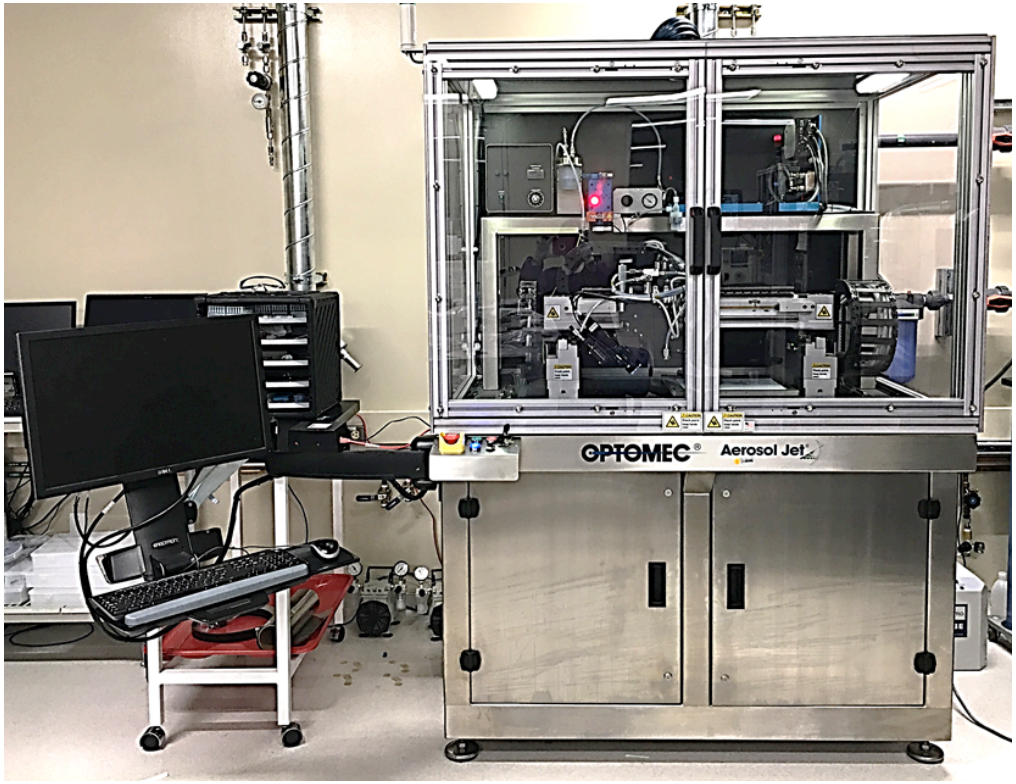
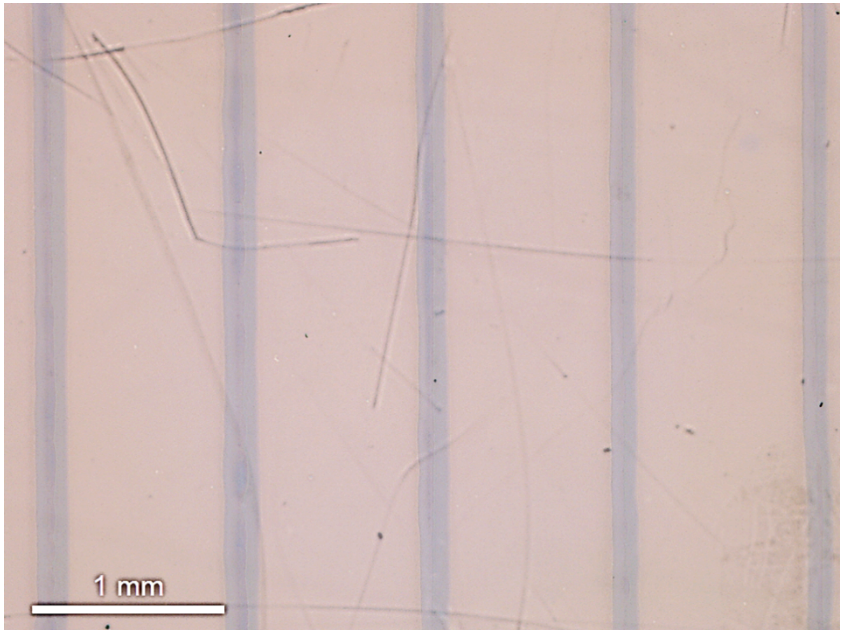
# Standard Operating Procedure of Optomec Aerosol Jet Printer in Pneumatic Atomizer Mode and Characterization of Printed PEDOT:PSS Lines




Kye Young Lee, Camila Cendra, Theo Gao

Stanford University

# Outline

1. Introduction: drop-on-demand printing techniques
    1. Working principles of aerosol jet printing
    2. Examples/applications of aerosol jet printing
    3. Comparison: aerosol jet vs. inkjet

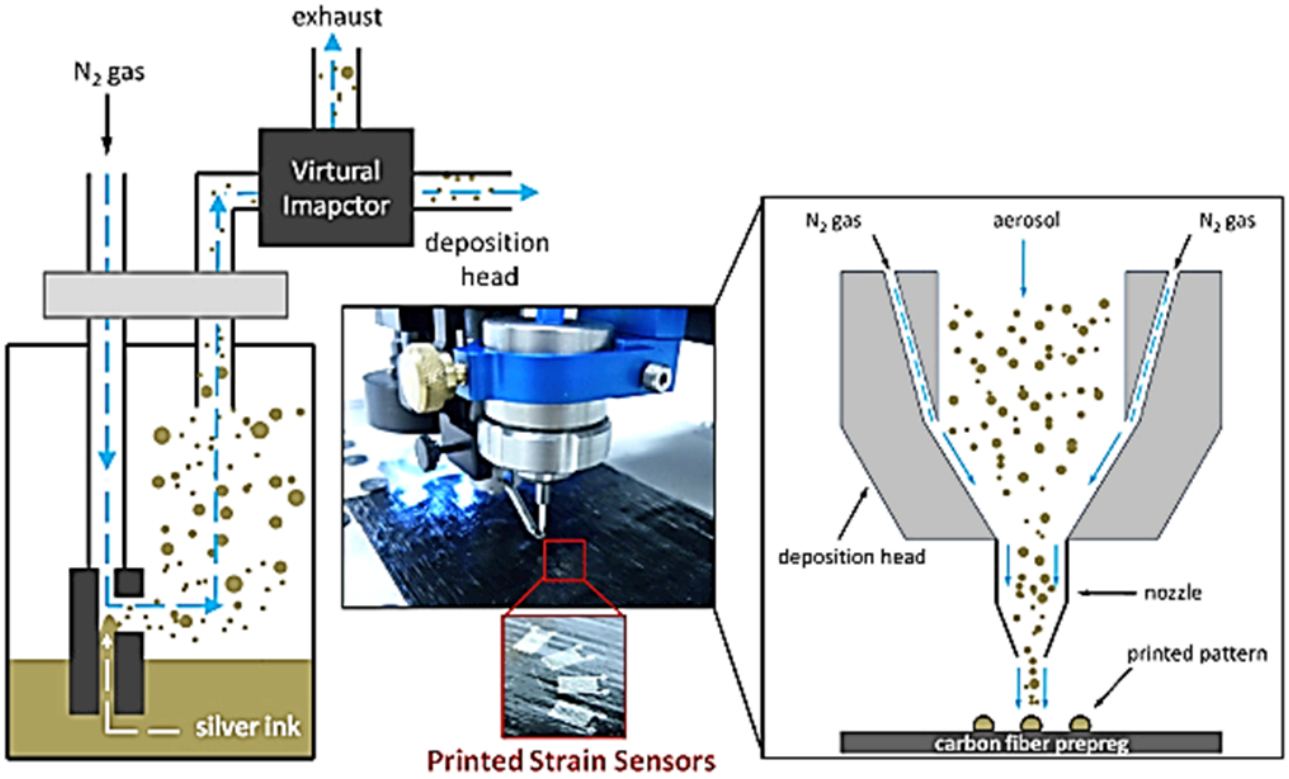
2. Standard operating procedure (SOP) of Optomec
    1. Assembly and initialization
    2. Troubleshooting
    3. Disassembly and cleaning

