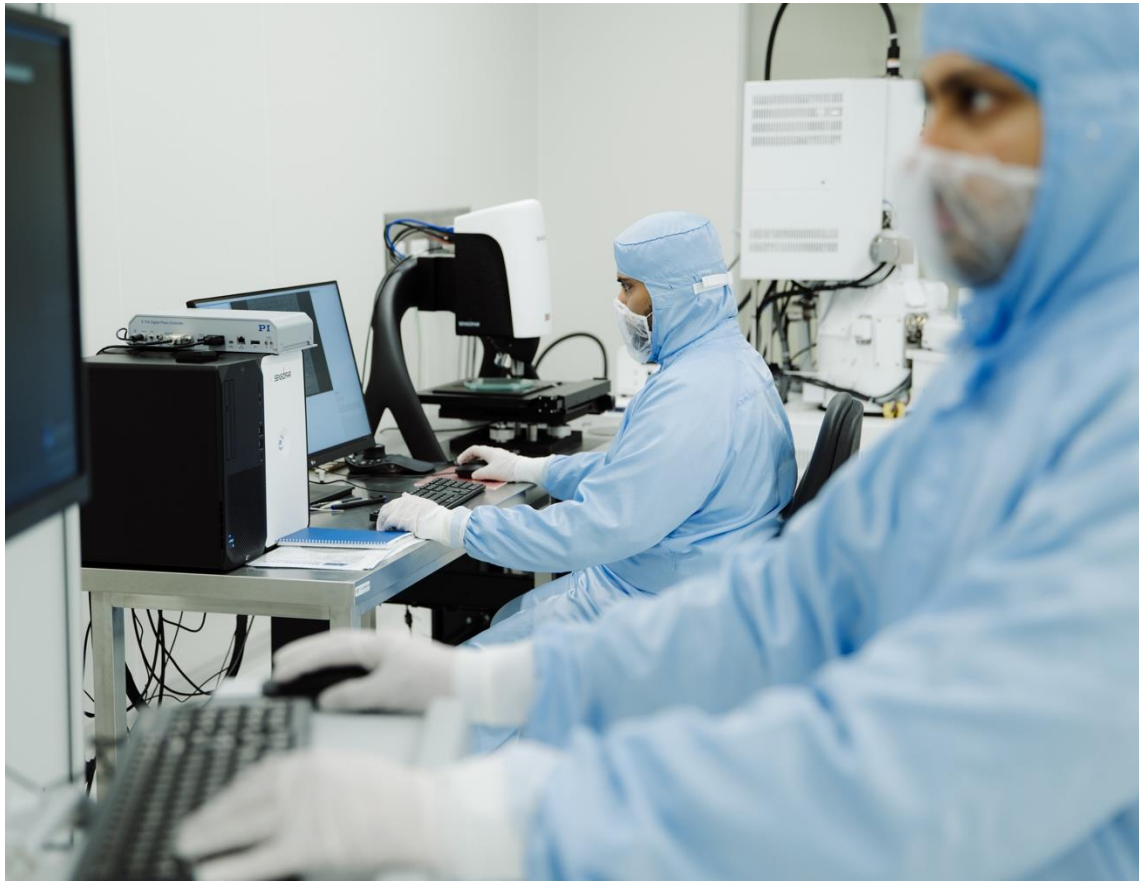
Introduction to MPD used for MEMS & Sensors

Thomas Russell | CEO & Co-founder

MESOLINE

Agenda

- About us
- Intro to Microchannel Particle Deposition (MPD)
- Comparison to other microfab methods
- Next generation products
- Applications
- From Micro-molding to MPD
- Mesoline’s printing service
- Summary



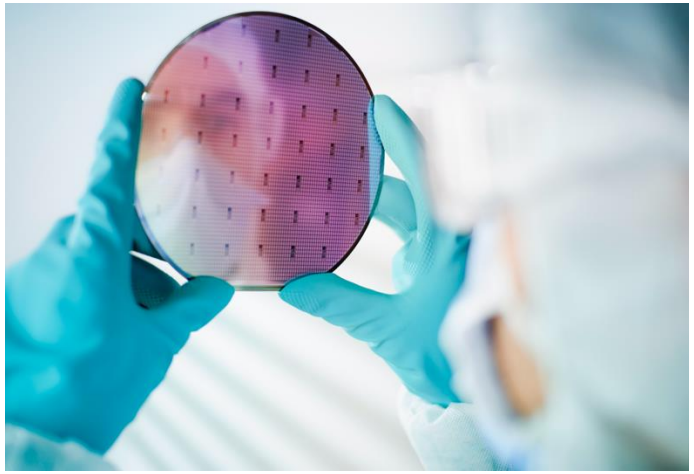
About us

Mesoline has developed a 6 & 8-inch substrate size compatible new microfabrication technology: **microchannel particle deposition (MPD).**

MPD offers ultra-small and reproducible micro features fabricated with extensive parallelization and high scalability. Mesoline offers MPD through manufacturing services.

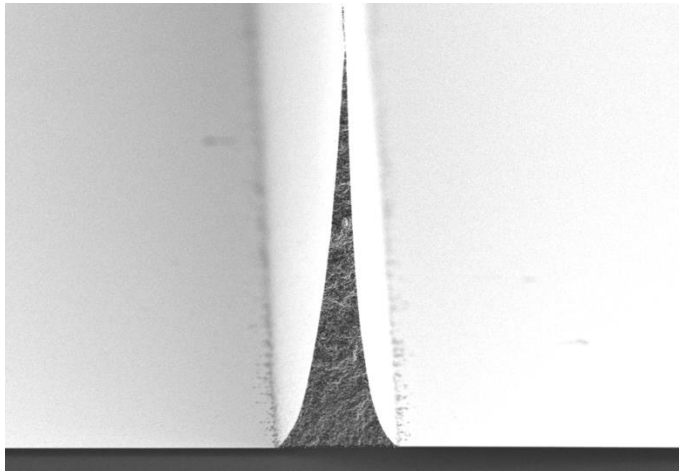
Founded out of Caltech in 2017, and Mesoline is acquired by Aalberts N.V. (stock listed) in 2021. We are headquartered in The Netherlands.

