Aerosol Jet® technology opportunities

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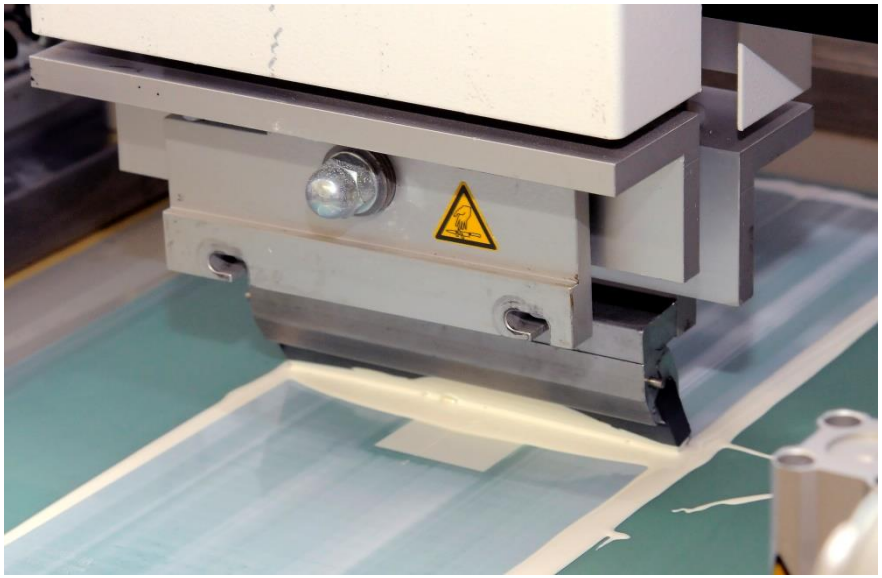
1. Introduction – history and formation
2. Aerosol Jet system
    - 2.1 System components
    - 2.2 Inks and substrates
3. Application of Aerosol Jet technology
4. Conclusion

- Printing technologie used for creating electronics (1950)
- Screen / sterncil printing, inkjet
- Technologies limitation, low flexibility



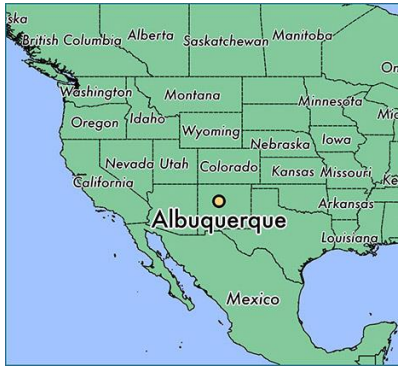
History

- **DARPA** (Defence Advanced Research Program Agency)
  - project **MICE** (Mesoscale Integrated Conformal Electronics) **(1990)**
    - Developing a tool for printing of the electronics
      - Ability to use CAD systems
      - Fast and easy to use
      - Wide range of printed materials
      - Wide range of substrates (including low-temp <200 °C)
    - Succes – **invention of the Aerosol Jet technology**
      - Established company - **Optomec Inc. (1997)**

OPTOMEC
Additive Manufacturing Systems — from Nano to MACRO™

- Optomec Inc.
  - Established 1997
  - Headquarters in Albuquerque (USA)
  - **LENS** a **Aerosol Jet**
  - Investments in research 30 mil. $
  - Close cooperation with
    - General Electric, Boeing, NASA, CEA LETI, Fraunhofer, US Army, US Navy, US Air Force, Sirris, Xerox….

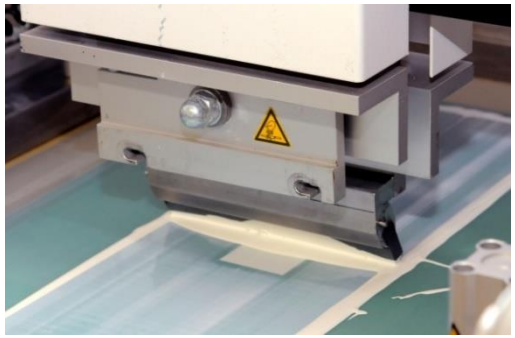
OPTOMEC
Additive Manufacturing Systems — from Nano to MACRO™



sirris
driving industry by technology

- **Aerosol Jet**
  - Selective deposition technology
  - Contactless printing technology
  - Fast creating or changing toolpath →optimal for **Rapid Prototyping**
  - Tisk aerosolu
    - Ink droplets 1 – 5 μm
    - Droplets nozzle outcoming velocity up to 50 m/s (180 km/h)
    - Minimal printed line width **10 μm** (Ag ink)
    - Minimal printed layer thickness **10 nm** (CNT ink)

