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Technologies for the additive manufacturing of 3D electronics

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Multi-material additive manufacturing enables the integrated generation of mechatronic functions.

FAPS

functionality

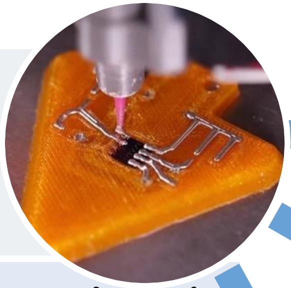
Rapid Prototyping

Source: Shapeways

Additive Manufacturing

Source: Concept Laser

Additive Mechatronics



Source: Voxel8

time

Electrical functions, e.g.
- Circuitry, cables
- Antennas
- Connectors, switches
- Shielding

Sensor functions, e.g.
- Resistive
- Capacitive/ inductive
- Photo-voltaic
- Strain gauge sensors

Actuating functions, e.g.
- Bi-metallic actuators
- Electric motors
- Di-electric Elastomeric Actuators

Control and other functions, e.g.
- Optical waveguides
- RFID
- OLED

Geometrical objects
- No physical requirements, except for the geometry
- Example: design studies

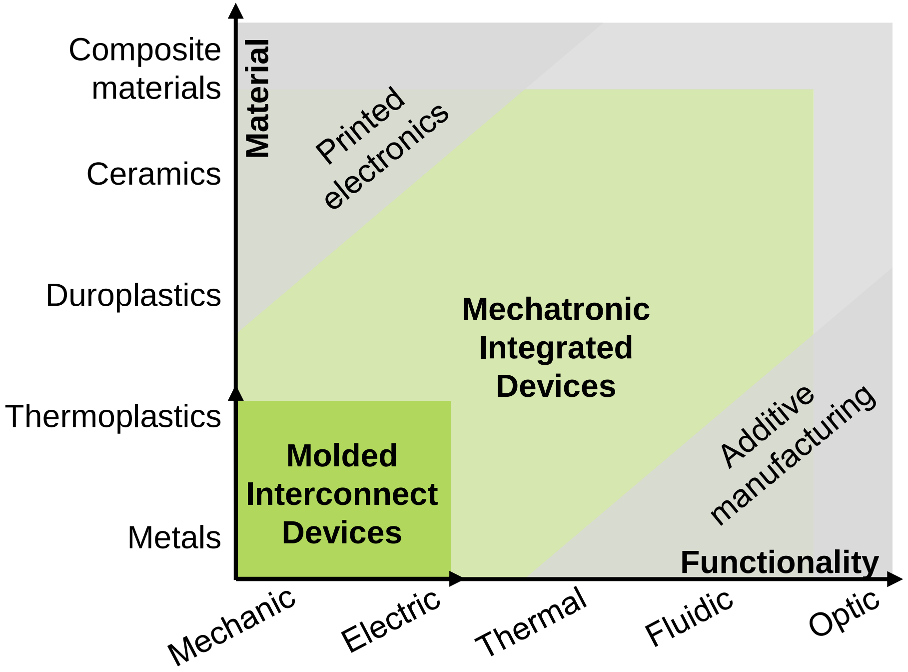
Mechanical objects
- Parts with high mechanical requirements
- Example: structural bracket

Mechatronic systems
- Products with integrated mechatronic functions
- E.g. three dimensional PCBs with integrated electronics

MID – from Molded Interconnect Devices to Mechatronic Integrated Devices.

MID-basic principle

3D-Substrate **3D-MID** **3D-Layout**



Molded Interconnect Devices

- 3D-MID are spatial *injection molded* parts with integrated conductor tracks.
- The technology allows the combination of *mechanic* (injection molding) and *electric/ electronic* (selective metallization) functionalities in one device.

Mechatronic Integrated Devices

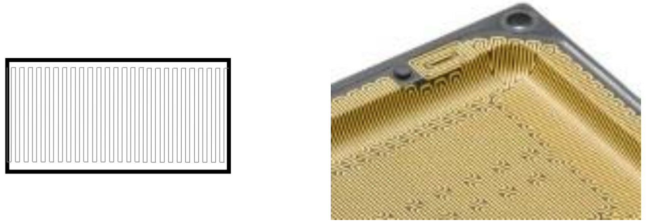
- 3D-MID are mechatronically functionalized spatial parts.
- The technology allows the combination of *mechanic, electric/ electronic, thermal, fluidic and optic* functionalities in one device.

The manifold integration capabilities of the MID technology offer big potentials for innovative product solutions.

Antennas

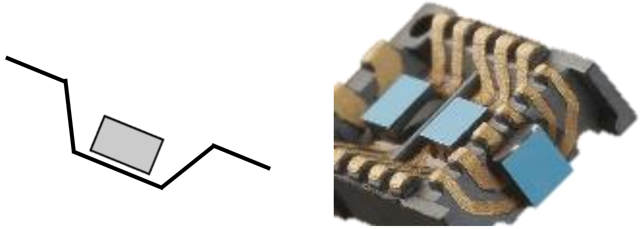
Mounting elements

Shielding / Security structures



HARTING Mitronics

Orientation of components



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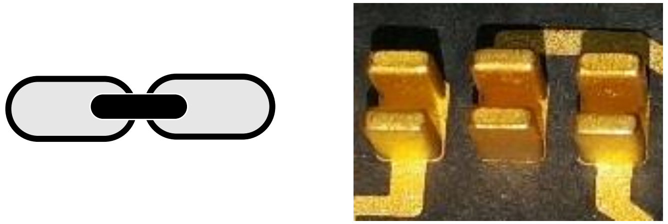
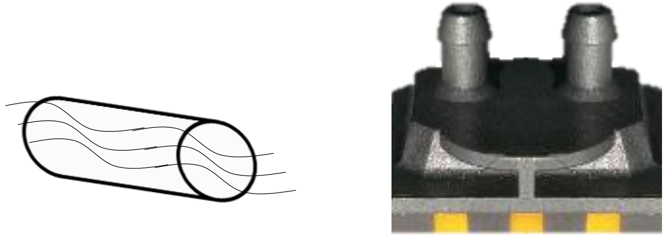
Contacting elements



HARTING Mitronics

Fluid channels



2E mechatronic

Design freedom

Reduction of components

Increased functional density

Weight reduction

The suitability of additive manufacturing processes for RF structures is examined by using a helix antenna as a demonstrator.