The Strength of MPD



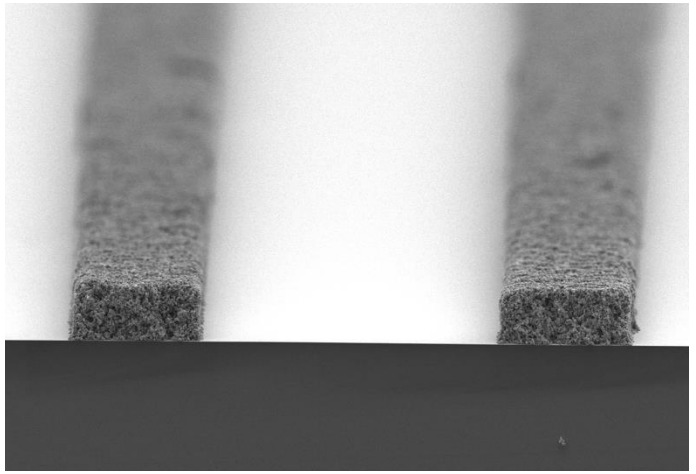
Scalability

Deposition at wafer-scale in just 15 minutes



Accuracy

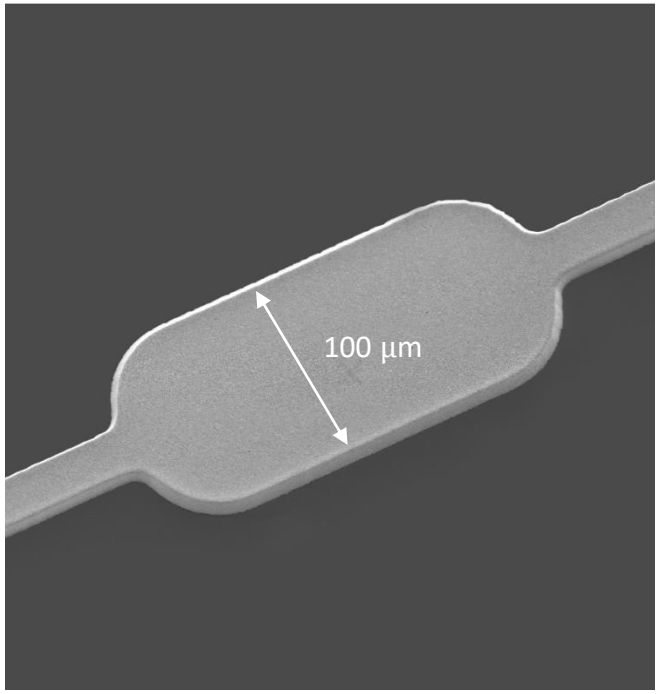
Full 3D-contolled microstructures

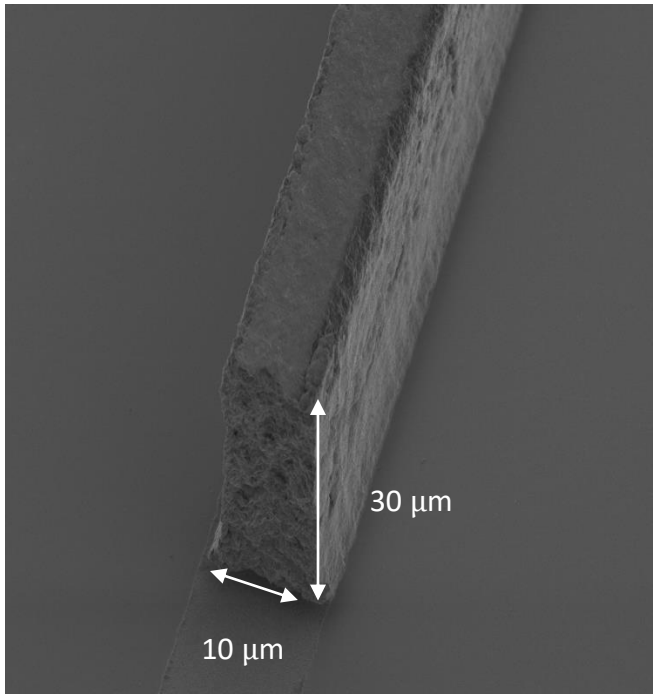


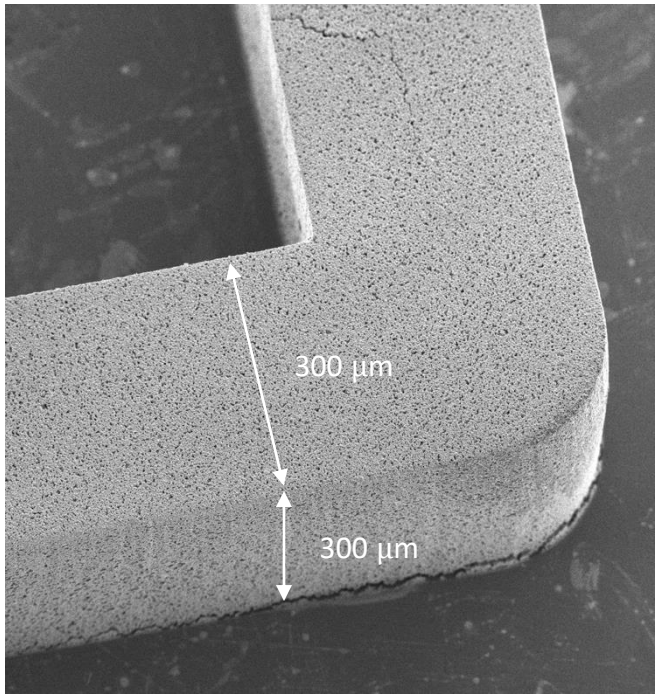
Reproducibility

Continuously stamping the same

What MPD Creates?



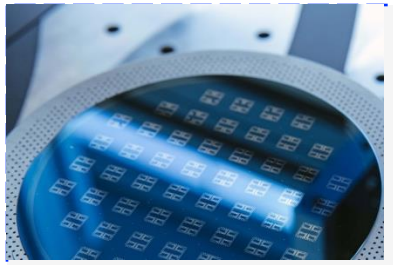




- **Width: 2.5 – 500 μm**
- **Aspect ratio: 1 - 5**
- **Min spacing: 5 – 500 μm**