Aerosol Jet vs. Screen Printing

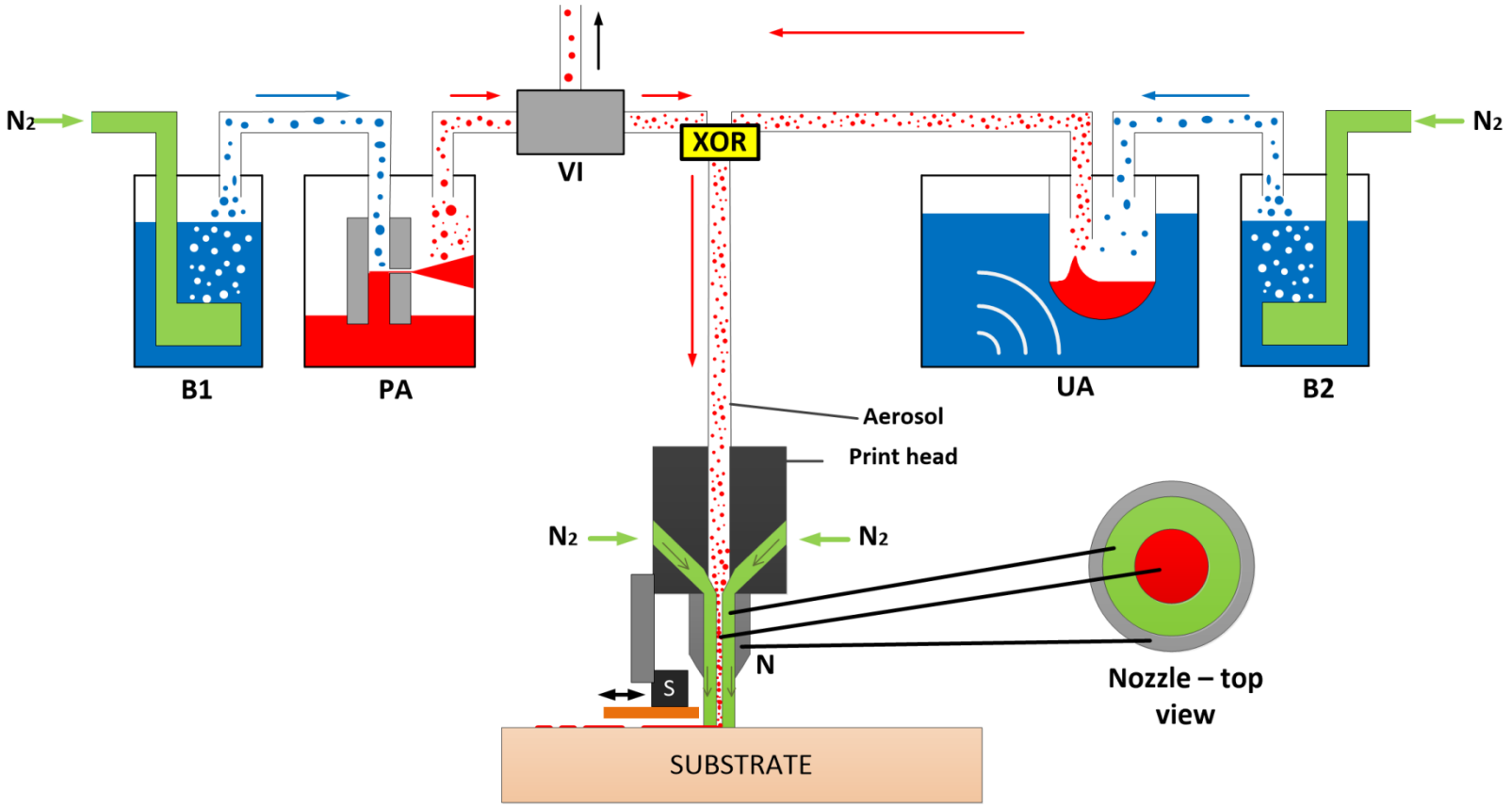


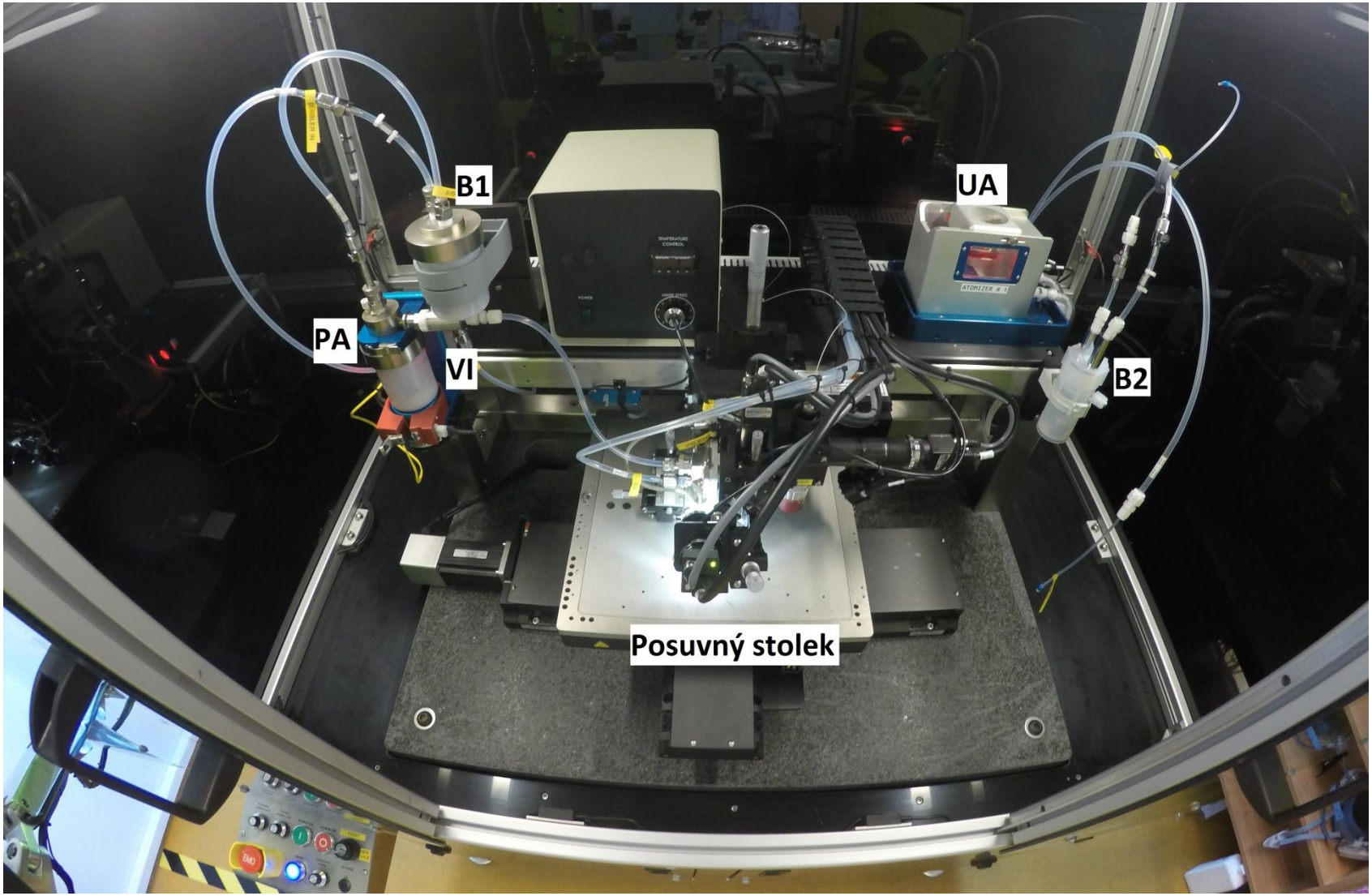
- Pros
  - Fine lines printing
  - Easy printing on 3D substrates
  - **Easy change of printed motive!!!**
- Cons
  - Not (yet) suitable for high volume manufacturing
  - High ink prices
  - Not suitable for covering large areas

Aerosol Jet vs. Inkjet

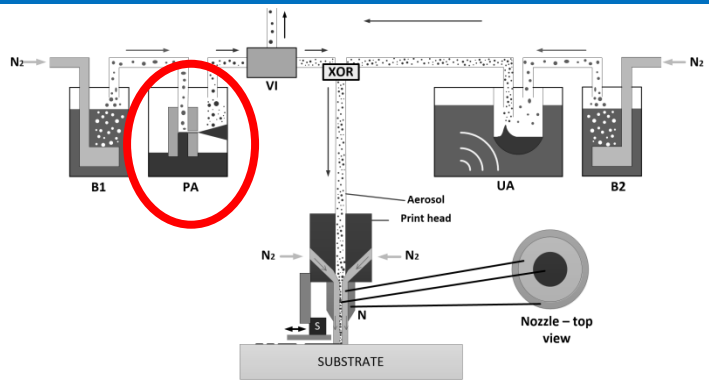
- Pros
  - Fine lines printing
  - Nozzle - substrate distance – variable
  - Ink‘s viskosity range
  - Printing on 3D substrates
- Cons
  - More complex operation
  - Higher ink prices

- Bubbler, Atomizers, Print heads,…



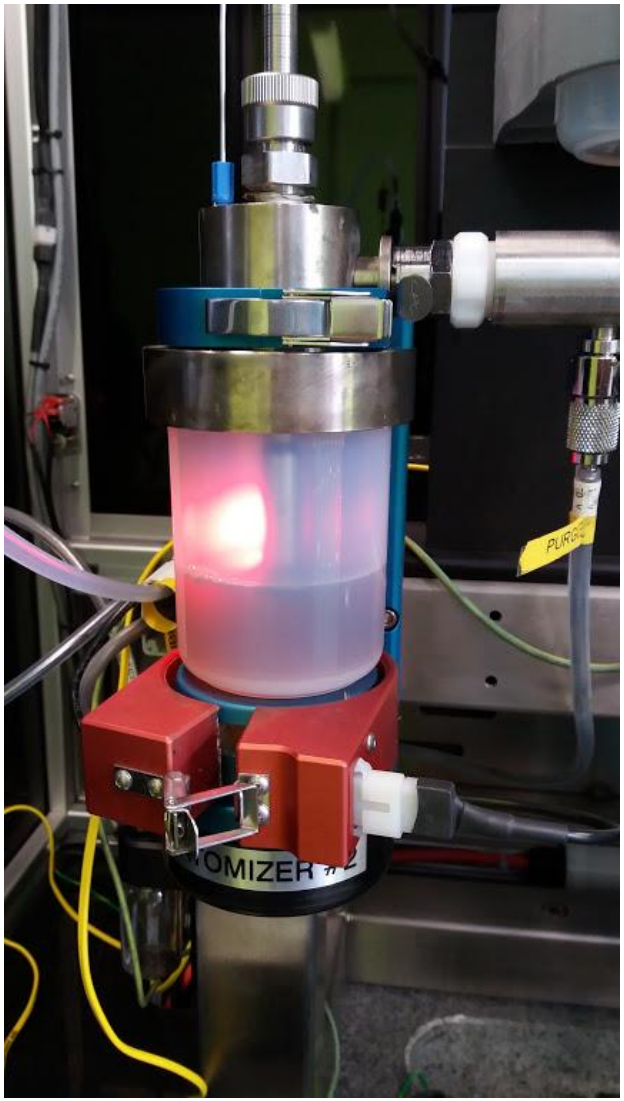

B1
UA
PA
VI
B2
Posuvný stolek

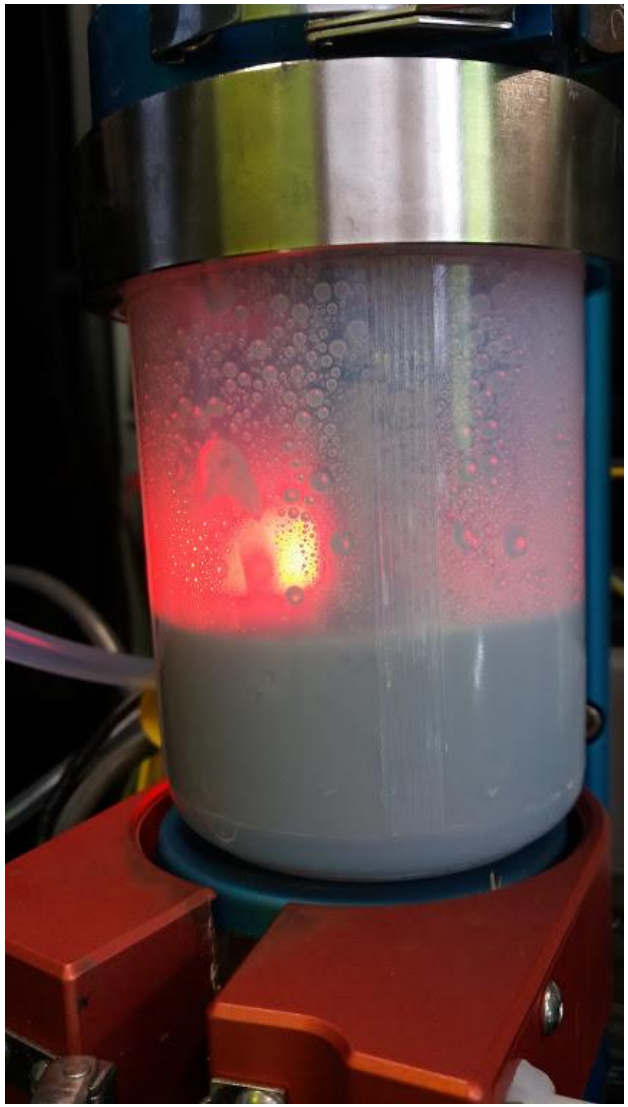
Pneumatic atomizer (PA)



