Printed 3D MIDs via Aerosol Jet – Manufacturing Technology & Applications

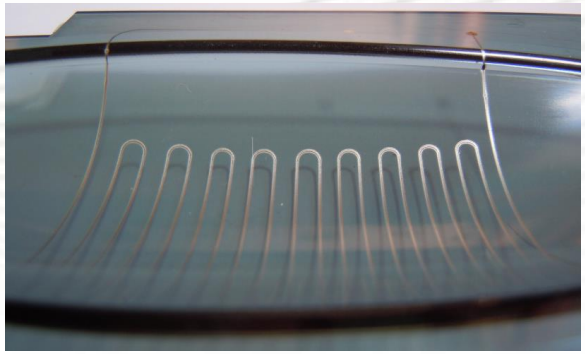
Neotech AMT GmbH - Dr. Martin Hedges
Tel: +49 911 274 5501
info@neotechservices.com

Agenda

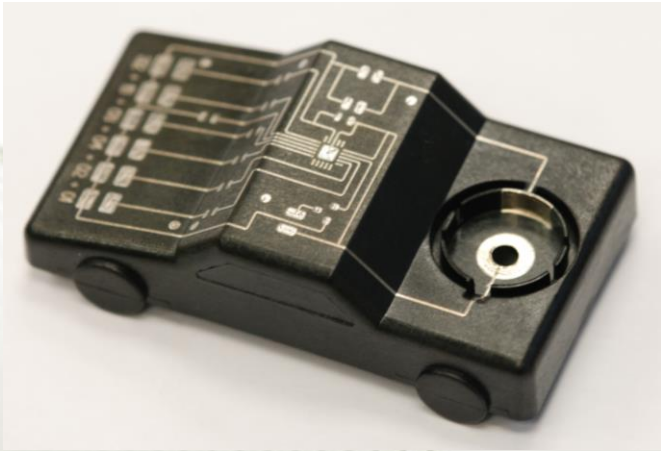
1. Company Overview
2. Aerosol Jet Process Overview
3. Materials & Capabilites
4. 3D Printed Electronics

Neotech Services/Neotech AMT GmbH

- Founded 2001
- Develop markets for new manufacturing processes
- EU Representative for Optomec Inc. (Manufacturers of Aerosol Jet)
- Developing 3D Printed Electronics since 2009
- Manufacture of commercial 3D Aerosol Jet printers started 2013