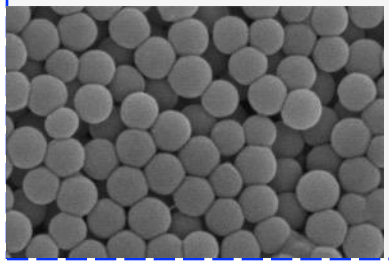
Detailed process flow

In-house technology

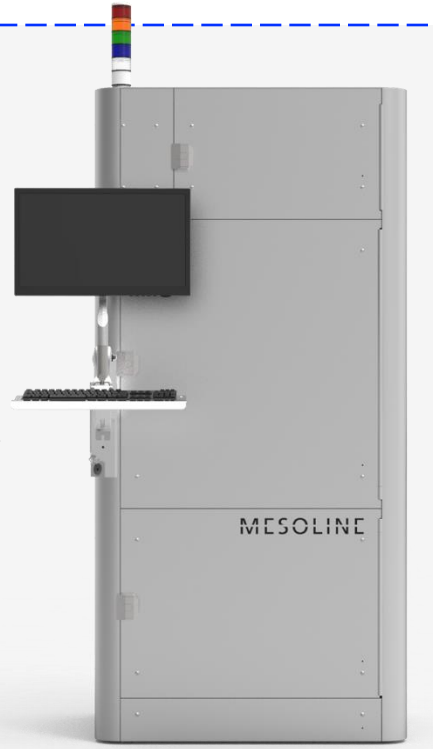


Wafer
(MEMs) Substrate is provided by 3rd party

Stamp
In-house developed and fabricated

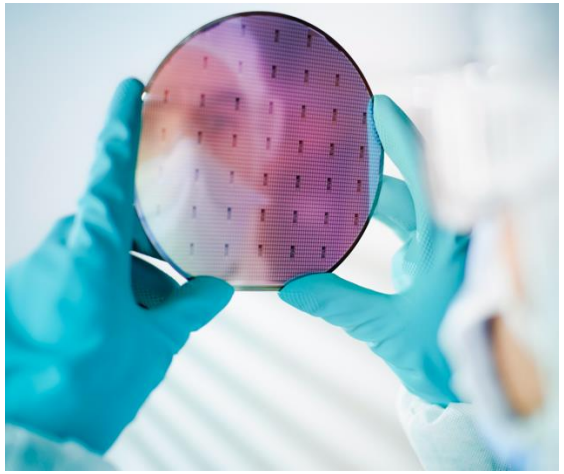


Ink
Provided by 3rd party or in-house developed



MPD machine

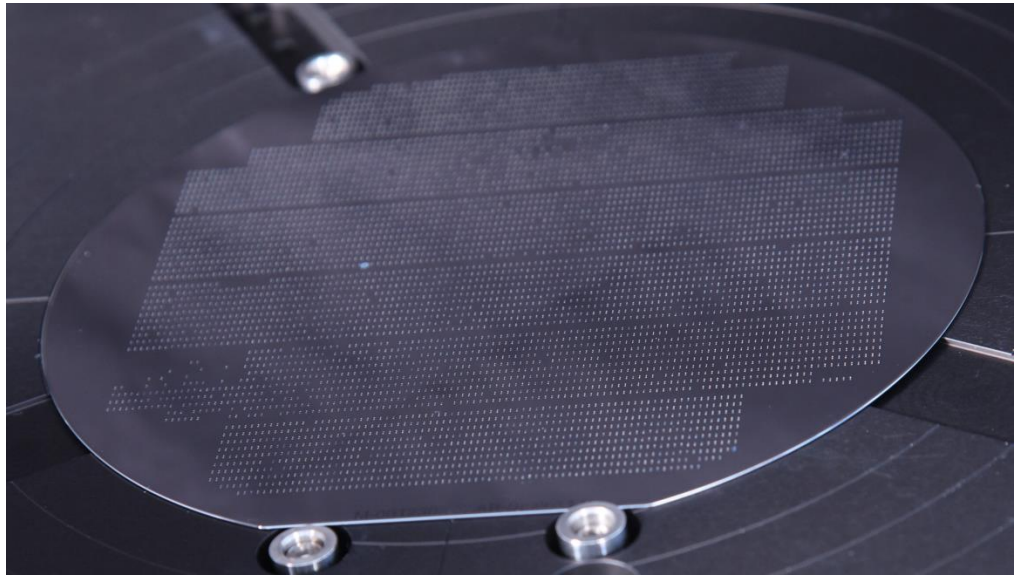
Sintering



Sellable product

Technology readiness

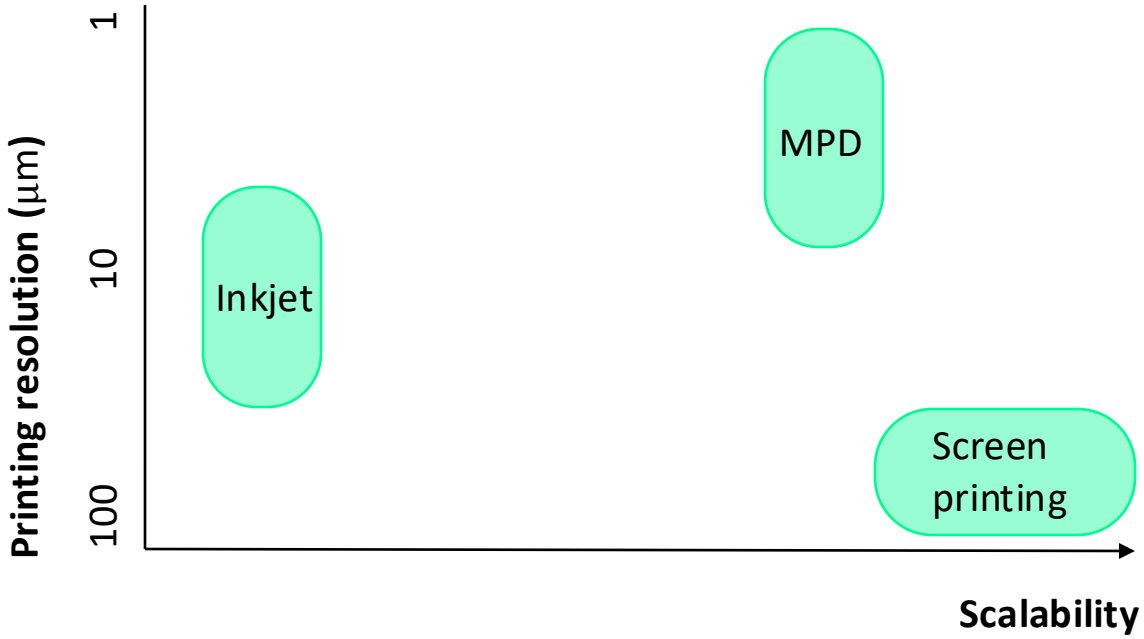
- **Extensive parallelization:** 40.000 features possible
- **Yield:** 95%+ on pre-production test-targets
- **Wafer-level process:** 6 and 8-inch
- **Alignment accuracy:** ±10 um over entire wafer
- **Feature thickness variation:** ≤ 5%
- **Multiple materials:** up to 4 in one process step

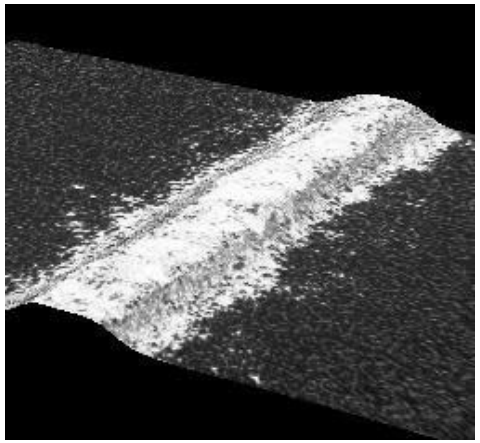


MPD printed 6-inch wafer with 95%+ yield

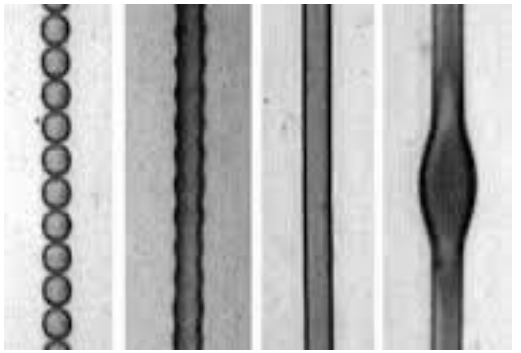
Additive manufacturing landscape

MPD offers ultra-small & reproducible features made from multiple materials while ensuring extensive parallelization and high scalability