3. Aerosol jet printing - start atomizing!
    1. Optimizing print patterns
    2. Printing example: lines of PEDOT:PSS

4. Conclusion

# 1. Introduction: Drop-on-Demand Printing Techniques

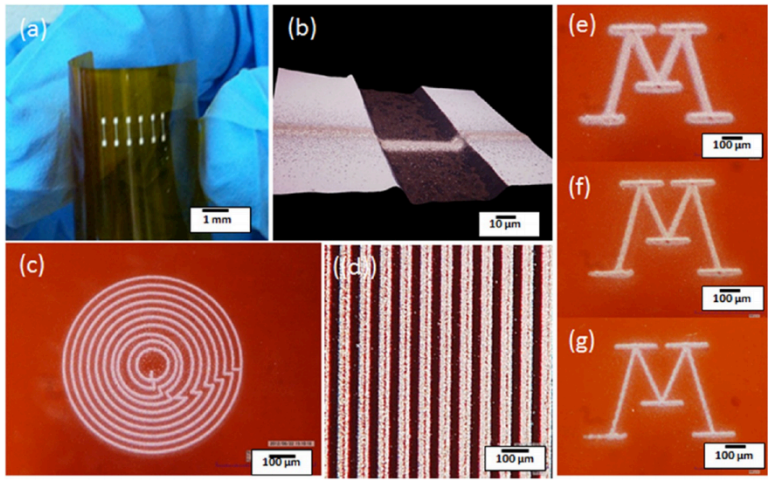
# 1.1 Working principles of aerosol jet printing



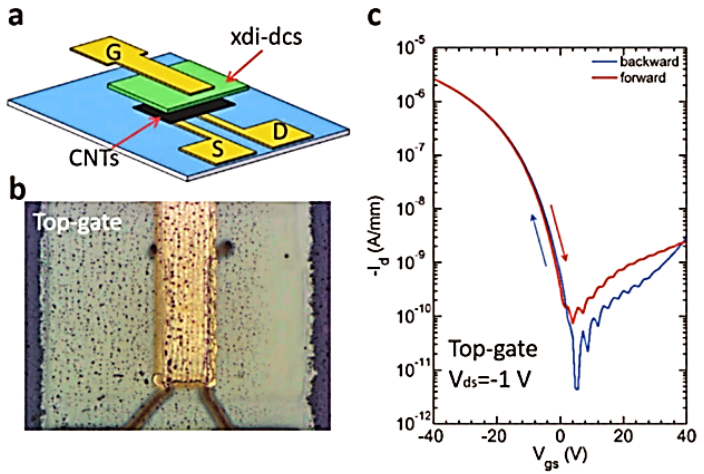

Smart Mater. Struct. 21 (2012) 115008

Atomization of ink into particles ~1-5 μm in diameter → Aerosol particles pushed into printhead by a $N_2$ gas stream → Sheath gas focuses aerosol to a jet with diameter ~10μm

# 1.2 Examples/applications of aerosol jet printing




ACS Appl. Mater. Interfaces 2013, 5, 4856−4864

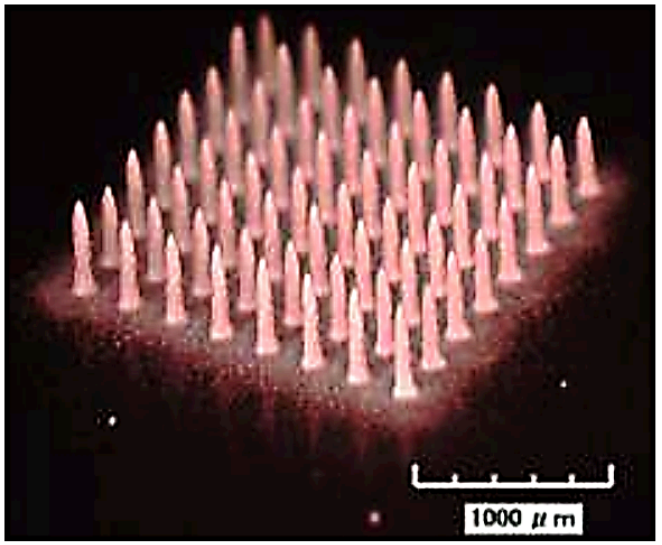



Adv. Electron. Mater. 2017, 3, 1700057

**Flexible silver patterns**

**All-printed CNT transistor arrays**

Optomec Inc.




Damle et al., unpublished work

**Conformal printing**

**$CeO_2$ micropillars**

# 1.3 Comparison: aerosol jet vs. ink jet printing

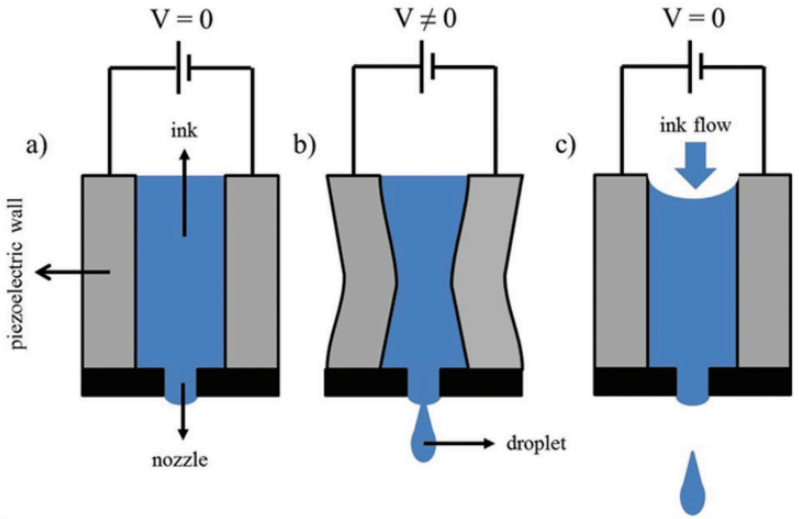
**Aerosol jet**

- Compatible with a wide range of ink rheologies (1-5000 cP)
- Can pattern large areas, as well as on uneven surfaces
- Utilizes more material
- Less prone to clogging
- Suitable for single-material deposition

