3D microprinted probes for testing at sub 20 µm pitch

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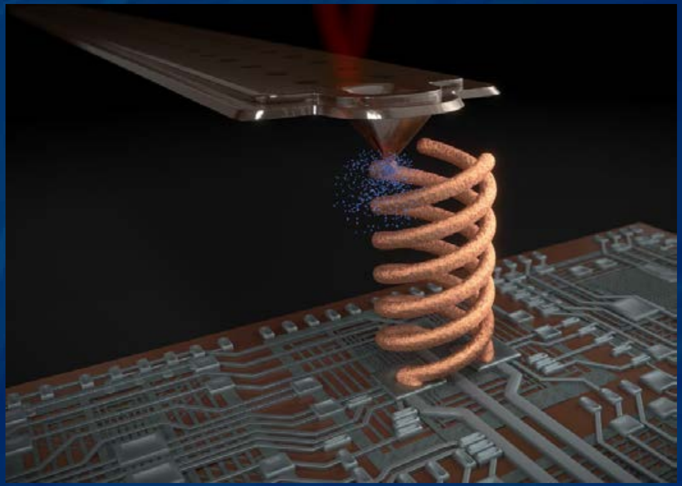
Outline

- Introduction: µ3D printing
- Objectives: µLED testing
- Methods: core-shell & manufacturing process
- Results: probe testing & simulation
- Discussion
- Conclusion
- Follow-up work

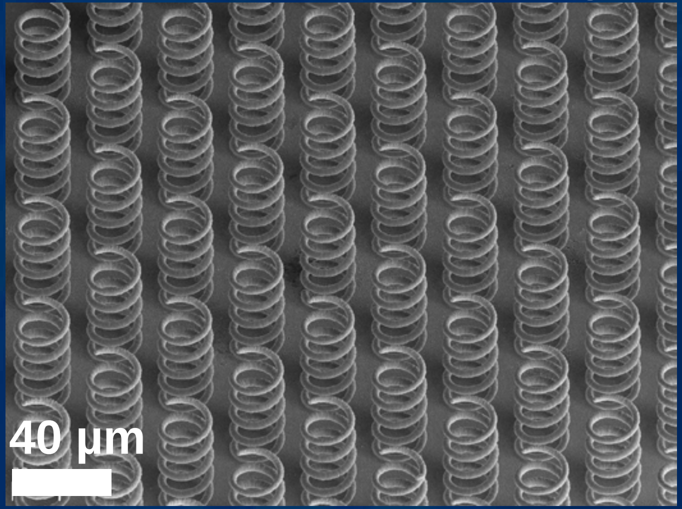
Introduction to µ3D printing

- 3D print with a 500-nm-wide nozzle
- Nanopositioning stages
- Micrometer-sized objects
- Template-free
- Local electrodeposition
- Print pure copper

render



SEM

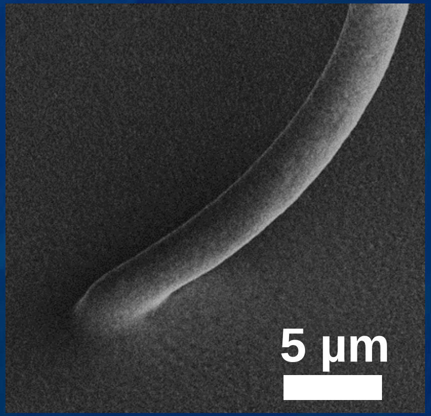


Motivation for µ3D printing in testing

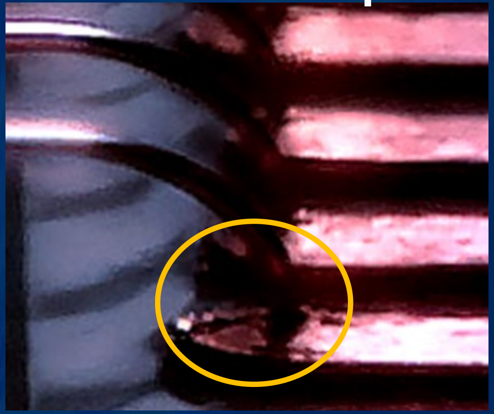
- **Unlocks a small probe pitch**
  - 3D design freedom
  - High material quality
- **Quick reconfiguration of probes**
  - Template-free process
  - Print directly on space transformer
- **Automated process**
  - Accurate dimensions probe printing
  - Seamless merging with contact trace

render

SEM



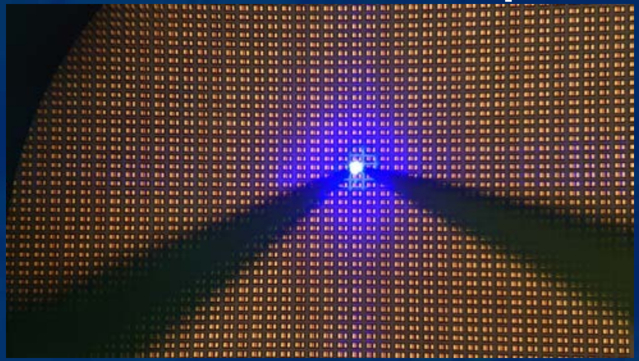
optical



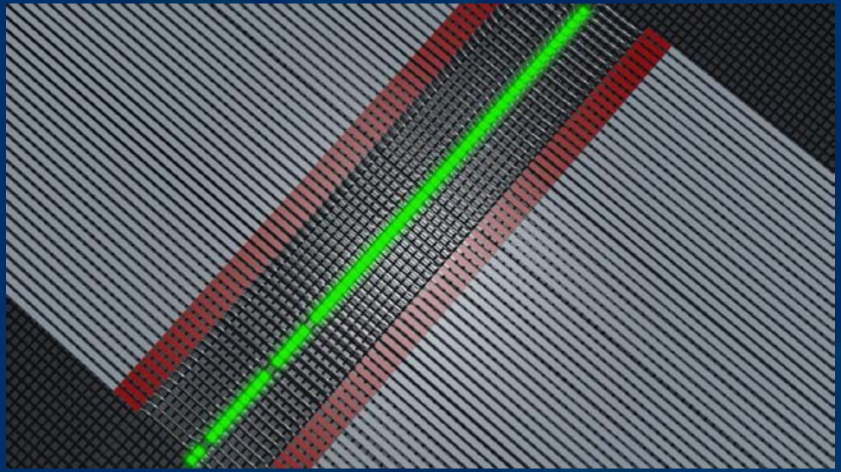
Initial case: µLED

- **µLED is an upcoming technology**
  - Wearables, smart devices, etc.
  - CAGR 82%*
- **Challenge: small-pitch probe arrays**
  - 18.5 µm / 35.5 µm (provisional)