FAPS

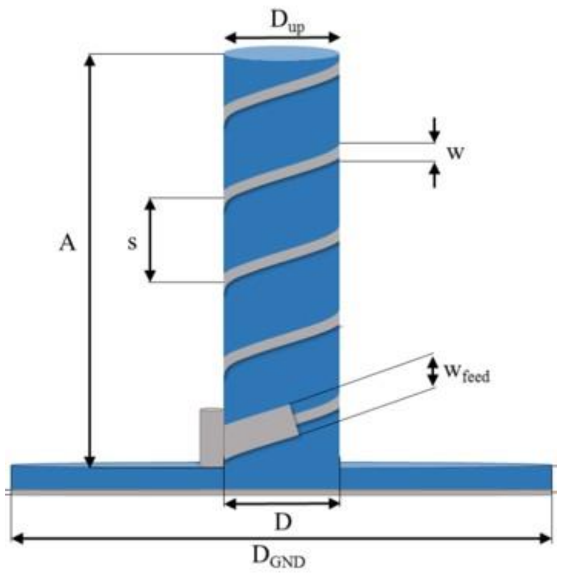
Applications for helix antennas

Communication technology

- IoT
- 5G
- WLAN @ 60 GHz

Radar sensor technology

- Autonomous driving
- Unmanned airplanes
- Imaging radar systems
- Locating technology



Process chain

1. Substrate generation

- Fused Filament Fabrication (FFF)
- Stereolithography (SLA)

2. Functionalization

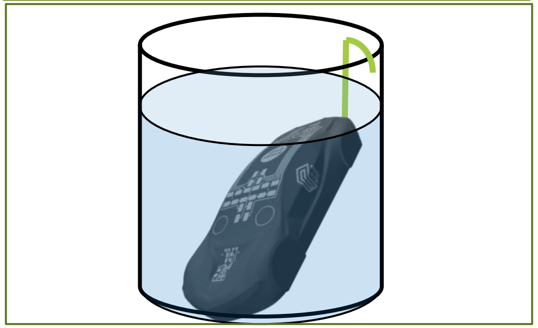
- Laser Direct Structuring
- Nanojet

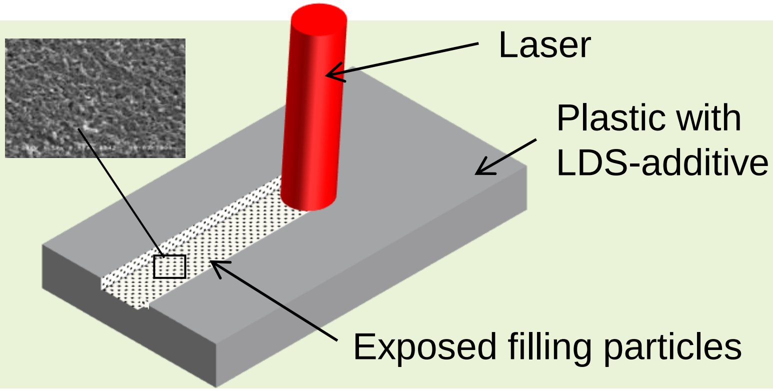
Challenges

- Limited accuracy of printed objects
- Uneven surfaces, high surface roughness
- Incompatible materials, e.g. no adhesion of ink

Laser Direct Structuring (LDS) consists of substrate production, laser structuring and chemical metallization.

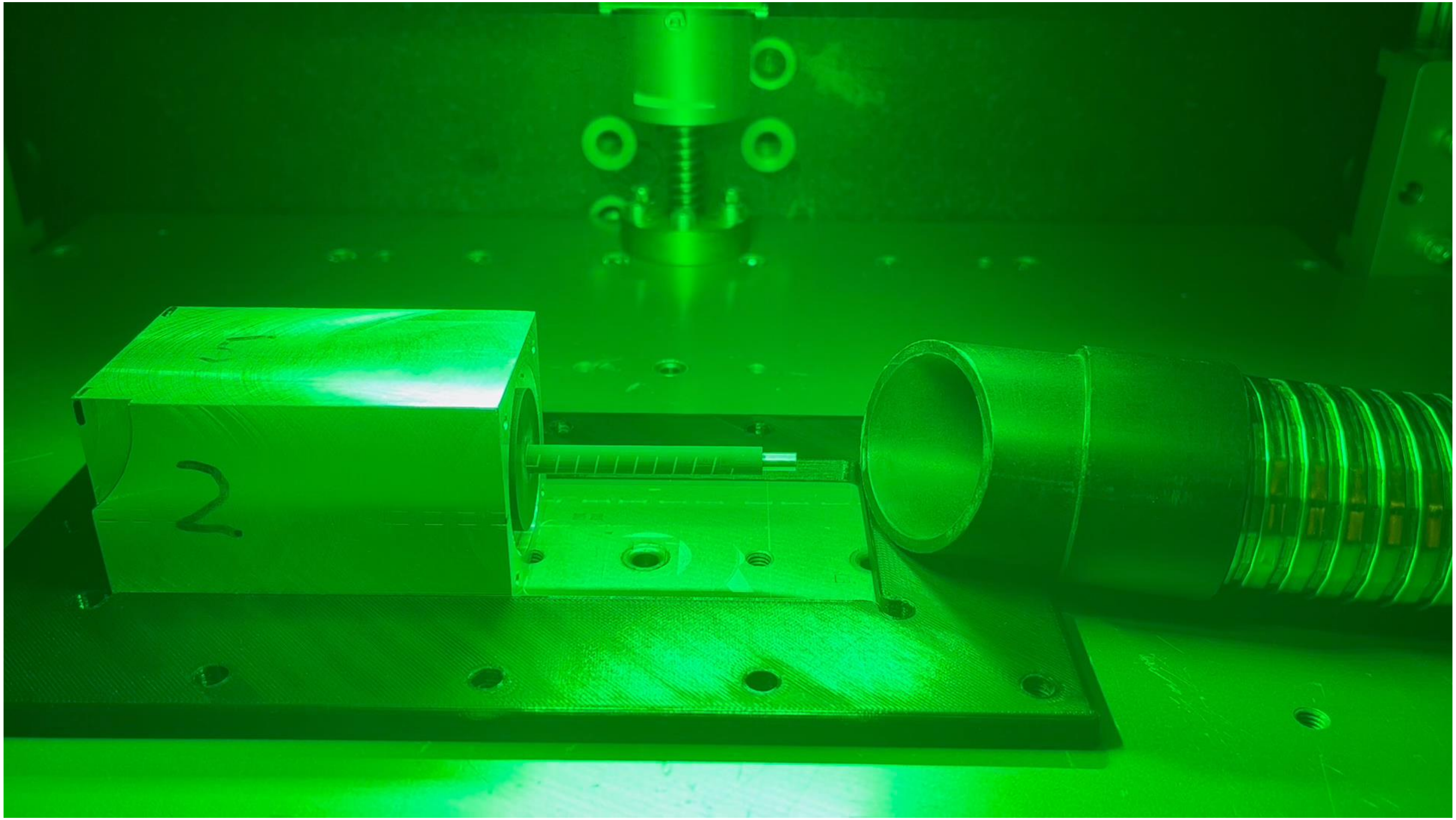
Production of the MID circuit carrier			Mounting of SMT components
Substrate Production	**Generation of circuit tracks**		**Assembly**
	Structuring	Metallization	
Injection molding	Laser structuring (additive)	Chemical Process	