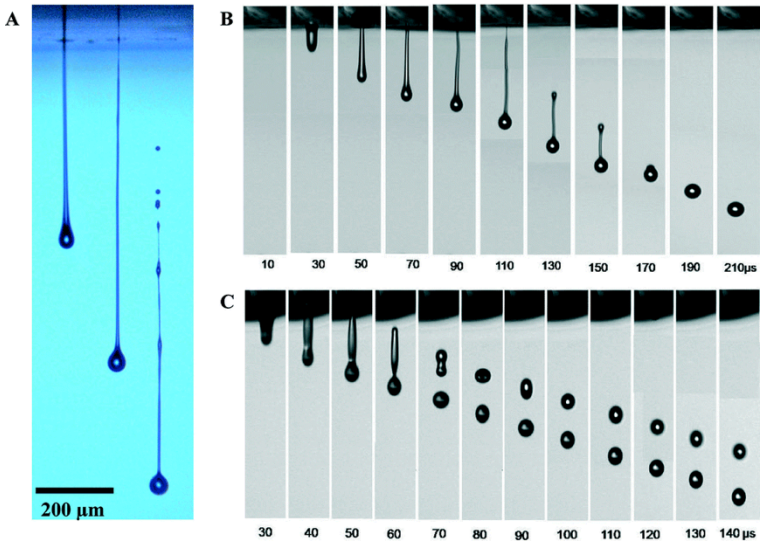
**Inkjet**

- Limited to low viscosity inks (<5 cP)
- Limited to small areas and flat surfaces
- Less wasteful of material
- Prone to clogging
- Easier to do multi-material printing

**Dimatix Printer 2800 Series**




**Adv. Mater. Technol. 2017, 2, 1700063**

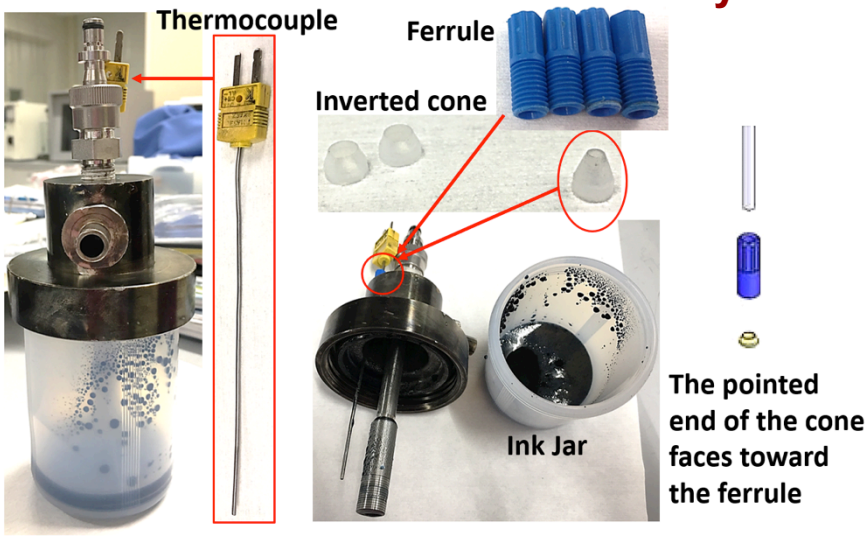



**Lab Chip, 2015,15, 2538-2558**

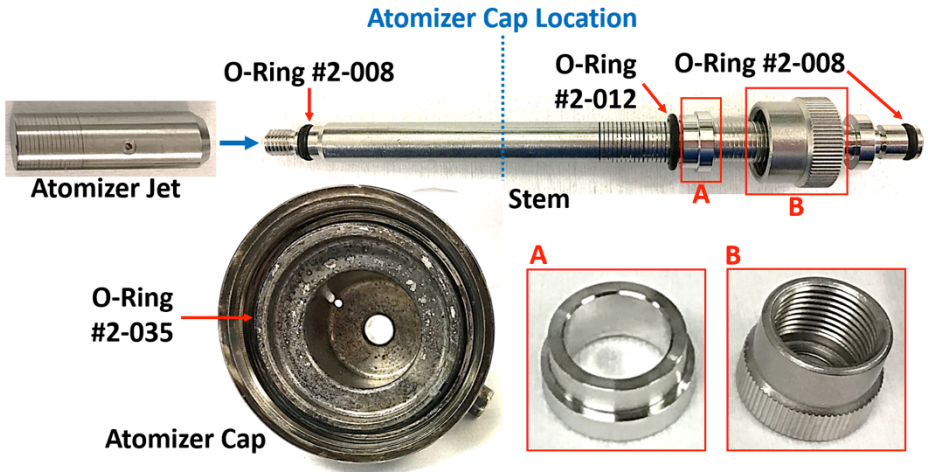
# 2. Standard Operating Procedure of Optomec in Pneumatic Mode