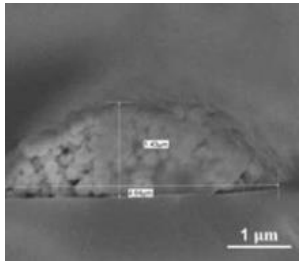


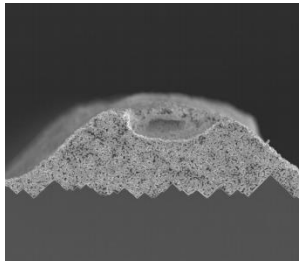
Example of **screen printing** which is inherently limited in size and precision

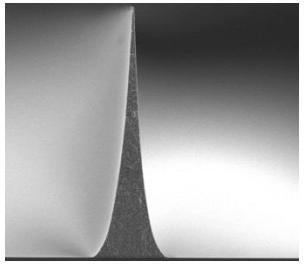


Example of **inkjet** which is inherently limited by scalability and drop-size variability

Comparison

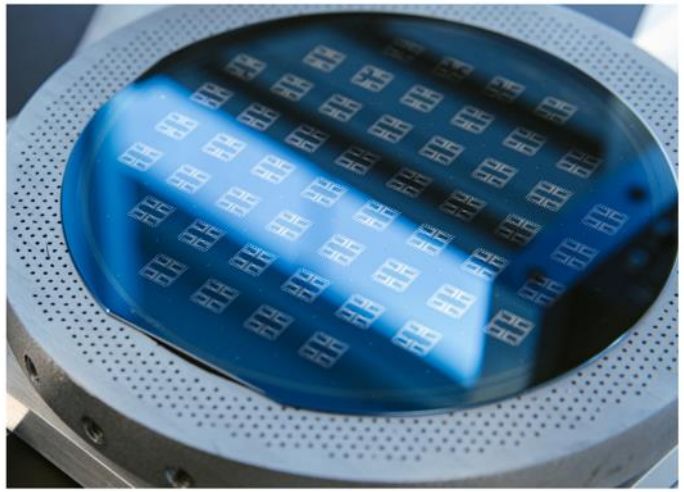




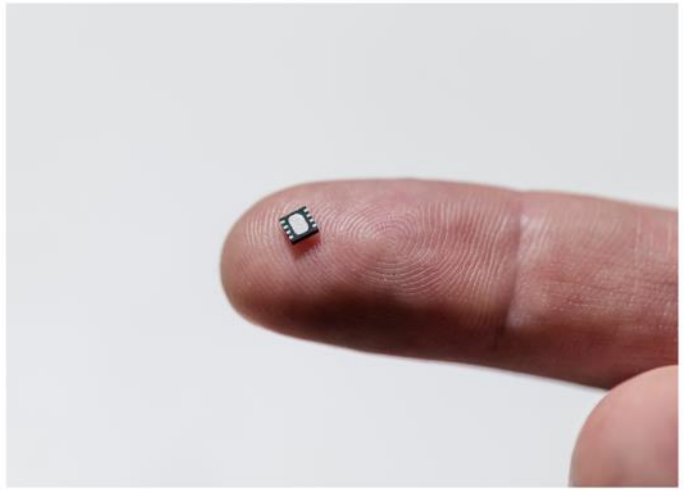


Fabrication Technology	Inkjet	Screen-printing	MPD
Feature size range (µm)	30 - 500	30 – 500	2.5 - 500
Min. line spacing (µm)	~20	~50	~2.5
Aspect ratio (h/w)	1	0.4	5
Scalability	Poor	High	Medium to high
Multi-material printing	Yes	No	Yes

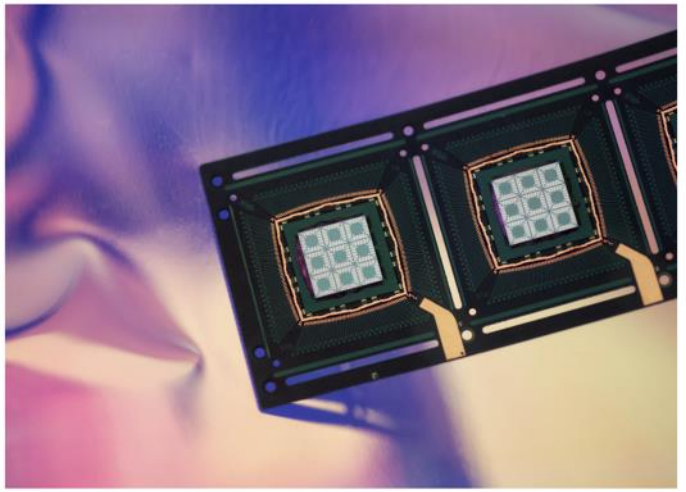
Next Generation Products



MEMS



Sensors

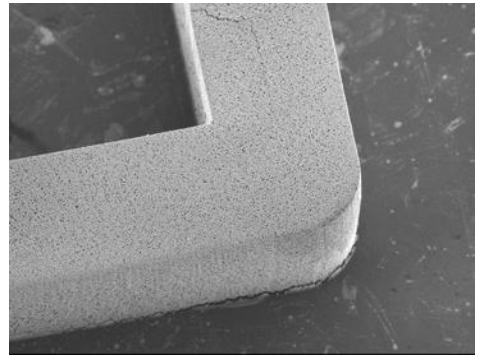


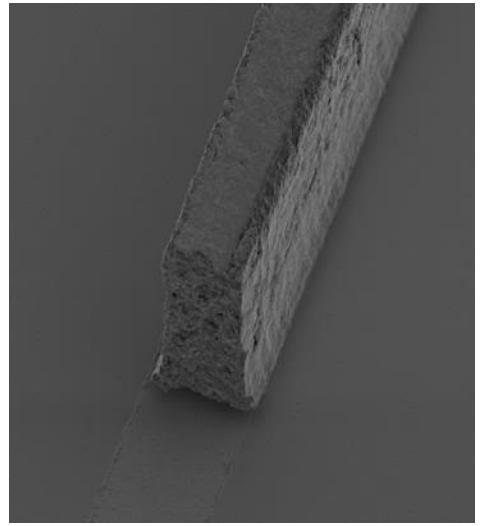
Packaging

We help our customers fabricate new MEMs and sensor products ranging from improved packaging solutions through deposition of functional elements

Deposition of nanomaterials

Printable Materials	**Applications**
Tin-oxide (SnO_2), Zink oxide (ZnO) and Tungsten oxide (WO_3)	Sensing element MOX sensor
Glass frit	Bonding/packaing
Palladium oxide (PdO), Copper oxide (Cu_2O_3) and Molecular Sieves	Hydrogen & moisture getter
Ferrite (Fe_3O_4)	Magnetic field sensor and zero power wakeup for IoT
Gold (Au), Platinum (Pt), Silver (Ag)	(Bio-compatible) conductor for biosensing or electrochemical sensor