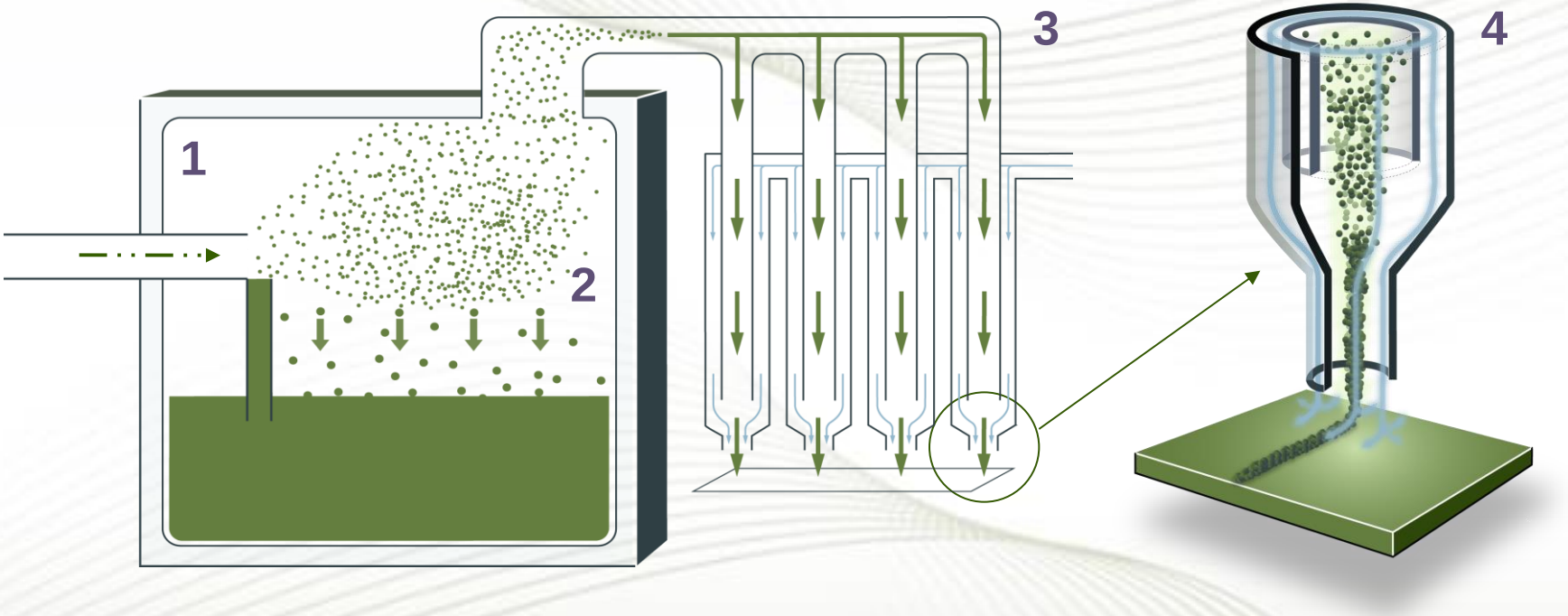


3D Heater Pattern on PC



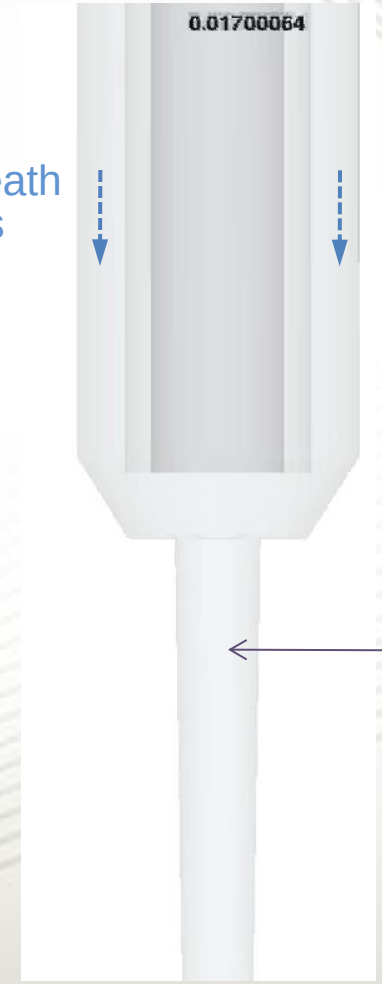
3D MID Demonstrator

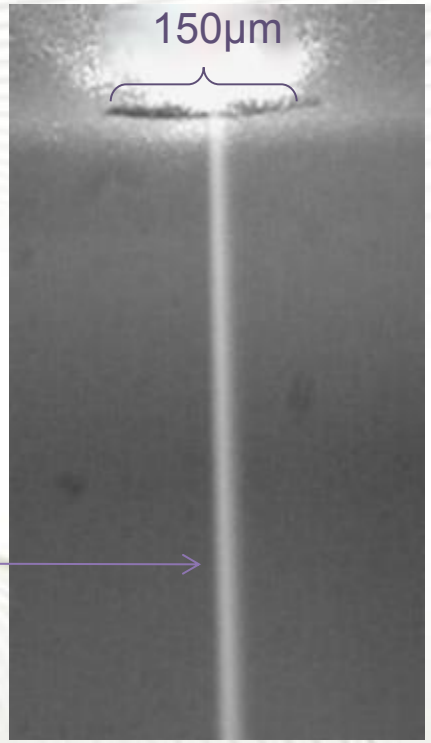
How the Aerosol Jet Process Works



1. Functional ink is placed in the atomiser, gas flow creates an aerosol
2. Aerosol droplets ca.1-5µm, larger droplets return to ink (gravity effect)
3. The aerosol is carried to the deposition head, excess gas removed
4. The aerosol is focussed inside the nozzle by a secondary gas flow (sheath gas)

Aerosol Jet Characteristics





No contact to nozzle

Natural stand-off from substrate – Enables 3D Printing

Capabilities Overview

Feature	Capability
Minimum Line Width*	10µm, 20µm pitch
Maximum Line Width	3 -10mm
Print Speed	Application Dependent Typically 10-100mm/s
Material Viscosities	0.7-1000+ mPa·s

** Depending on Material and Substrate*

Examples of Materials Compatibility

Metal Conductors Nano Ag – Clariant, Paru, Xerox,ANP... Nano Au - UT Dots, Harima Nano Pd - Nanomas Thick Film Au – Dupont Cu & Al – emerging commercial inks	**Ceramics & Oxides** Yttria Stabilised Zirconia, Barium Titanate particulate material Ceramic precursors (BaTiO3) Al_2O_3, RuO_2 &TiO_2 SiO_2, $InSnO_2$, other metal oxides...
Metal Alloys/Composite Material: Ag Conductive Adhesive CuNiMn – Fraunhofr IFAM	**Nano-Particle Composites** TiO_2 in PLGA (polylactide- co-glycolide) TiO_2 in SolGel, SolGel + nano-TiO_2+ZnS PTF with Barium Titanate- Asahi
Conductive Polymer PEDOT:PSS - Heraeus Carbon Nano Tube (CNT) - Brewer Science	**Dielectrics** UV Epoxy - Norland, Locktite, Summers, etc. PMMA - Alpha Aesar, PVP - BASF Polyimide - Huntsman PTF with Barium Titanate- Asahi PTFE - 3M, Dupont
OE Semiconductor P3HT, PQT, CNT...	**Biomaterials** Peptides & Proteins Antibodies - Fluorescing, Somatic DNA oligos, Prokaryotic cells, E.coli Simple eukaryotic cell (yeast) Mammalian cells (3T3, HDF)…
Resistor PTF Carbon - Asahi, Dupont Metal Oxide - Dupont	**Novel Materials** Etch materials & Etch resists. Solder Mask Photopolymerizable SolGels