# 2.1 Assembly and initialization

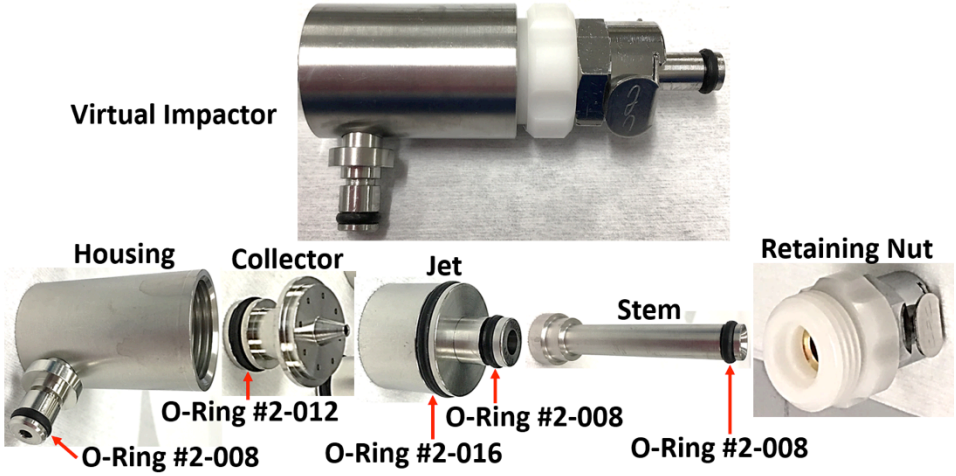
## Pneumatic atomizer assembly



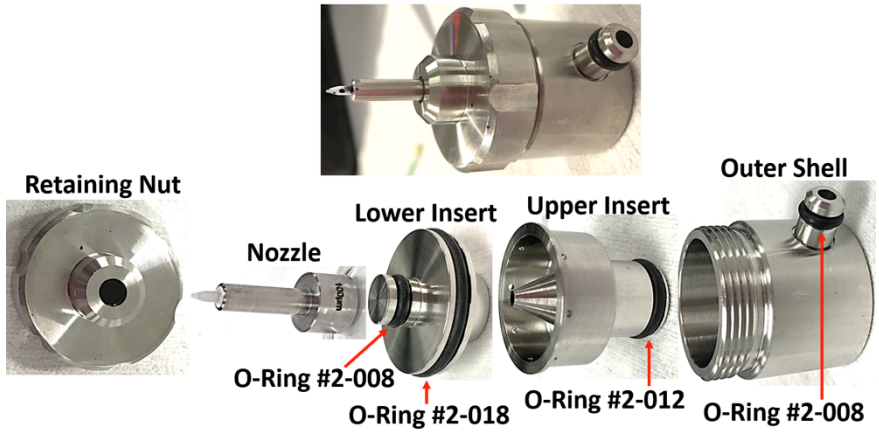

## Pneumatic atomizer stem assembly




## Virtual impactor assembly

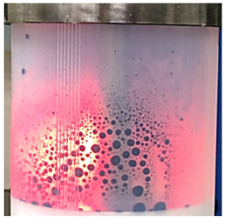



## Printhead assembly for fine feature nozzle

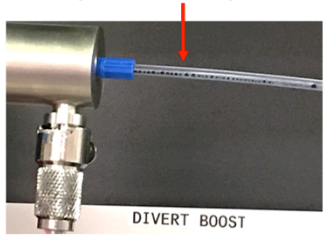


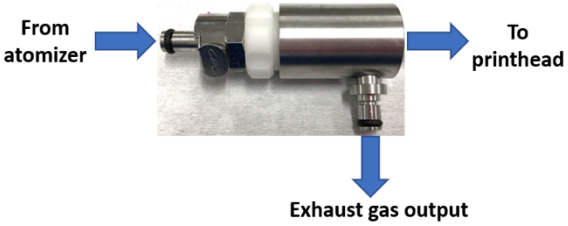
# 2.1 Assembly and initialization

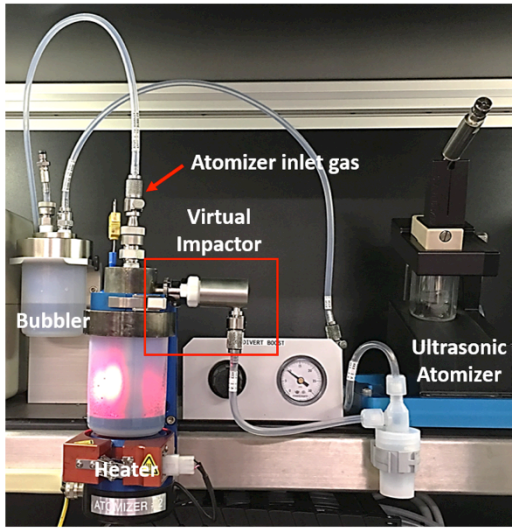
Atomization of PEDOT:PSS ink when atomizer flow is on



A tube connects the virtual impactor with the printhead

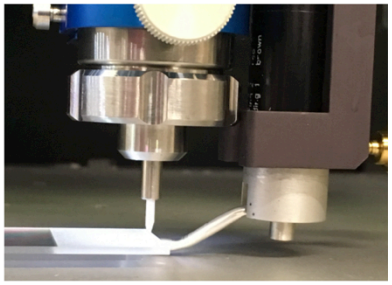


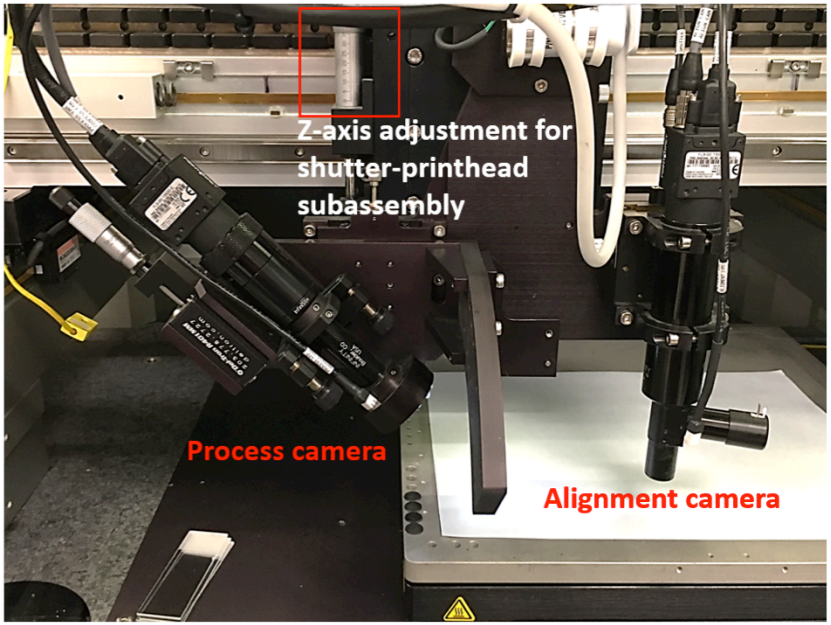



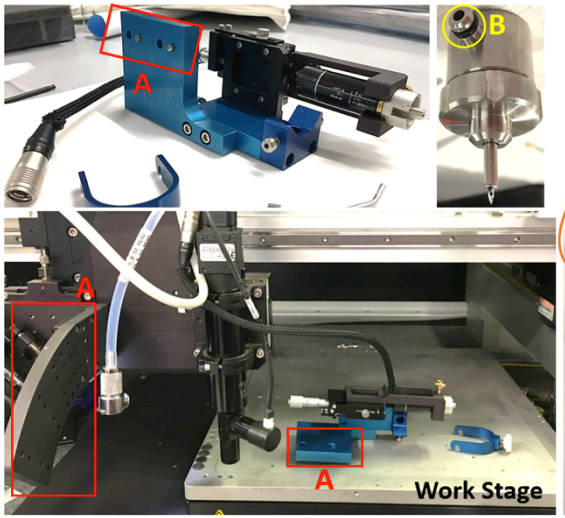




Adjusting deposition head (nozzle tip) and shutter height using glass slides

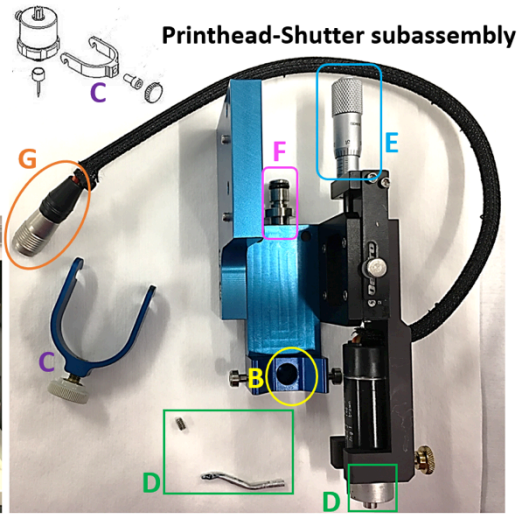
Deposition head is adjusted correctly (with fine feature nozzle)