Metal oxide gas sensor

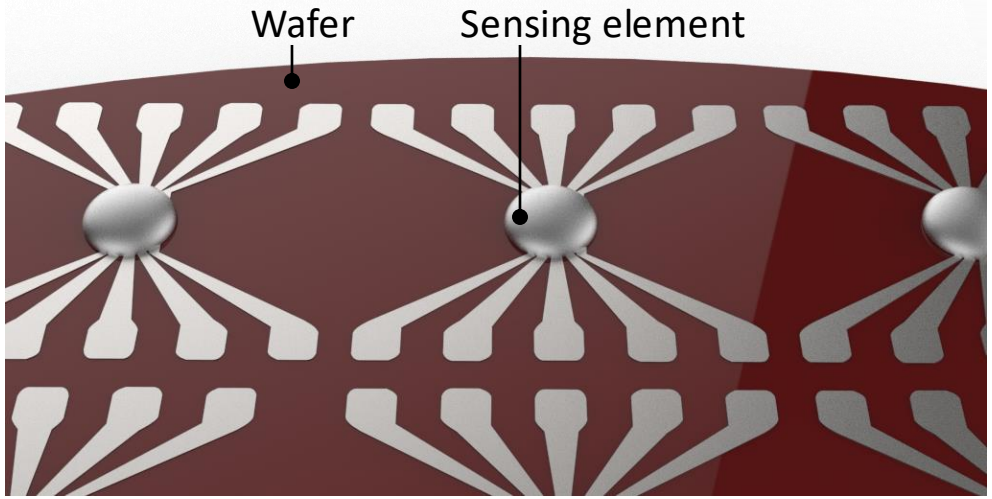
Metal Oxide Gas Sensor (MOx)

Pro's & cons

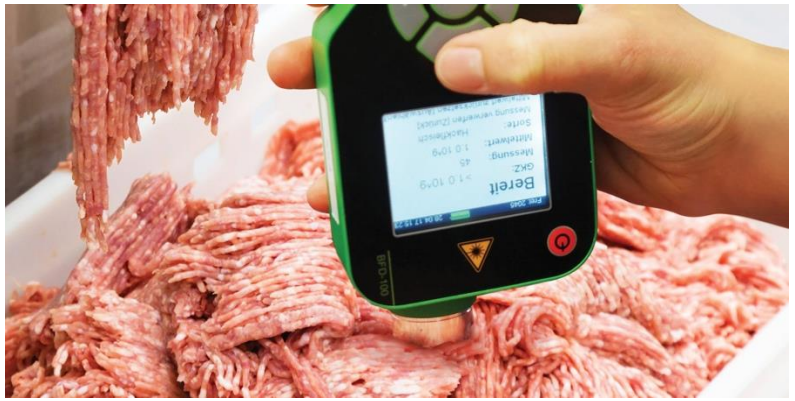
- Good sensitivity
- Low costs
- Poor selectivity
- Medium power consumption

Working principle

The sensing element changes resistance if a certain (target) gas is present in the atmosphere around it. By measuring the resistance or impedance change one can determine how much of a gas is present



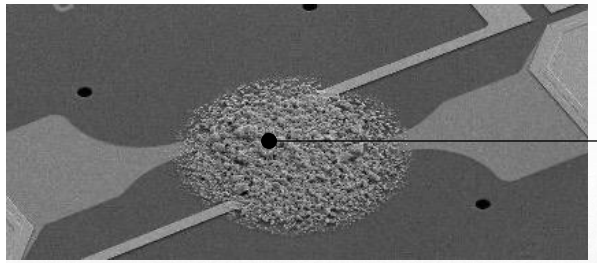
Gas sensor use-cases



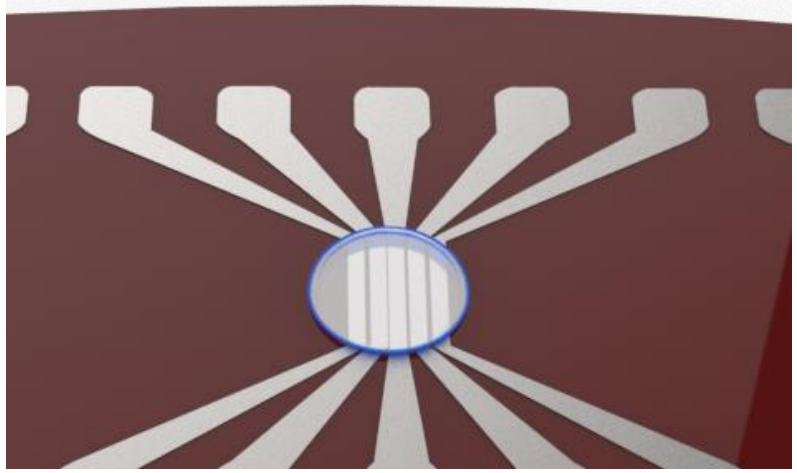
- Diaper state detection
- Food freshness detection
- Wildlife fire detection
- Methane detection

Selectivity

Poor selectivity Traditional Drop-casting

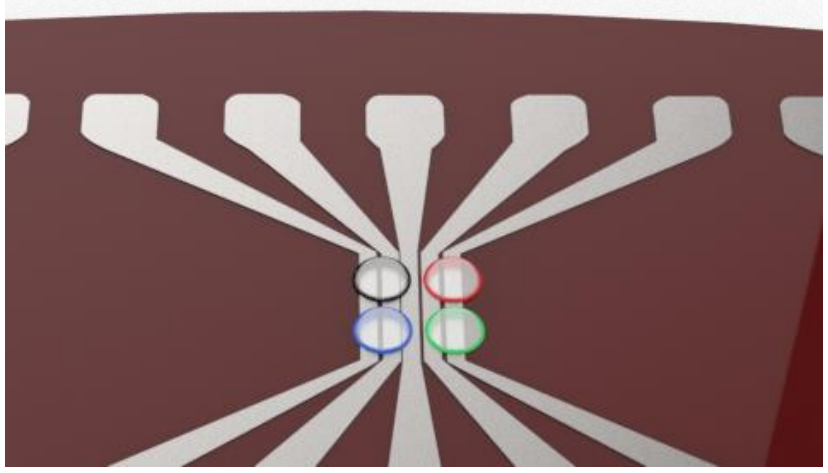


Drop-casted sensing element



Good selectivity Electronic nose

Most popular solution: Use so-called electronic nose, an array composed of different metal oxides, could be operated at different temperatures, each showing a different response spectrum to gasses, in combination with pattern recognition software.



How to manufacture?