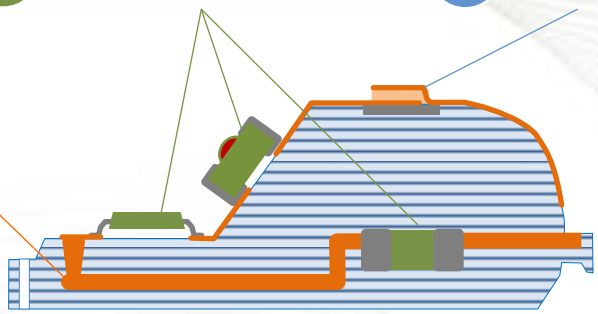
Strategies 3D Printed Electronics

Method 1: Embed in part manufactured layer by layer process: SLS, SLA, etc:

1 Circuit structures

2 SMD components

3 Printed Device



Project 3DAMEEA
Courtesy:

FAPS

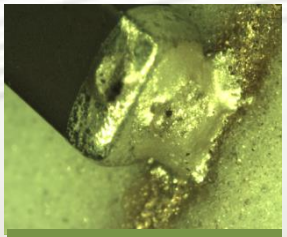
1

Printed 3D circuit tracks

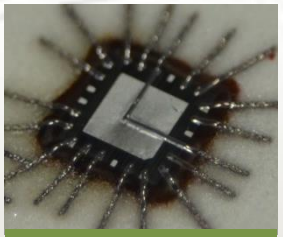
On Surface or Embed

2

Mounted + interconnected electronic components



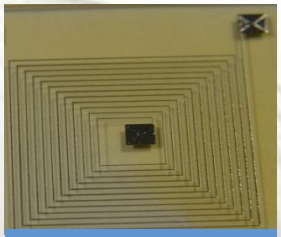
On Surface



Embed

3

Printed Devices



On Surface or Embed

Method 2: Print on injection moulded parts: 3D MID

How to Create Complex 3D Features?

Motion 3D - CAD/CAM tool path generation software:

1. Enables fully 3D features

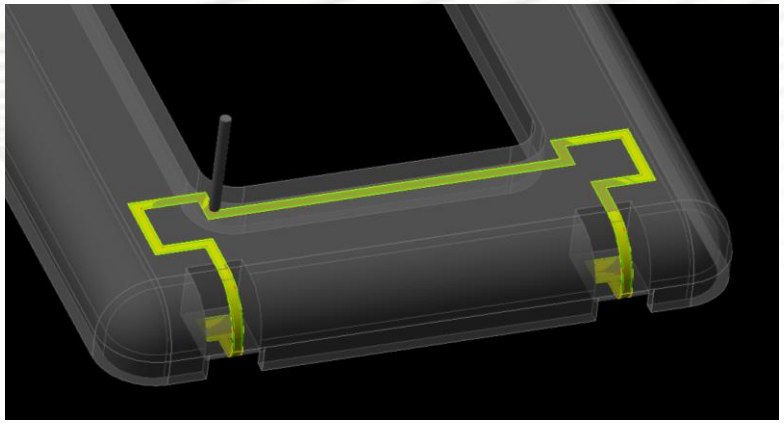
2. Free choice of print strategy: simultaneous 5 axis, 4+1 or 3+2 indexed printing

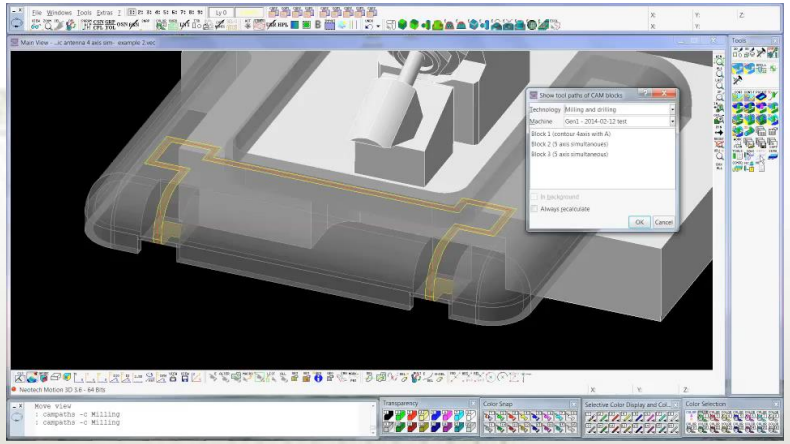
3. Optimised cycle times via free definition of the print sequence