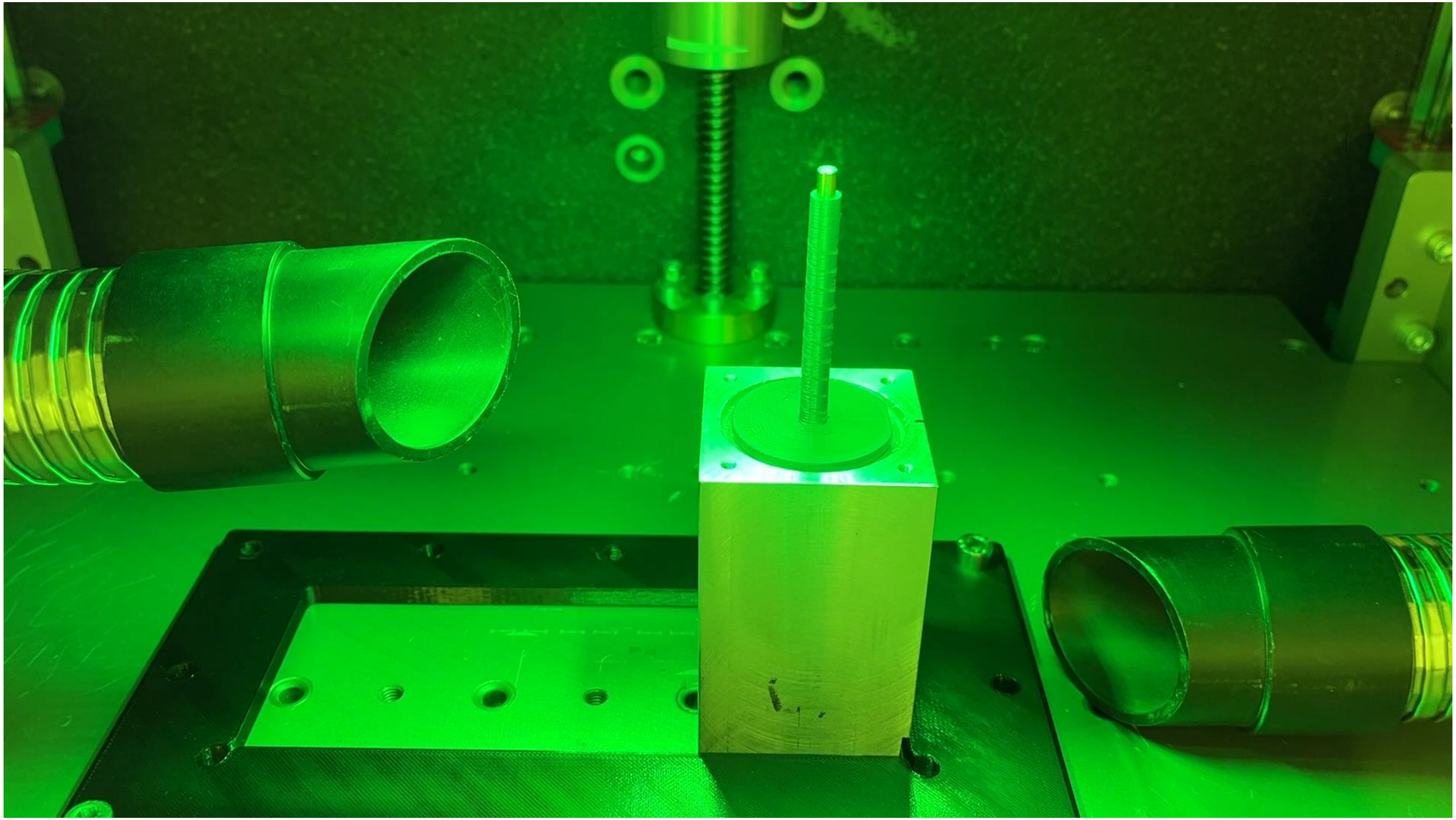


- Thermoplastic material filled with laser activatable additive
- Laser structuring causes ablation and activation of the additive on the substrate surface
  → micro-rough surface with catalytic nuclei
- Metallization in electroless copper bath
  (typical layers: Cu-Ni-Au)

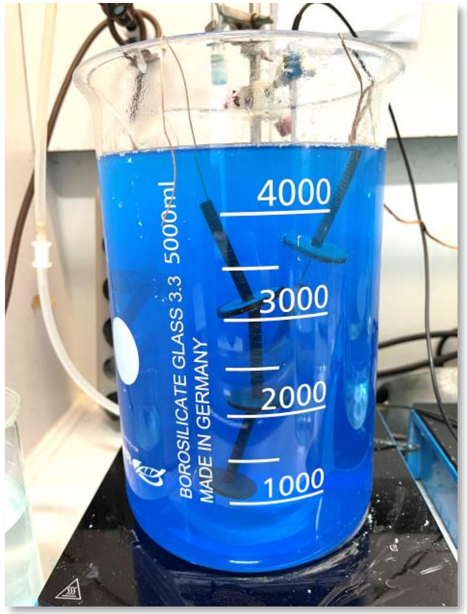
The video shows the structuring of a helix antenna via laser (1/2)



The video shows the structuring of a helix antenna via laser (2/2)



After laser structuring, the layout is chemically metallized in a copper bath.



Metallization
(Cu)

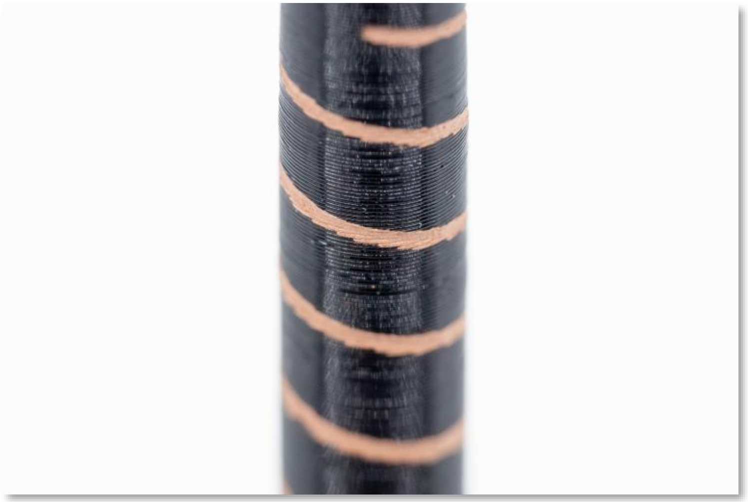
Makrolon
(FFF)