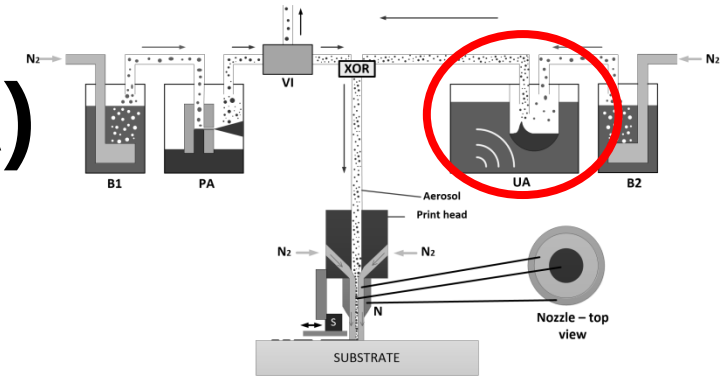
- Jar with ink
- Suction by Venturi effect
- Sputtering on the jar wall >> ink smashed to **aerosol**
- Viscosity 1-1000 mPa·s
- min 15 ml of input material
- Deposition of wider (25+ μm) or thicker lines

RICE

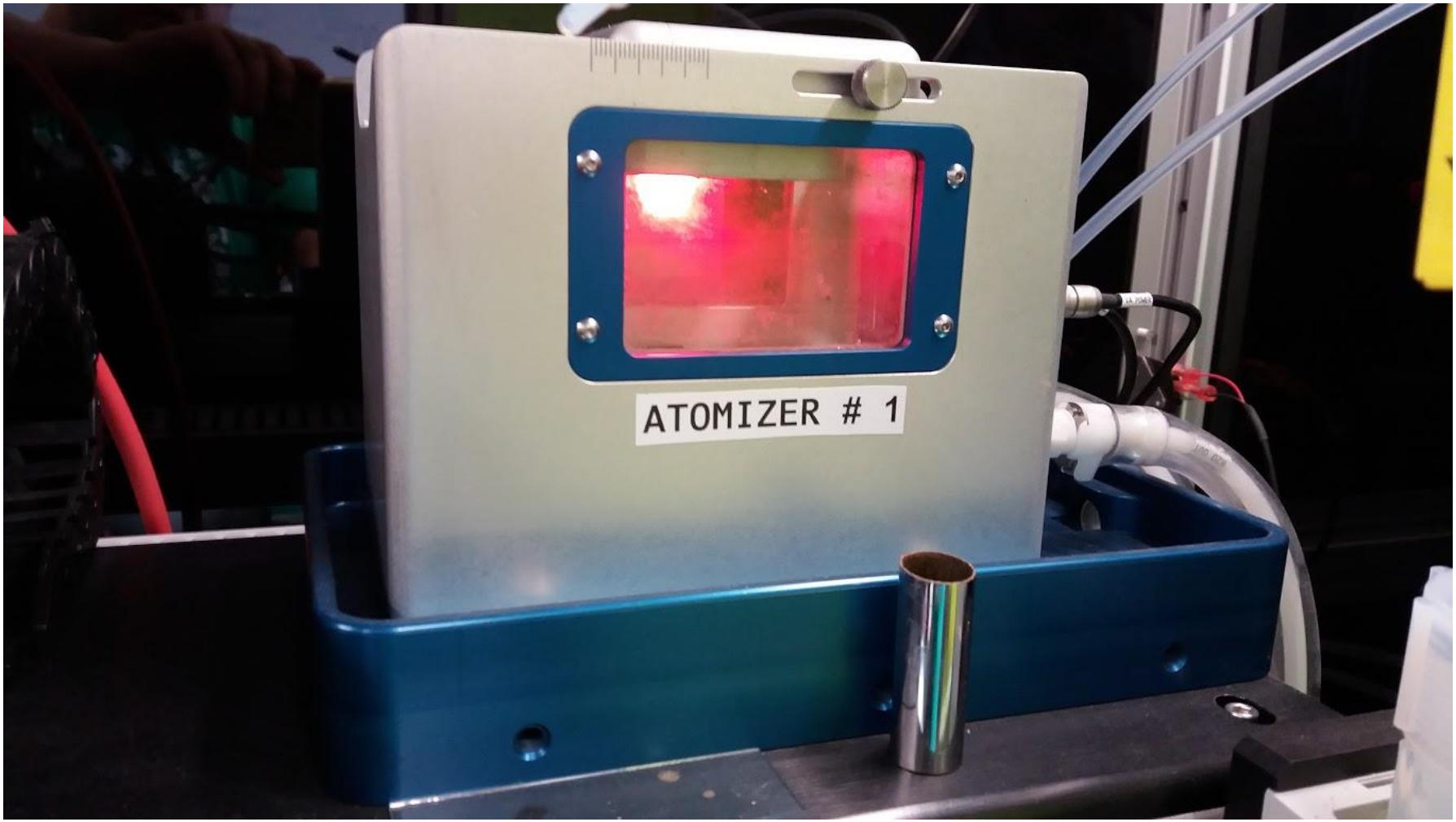




Ultrasonic atomizer (UA)

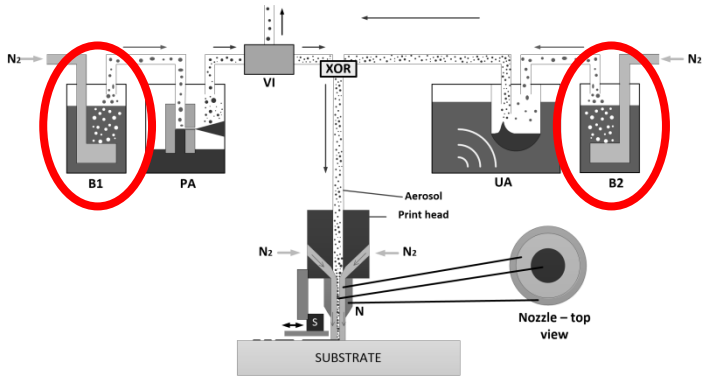


- PFA sleeve with ink
- Ultrasonic smashing of ink >> **aerosol**
- Viscozity 1-5 mPa·s
- min 1 ml of input material
- Deposition of narrower lines (10+ μm) or thin layers


ATOMIZER # 1

Bubbler

- Possible (not needed) to use
- Filled with solvent
- Nitrogen „bubbling through“
- Improves atomization
- Aditon of solvent to ink