4. TCP Mode for consistent print speeds on 3D Surfaces.

5. Printing path simulation

6. Machine specific G-Code post processor





Print tool-path simulation
3D Antenna Demonstrator

Printed 3D MID Process Flow

Aerosol Jet 45X

High Volume Mass Production System

Applications
3D Antenna for Mobile Devices

1. Current Process Route: Printing and oven sintering Ag inks on a wide range of resins

2. Low temperature sinter route developed for printing on polycarbonate and electro-mechanics assemblies

3. RF Performance: matches industry standard

1. Production Costs: cost reduction of compared to current manufacturing techniques (design dependent)

2. Mass production trials ongoing at early adopter

3. Mass production equipment available (>1m parts p.a. per system): Aerosol Jet 45X & LBS 45XE

Demonstration Antenna
Courtesy: Liteon Moblie Oy

3D MID with Integrated Sensors

Demonstrator – Automotive Tank Level Filling Sensor

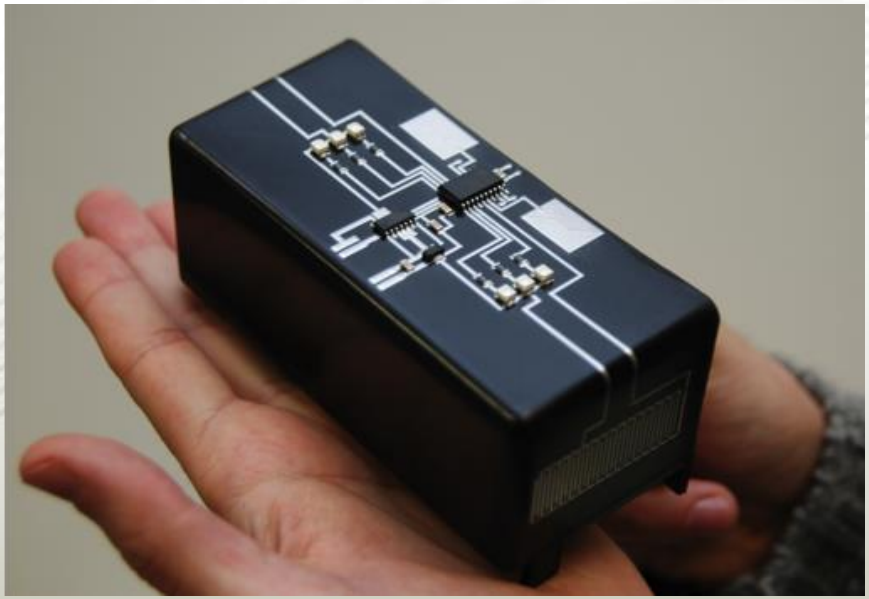
Developed under the FKIA Project: Bayerische Forschungsstiftung

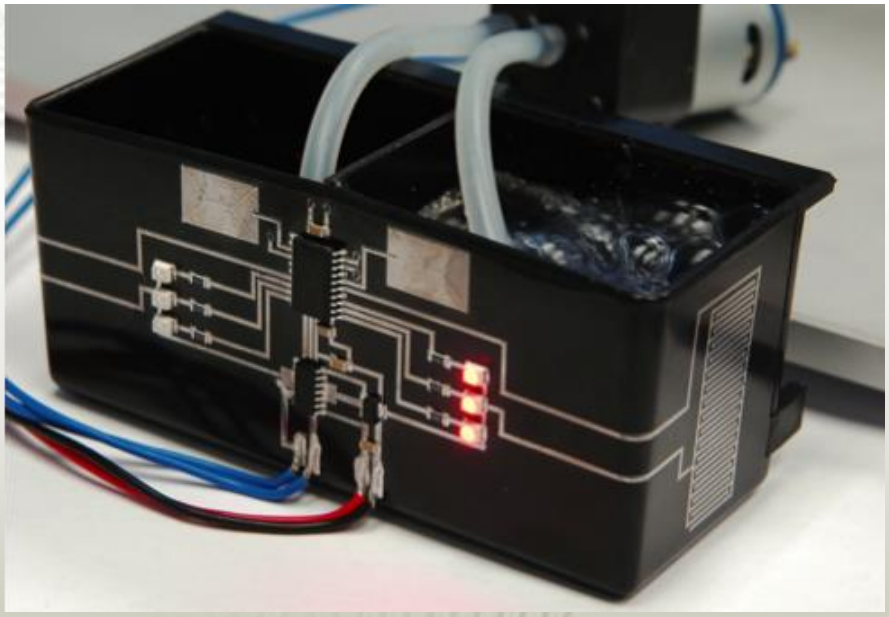
Two capacitive Ag sensors & circuit printed on a moulded PA6 tank.

SMD components mounted using conductive adhesive to complete the sensor device.

The sensors register the water level as it rises, lighting the LEDs to indicate the fill level.

When the tank compartment is full the circuit senses the water fill level and reverses the pump direction.



