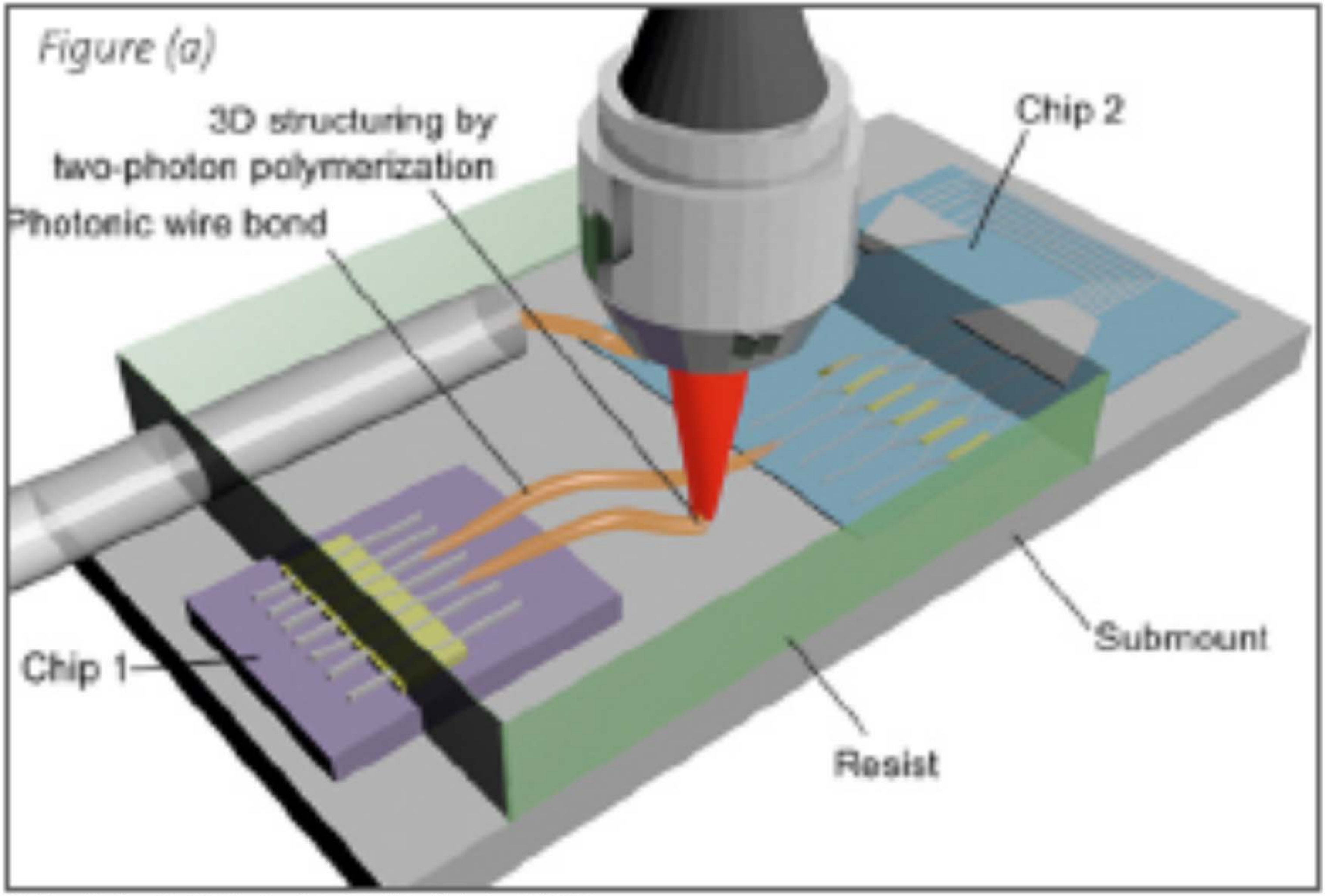
Picture source unspecific internet

Auflösung 3D SLA Strukturen



SEM micrographs of various 2D patterns in positive and negative tone photoresists fabricated with a Photonic Professional GT.

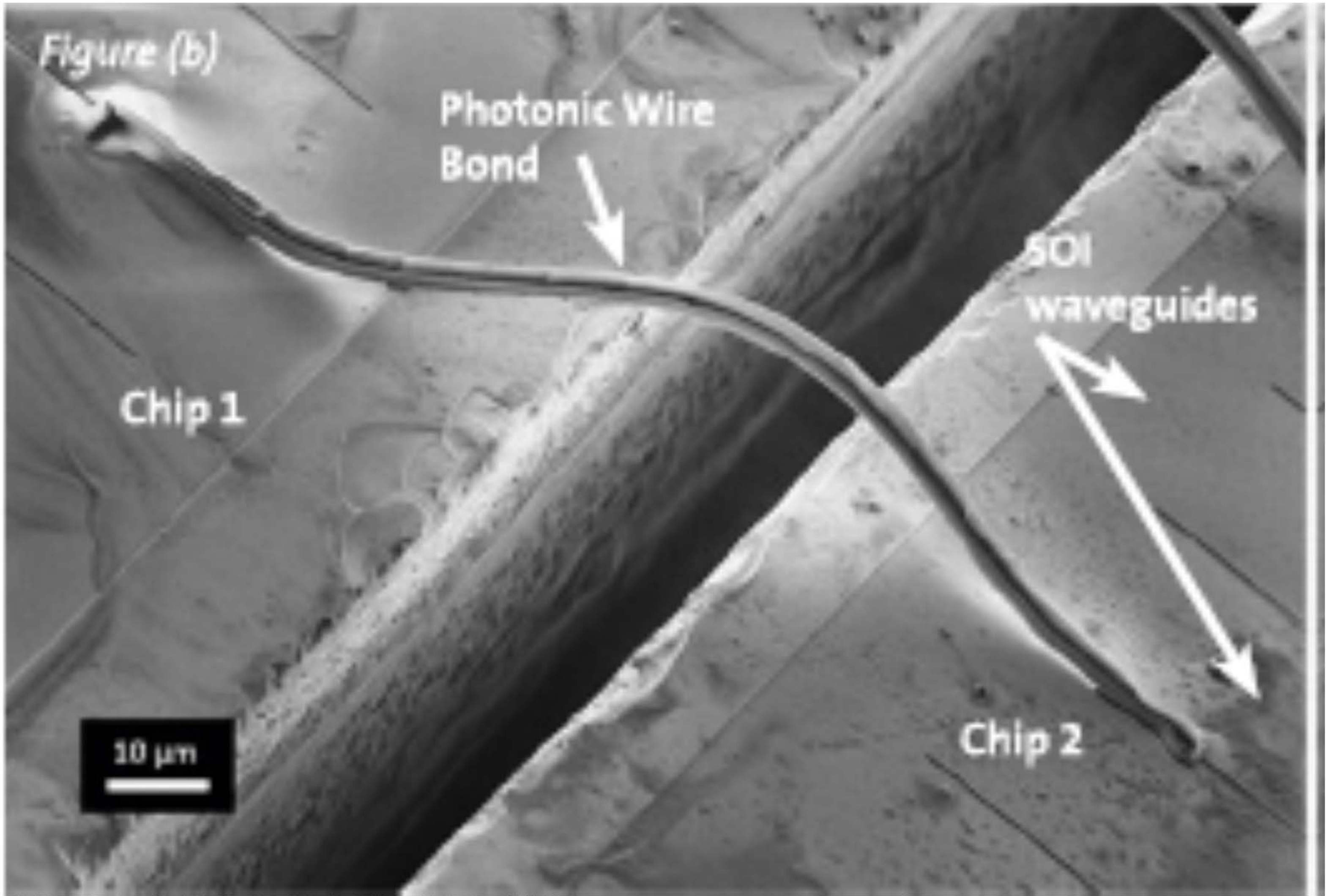
3D gedruckte Brückenstruktur



All pictures: Courtesy of Prof. Christian Koos, Karlsruhe Institute of Technology (KIT/IPQ), Germany
Reference (1): N. Lindenmann, G. Balthasar, D. Hillerkuss, R. Schmogrow, M. Jordan, J. Leuthold, W. Freude, and C. Koos, "Photonic wire bonding: a novel concept for chip-scale interconnects," Opt. Express 20, 17667-17677 (2012).