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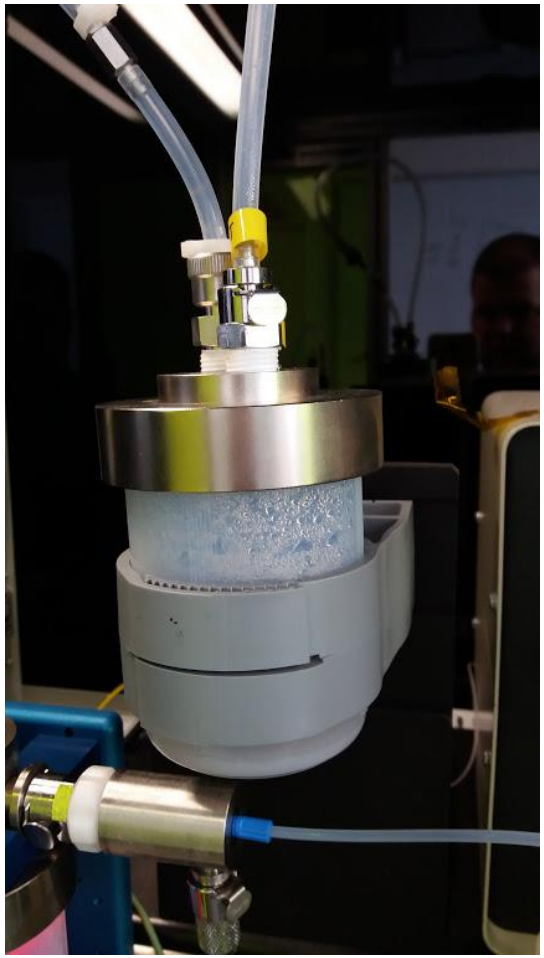
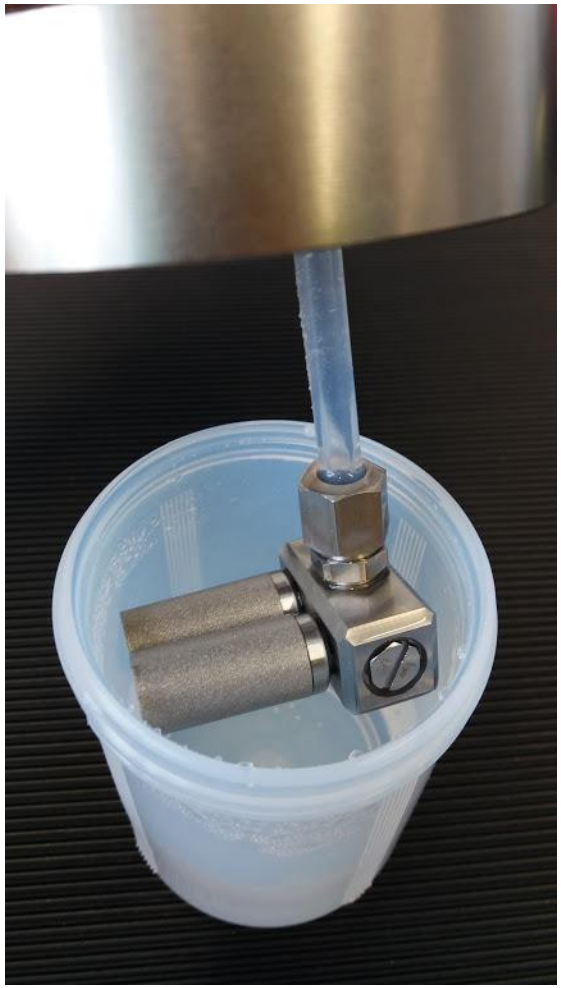
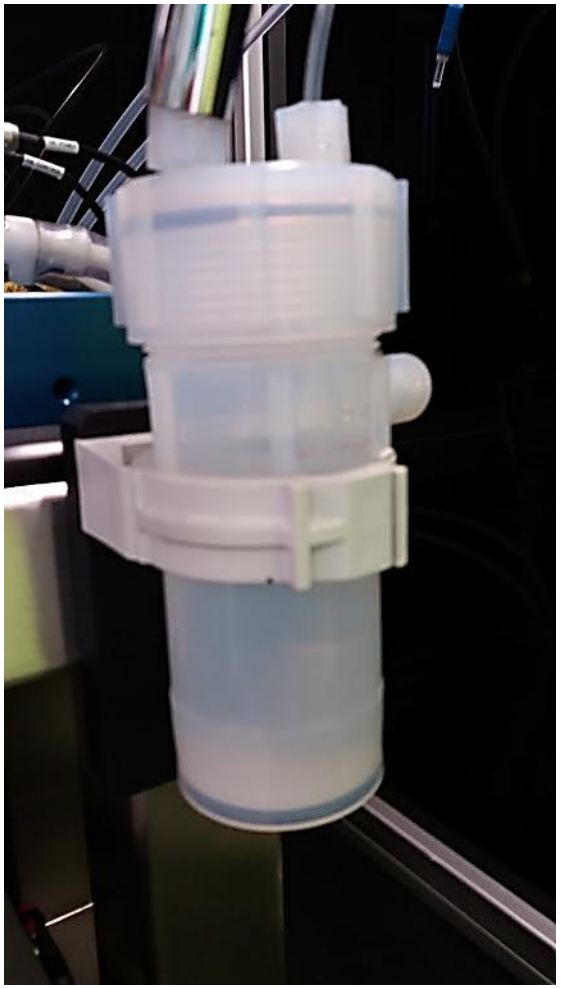
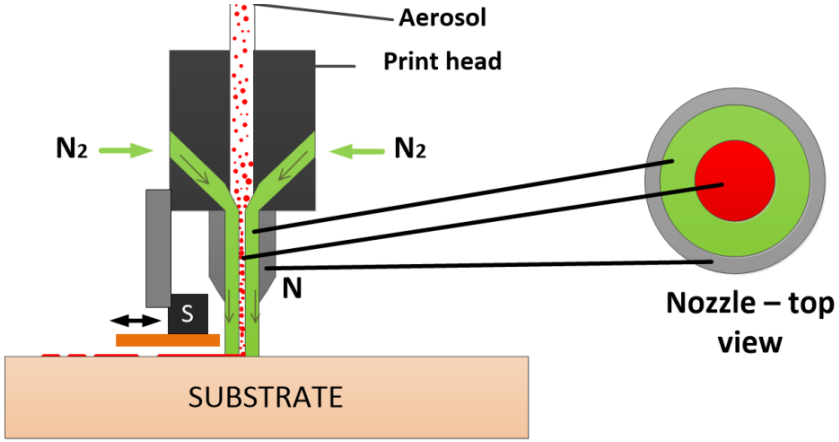