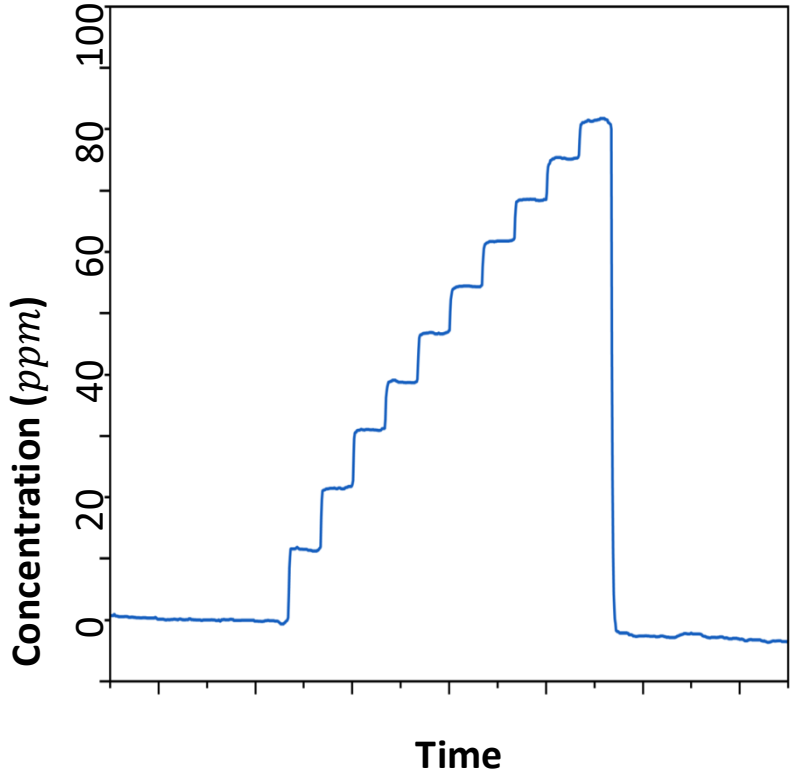
Drop-casting vs. MPD

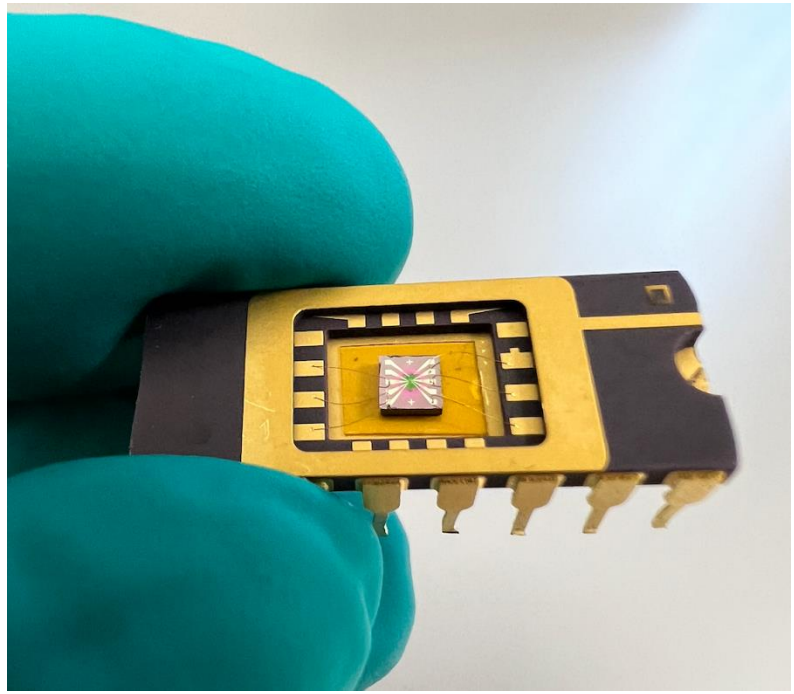
Fabrication technology	**Drop-casting**	**MPD**
Min feature size (µm)	30	2.5
Aspect ratio	0.2	3
Time to print full wafer	Up to 10 hours	15 minutes
Accuracy	poor	High
Min. line spacing (µm)	30	5
Deposition scale	Locally	Wafer
Multiple materials	Yes	Yes

MPD methane sensor prototype

Key Features

- Ultra-low consumption (20mW)
- Linear dependance on concentration
- Low-costs (Couple $)
- Fast response (T_{90} < 30s)
- MEMS-based MOX
- Compact size (4mm^2)

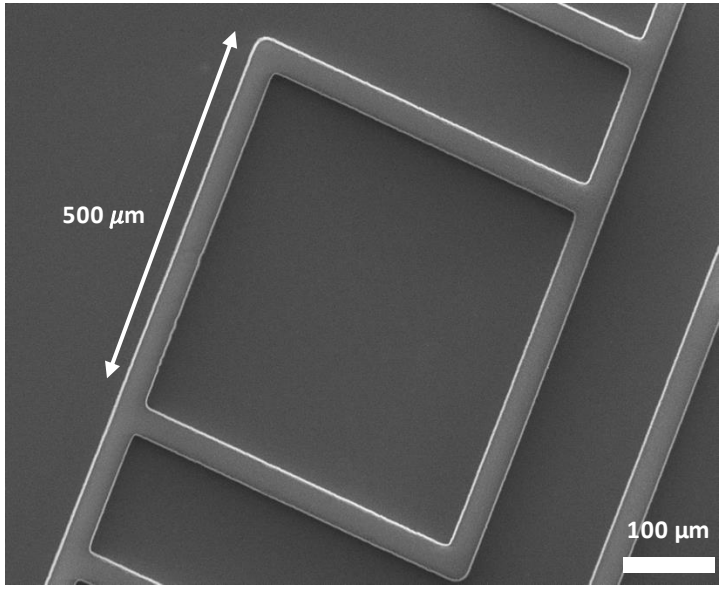


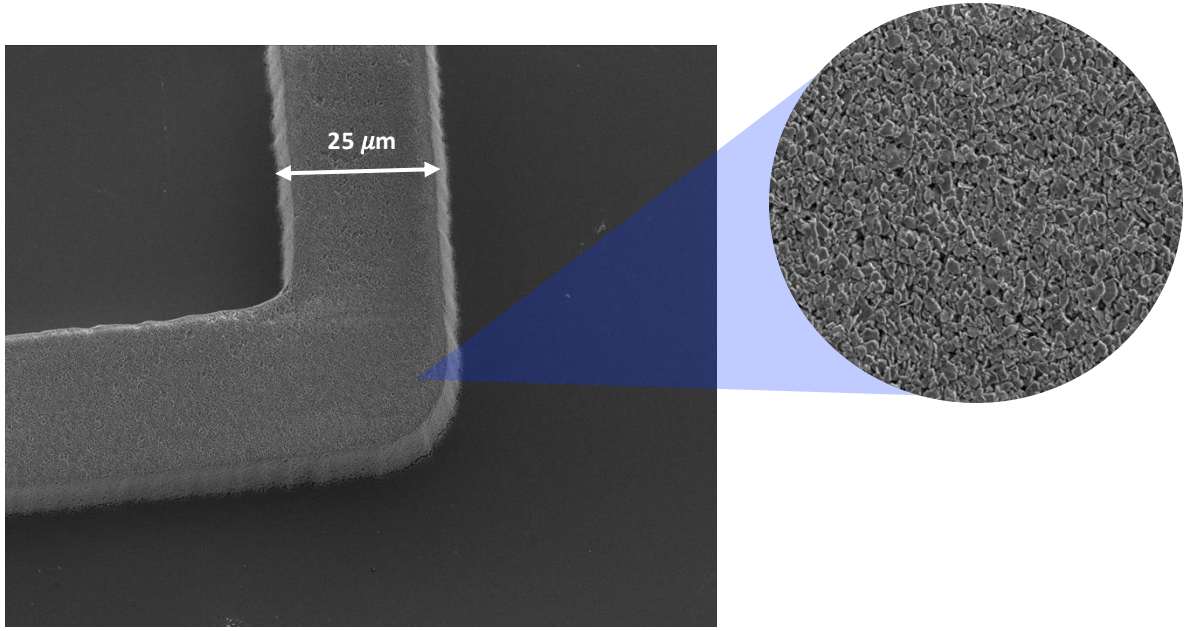


MPD enabled MEMS MOX methane gas sensor prototype

Glass Frit Printing

MPD can be used to replace screen-printing to deposit lead-free glass frit for bonding with smaller and ultra-accurate bonding rims to improve device form factors. Typical bonding rim widths are between 20 – 40 μm. Full 6 and 8-inch wafers can be deposited with glass frit.