nanoscribe

3D gedruckter optischer Wellenleiter



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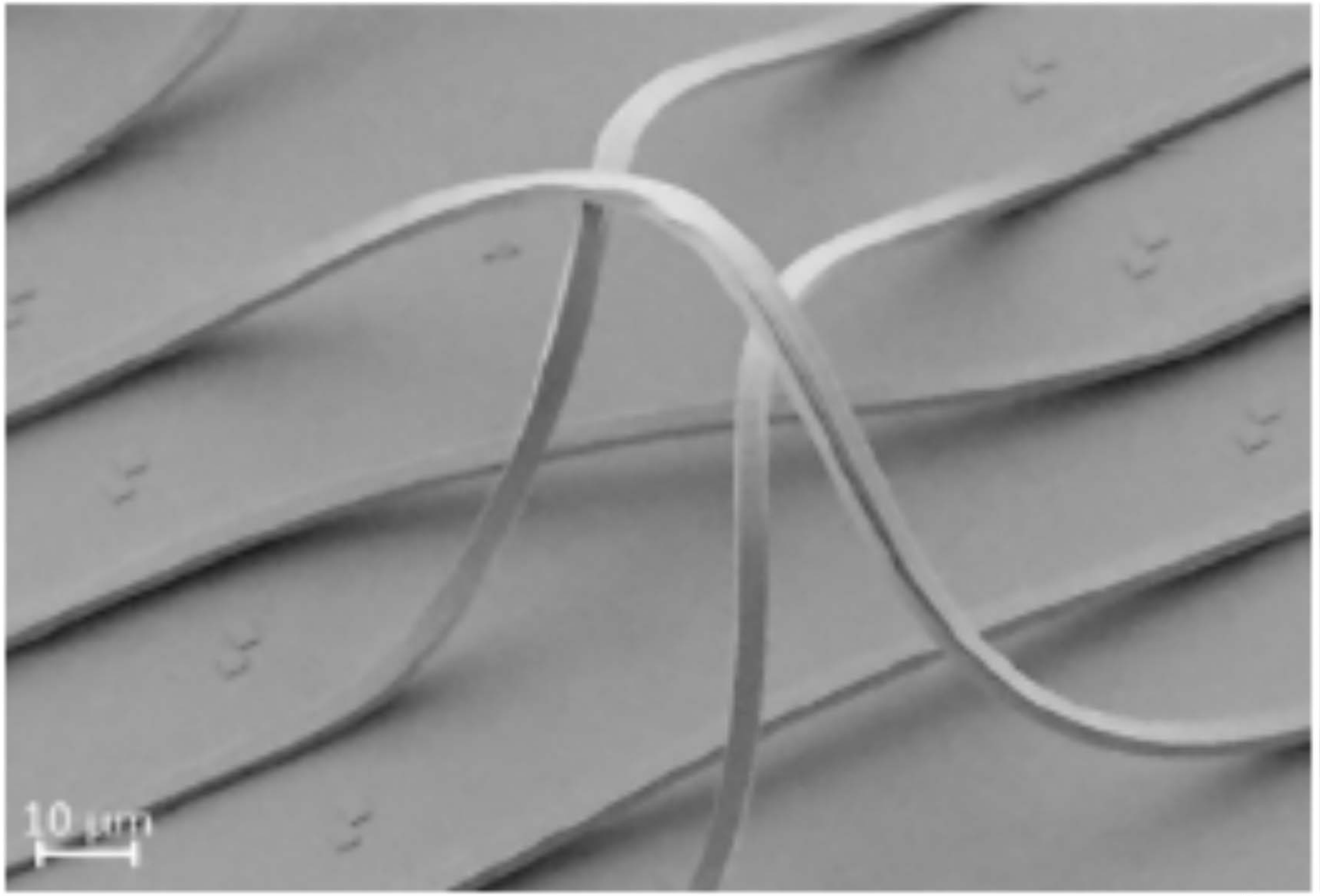

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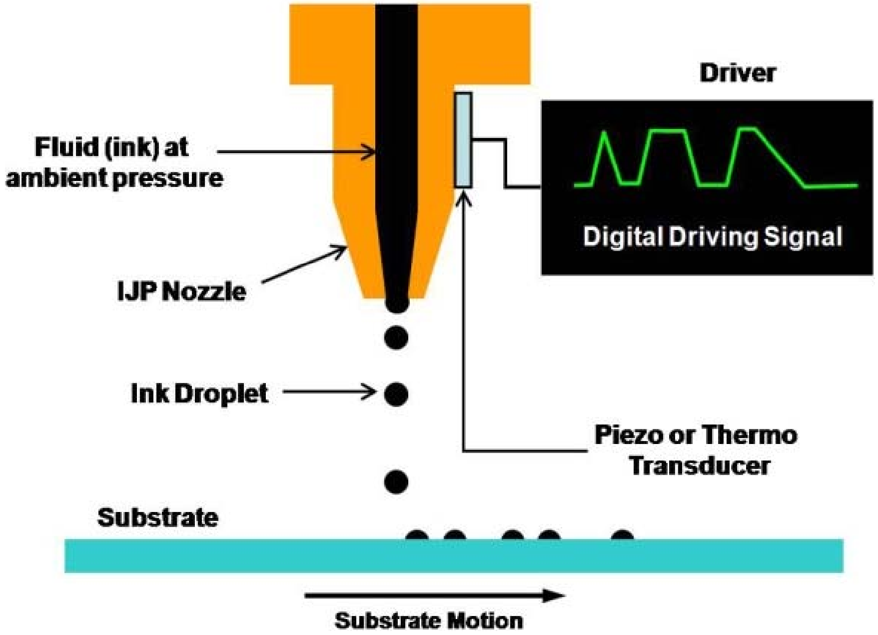
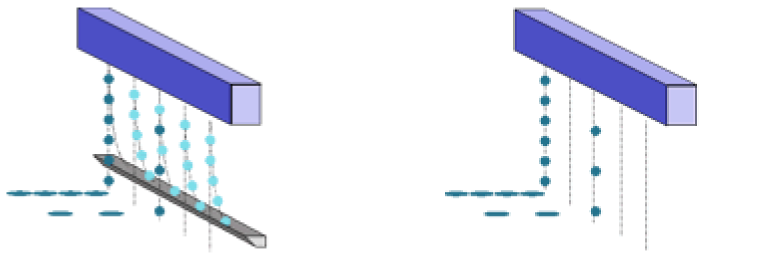
InkJet



http://spie.org/Images/Graphics/Newsroom/Imported/0969/0969_fig1.jpg

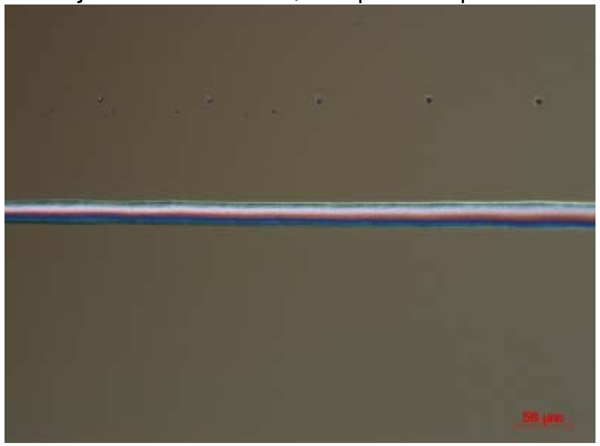


Continuous Inkjet (CIJ) | Drop on Demand Inkjet (DOD)

http://www.xennia.com/media/48900ded-7a59-4ebb-b5b3-b6b67d4e2455/asfnog/cij-dod-diagram.gif

- mehrere Nozzles
- kleine Volumina (1pl – 80 pl)
- Beheiztes Bed und Nozzle für Viskositätsjustierung
- Enger Anwendungsbereich druckbarer Viskositäten
- Pixel im Design ≠ Gedrucktes Pixel
- Dropwatch System– Versatz der Düsen bei der Produktion