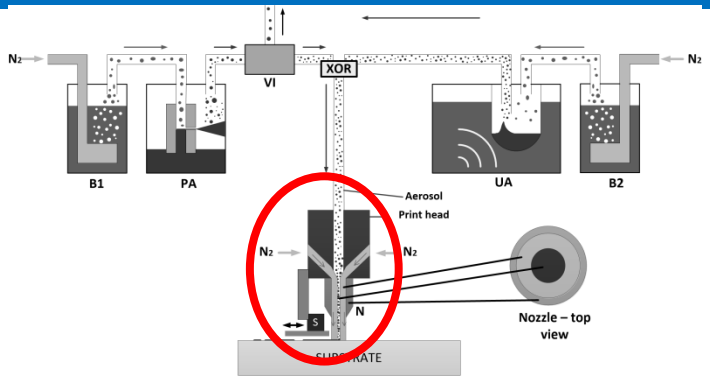
Deposition heads

- 2 types
  - Fine
  - Wide

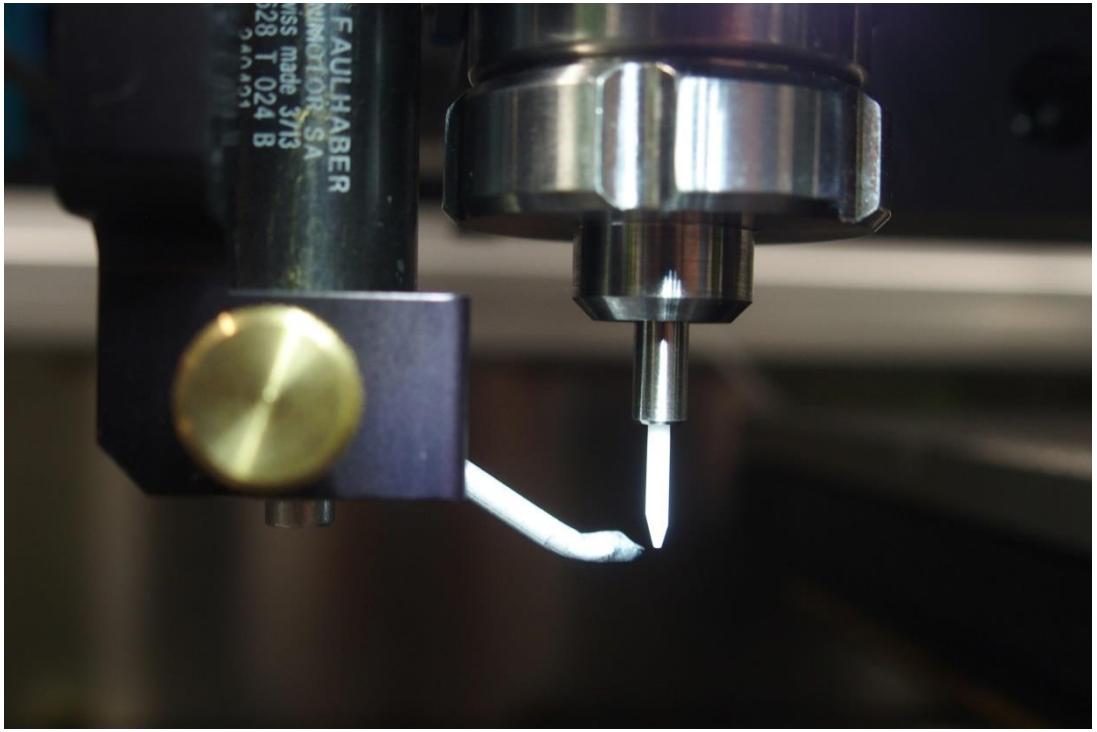


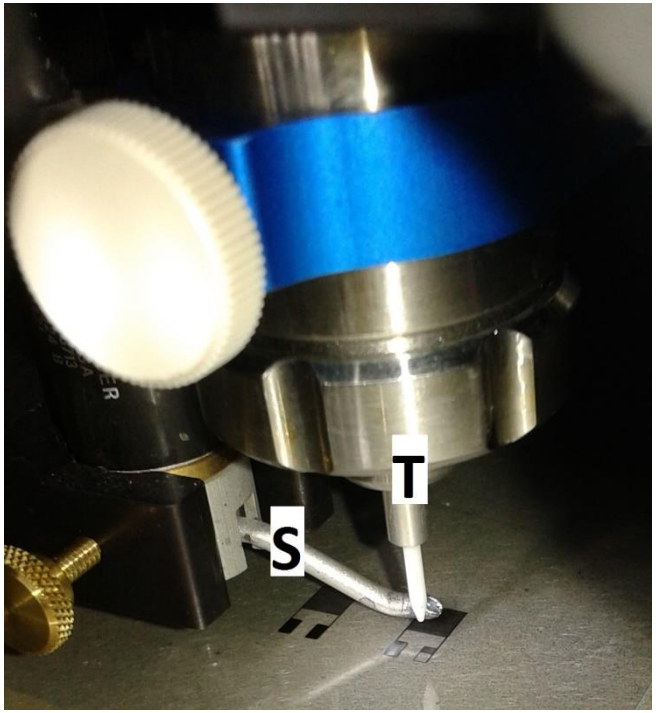
- Nitrogen focusation – 3 advantages
  - No contact aerosol-nozzle >> **resistent to clogging**
  - Aerosol focused to thin stream >> **fine lines printing** (from 10 μm), easy line width management
  - Aerosol well focused 15 mm from nozzle tip >> possibility for **printing on 3D/curved/stepped substrates**

Fine deposition head

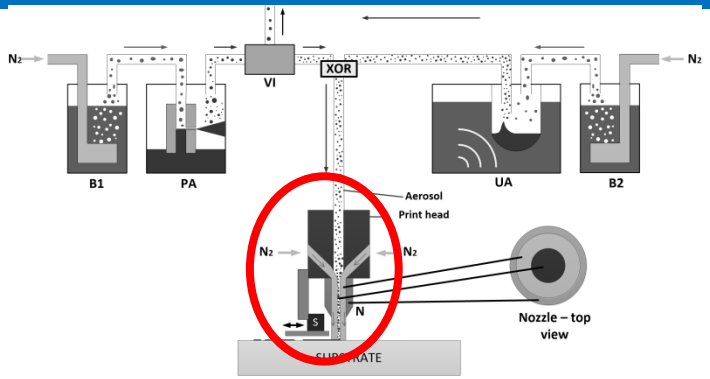


- Nozzle – stainless with ceramic tip
- Nozzle hole diameter 100, 150, 200, 250, 300 μm
- Shutter
  - stops aerosol deposition on substrate


FAULHABER

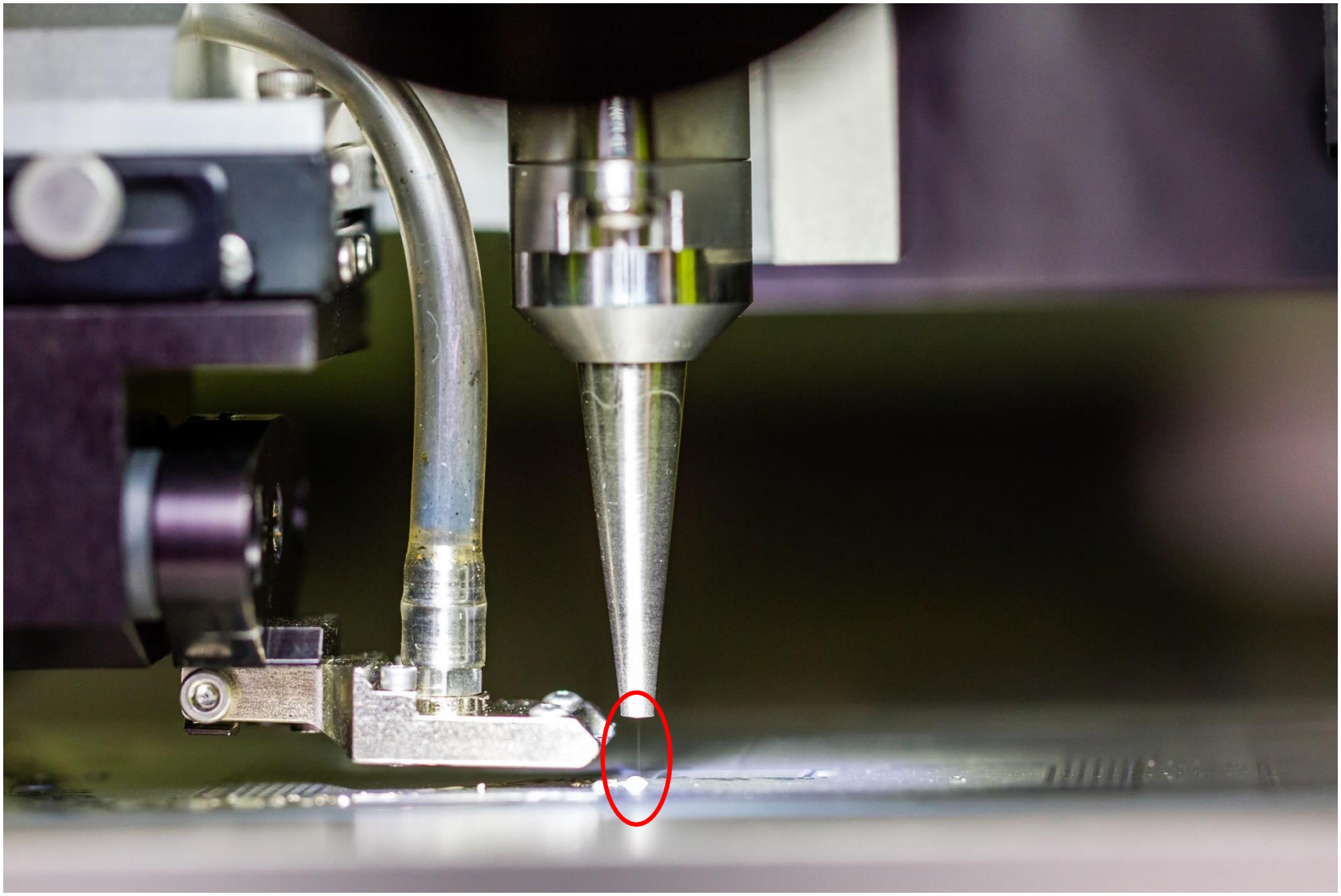

T
S

Wide deposition head



- Stainless nozzles
  - Round (0,75 mm)
  - Oval (0,25x1,5 mm and 0,25x3 mm)