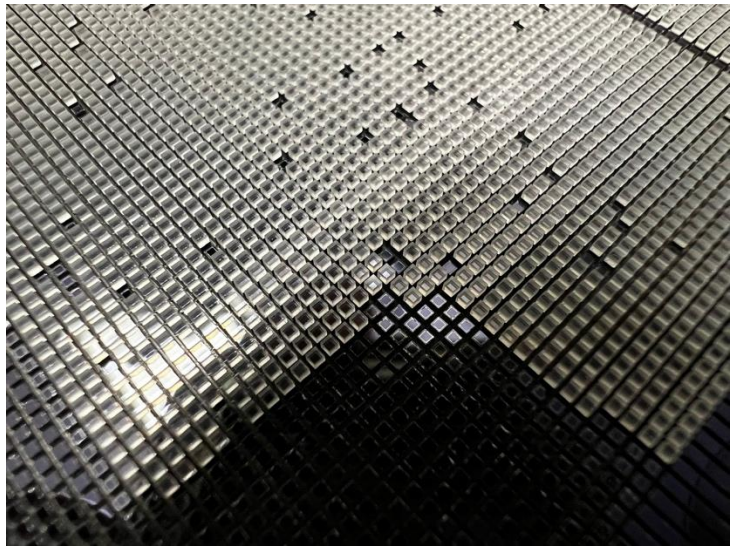


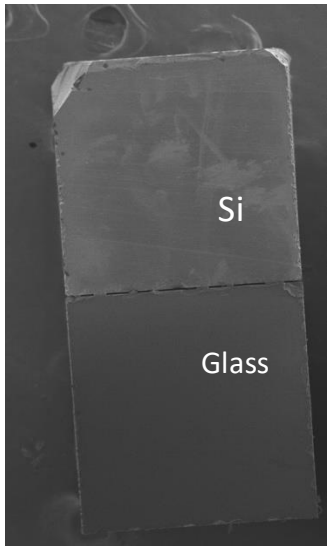


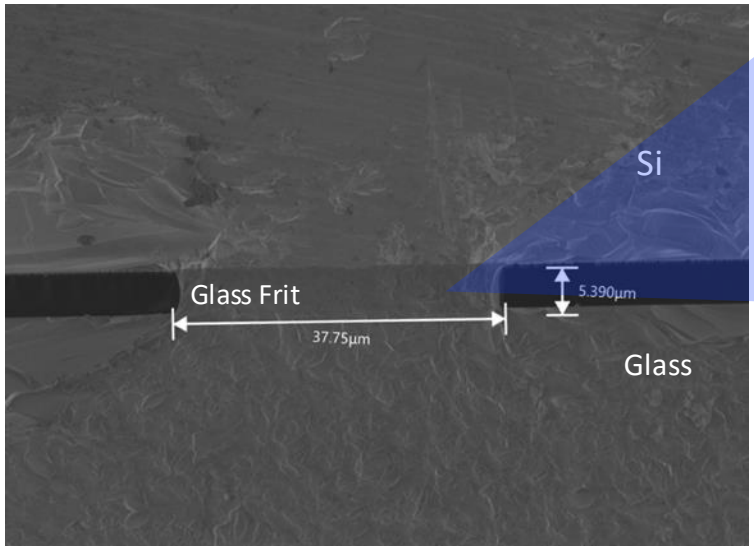
Glass Frit Bonding

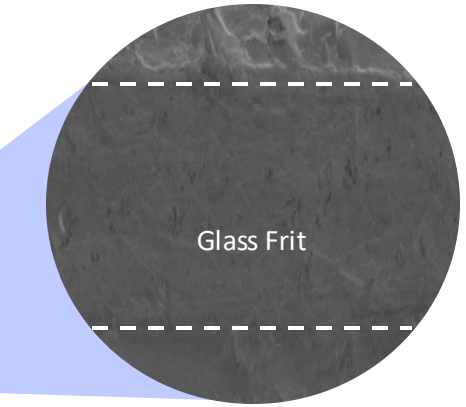
MPD was used to accurately deposit glass frit bond lines on a Si wafer. The Si wafer was bonded to a Borosilicate bonding pair at 450℃ with an EVG bonder. Subsequently, the wafers were diced.

The bonding rim after bonding is ~38 μm wide and 5.3 μm thick.