Fujifilm Dimatix, Kopf: 10 pl

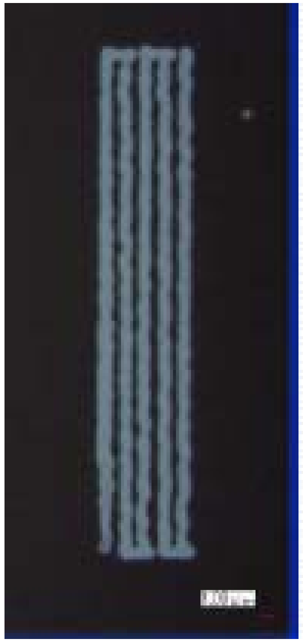


w=40 µm, d= 2 µm

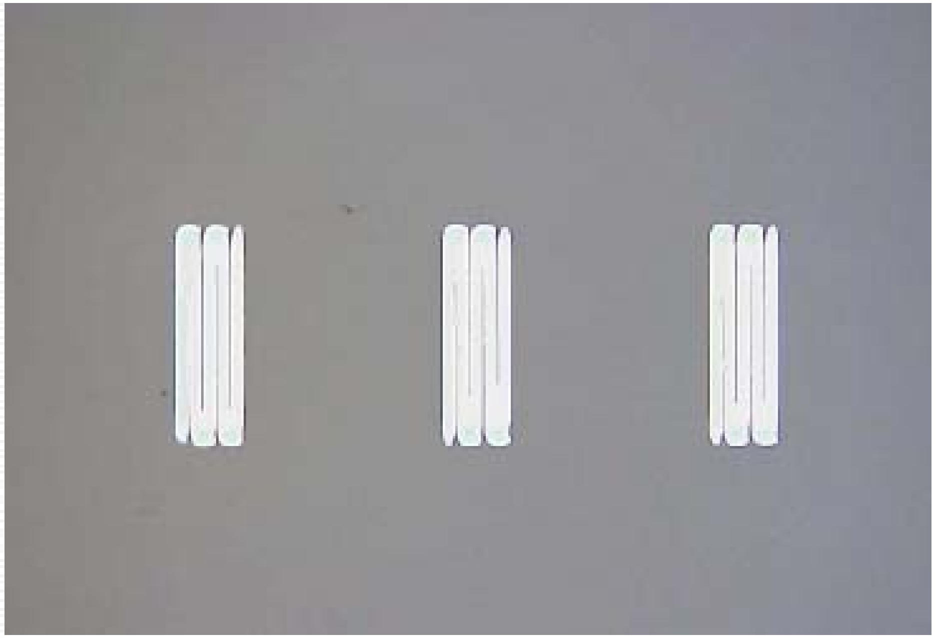
Super InkJet Technology

SIJ S050 Datasheet

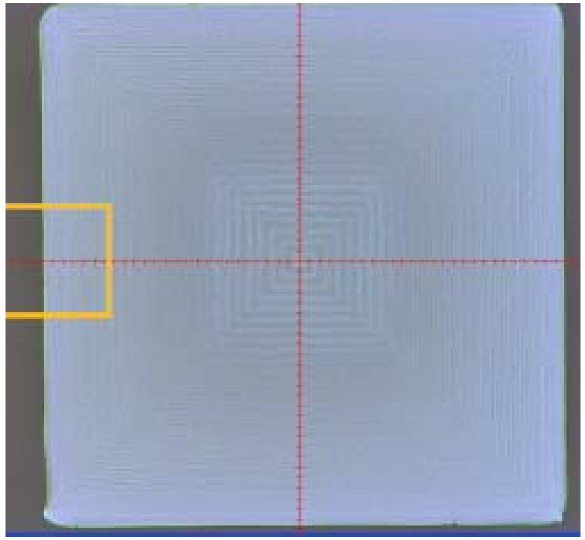
- sehr kleine Volumina (1fl – 10 pl Tropfengröße) → sehr kleine Strukturen
- Viskositäten bis 10000 mPas (50000 mPas)
- Patentiertes elektrostatisches Druckprinzip
- große Materialauswahl
- eine Düse (Nozzle)
- sehr geringes Materialreservoir
- Hoher Preis trotz Entwicklungsstadium



1 µm L & S



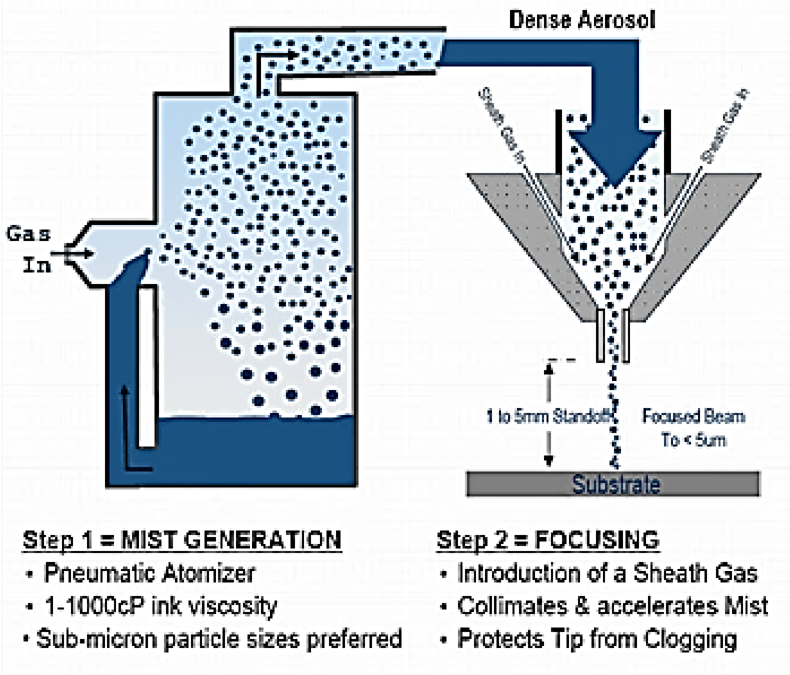
10 µm L & 0 µm S



20 µm L, (1 x 1) mm, d=2 µm

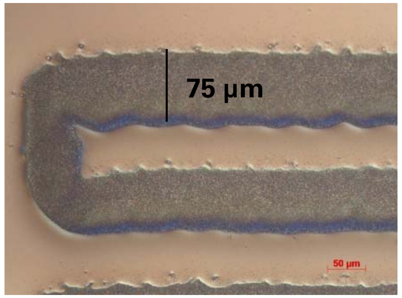
Aerosol Jet

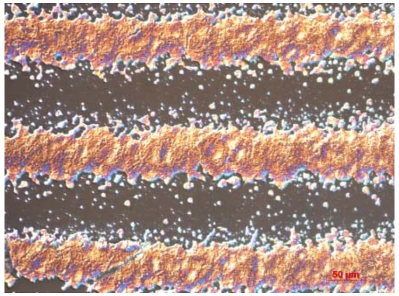
Aerosoljet-Druck



http://magazine.solarzoom.com/201012/images/ss5.png

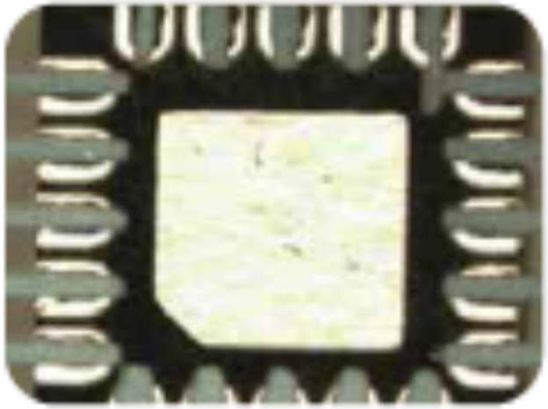
- Viskositäten bis ca. 5000 mPas druckbar
- Strukturgrößen unter 20 µm möglich
- langsames Verfahren (eine Nozzle)
- hoher Materialverbrauch (kontinuierlicher Fluss)
- hoher Materialeinsatz (Schlauchsystem)