optical



render



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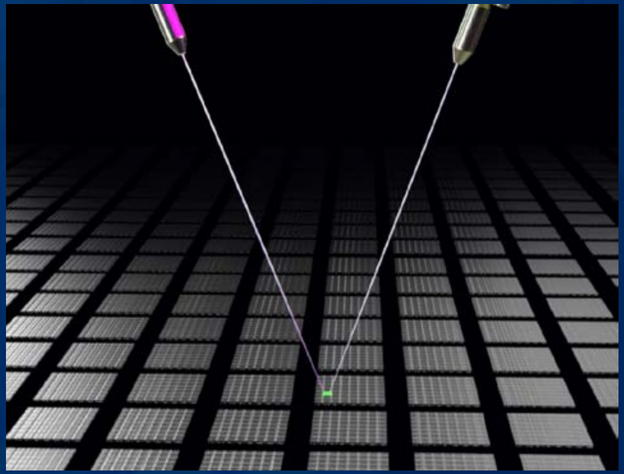
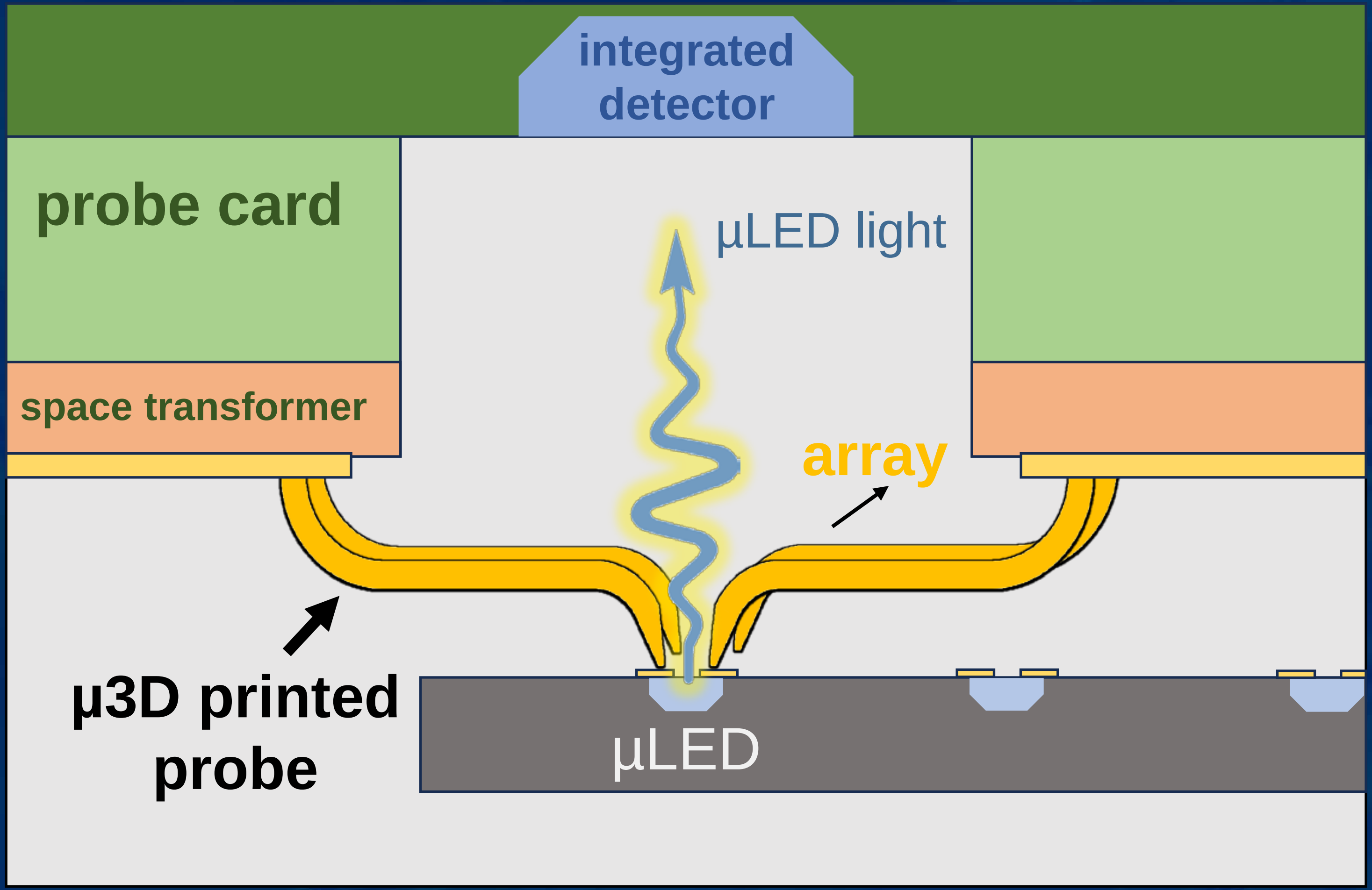


* Markets and Markets Research Private Ltd. Jan. 19, 2023

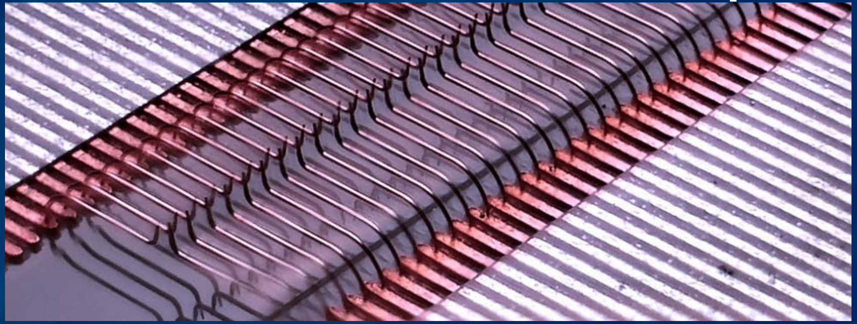
µLED testing principle



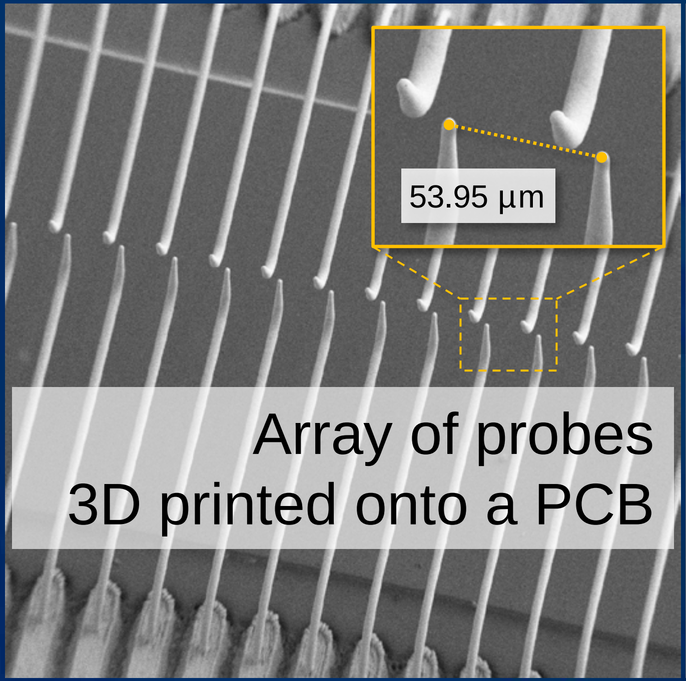
µ3D printing results

- Copper probes
- Up to 128 probes per array
- FR4 Printed Circuit Board (PCB)