Xantar
(FFF)

Experimental resin
(SLA)

Challenges of Laser Direct Structuring (LDS)

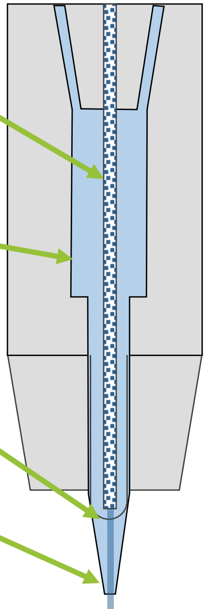
- Substrates containing the LDS-additives are laser-structured and metallized in an electroless copper bath
- Height differences of the FFF-surface lead to inhomogeneous activation of the layout
- Challenges due to residues from the lasering process causing unwanted metallization

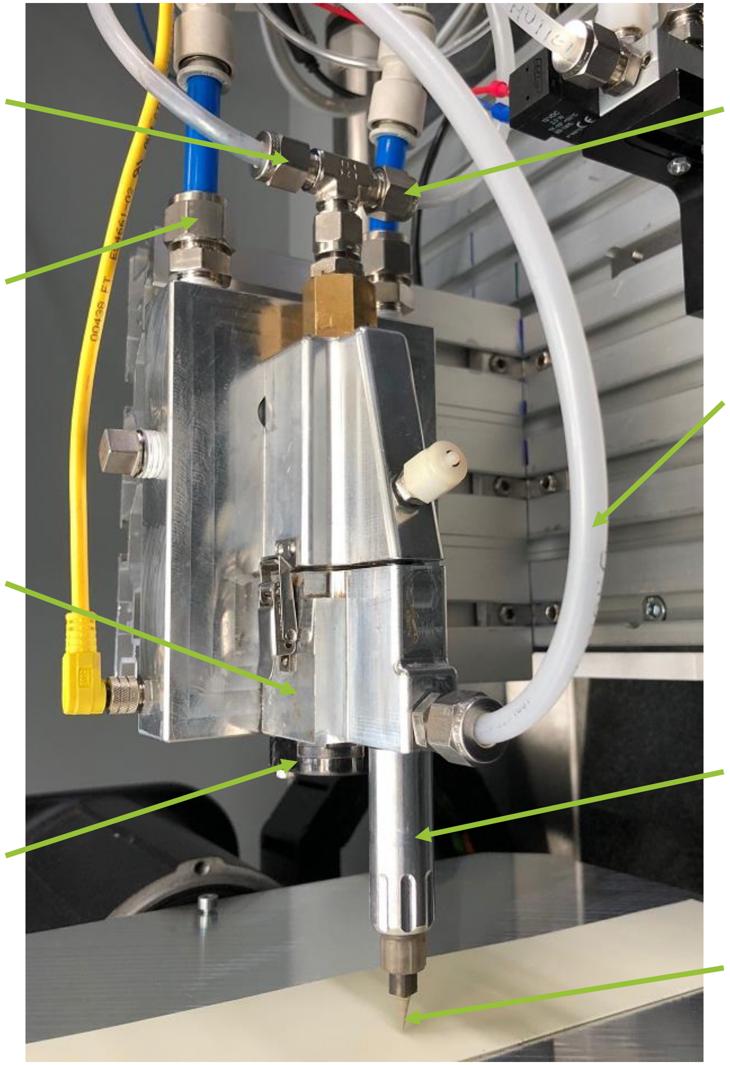


The Nanojet process enables the generation of fine structures which are required for high-frequency applications.

Nanojet

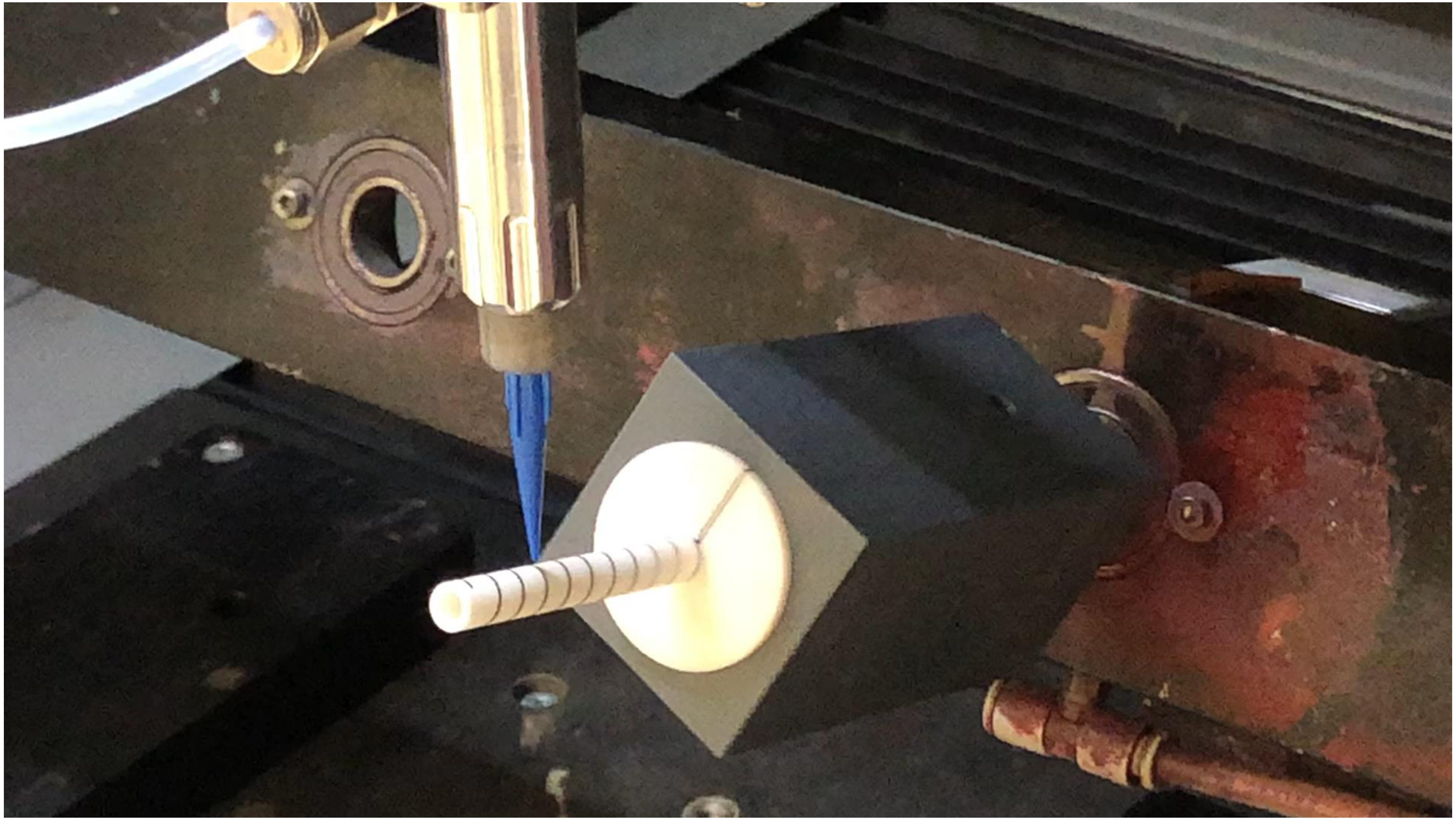
- Aerosol generation by ultrasonic atomization of functional ink
- Aerodynamic lenses focus the aerosol
- Changeable nozzles allow line widths from 20 µm to 1 mm
- Particle focusing in flow cell by lens and sheath gas
- Ink viscosities < 20 mPas