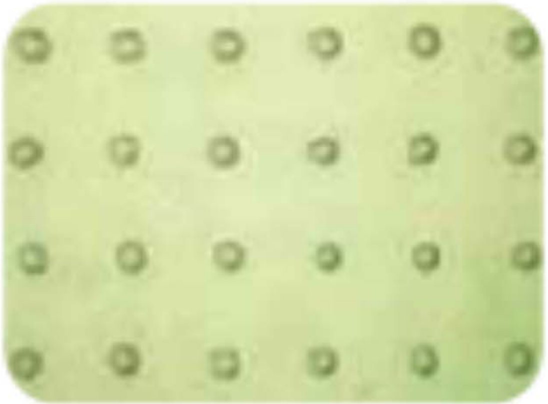


w=75 µm, d= 2 µm

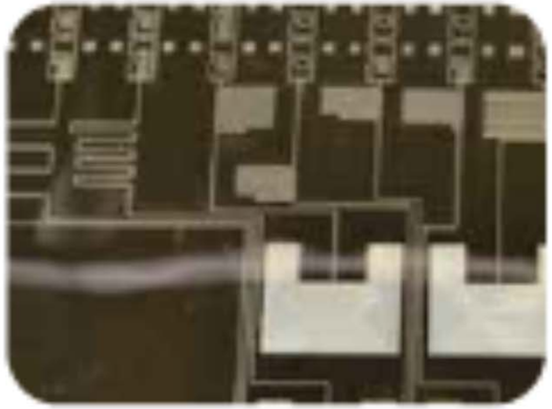
Aerosol Jet Printing Examples



QFN Chip

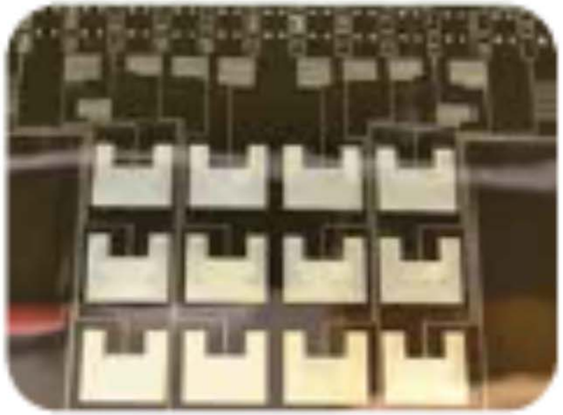


Printed Biologics



Phased Array Antenna, Ag
Printed on Kapton

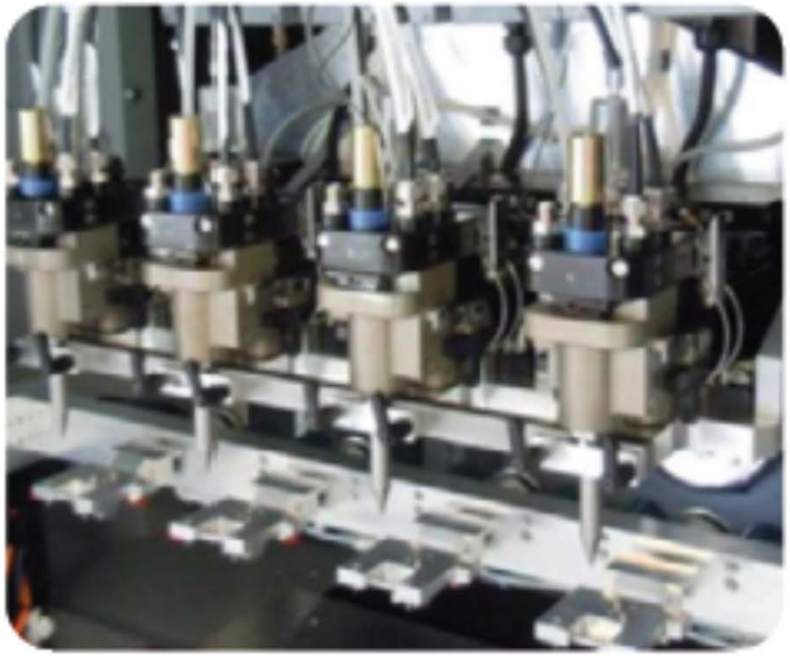
Smart Phone Main Antenna



Phased Array Antenna

Strain Gauge on
Aluminum Structure
Courtesy: Fraunhofer IFAM

Industrie Aerosol Jet Scaling ?



Quad Aerosol Jet Print Engine Integrated with multi-axis automation platform.
Photo courtesy of Neotech AMT GmbH.

Aerosol Jet Marathon II Print Module

Application: Smart Phone Antenna
Normal resolution 100µm, best conditions: 40-60µm

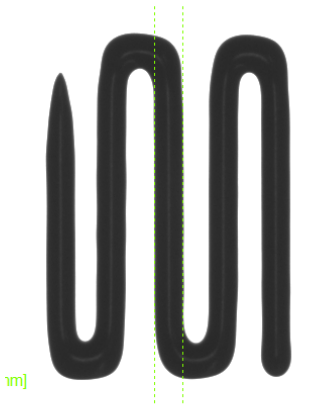
Dispenser

→ Leitfähige und isolierende Strukturen

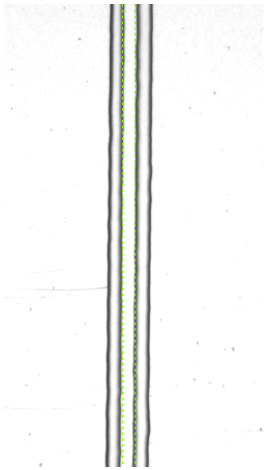
(http://www.chjtech.com/UserFiles/Product/image/20140617/20140617085937_0010.gif)

Versuchsmaterialien	Viskositäten (mPas)
- Ag-Nanopartikelpaste CA-2503-4	200000
- Polyimid PI 2611	11000
- Ormoclad	2500

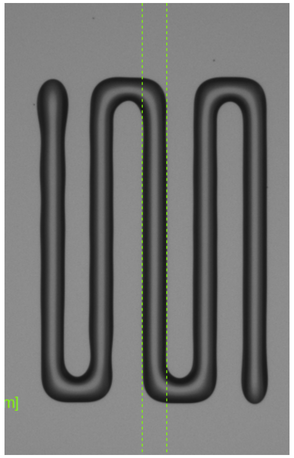
Substrate: Si, PEN, PI



Ag-Paste auf Si
(L=104µm)

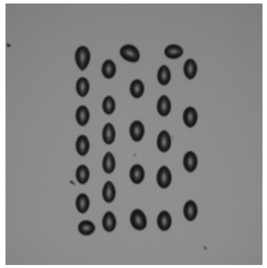


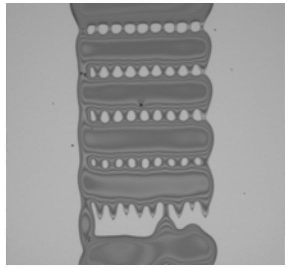
PI auf PEN
(L=51 µm,
B=50 µm)



Ormoclad auf PI
(L=90 µm)

Herausforderung:





SHS Selective Heat Sintering - Thermoforming

Properties	Condition	VisiJet M3 Dentcast	VisiJet M3 PearlStone	VisiJet M3 Stoneplast	VisiJet S300
Composition		UV Curable Plastic			Wax Support Material
Color		Dark Green	White	Natural	White
Bottle Quantity		2 kg	2 kg	2 kg	2 kg
Density @ 80 °C (liquid)	ASTM D4164	102 g/cm³	104 g/cm³	102 g/cm³	N/A
Tensile Strength	ASTM D638	32 MPa	40 MPa	41 MPa	N/A
Tensile Modulus	ASTM D638	1724 MPa	1794 MPa	1850 MPa	N/A
Elongation at Break	ASTM D638	12.3%	7.7%	17%	N/A
Flexural Strength	ASTM D790	45 MPa	N/A	51 MPa	N/A
Heat Distortion Temperature	ASTM D648 @ 0.45 MPa	N/A	88 °C	56 °C	N/A
Ash Content		0.01%	N/A	N/A	N/A
Melting Point		N/A	N/A	N/A	60 °C
Softening Point		N/A	N/A	N/A	40 °C
USP Class VI Certified		No	No	Yes	N/A
Printing Modes Compatibility		UHD, HDX, HDP	HDX, HDP	HDX, HDP	UHD, HDX, HDP
Description		Wax-up castable material	Solid stone appearance	Transparent, clear or stone finish**	Non-toxic wax material for hands- free melt-away supports