- Shutter
  - Stops aerosol deposition on substrate
  - Exhausted to waste jar

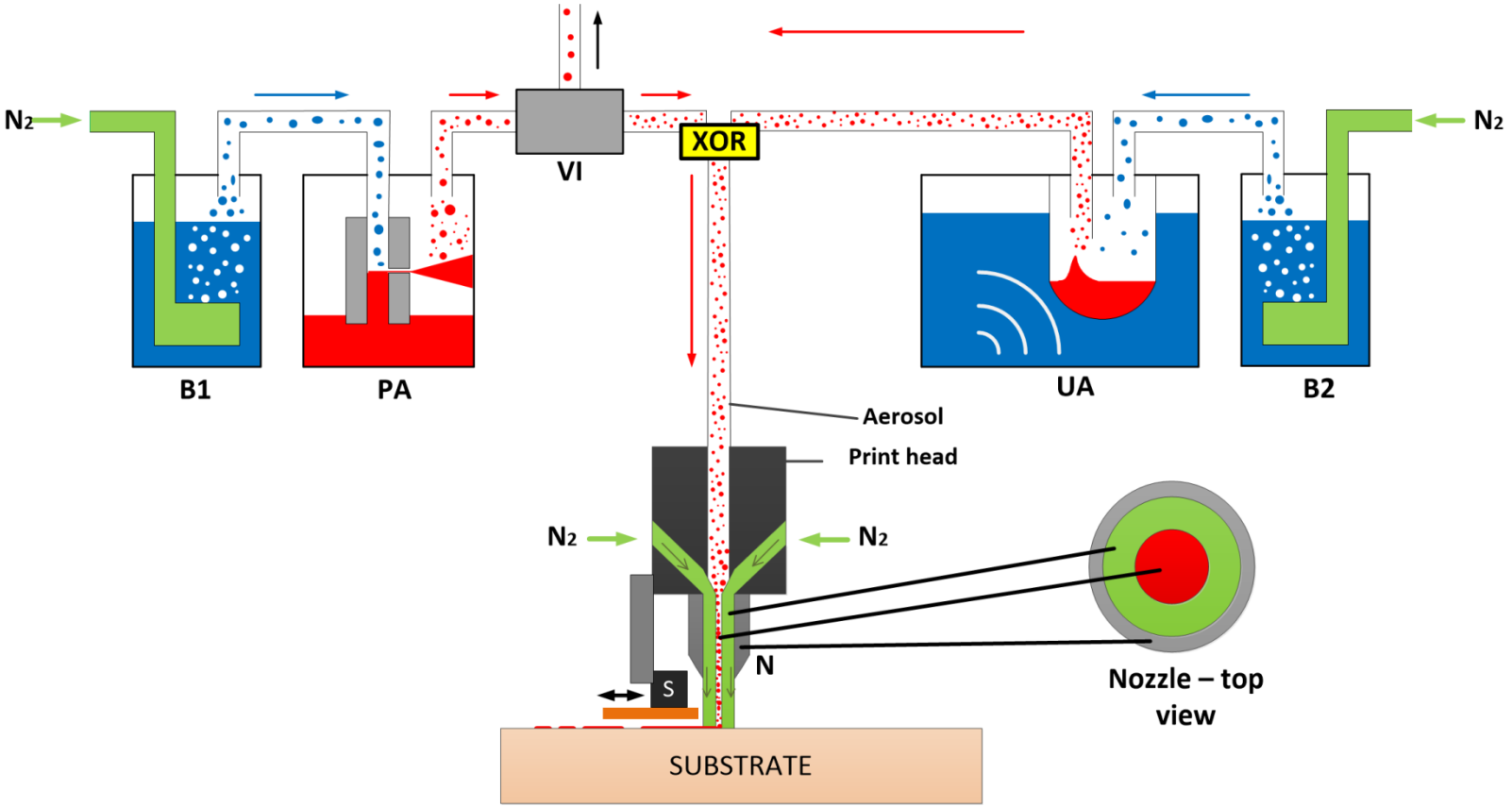


Printing - complex process

- Atomizer flow **ATM** [sccm]
- Ultrasonic current [mA]
- Virtual Impactor exhaust flow **EXH** [sccm]
- Focusation gas flow **SHT** [sccm]

- Platen temperature $\mathbf{t_{plat}}$[°C]
- Ink temperature $\mathbf{t_{ink}}$[°C]
- Motion velocity **v** [mm/s]
- Etc.

Aerosol Jet function summary



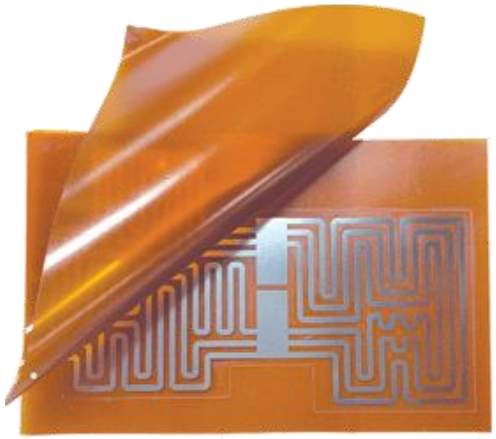
Aerosol Jet inks

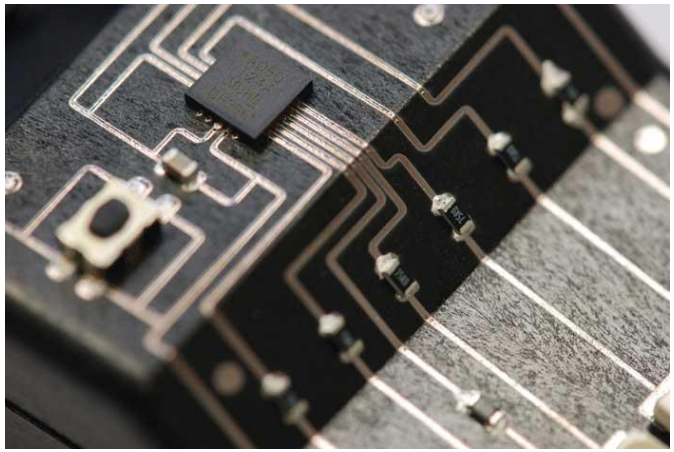
- Viscosity 1 – 1000 mPa·s
- Solid particle size up to 500 nm
- Compatibility with substrate
- Compatibility with systém (orings, metal)
- Capability of atomization??

- Possible ink modifications
  - Adding different solvents (even mixing them)
  - Functionalizing with different chemical groups (primary for organic materials)

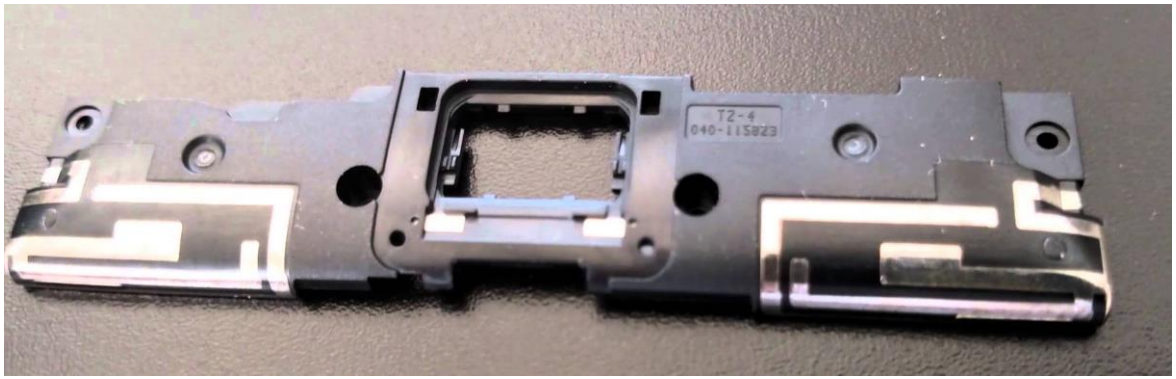
- Compatibility with ink
- Broadly any substrate for printing
  (2D, 3D, platen max size, platen max load,…)

- Classic PCB, ceramics, Si wafer, metals, foils (PET, PEN, Polyimide…), plastic, paper, ….





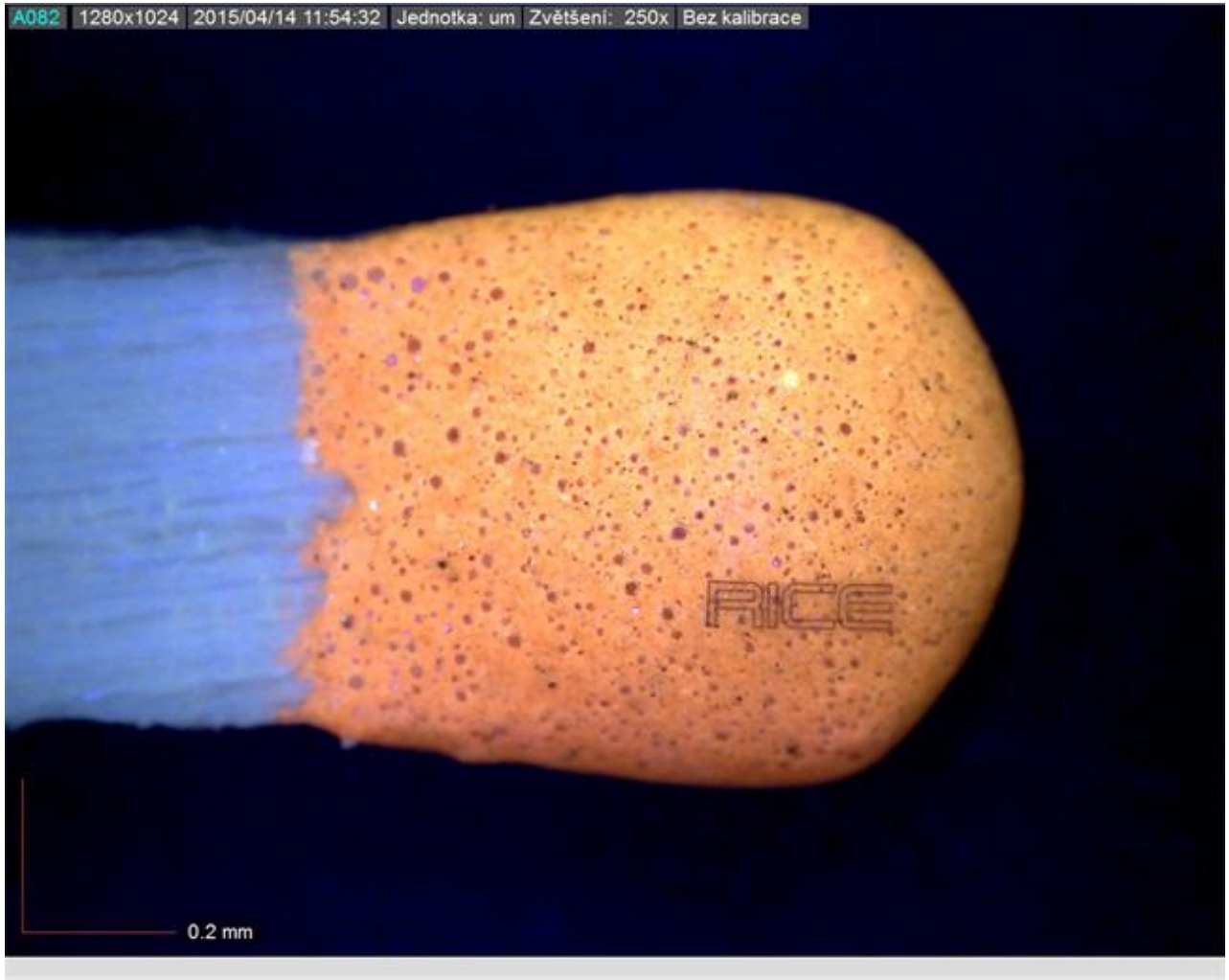
- Commercial usage – mobile devices printed antennas
  - Company - Lite-On
  - 24/7 Aerosol Jet Marathon series
  - 4 print heads, 5-axis motion system