Process parameter	Value
Atomizer voltage	28 V
Chiller temperature	22°C
Aerosol flow rate	8 sccm
Sheath flow rate	50 sccm
Lens diameter	750 µm
Nozzle diameter	233 µm

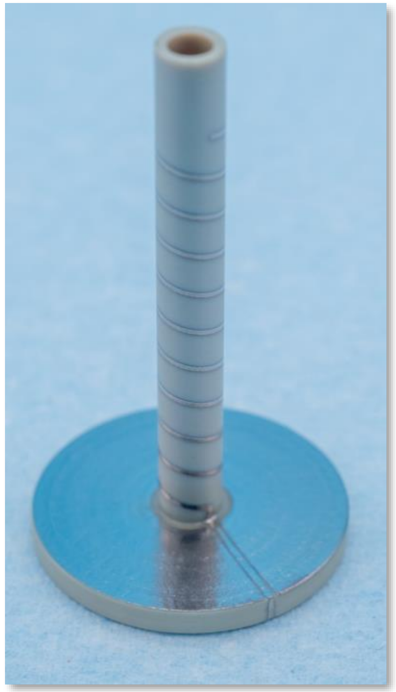
The video shows the structuring of a helix antenna via Nanojet



Printed helix antennas on different substrate materials

Formlabs Clear V4
(SLA)

PEEK
(FFF)



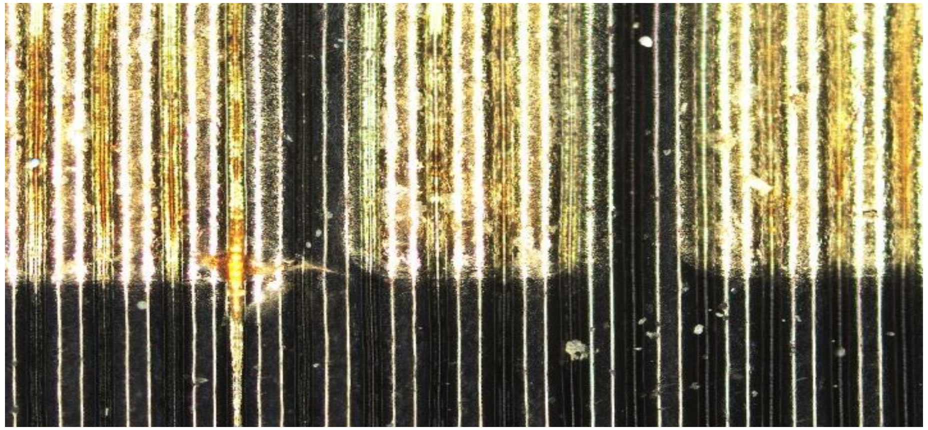
PEEK
(subtractive)

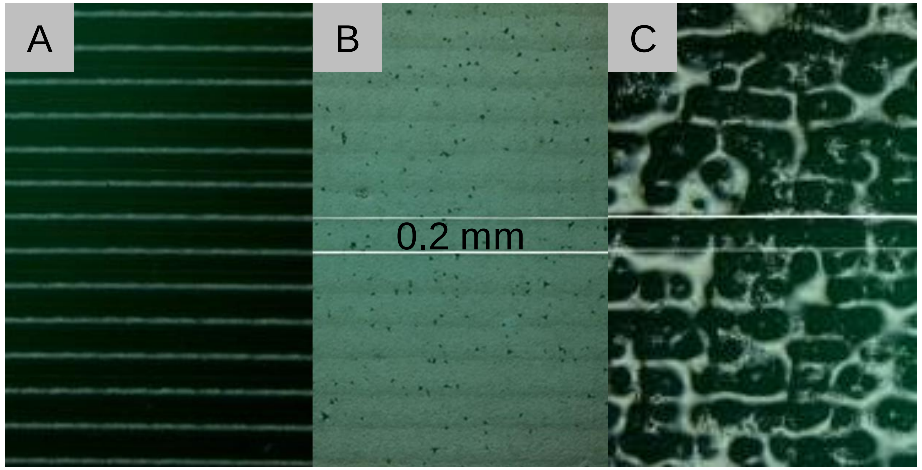
EPX82
(SLA)

Challenges of the Nanojet process

- Spreading of the low viscous silver ink in the grooves of the 3D-printed substrates
- The surface quality of the substrates needs to be optimized, e.g. via laser
- Substrate treatment in CW mode with material-dependent results:

Material	Power in W	Speed in mm/s	Repetitions	Result
PP	18	2,000	20	++
Nylon 6	18	2,000	80	+
PETG	20	1,500	80	o
ABS	20	1,500	80	o
PC	18	1,500	30	-