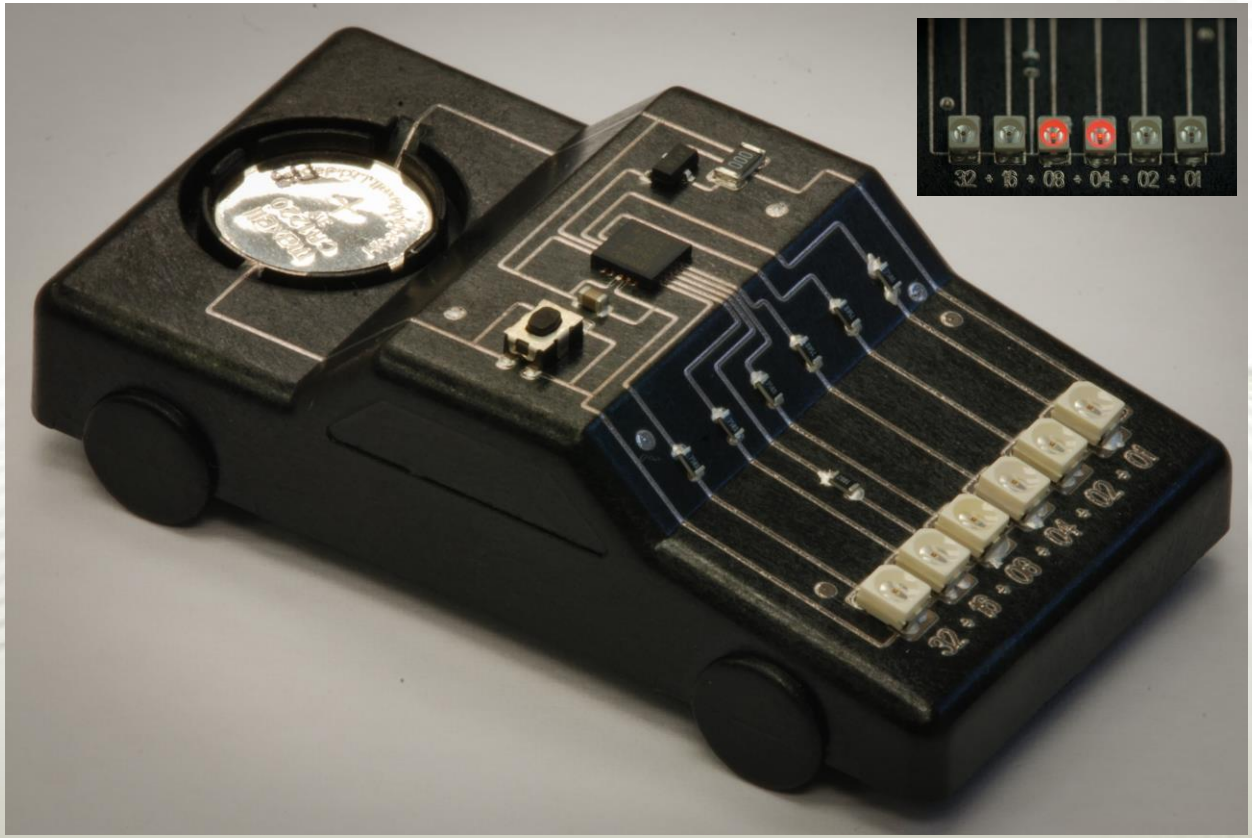


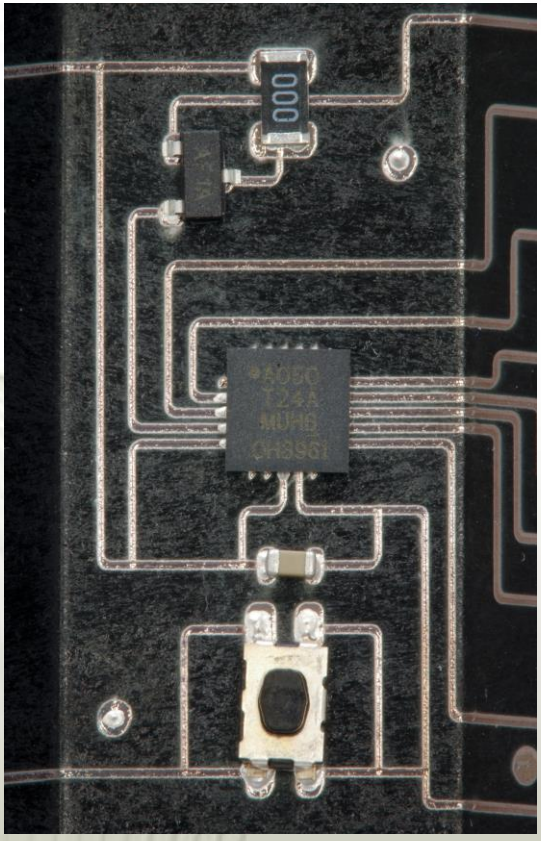
3D MID Demonstrator

SMD components mounted with conductive adhesive

Sensor measures ambient temperature

Display via LED





3D Heater Patterns on PC

Project with Bayer Materials Science – Automotive Glazing

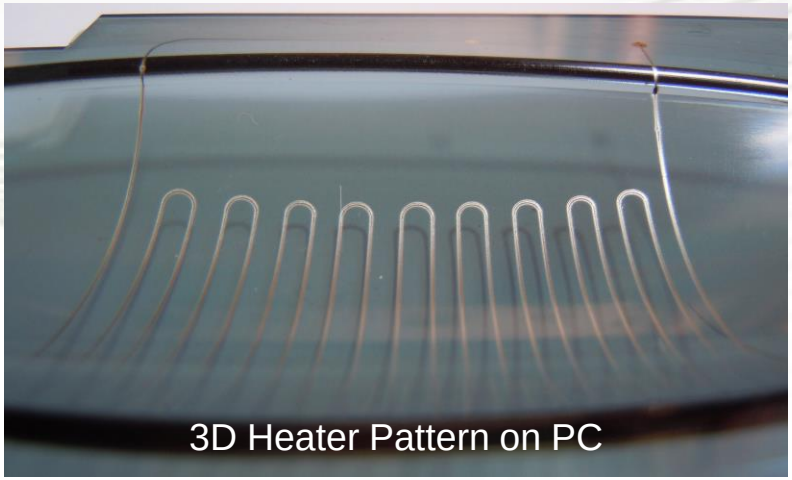
Ag heater circuits printed on PC.