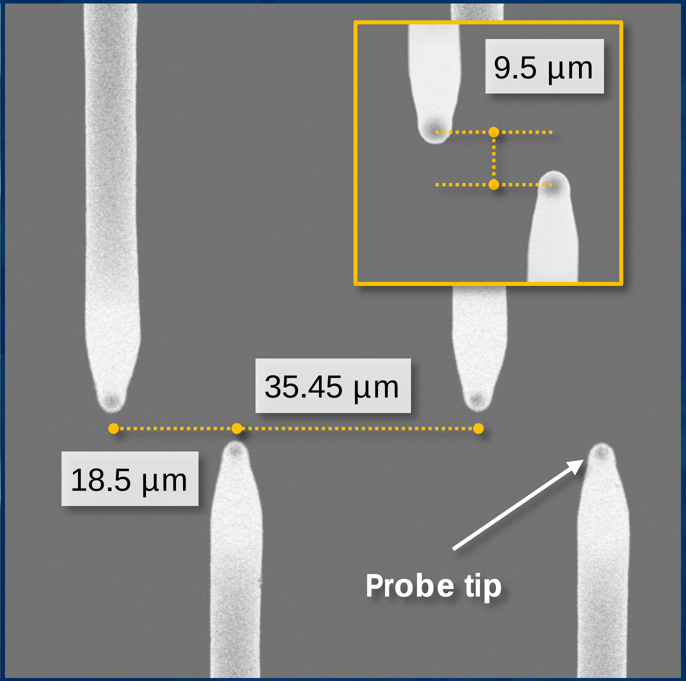
optical



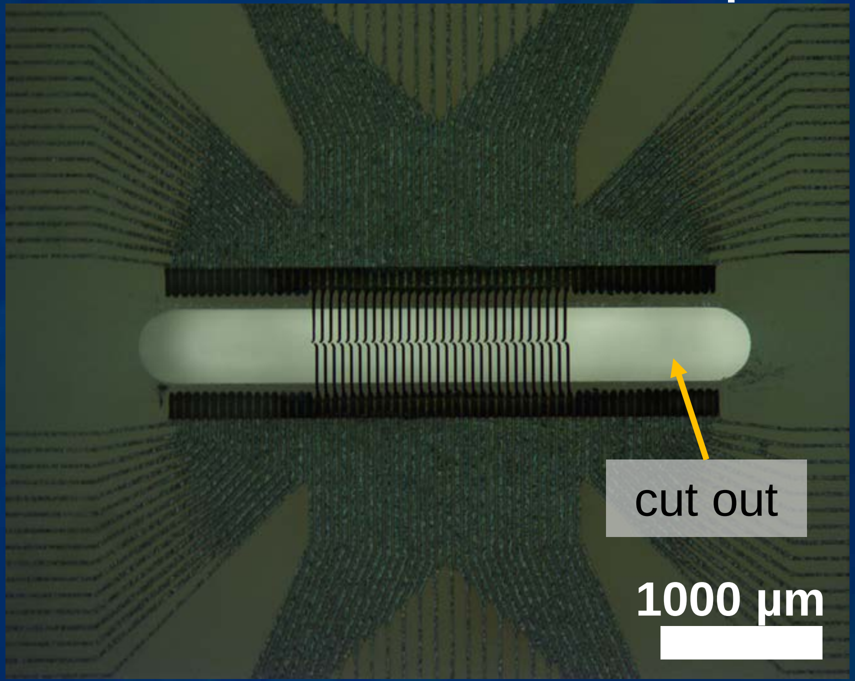
SEM



SEM

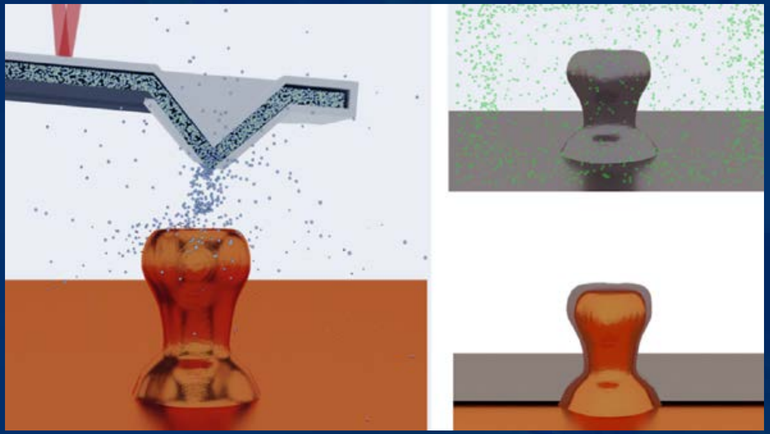


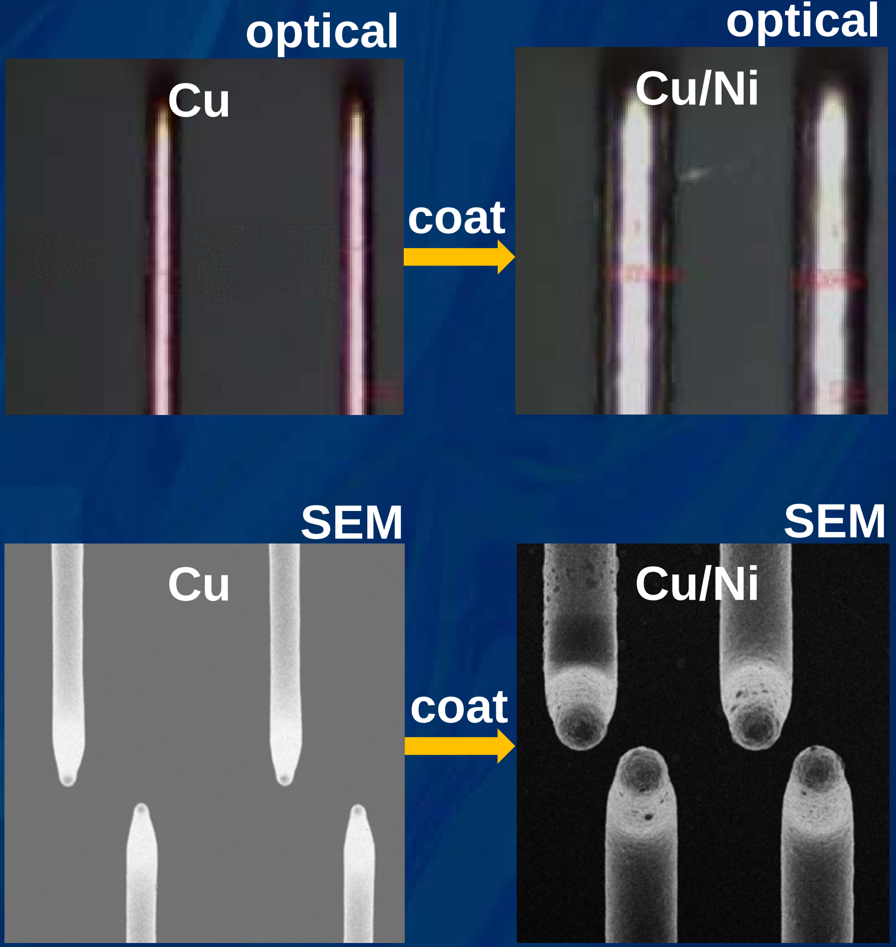
optical



Core - shell

- **Print copper**
  - Conductivity: 87% of bulk[1]
  - Yield strength: 0.4 to 1.0 GPa[2]
- **Coat with nickel for strength:[3]**