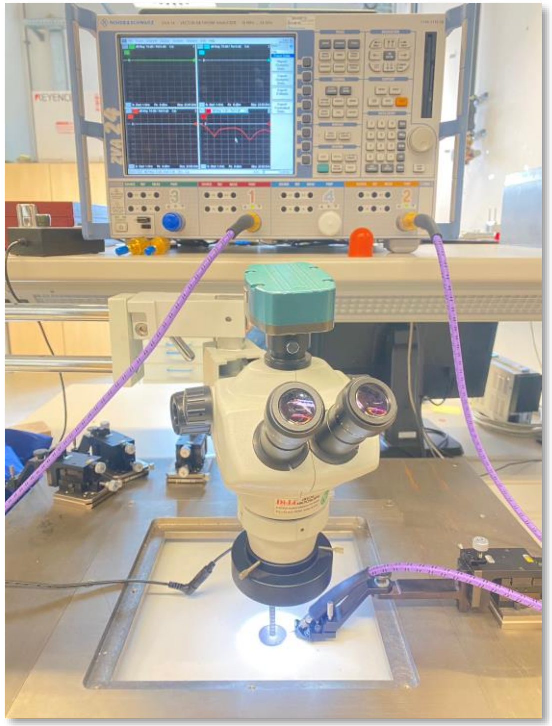


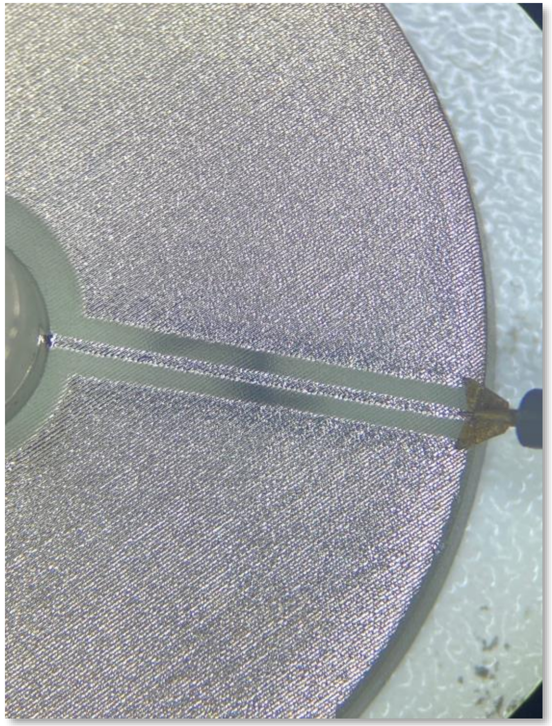
PP before treatment | PP after treatment | PC after treatment

Characterization of the specimens

1. Optical inspection of the applied structures

- Quality of the functionalization
- Edge accuracy
- Process residues
- Dimensions



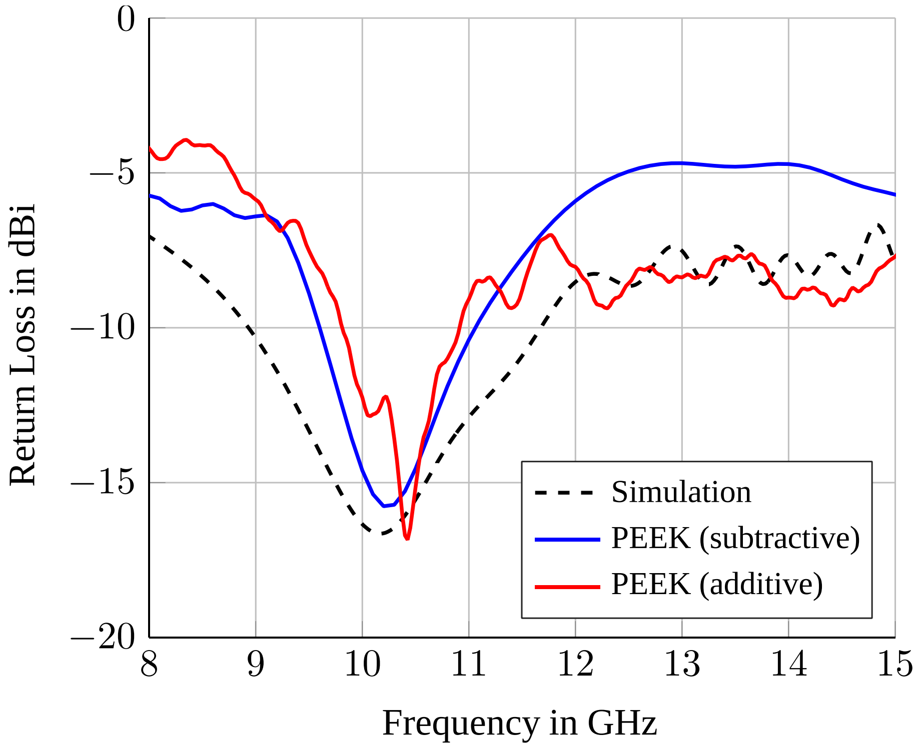


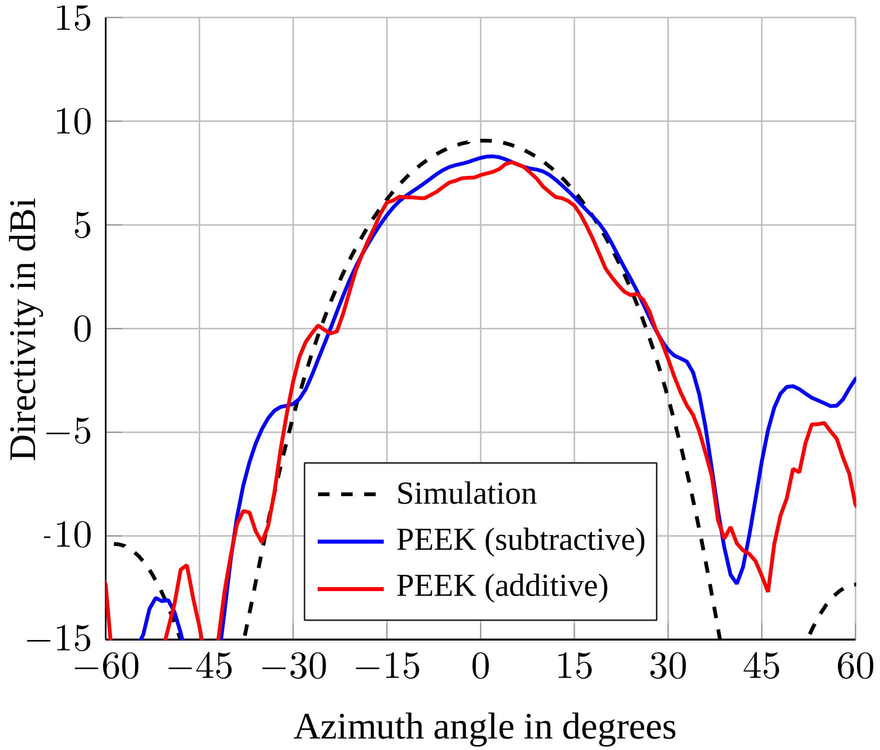
2. Electrical measurement of the return loss using a network analyzer with GSG probes