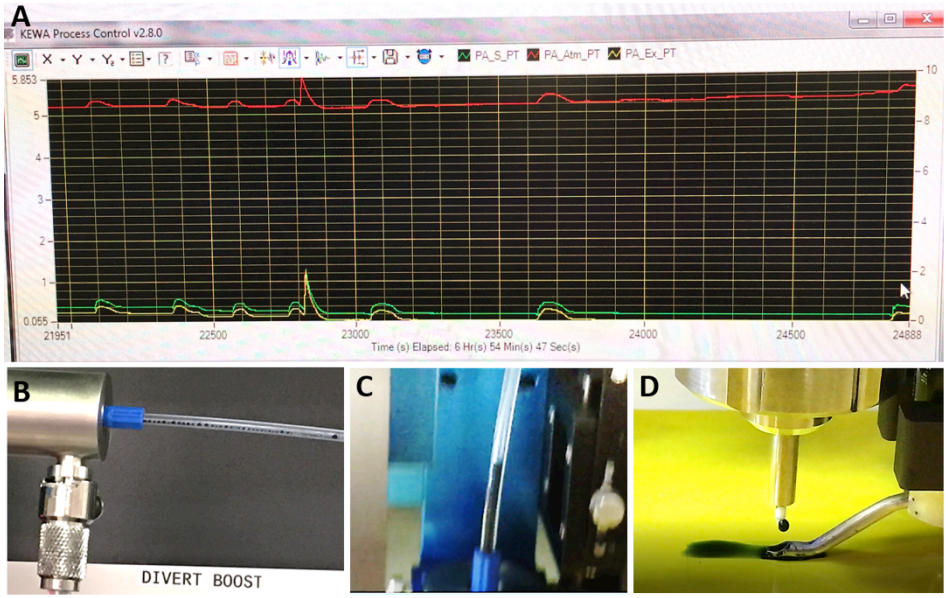



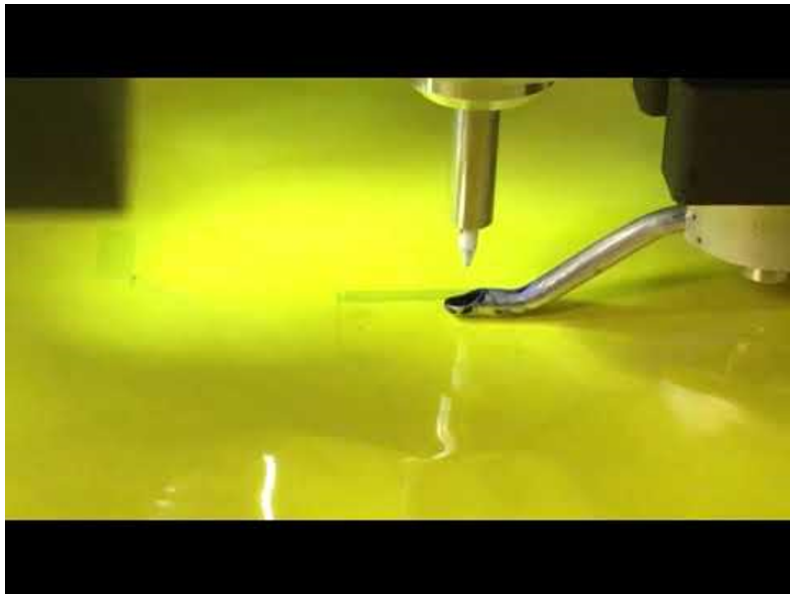

Printhead-Shutter subassembly



# 2.2 Troubleshooting

1. Software issues -- not starting or freezing, not executing the uploaded toolpath file, not measuring applied gas flow values
   → **Close/restart KEWA, restart computer, set all gas flows to zero in proper order**
2. Unusual gas flow values (leakage or clogging)
   → **Check for leaks in tubing, printhead, virtual impactor & atomizer (in that order)**
   → **Clean or replace parts as needed**
3. Bad jetting behavior
   → **Adjust "push" (Δ of exhaust & atomizer flow)**
   → **Adjust height of atomizer in the jar**
   → **Dilute ink to reduce viscosity**



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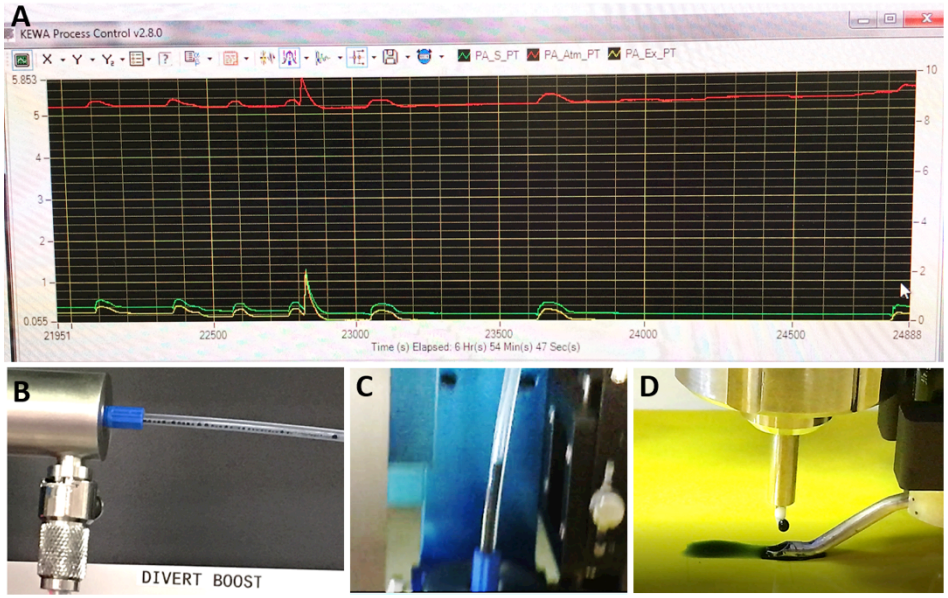
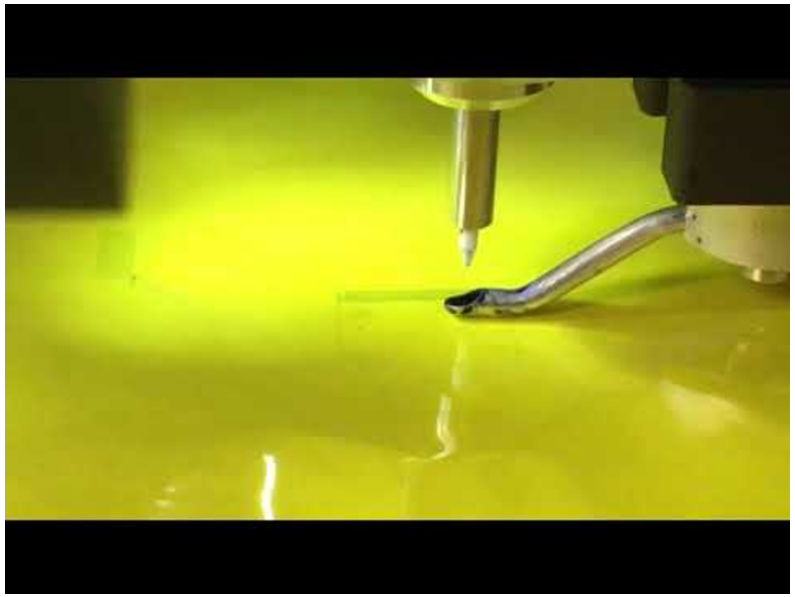