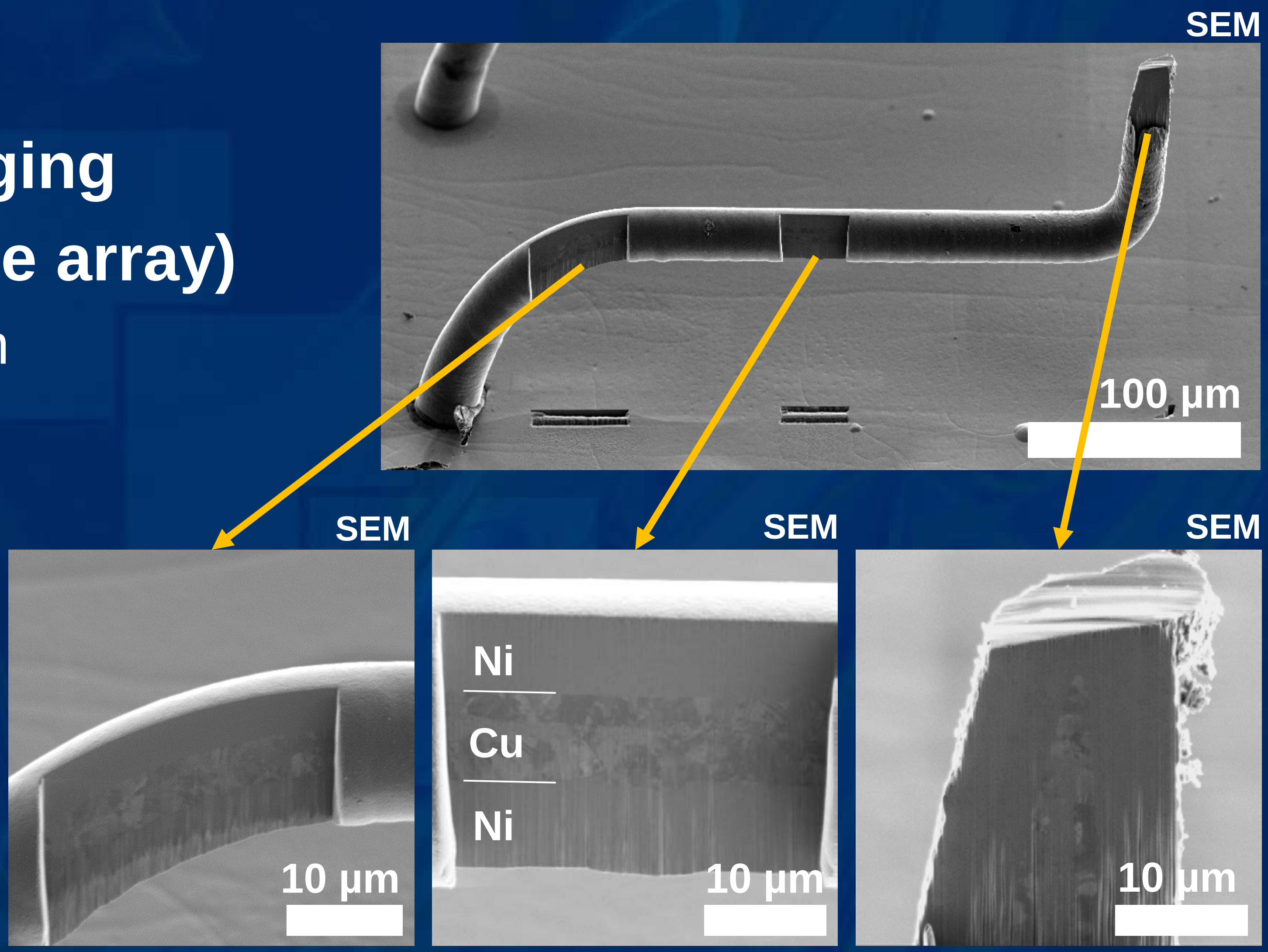




[1] Schürch *et al.* Materials & Design, 2023.
[2] Ramachandramoorthy *et al.* Appl. Mat. Today, 2022.
[3] Jain *et al.* Materials & Design, 2023

Quality inspection by Focused Ion Beam

- **Void-free materials**
- **Seamless layer merging**
- **Diameters (128-probe array)**
  - Cu: 8.6 ± 0.5 µm
  - Cu / Ni: 21.9 ± 1.5 µm