3. Measurement of the radiation pattern in an antenna measurement chamber

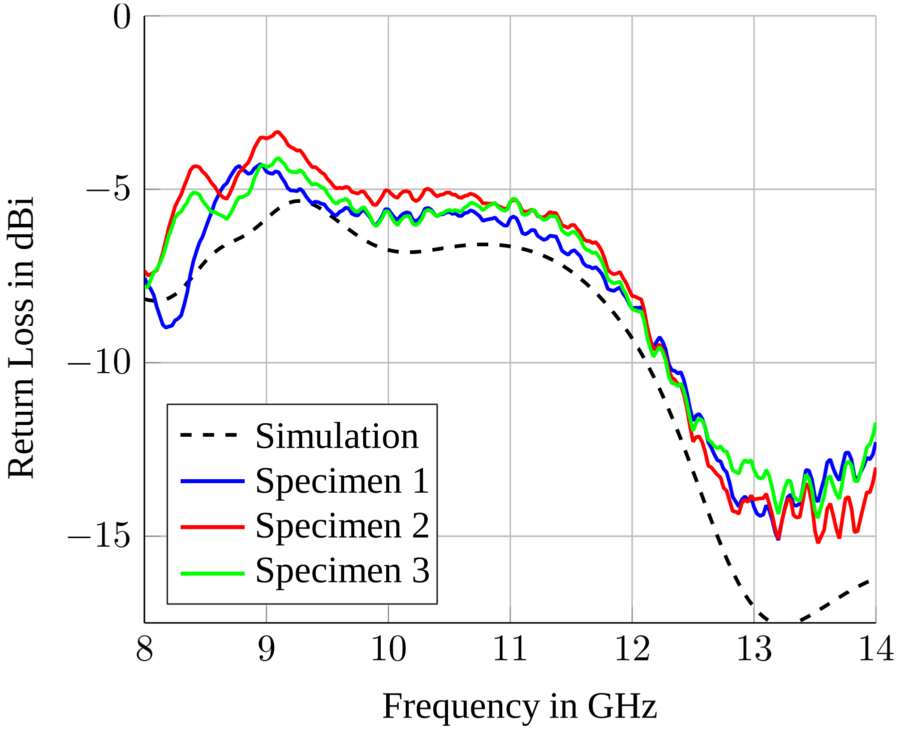
Comparison of printed helix structure on subtractively and additively manufactured PEEK substrate.

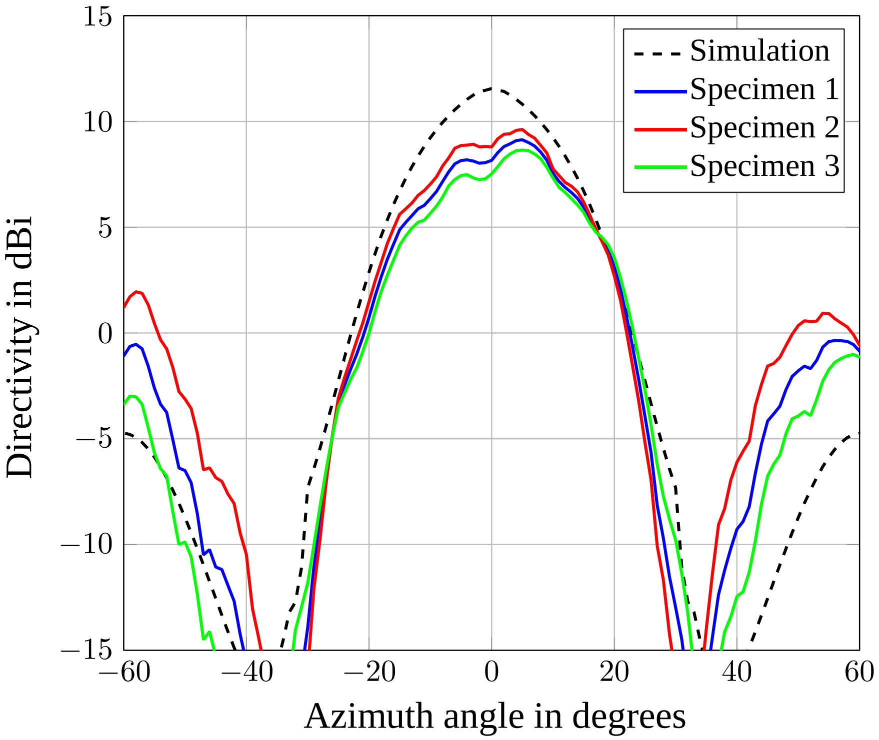
- The subtractively manufactured antenna exhibits a 7 dBi gain compared to the 6 dBi for the additively manufactured antenna.
- The influence of geometric deviations and surface roughness on the radiation characteristics is measurable, but rather small.

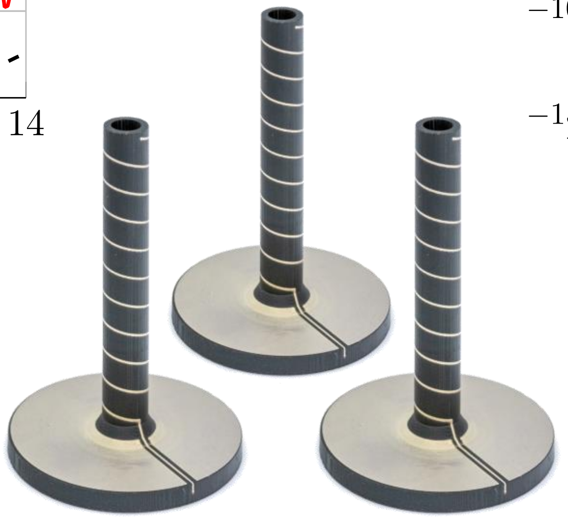




Three identically manufactured EPX82 antennas with printed traces demonstrate good repeatability of the process chain.



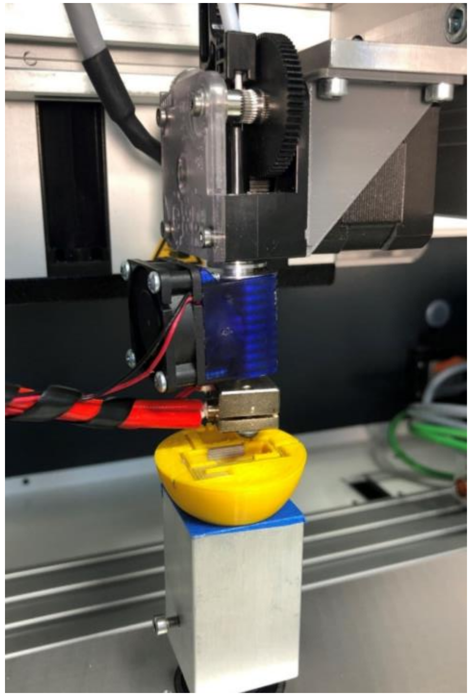


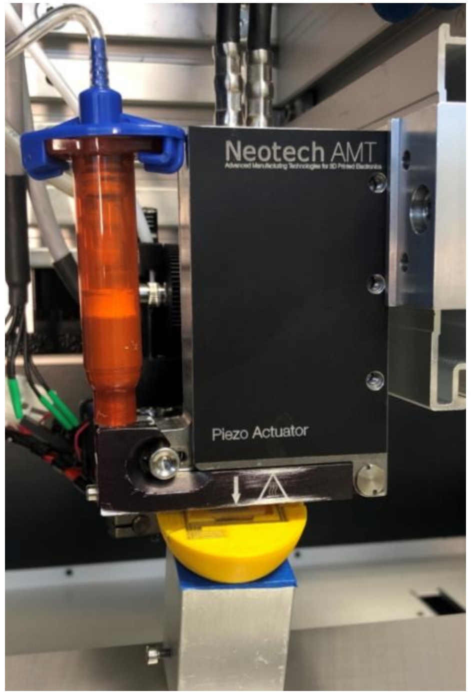


The combination of additive manufacturing, printed electronics and component placement significantly increases the design freedom of electronic assemblies.