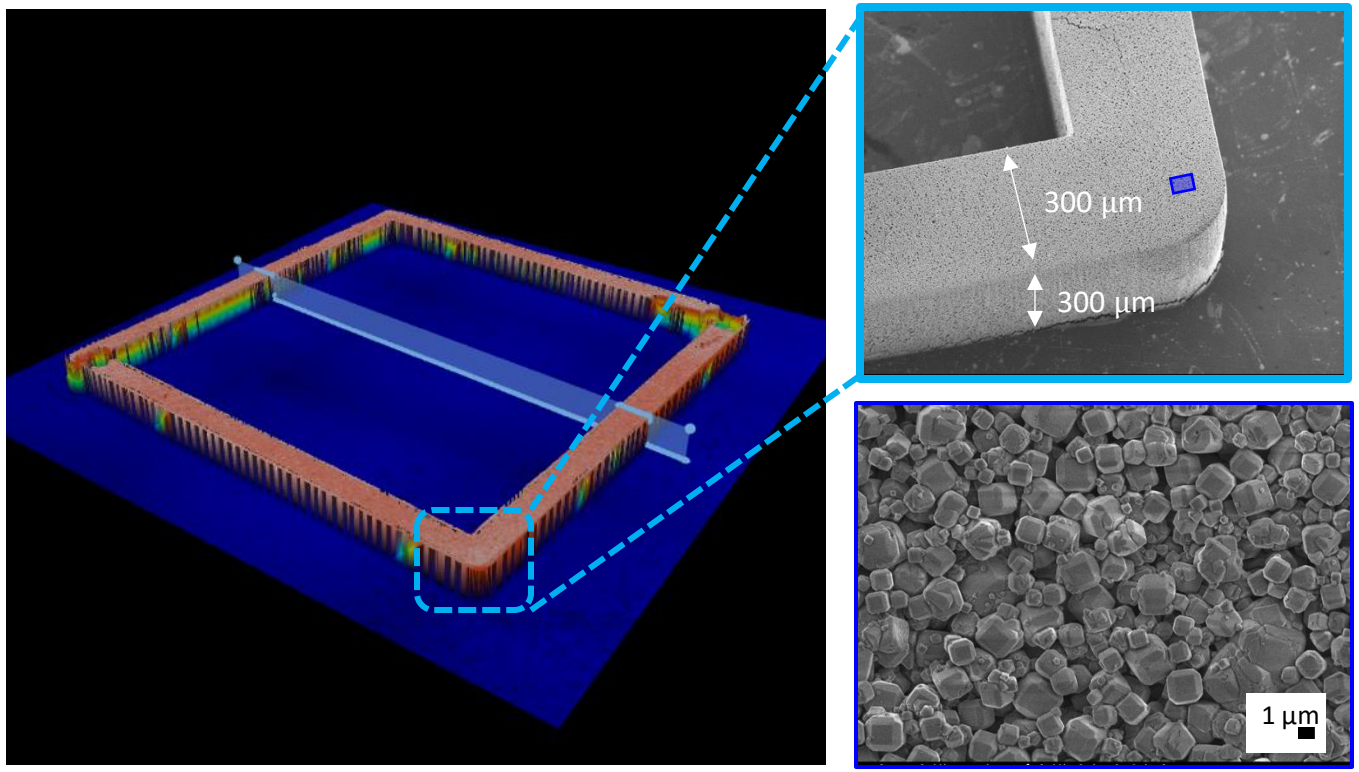


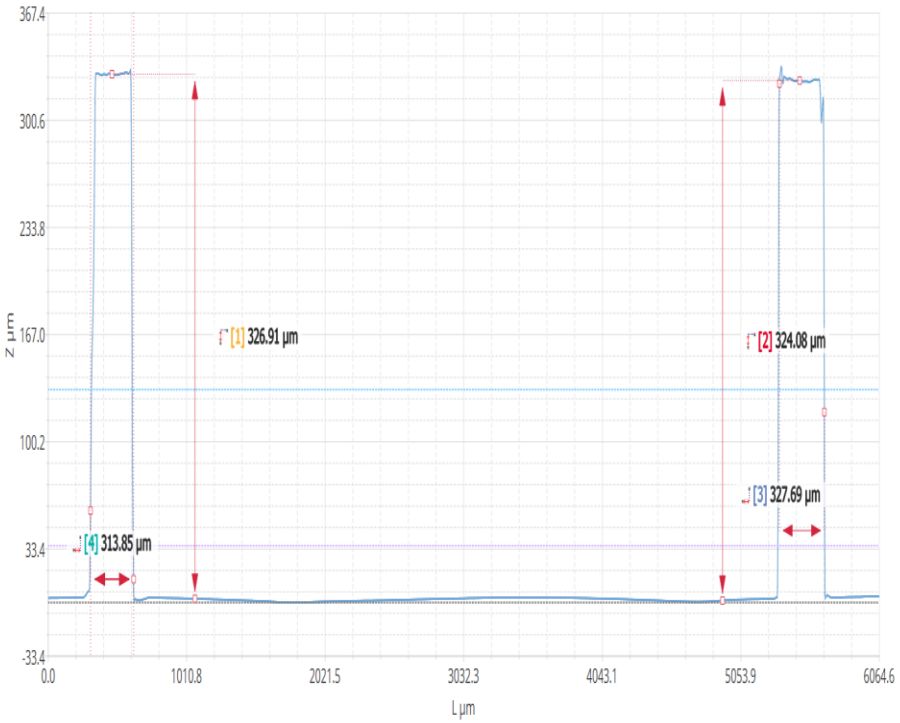




Moisture Getter

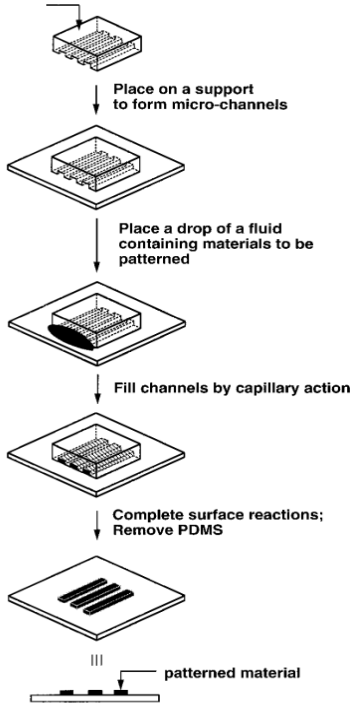
We have used our MPD technology to print moisture getters of approximately 300 x 300 μm in dimensions with a square structure of 5 by 5 mm. MPD allows for more accurate deposition of getter material to decrease the device footprint while having the same getter capacity.





From MIMIC to MPD

MIMIC micromolding steps (1996).



Timeline

1996

Paper: Micromolding in Capillaries (MIMIC). Harvard University

2014

R&D with nano-inks. Caltech

2017

Mesoline is the first and only company to commercialize and perfect MPD, an advanced version of the MIMIC process.

Printing Services

Mesoline's manufacturing location is a 1.400 m^2 (15.000 ft^2) facility in Rotterdam, NL. It includes a state-of-the-art cleanroom, offering MPD production lines with quality assurance.

- Mesoline offers MPD printing services from design and prototyping to production on 100 mm (4-inch) up to 200 mm (8-inch) wafers
- Our production process is ISO-9001 certified
- Quality assurance systems include: 1) SEM, 2) EDX analysis, 3) DLS, 4) optical profilometry, 5) confocal microscopy
- Total wafer capacity is 10.000 per year

Quality Assurance

Mesoline's MPD manufacturing process is ISO-9001 certified.

We maintain certification and rigorous compliance to ISO Quality Management System standards and apply them to every manufacturing process we undertake. Total quality from design through delivery is our objective in every customer engagement.

We provide quality control throughout the process:

1. Incoming wafers are inspected via optical profilometry;
2. Incoming powders are characterized through EDX analysis;
3. Our stamp manufacturing process includes various quality assurance steps to make sure the stamp is fabricated according to our standards before printing on actual wafer;
4. Inks are characterized through DLS (dynamic light scattering), SEM and EDX;
5. Outgoing, printed wafers are inspected via optical profilometry.

CERTIFICATE

Certificate
K-0215232 / 1

kiwa

Issued on	2023-12-18	Page	1 of 1
First issue	2023-12-18	Valid until	2026-12-17

ISO 9001:2015

With this certificate Kiwa confirms that the management system implemented by

Mesoline B.V.

meets the requirements of ISO 9001:2015 for the scope:

Design, manufacturing and production of microstructures using the microchannel particle deposition process.

Ron Scheepers
Country manager Kiwa Nederland

Consult www.kiwa.com in order to ensure that this certificate is still valid.

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Summary

- Mesoline has developed a new microfab method: microchannel particle deposition (MPD)
- MPD offers ultra-small & reproducible features while ensuring extensive parallelization and high scalability
- Superior microfabrication alternative in various market such as MEMS & sensors. More to discover!
- Mesoline provides MPD through manufacturing services

Thomas Russell
CEO & Co-founder
Thomas@mesoline.com

MESOLINE