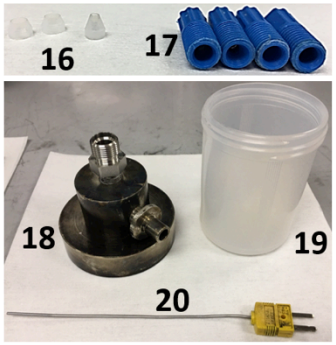
# 2.3 Disassembly and cleaning

## After printing, the Optomec must be promptly disassembled and cleaned

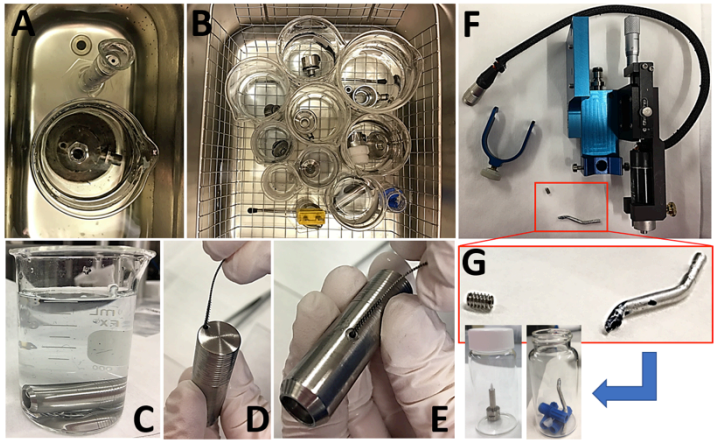
1. Turn off the three gas flows in the following order:
   **atomizer → wait 10s → exhaust → wait 60s → sheath**
1. Remove pneumatic atomizer, virtual impactor, printhead → disassemble
2. Disassemble the printhead-shutter subassembly
3. Dispose of tubing
4. Clean up the work stage

## Cleaning procedure

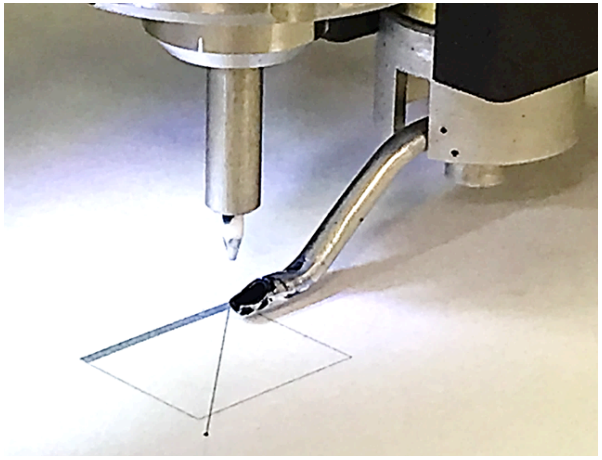
| Cleaning solution | Non-critical parts | Critical parts | Critical parts (no Branson) |
|---|---|---|---|
| **1) Water** | 10min × 2 times | 10min × 2 times | 20min × 3 times (or 10min × 5 times)* |
| **2) Branson** | 10min × 2 times | 10min × 3 times | -- |
| **3) Isopropyl alcohol** | 10min × 2 times | 10min × 3 times | 10min × 3 times |
| **4) Rinse with isopropyl alcohol and blow dry with $N_2$ gun** | | | |