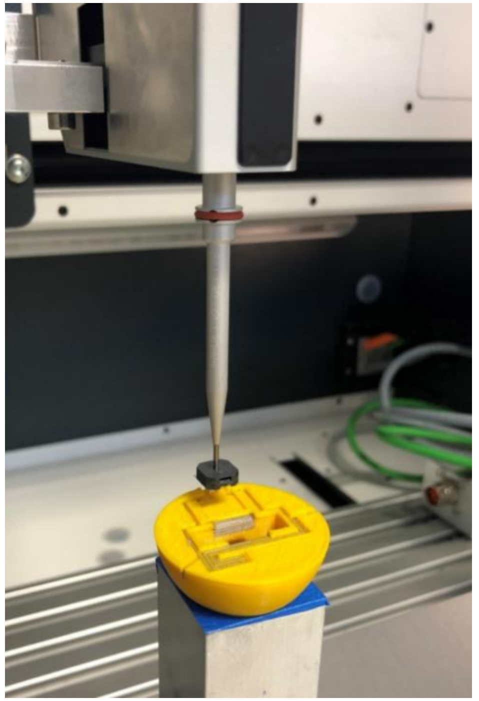
- Generation of solid bodies in any direction with 5 degrees of motion freedom
- Contactless printing of silver conductive paste with Piezojet
- Pick & Place of electronic components directly into the paste
- Curing of the paste with light or after the built process in convection oven

Neotech AMT


FFF

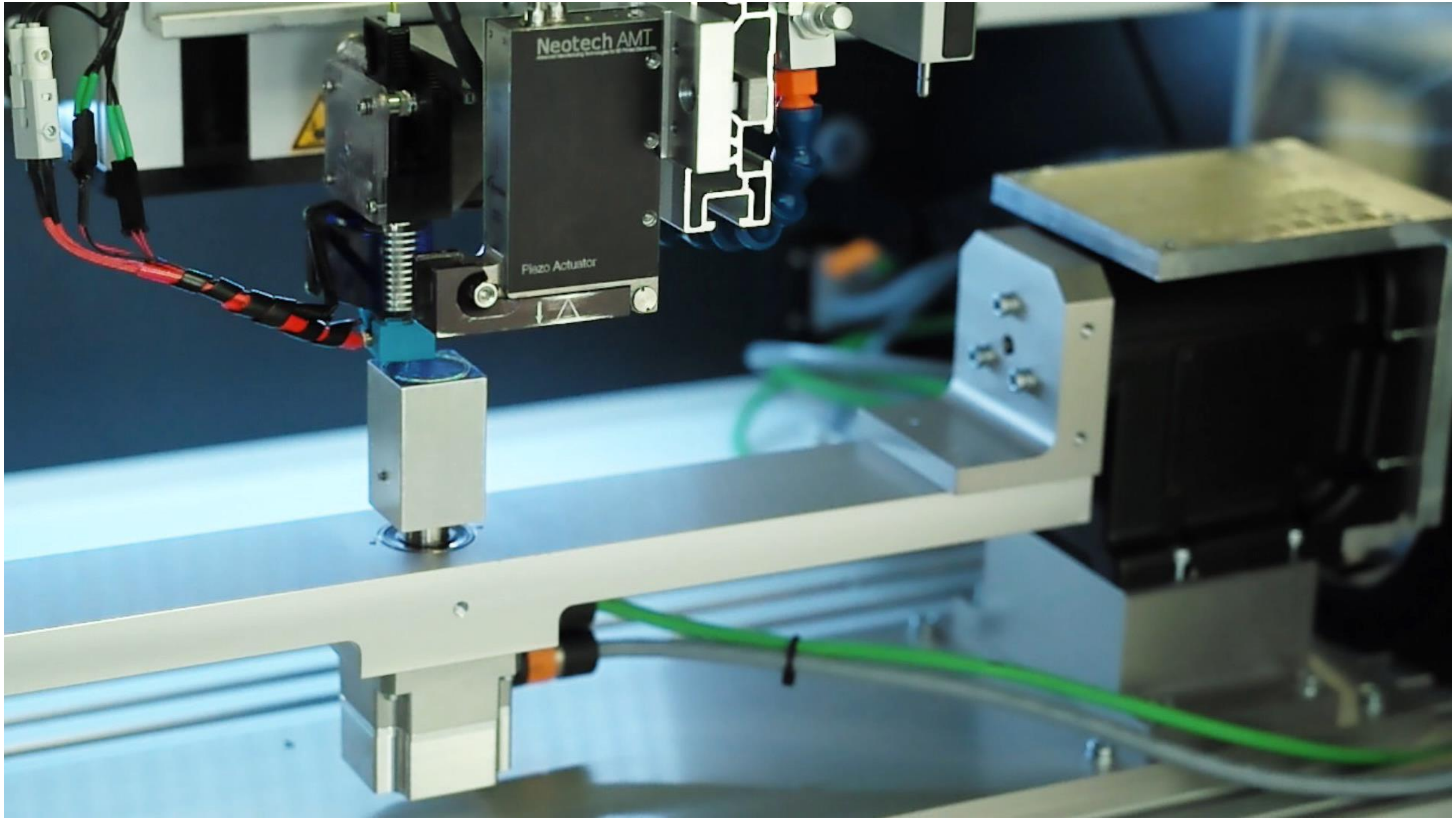


Piezojet


Pick & Place

FAPS

A time lapse video shows the manufacturing of a demonstrator with automated tool changes between FFF, Piezojet and Pick & Place.



An egg-shaped timer that can be set to 1 to 5 minutes demonstrates the potential of additively manufactured electronics.

- 20 white LEDs mounted in five rings on the outer shell
- Each LED ring represents a minute
- Embedded PIC16F627 microcontroller
- Powered by two 3 V button cells in series
- Touch switch realized by two comb-shaped pads and a transistor
- Piezo buzzer for acoustic signals
- Conductive paths with a cumulated length of 2 meters

FAPS

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