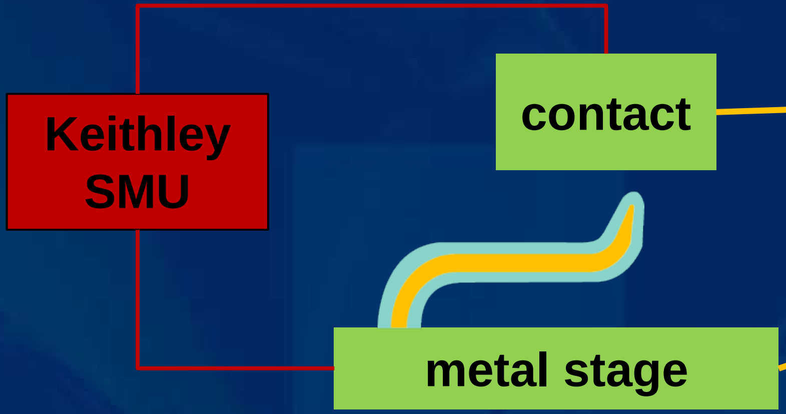
Manufacturing process

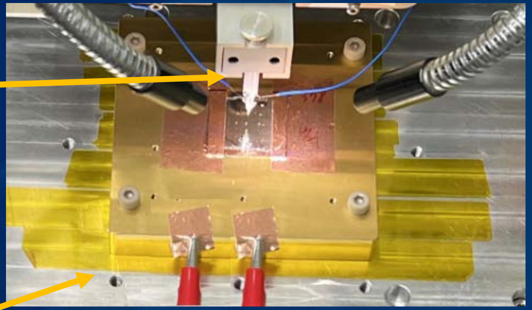
Step 1.
Make space transformer

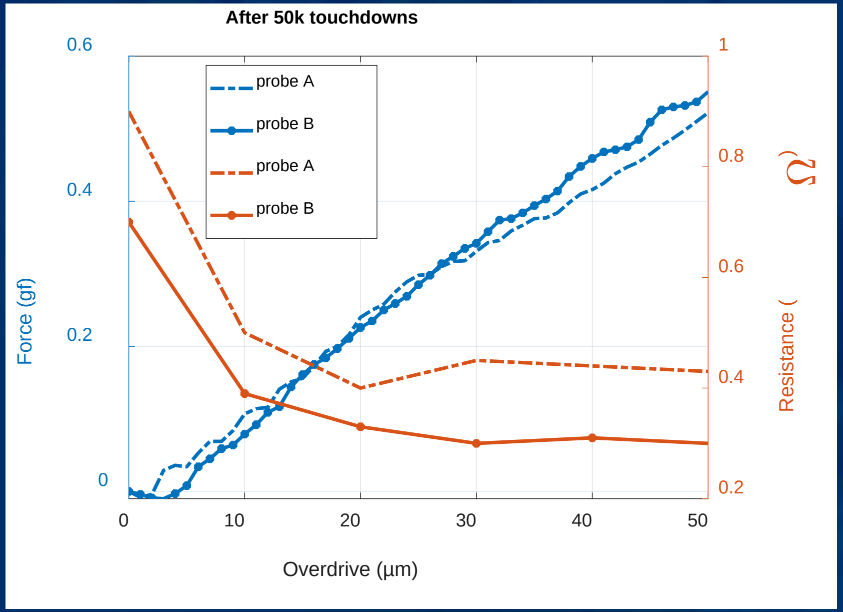
Step 2.
Local 3D printing

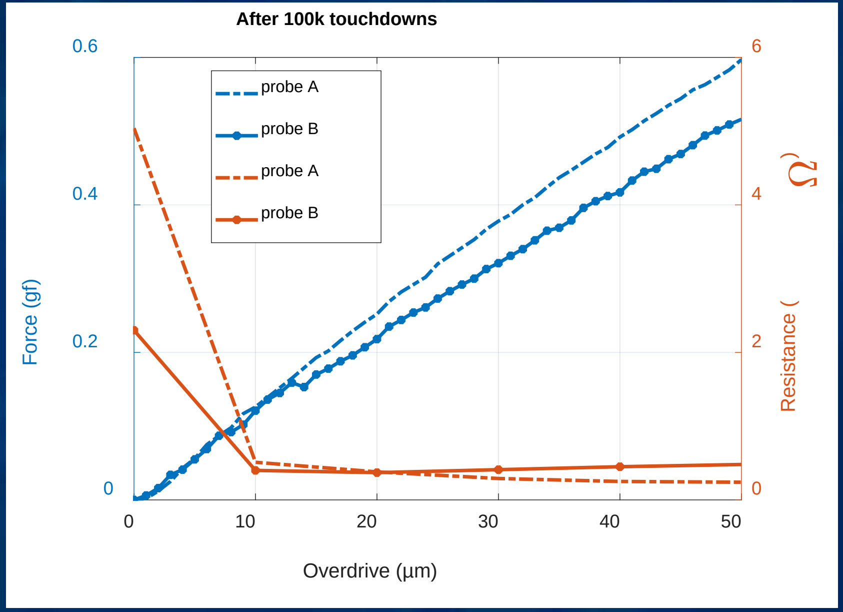
Step 3.
Global coating

Results: force and resistance



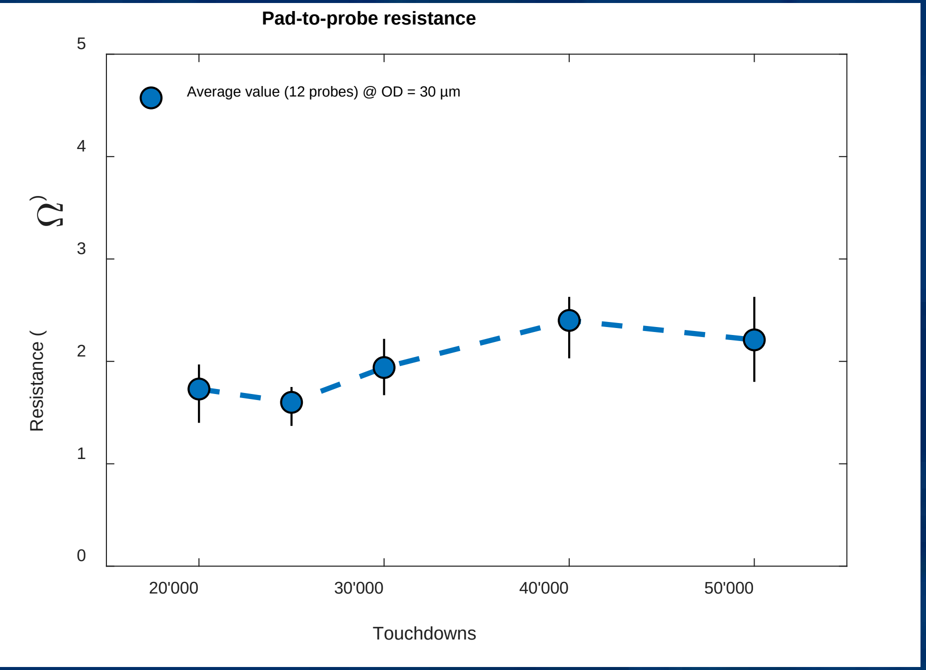


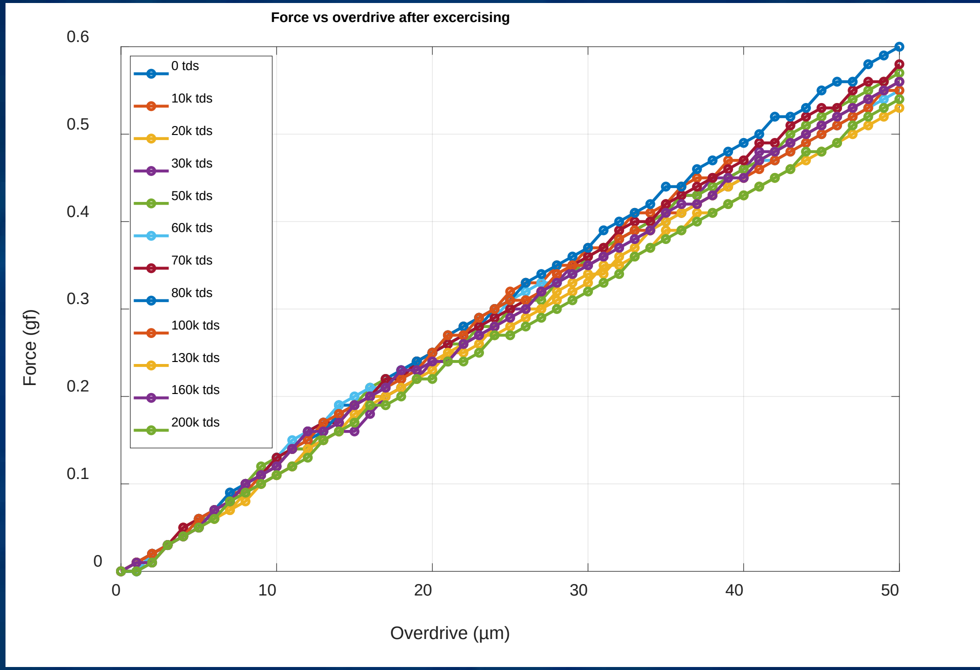




Longevity

- Tip wear <10 µm for 250k touchdowns
- Tests done on Au sputtered wafer
- Compatible with standard cleaning (ITS)





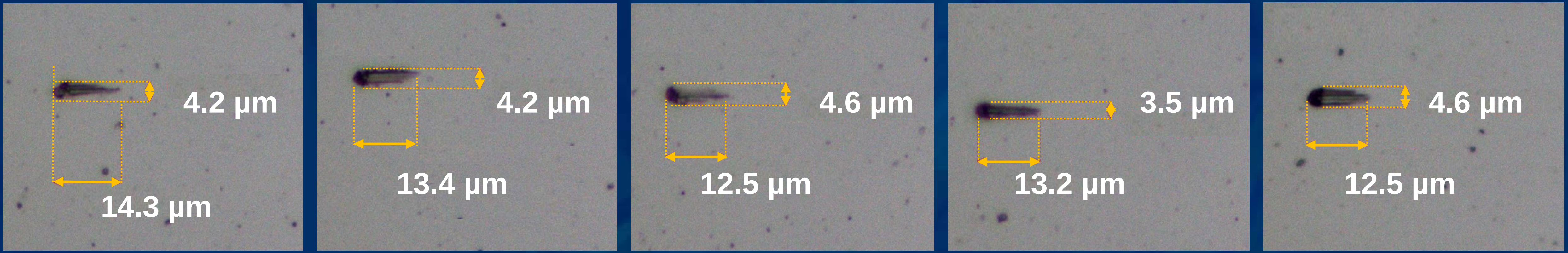
Scrub length

- **Scrub length at 50 µm overdrive (OD)**
  - Measured: 13.2 µm (mean)
  - Simulated: 13.5 µm