Low Temperature Sintering – PC has limit of 120°C

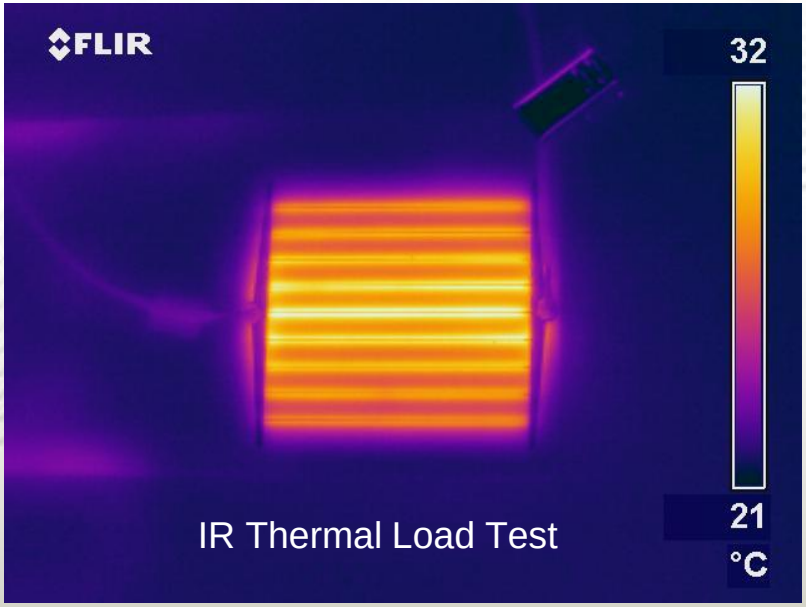
Thermal Load Testing – at 6V/0.9A temperature of 107°C.

Even heating across the device

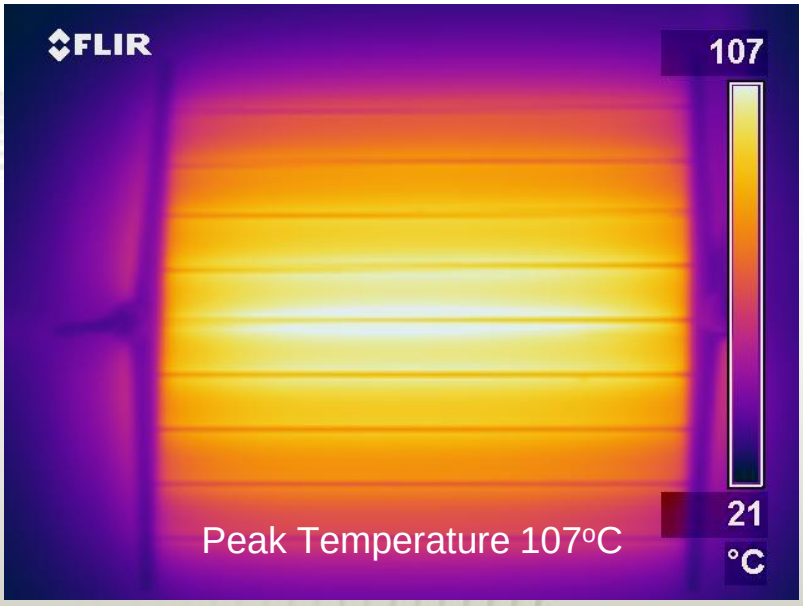
Developing large area print system to 2m x 2m parts



3D Heater Pattern on PC



IR Thermal Load Test



Peak Temperature 107°C

Beyond Simple Circuits?

Current MID manufacture limited to metallic circuits/antenna + some sensors.

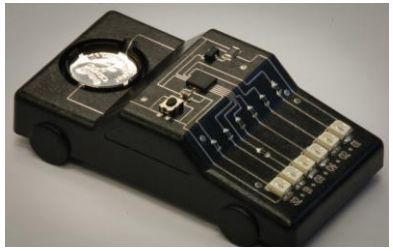
These have SMD components added to make complete device.

Is it possible to add extra functionality to move from traditional 3D MID to 3D Printed Plectronics?