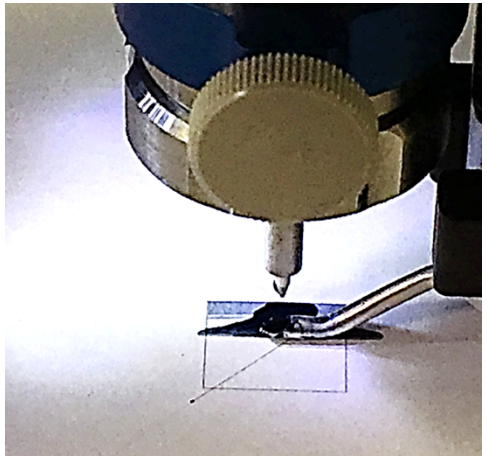




**Thorough cleaning is the most critical step in Optomec SOP!**

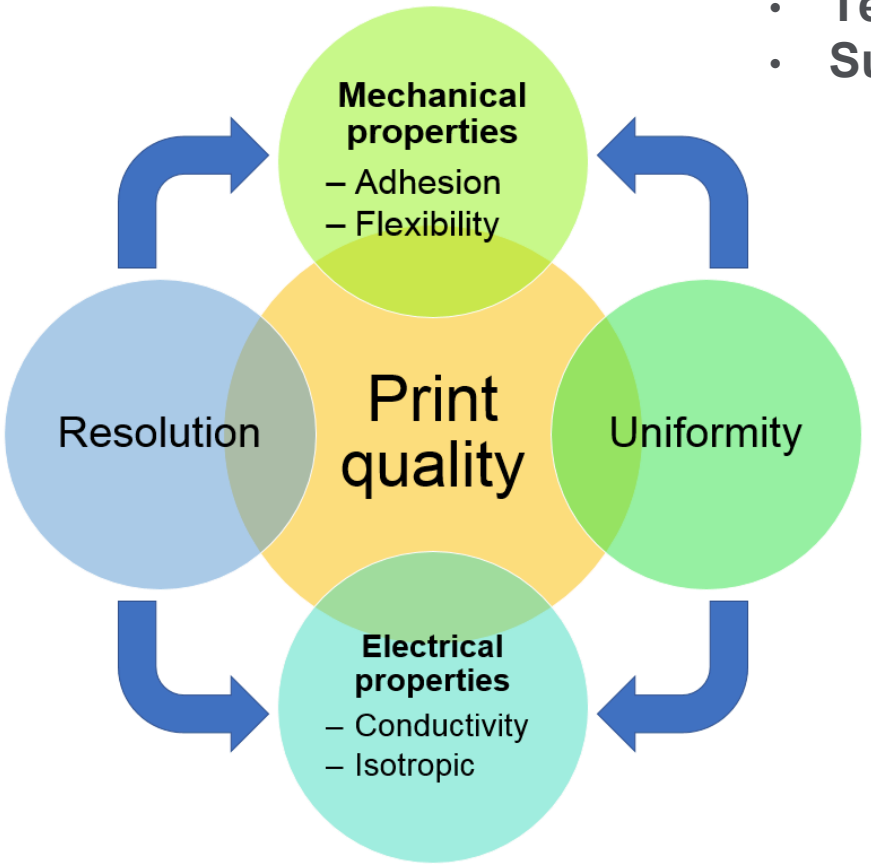


# 3. Aerosol Jet Printing: Start Atomizing!

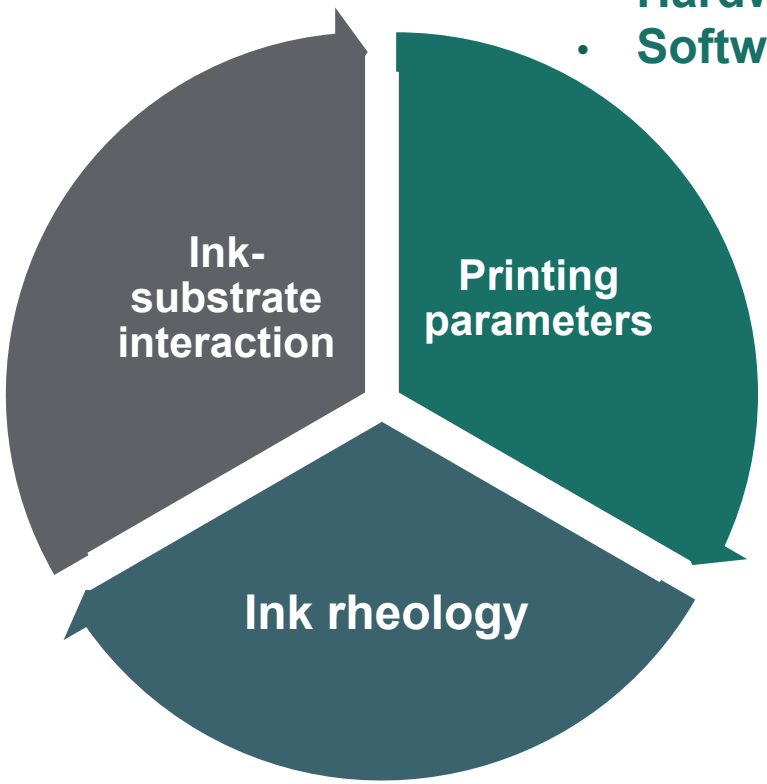




# 3.1 Optimizing print patterns



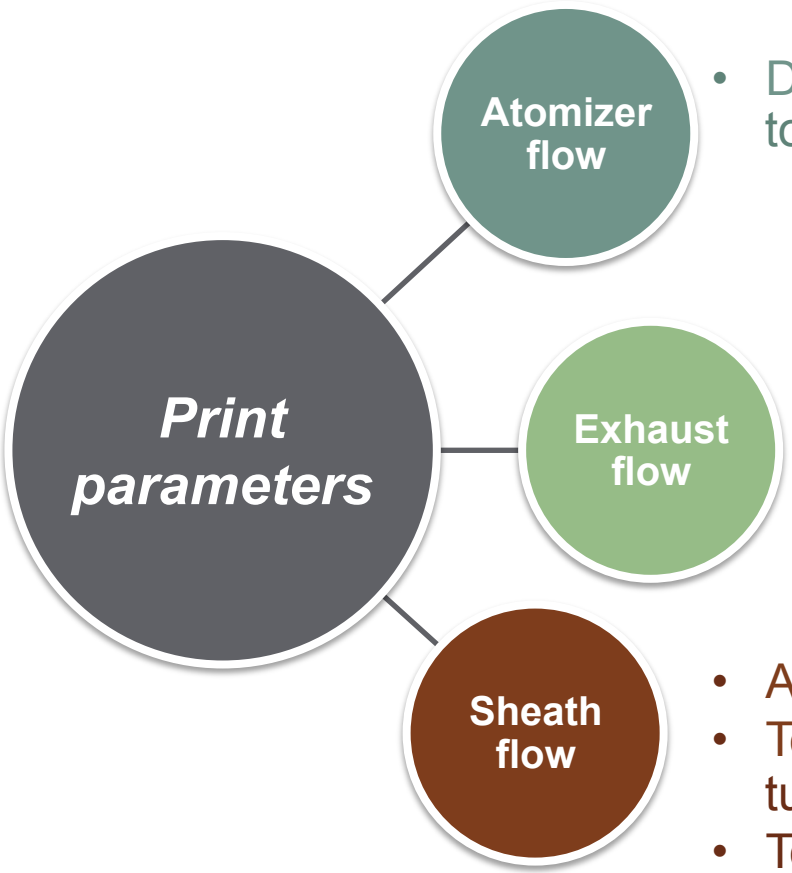

- Temperature
- Surface treatments




- Hardware
- Software

- Dilution
- Rheological modifiers

# 3.1 Optimizing print patterns

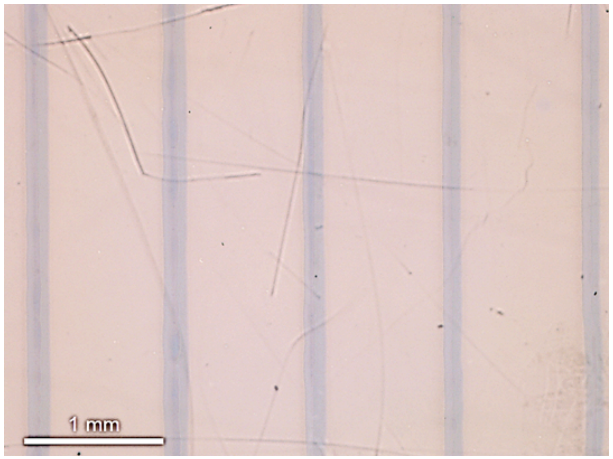


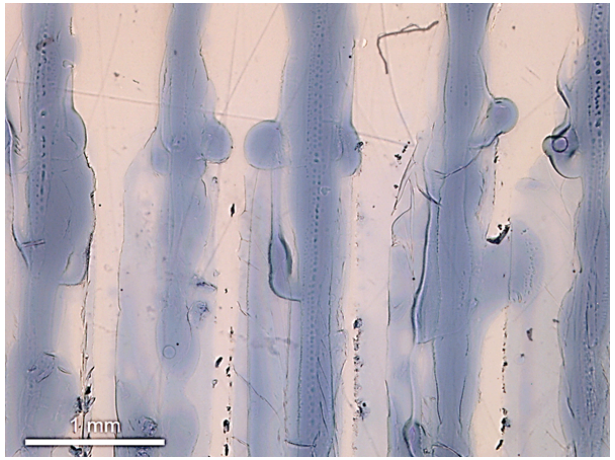

- Density of aerosol generated and transferred to printhead

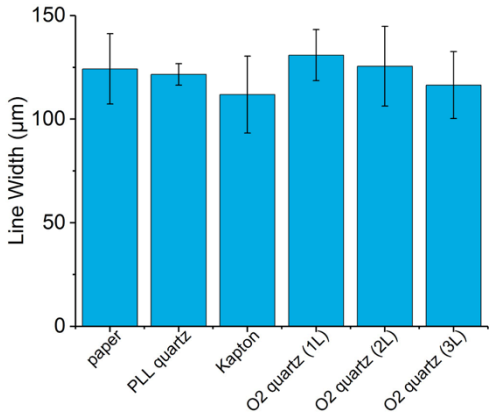
- Reduce atomizer flow
- Determines particle size distribution

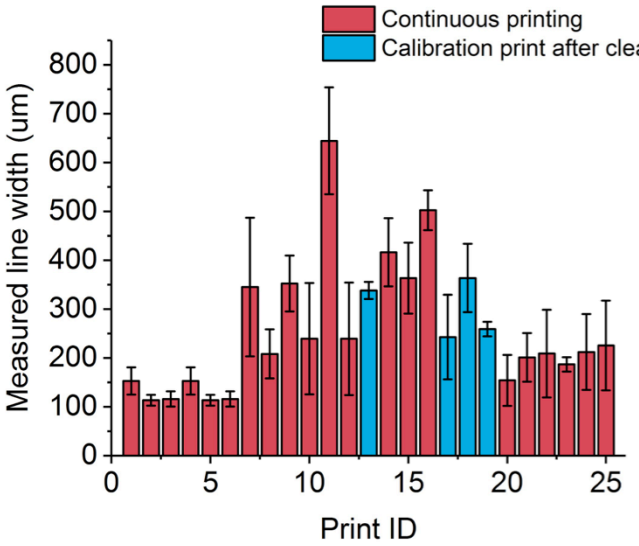