simulated by FEM

Overdrive (µm)	Scrub length (µm)
25	7.8
40	11.5
50	13.5

optical

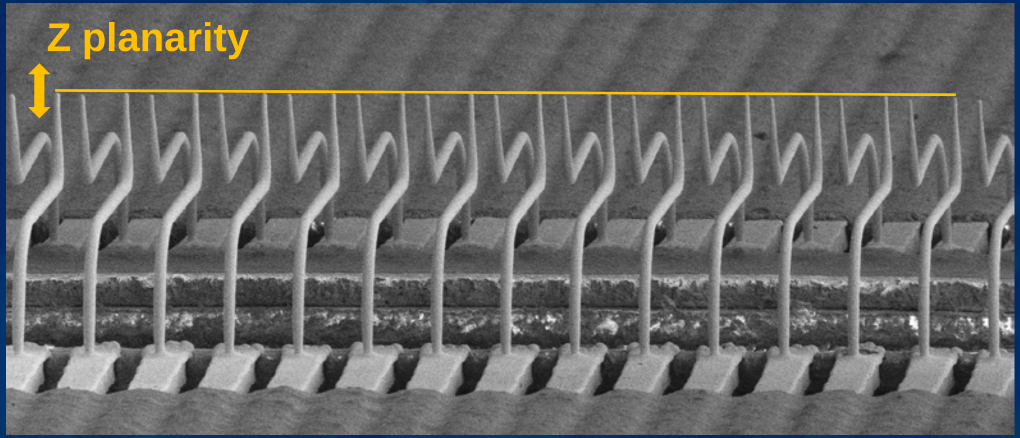


Z planarity and XY position in array

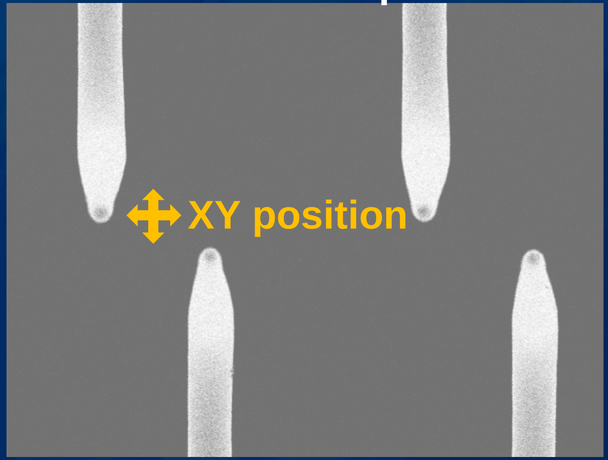
Analysis on 128-probe array:

- **Z-planarity: ± 1.4 µm**
  - Space transf.: ± 1.0 µm
  - Printing: ± 0.1 µm
  - Coating: ± 0.3 µm
- **XY position accuracy**
  - ΔX: < ± 1.5 µm
  - ΔY: < ± 1.5 µm

side view SEM



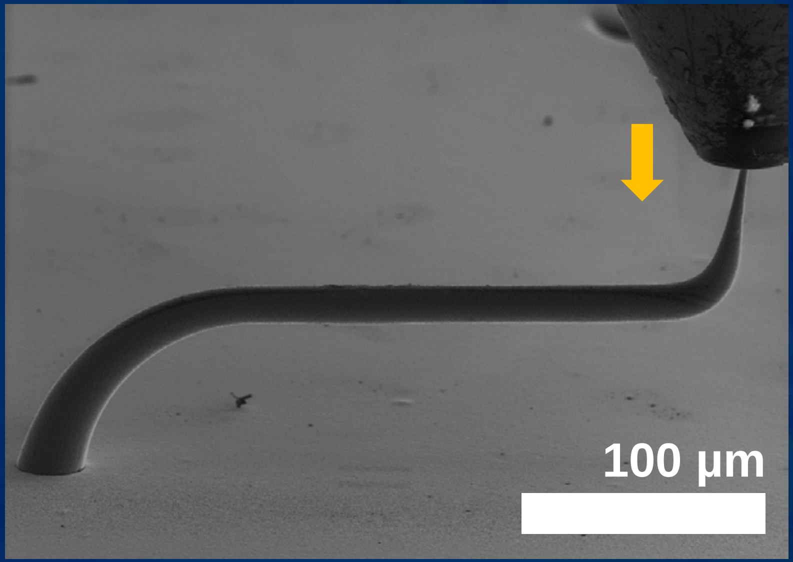
top view SEM

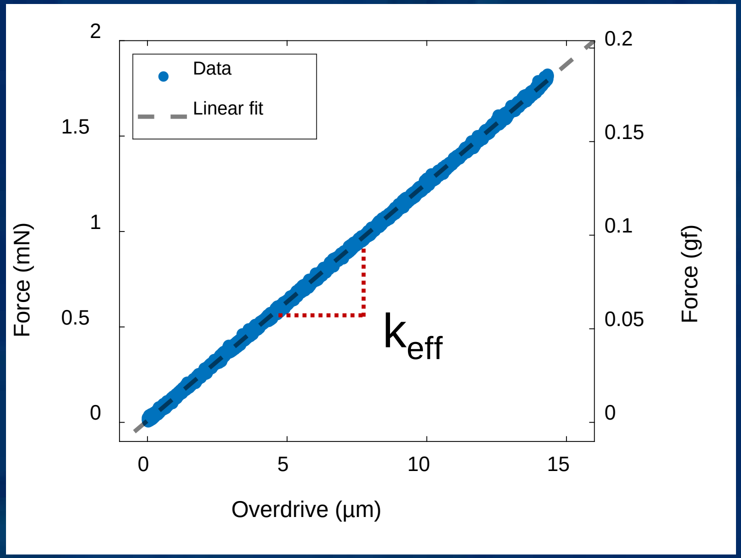


In situ mechanical testing

- Measure the effective spring constant (k_{eff})
- Study probe deformation and failure
- Calibrate Finite Element Model simulations

***in situ* SEM**





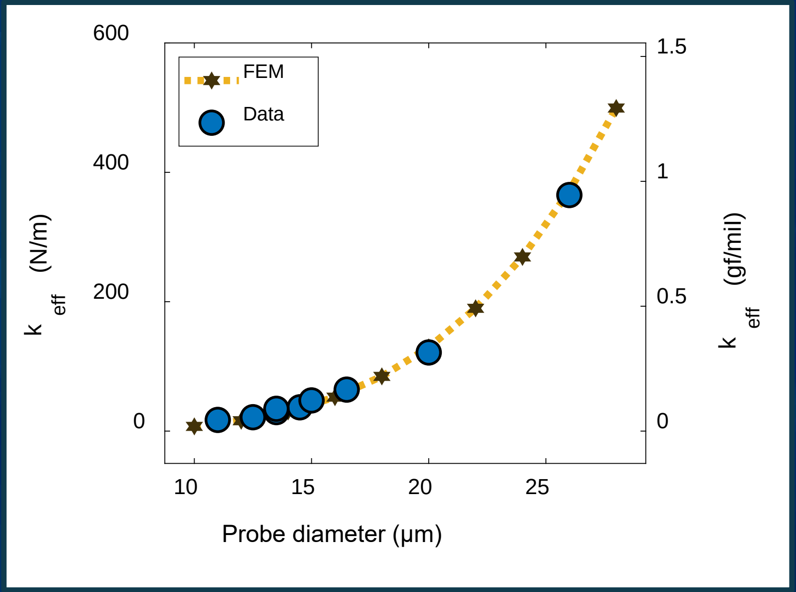
Cu / Ni with a 20-µm-diameter:
k_{eff} = 125 N/m (0.32 gf/mil)