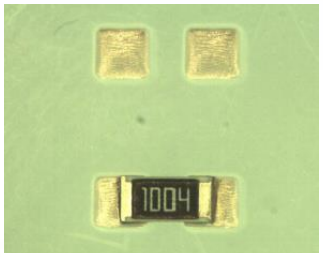
Component	Function
Conductors	Carry Current
Antenna	Broadcast/Receive
Sensors	Input
Resistors	Control Current Flow
Capacitors	Filter, Charge Storage
Inductors	Filter,Transform/Transfer
Diodes	Valve
Transistors	Amplify, Switch
Memory	Information Storage
Emitters	Display Output
Power Source	Energise Circuit

Additional Functionality via 3D Printing

3D Today

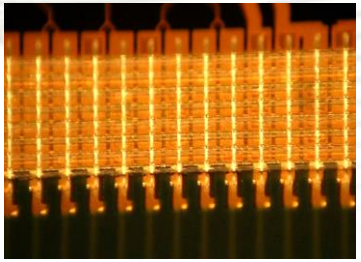


Conductive Circuits

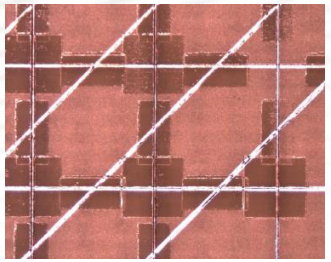


Chip Bonding

2D Today - 3D Future

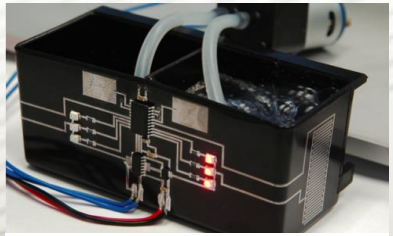


3D Interconnects

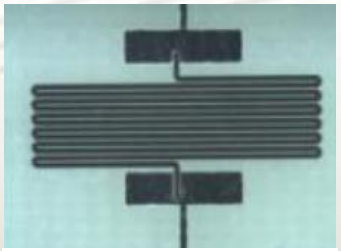


Multilayer Circuits

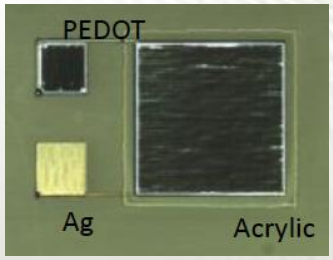
COMPLEXITY



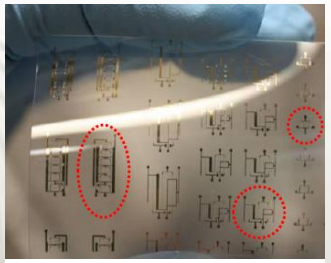
Sensors



Resistors



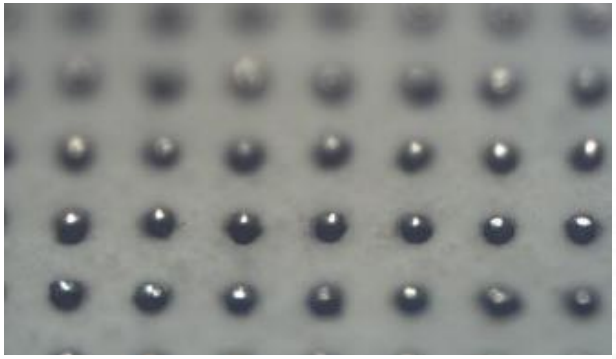
Capacitors



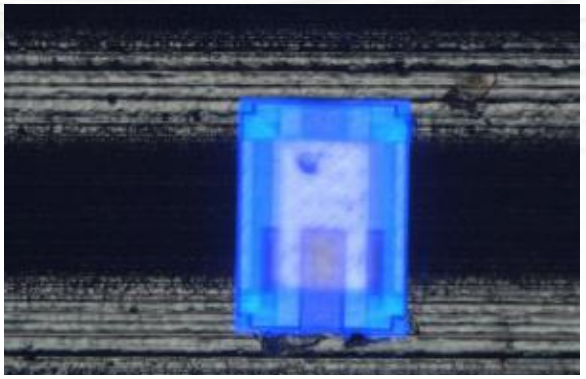
Transistor Circuits

Near Term 3D Application
Chip/SMD Attach

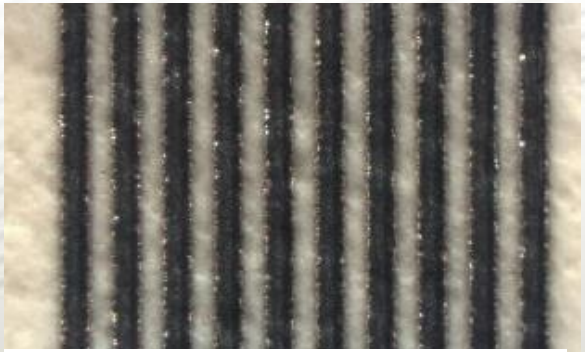
Printing of conductive adhesive to attach SMD components as alternative to soldering



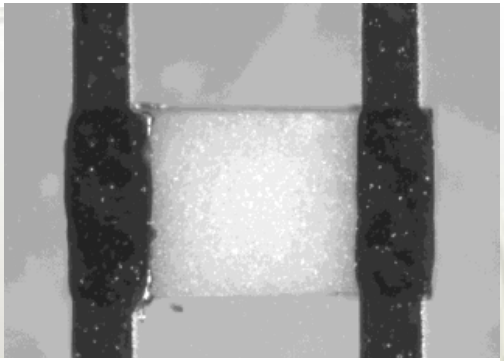
50um diameter dots
Conductive adhesive on Teslin.