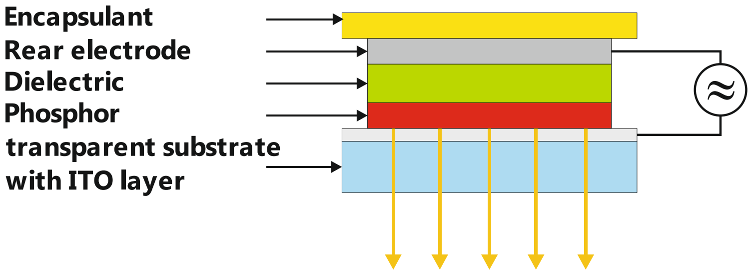
Picture source unspecific internet

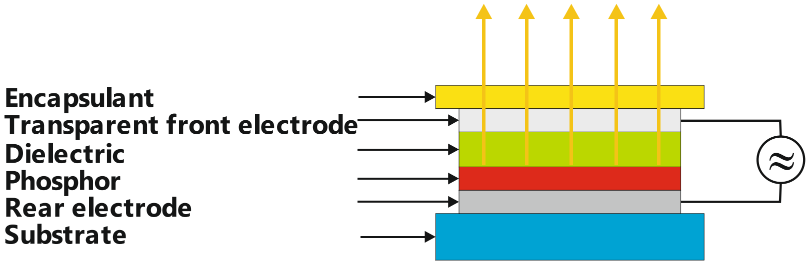
Thermoforming Dental

Normal resolution 40 µm, best conditions 29µm, approx. 890dpi

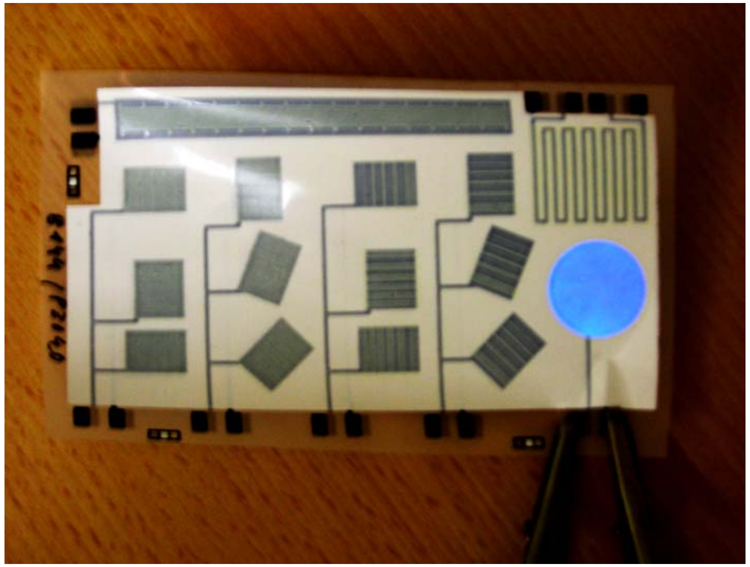
Picture source unspecific internet

Screen Print - Electroluminescence devices



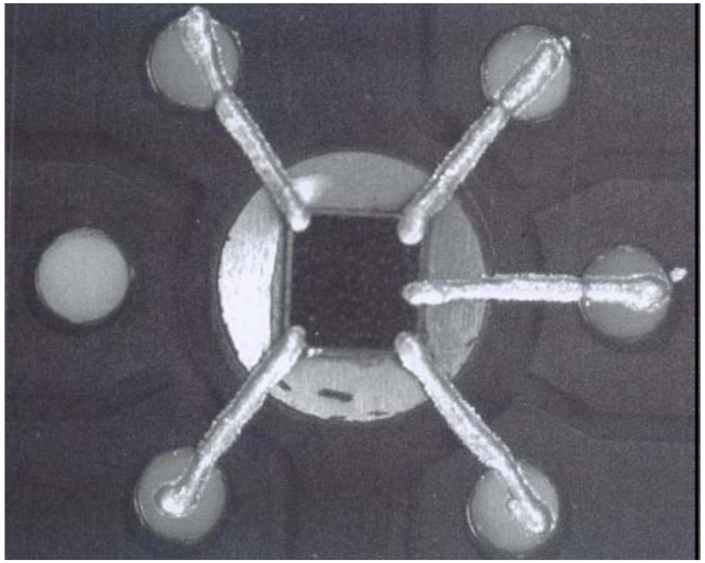


Build sequence 1 **Build sequence 2**



Electroluminescence
demonstrator Ver. 1

InkJet



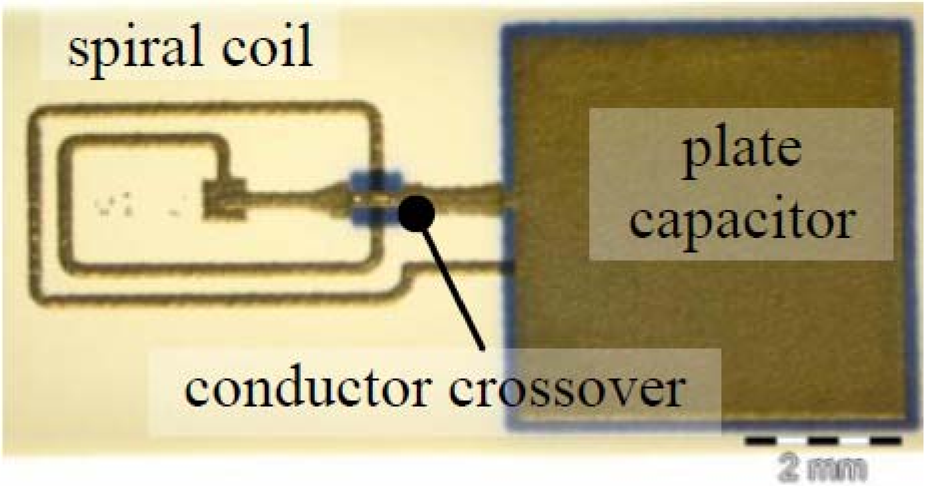
Multifunktionale SmartCard
(EU-Projekt FORMAT)

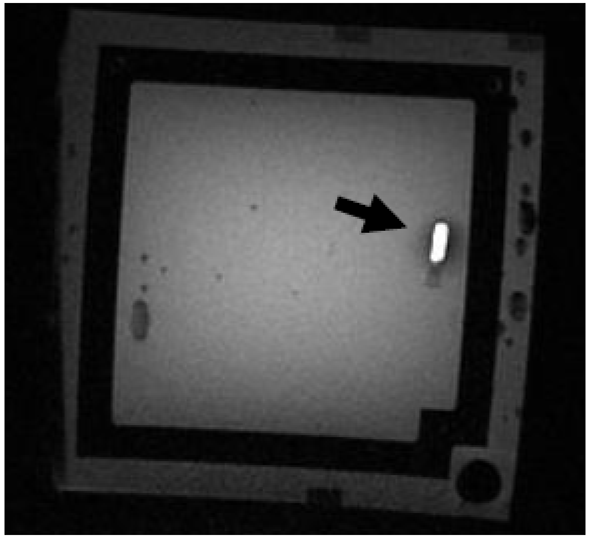
flexible Batterie (aufladbar)
flexibles Display (80 x 16 Punkte)
Display-Treiber (104 Pads, Pitch 150µm)
biometrischer Sensor
Tastatur
Dual Interface (RFID, Kontakt)

Direkte Chipkontaktierung
Von SmartCard-Modulen

Screen Print Planare Resonanz-Marker

- **Zusammenarbeit mit der Otto-von-Guericke-Universität Magdeburg**
- **Sichtbarmachung von medizinischen Instrumenten im MRT**