- Affects degree of focusing of the mist
- Too high will flatten line width but may cause turbulence
- Too low can result in poor resolution

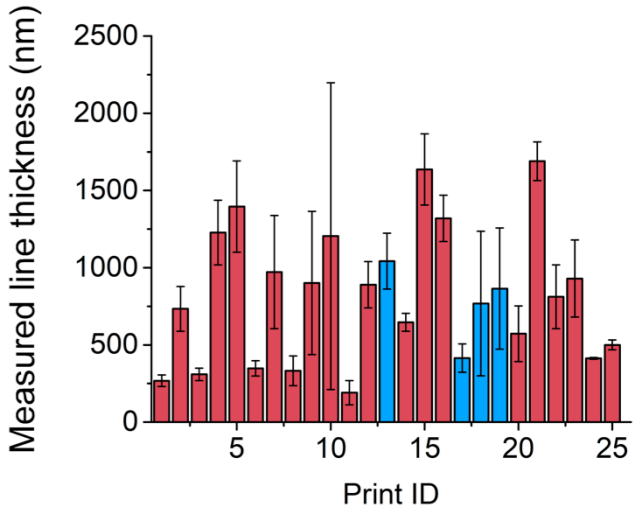
# 3.2 Printing PEDOT:PSS




**4-point probe conductivity: 14.12 ± 10 S/cm**

**In literature: 14.82 S/cm**

# 4. Conclusion

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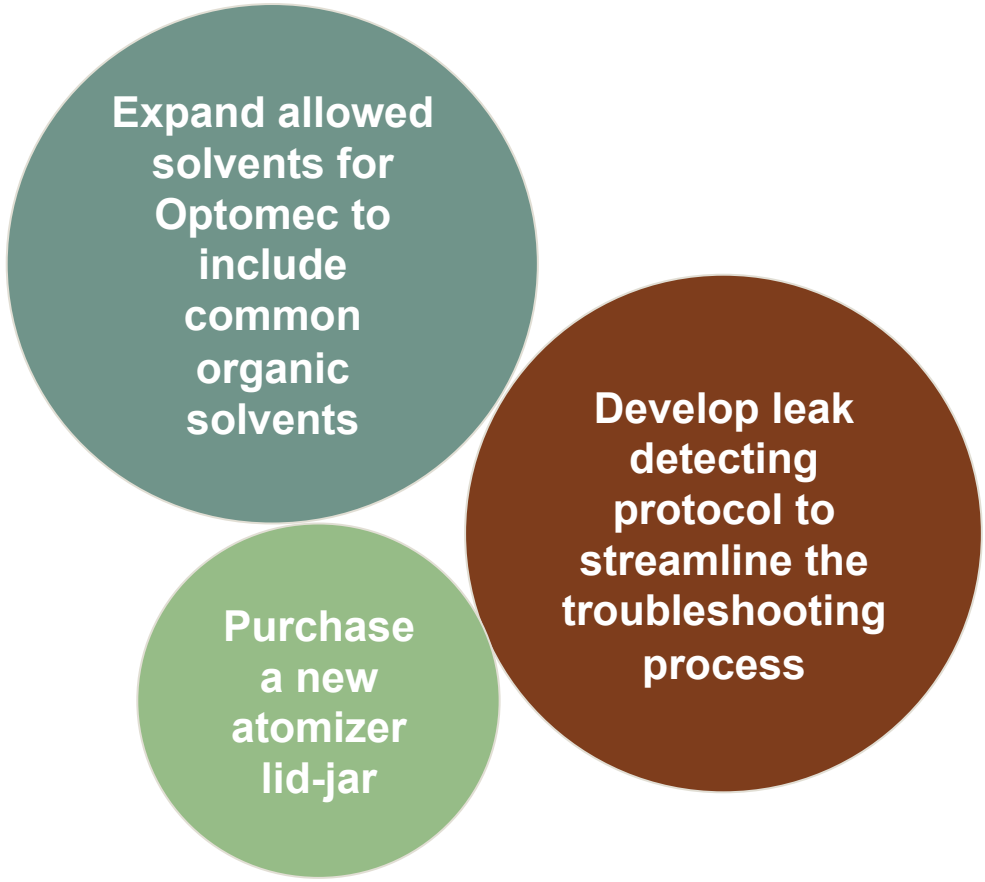
## Summary

Drop-on-demand printing techniques: aerosol jet vs. ink jet

Standard operating procedure of Optomec in pneumatic mode

Optimizing print patterns and characterization of PEDOT:PSS lines

## Suggestions for future users





## Thank you:

Hye Ryoung Lee, Swaroop Kommera, Randall Stoltenberg, Antonio Ricco, Donald Gardner

# Any Questions?