Cree DA3547 LED attached directly to printed Ag lines



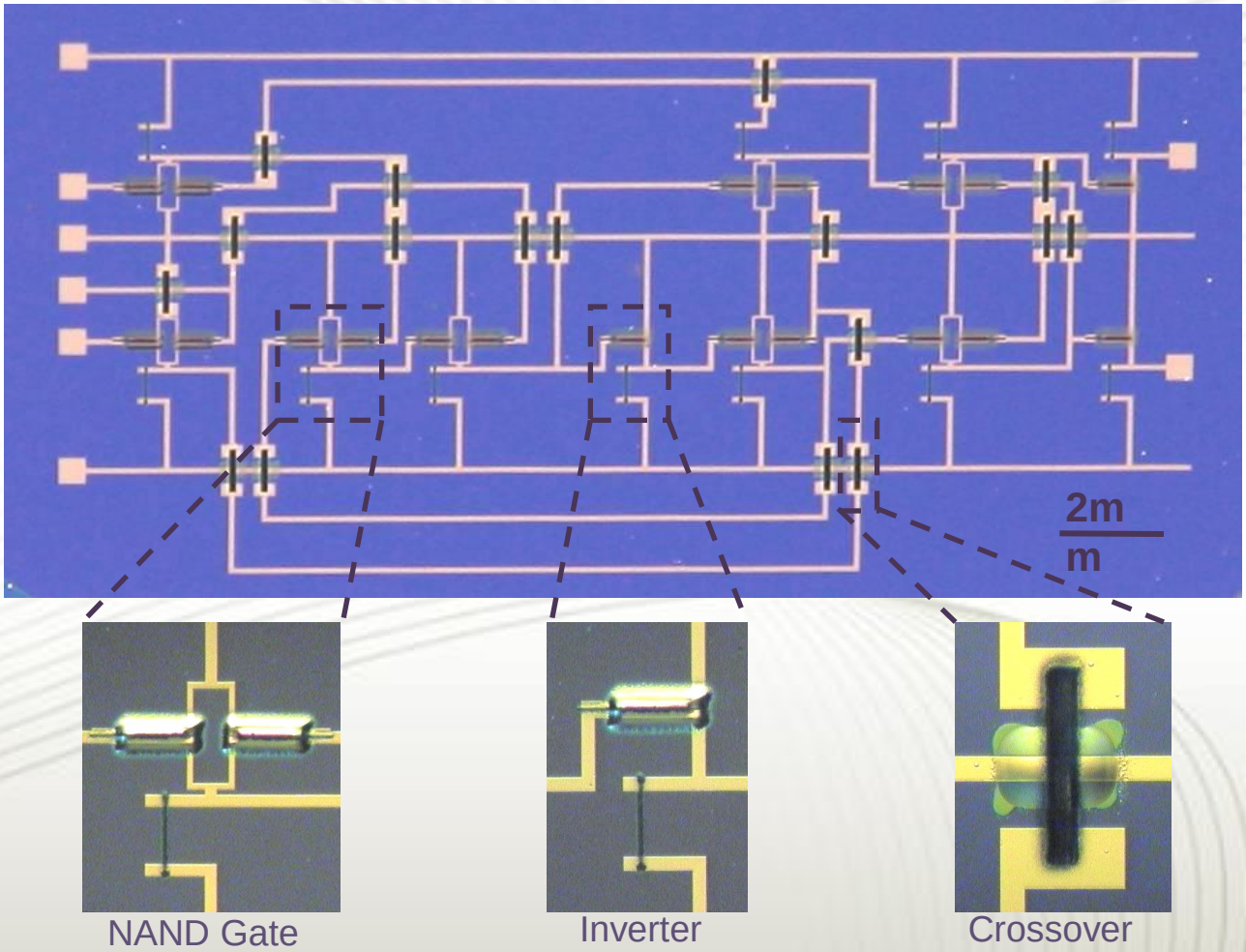
50um wide lines
Conductive adhesive on Teslin.



0603 resistor attached to glass
Contact resistance of 20 μΩ-cm2

Future Concept Application
All-Printed OE Circuit

Circuit consists of 8 NAND Gates, 3 Inverters



*Optomec collaboration with Dan Frisbie Group UMN

Summary

Process
- Aerosol Jetting technology
- Maskless deposition of functional inks
- CAD Driven, Direct Write process

Capability
- Non-contact
- Fully 3D capable process
- Scalability: fine printed features to wide area

High Utility
- Wide range of materials compatibility
- Wide range of applications
- Scalability for volume manufacture of 3D MIDs

Thank You!

Neotech Services MTP

Dr. Martin Hedges
Tel: +49 911 274 5501
info@neotechservices.com