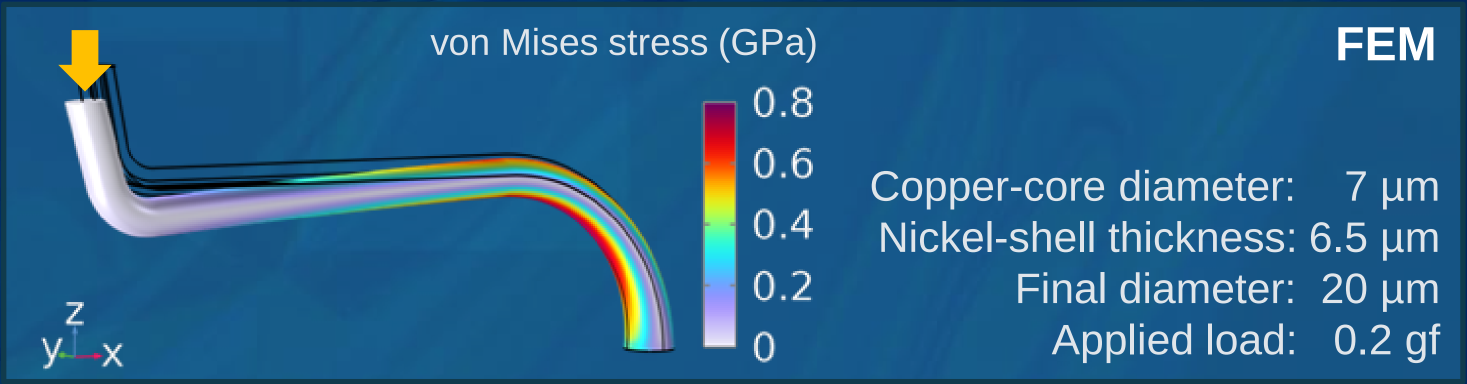
Due to Ni coating:
- k_{eff} is 40 times larger
- No plasticity for OD < 50 µm

Finite Element Method simulations

Calibrated model enables:

- **Designing complex geometries**
  - k_{eff}
  - Scrub length
  - Plasticity onset
- **Core-shell optimization**
  - Geometry
  - Material
  - Layer-stack





Discussion

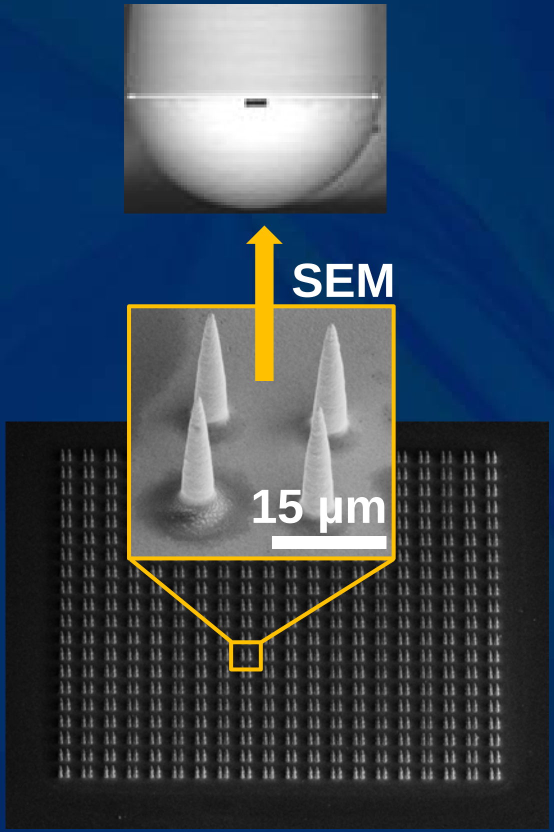
- **Array size to increase (128 to 256 probes)**
- **Optimize coating material and stack**
  - For longevity (creep, wear)
  - Larger temperature range
- **Optimize space transformer**
- **Probe station for fine-pitch**
  - ‘Chicken & egg’ situation?

Conclusions

- **We introduced µ3D printing for testing**
  - Fine pitch, below 20 µm demonstrated
  - Quickly reconfigure without template changes
  - High-precision µ3D printing on variety of space transformers
- **Prototype ready for µLED testing**
- **Many other applications are possible**
  - Design process established with a Finite Element Model
  - Use the potential of µ3D printing to create even finer probes

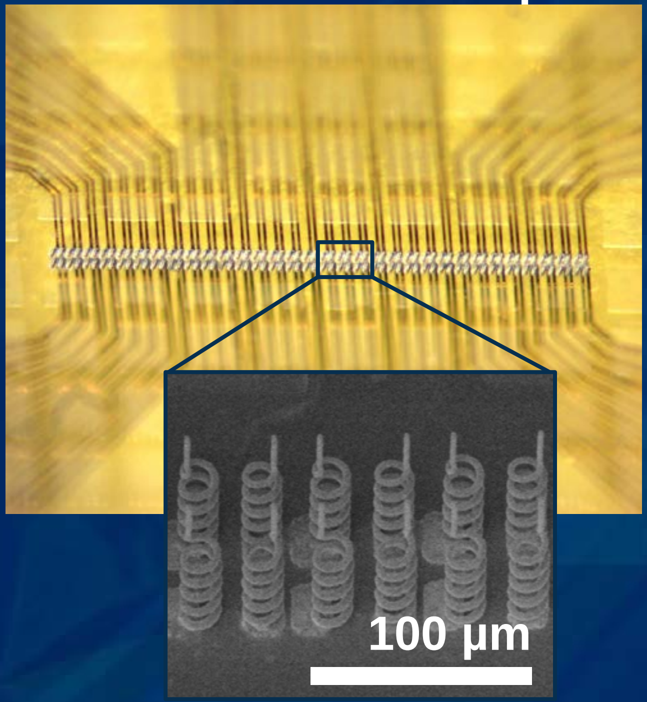
Follow-up work

Micro bump contacting



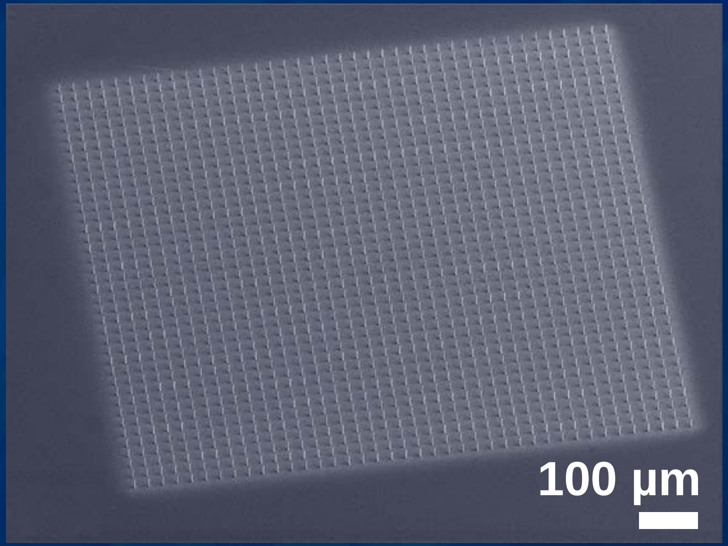
µLED testing on polyimide membrane 18.5 µm / 35.5 µm pitch

optical



40 x 40 array contact needles 25 µm pitch (2D)