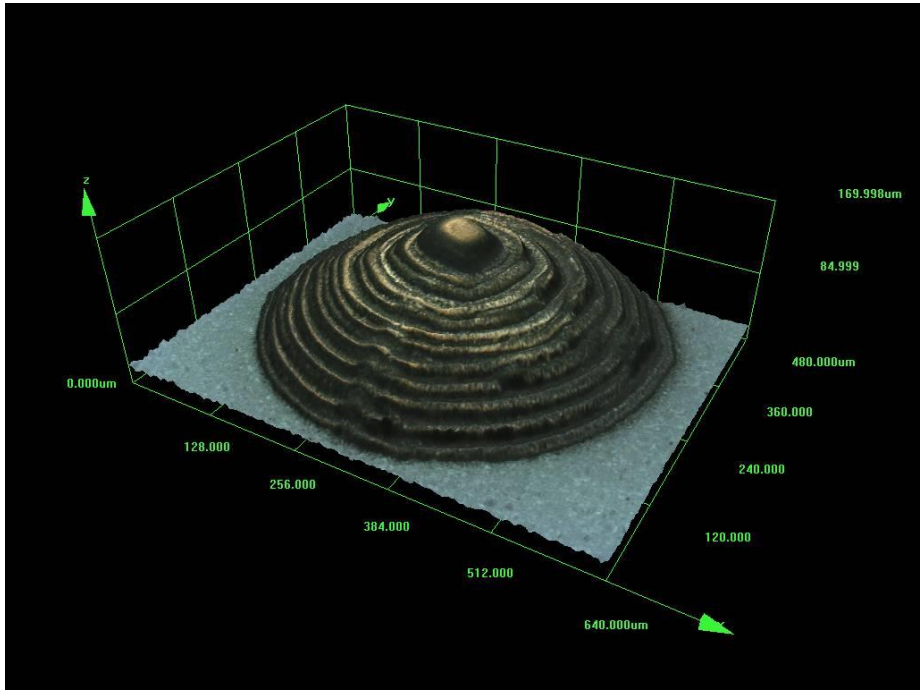
Our application

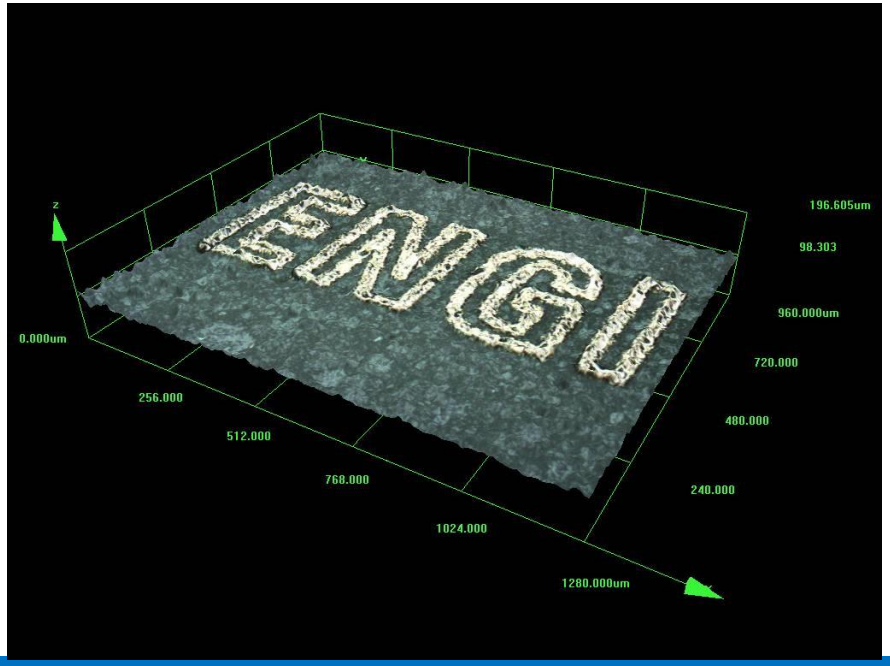
- Printed electronics
  - Electrical circuits, passive components (R, L, C), RFID antennas
- Sensing application
  - Active layers - PEDOT, CNT, Graphene…
  - Auxiliary contacts, interconnections
  - Interdigital electrodes
- SMD chips interconnecting
  - Electronics
  - Power electronics
- Future ??
  - Printing on fibres? Flexible ink development? Strain gauges? Thermistors? Printing of bioactive materials, enzymes?