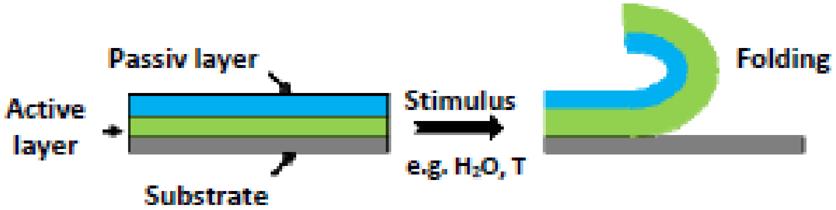


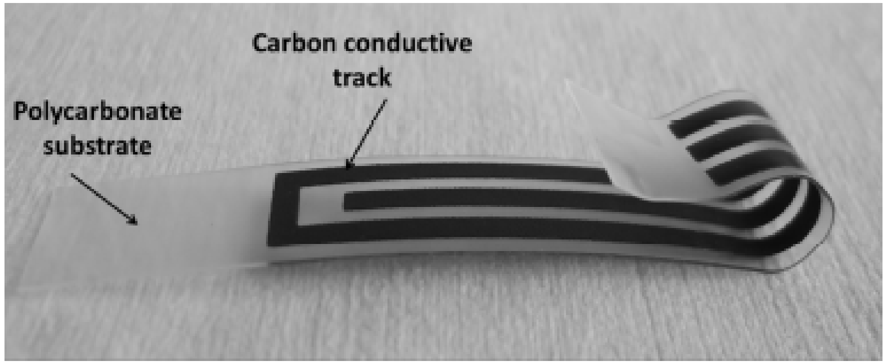
Screen Printed Carbon Inks → Electrodes

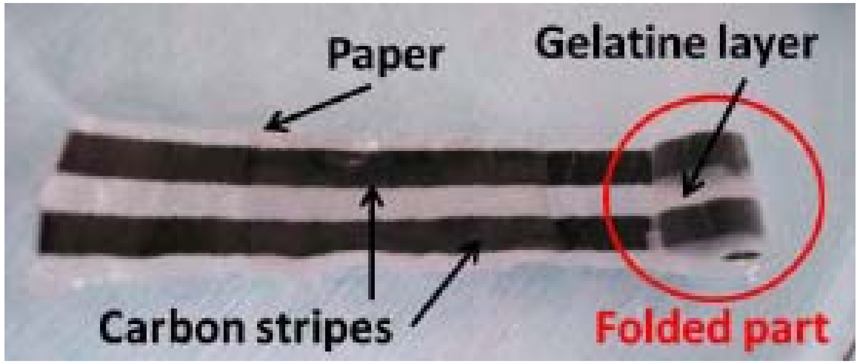
- Überwachung und Stimulation von Nervenbahnen

- Druck auf flache Folien
- Umformen des thermoplastischen Substrats

- Realisierung einer selbstfaltenden Elektrode

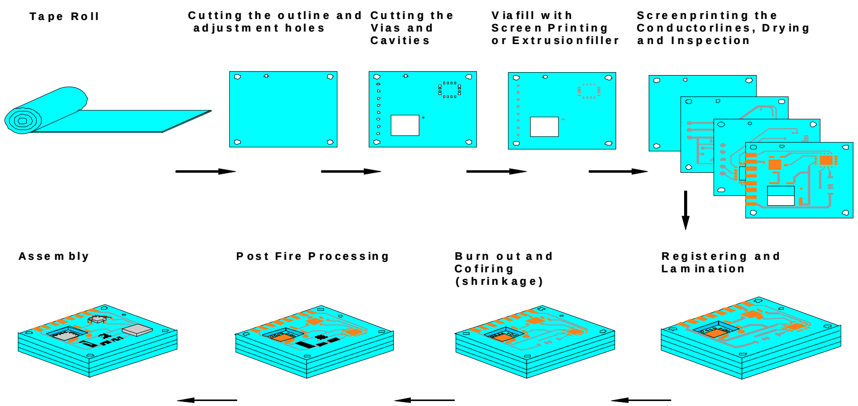




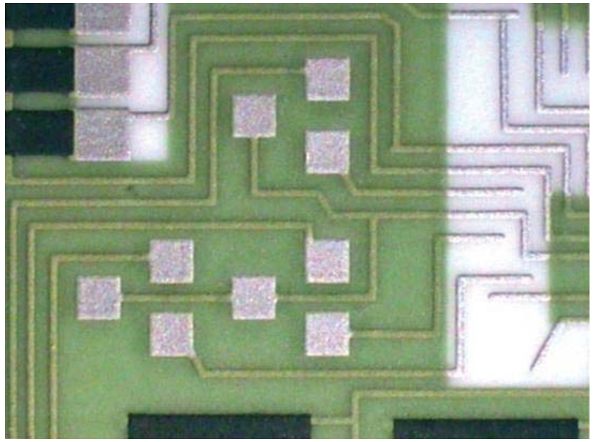


AM in Thick film technology

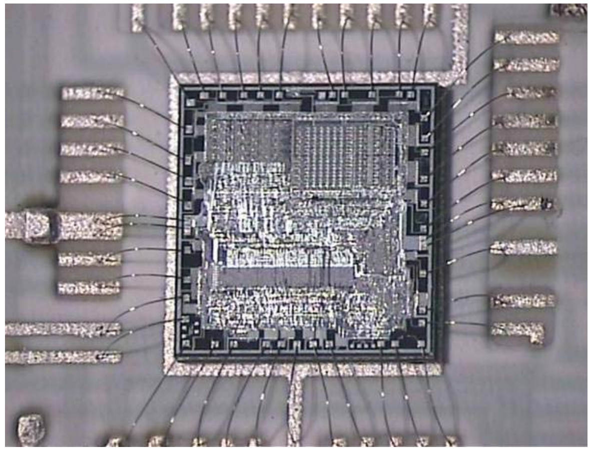
- Multilayer technique on rigid ceramics
- Multilayer technique with LTCC
  - 3D LTCC- Substrate
  - Micro-fluid LTCC systems
  - Embedded passive components
- Application of polymer thick-film paste
- Application of photo structured thick-film paste
- Laser processing
- Assembly



Prozessablauf LTCC



Thick film substrate (Al2O3) with printed and cured conducting lines



Thick film substrate with assembled IC and wire bonded connections

Future AIM: AM➔„Assembly-free“ (organic) Electronic Systems

NOW Assembled Electronic

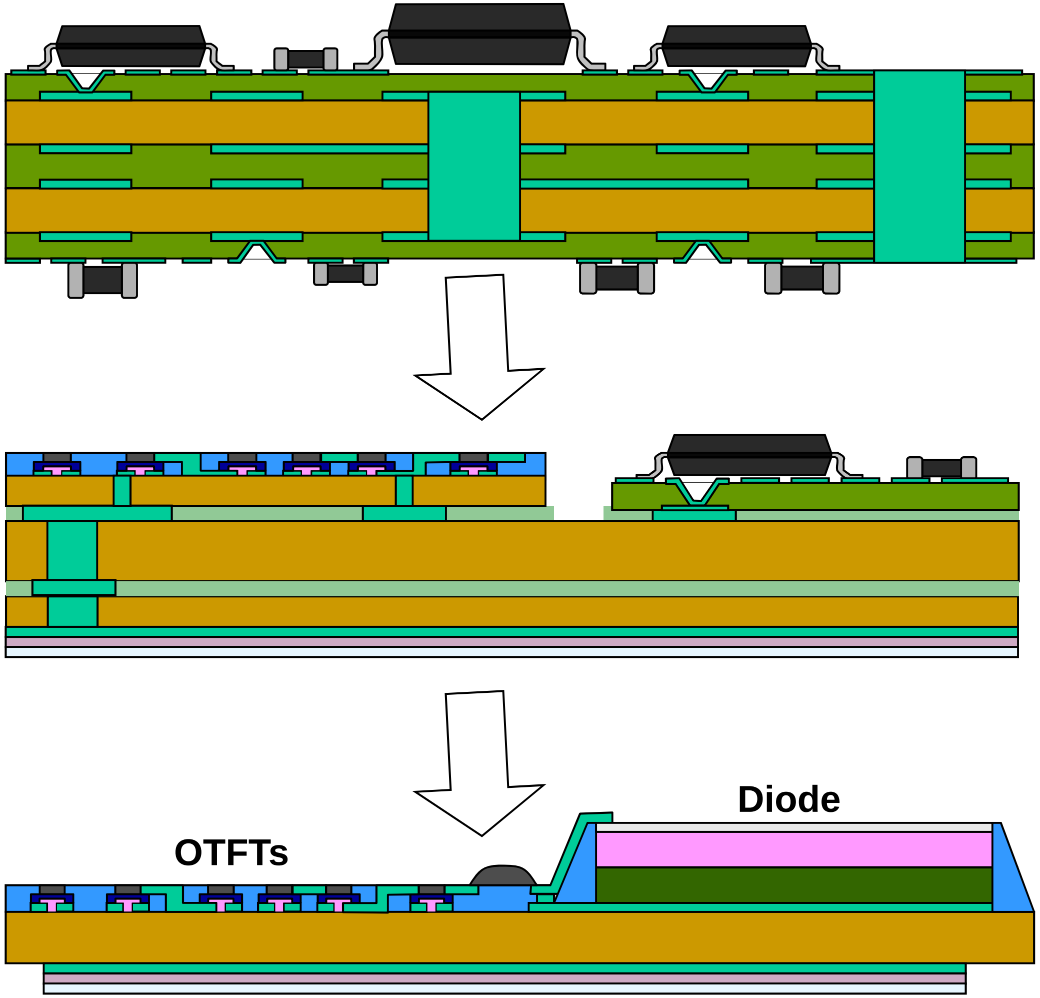
Many packaging Levels Assembly and Interconnection, board assembly

SOON Plastic Film Assembly

Heterointegration of Plastic film subsystems

FUTURE Plastic Electronics

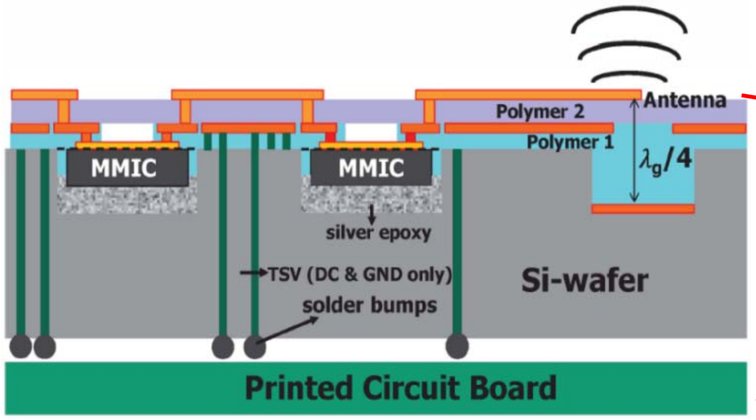
Mainly coating and patterning steps with functional materials

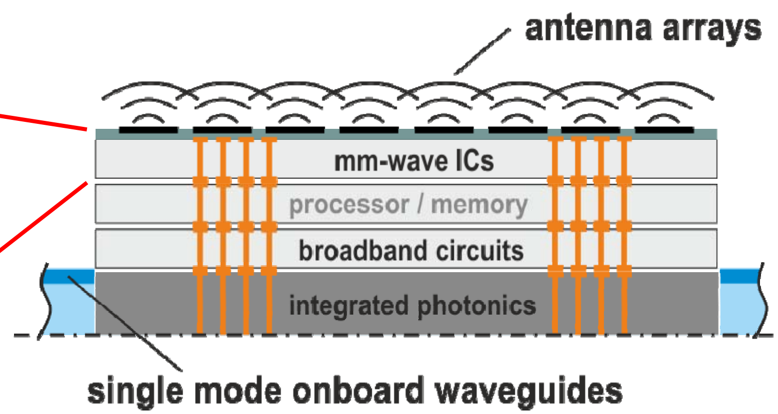


DFG SFB 912 HAEC – wireless communication

STOA: Si-Interposer System up to 170 GHz

HAEC: Optical and Wireless Integration





- Structured cavities in Si-interposer
- Polymer-based multilayer waveguides and antennas
- 3D chip in foil stacks

Cooperation with Sony Research Labs Stuttgart

Reference: E. Topak,..., K. Bock et al., Proc. of EMW 2013

100 Gb/s per optical link

- Novel coupling & waveguides

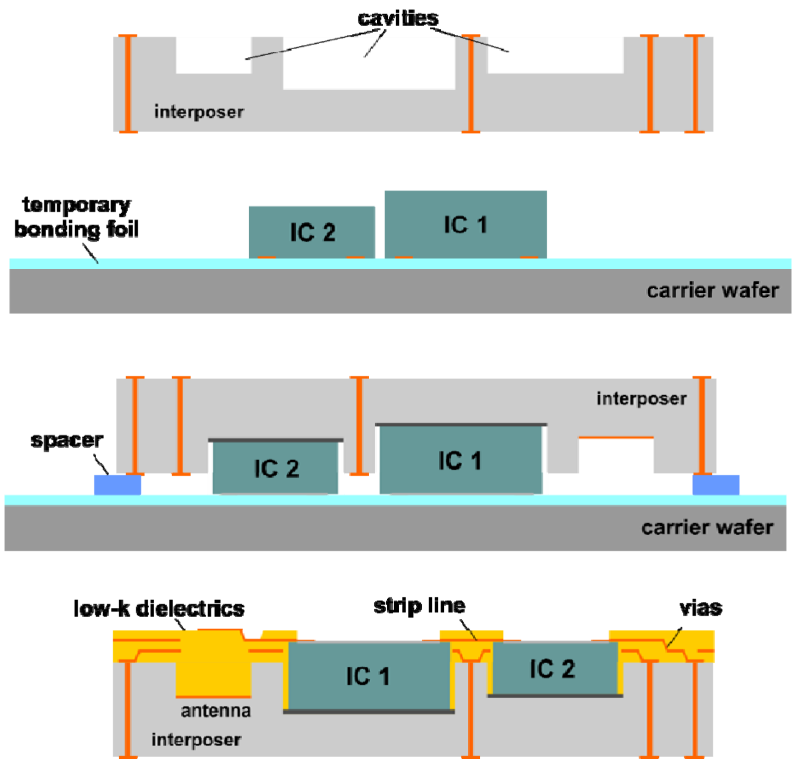
Wireless > 180 GHz

- Co-integration using polymer waveguides

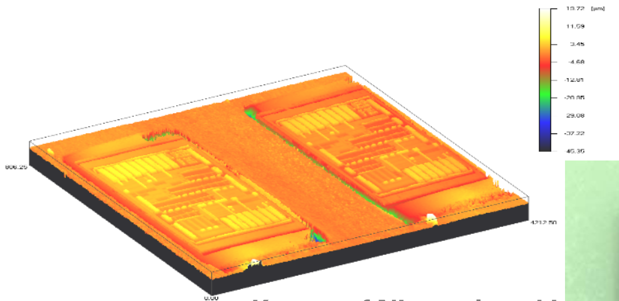
Petabit-scale HAEC Box

- 3D-stacked heterogeneous package

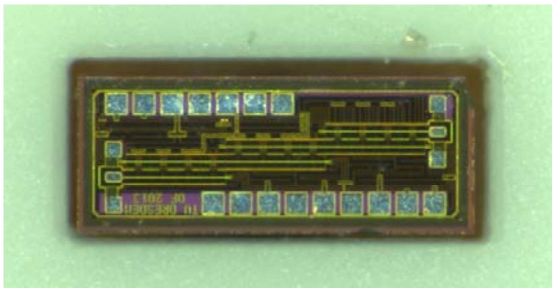
Embedding of mm-wave ICs

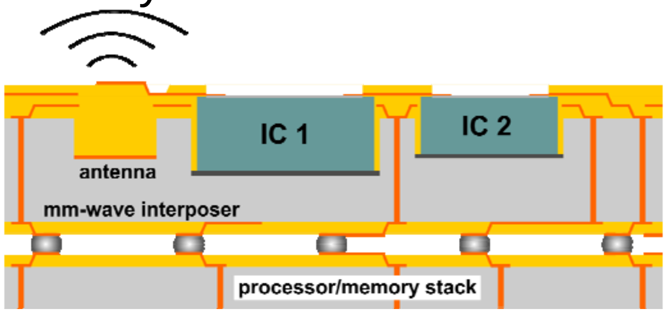


- Structuring of interposer (cavities & through interposer vias)
- Alignment and temporary bonding of Ics
- Bonding of ICs with interposer
- Debonding & fliping
- Sequential build-up of metal/low-k dielectrics multilayer