- Logo RICE
  Au ink
  10 µm line

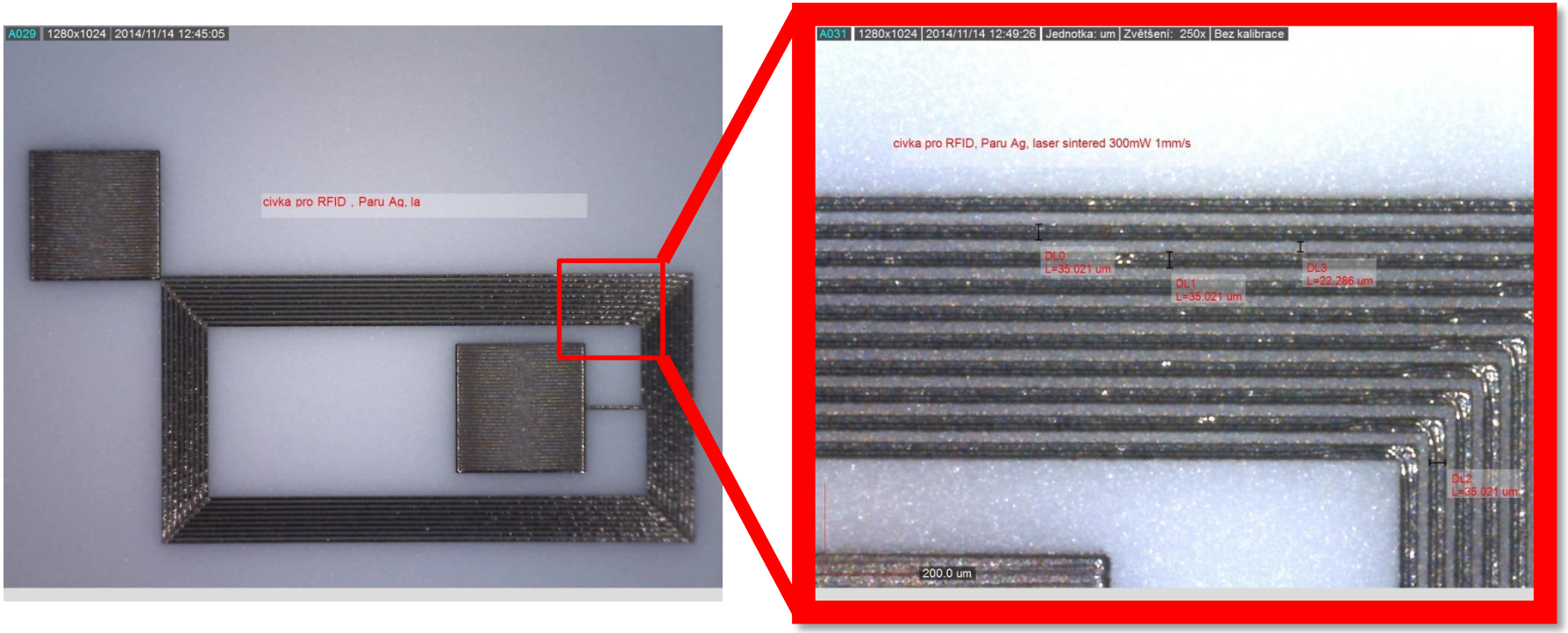


- Miniature 3D objects (Ag ink), multilayer printing

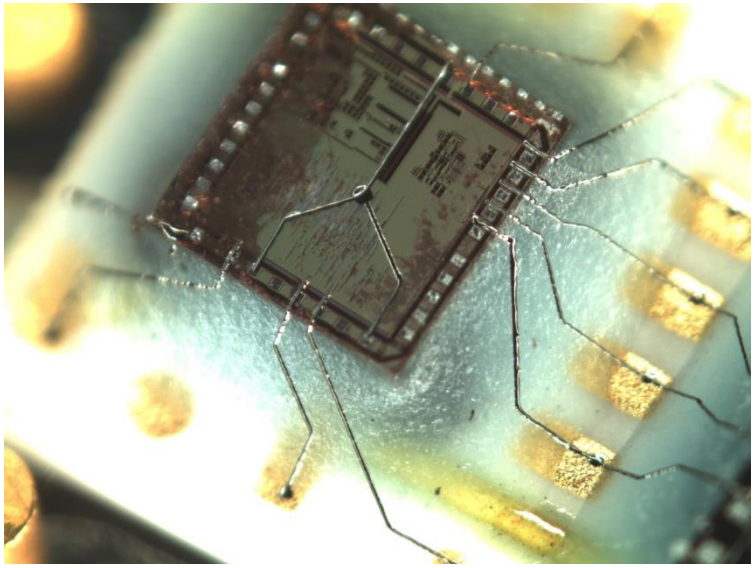


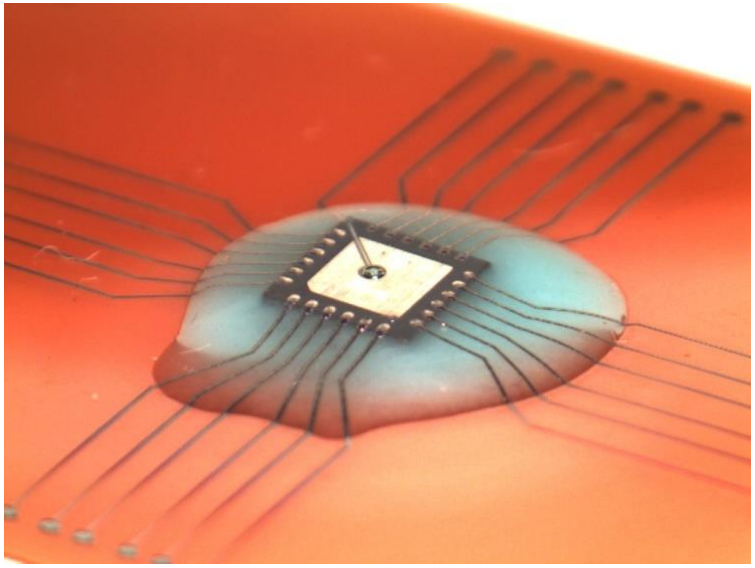


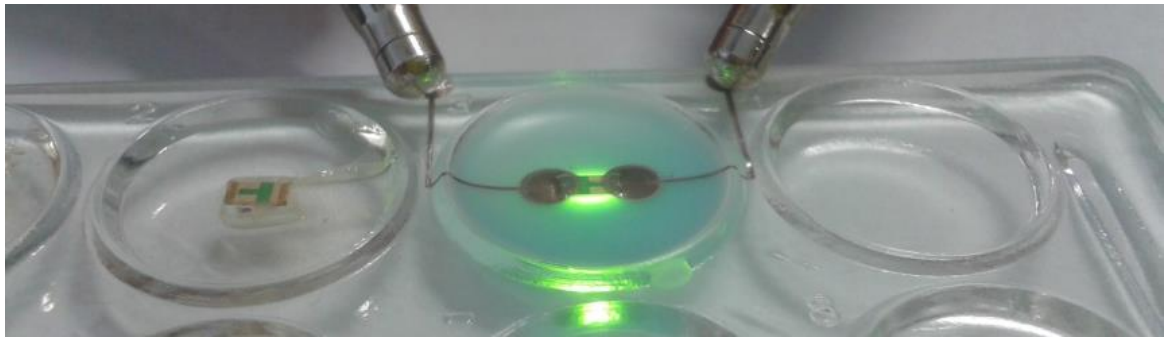
- RFID antenna, IDE (Ag ink)



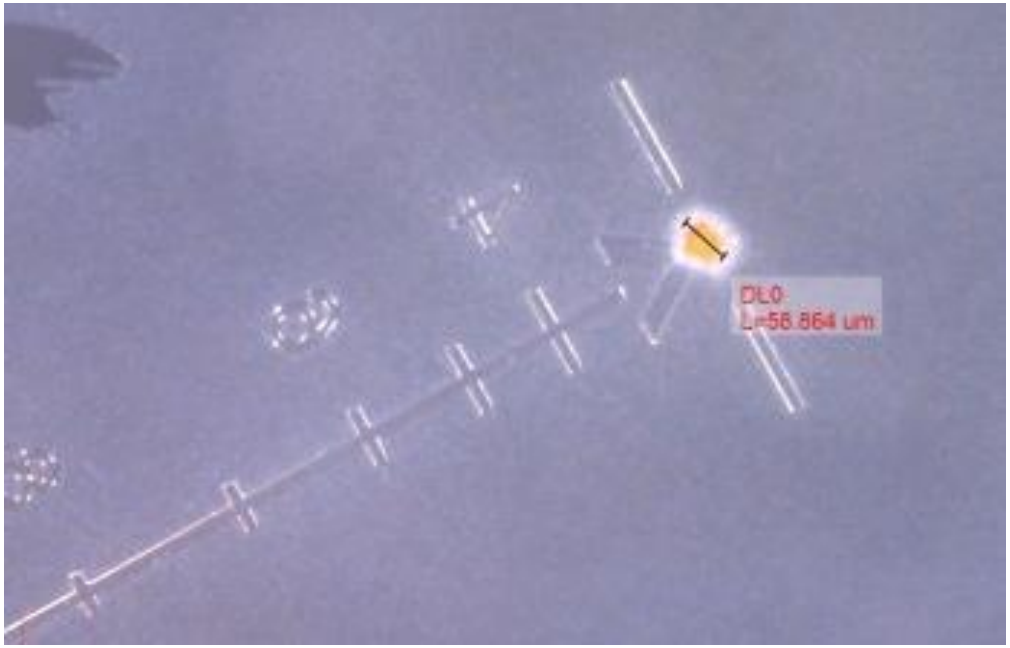
- Chip interconnections (Pt, Au and Ag ink)

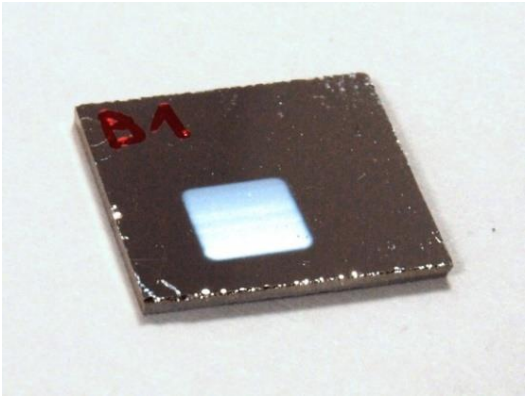


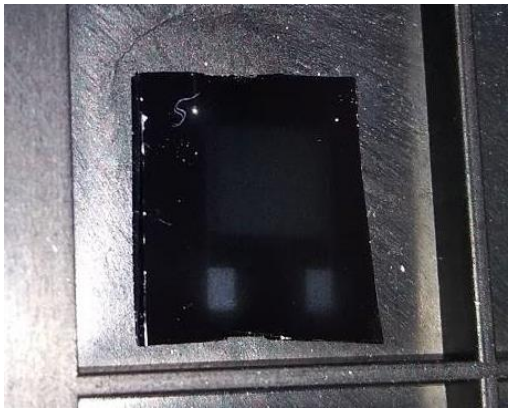




- Our available materials: Ag, Pt, Au, CNT (carbon nanotubes), Graphene, PVP dielectrics, Polyimide,…







Optomec Aerosol Jet

- Unique, modern additive deposition technology
- Aerosol generation (atomization) + nitrogen focusation
- Printing on 3D or non-planar substrates
- **Rapid Prototyping**
- Using Inkjet, Aerosol Jet, Dispensing, Screen printing >>their synergy in manufacturing >> **hybrid made electronics**

- **Wide range of inks, substrates >> huge capability of technology in R&D** (research and development)

Questions are welcomed ☺

Thank you for your attention