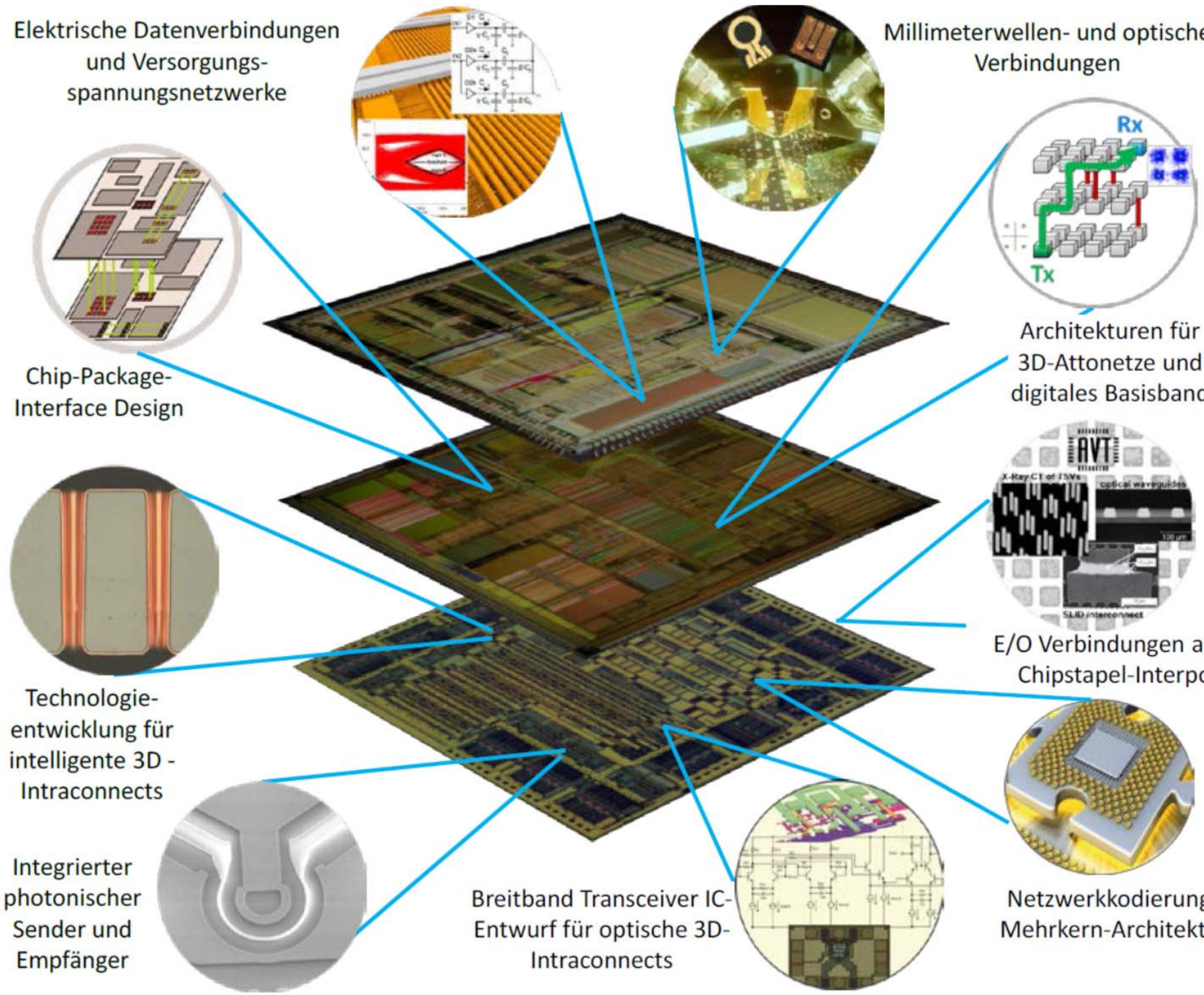
Krzysztof Nieweglowski





ESF-Nachwuchsforschergruppe: Atto3D
09/15 - 08/18

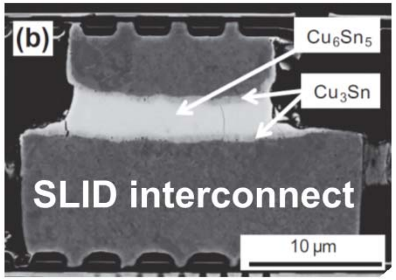
„Kommunikationsinfrastrukturen für Attonetze in 3D Chipstapeln (Atto3D)"

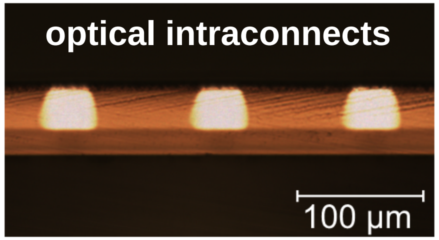


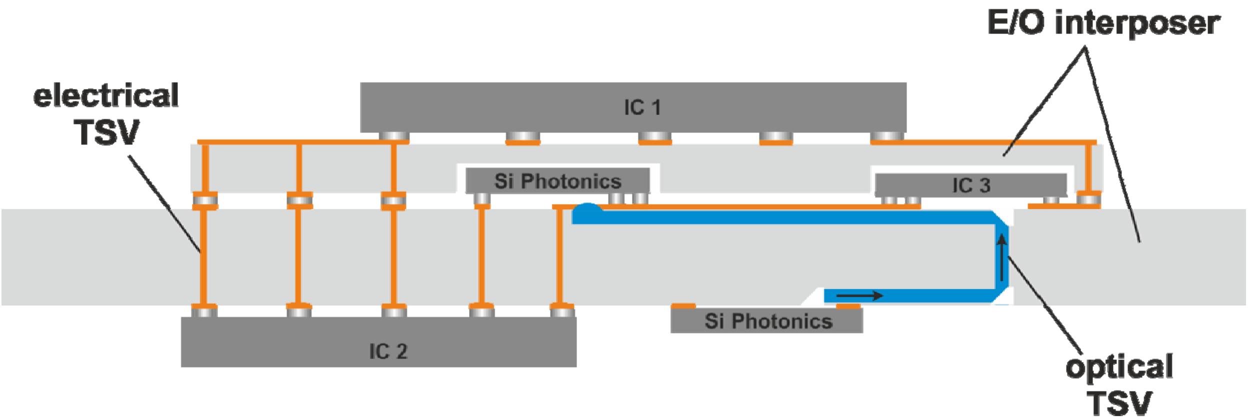
ESF-Nachwuchsforschergruppe: Atto3D 09/15 - 08/18

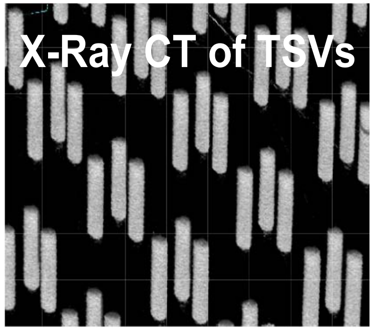
Technology plattform for electro-optical intraconnects on reconfigurable 3D-chip stack interposer

- Parallel fabrication of electrical and optical interconnects on interposer-level (interconnect to electrical and optical TSVs)
- Technologies for assembly and chip placement for 3D-chip stack
- Microanalysis and reliability investigation









Krzysztof Nieweglowski

AVT ZENTRUM FÜR MIKROTECHNISCHE PRODUKTION
Europäische Union
Europa fördert Sachsen. ESF Europäischer Sozialfonds

Conclusions

- Multi-Functionality ➔ Challenge for Electronics Packaging
- Highest performance, RF, lowest power ➔ modular technology integration: packaging develops towards integrated process comparable to the device front-end technology
- Front-end and back-end (packaging) merges ➔ functional substrates based manufacturing
- Digital manufacturing and additive technologies like (3D) printing and self-alignment and self-assembly combined with thin- and thickfilm processes
- New materials and process co-integration
- Packaging concept needs to be considered early in the product planning (change of paradigm)