SEM



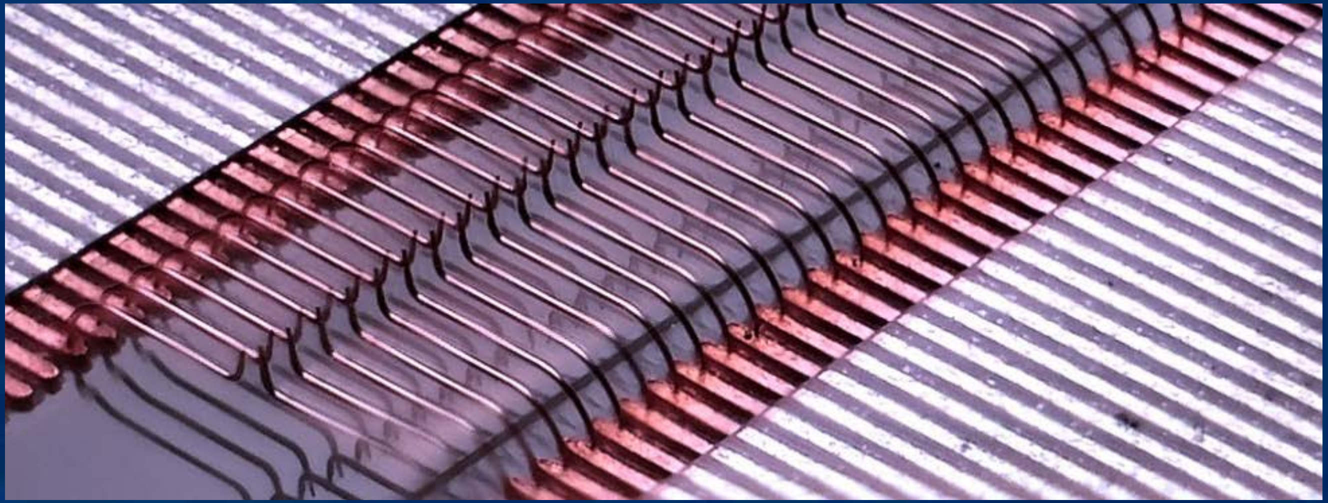
Thank you!

- Questions?
- Comments?

▶ Meet us at booth #215

▶ E-Mail: hello@exaddon.com

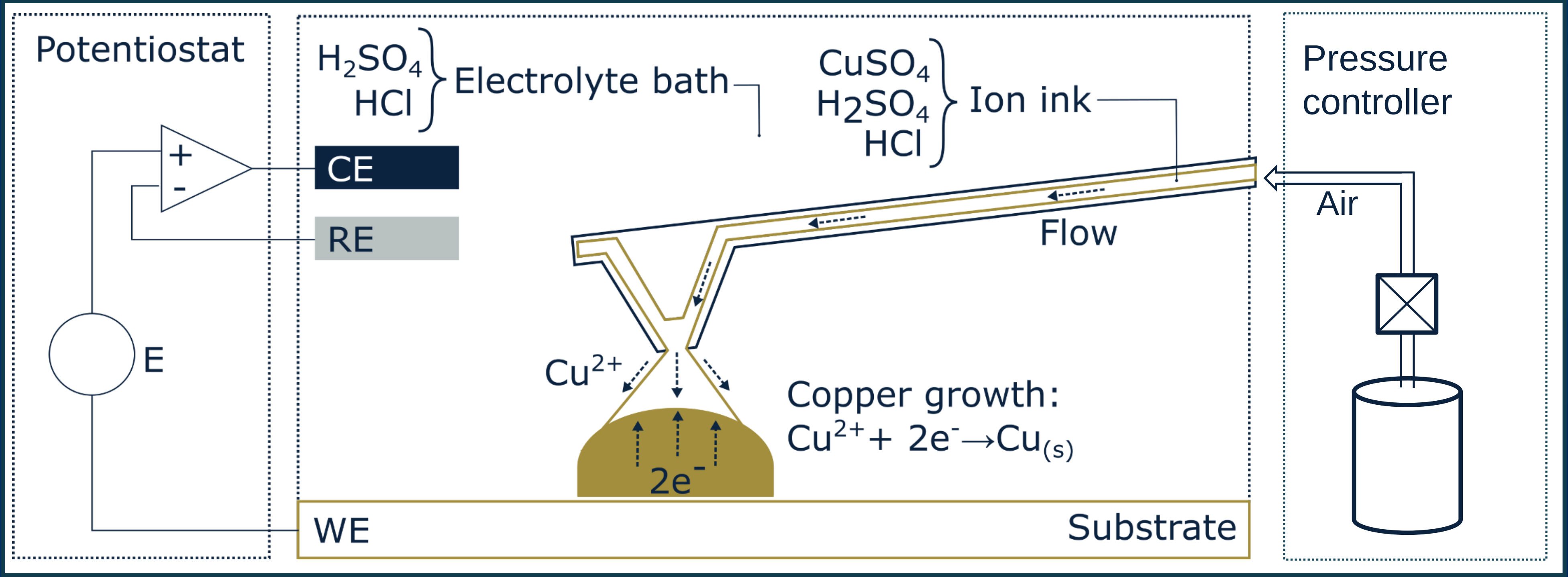
▶ Web: probes.exaddon.com



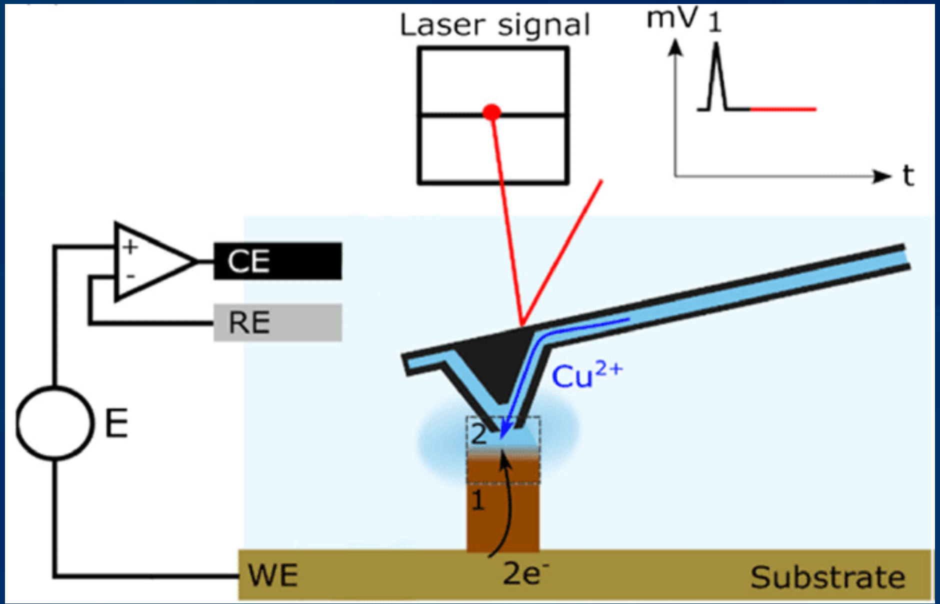
BACKUP SLIDES

μ3D printing process

- The metal printing is conducted within an electrochemical cell
- The ion ink is delivered via a microchannel inside the cantilever
- Pressure controller regulates the air pressure propelling the electrolyte
- A potentiostat regulates the voltages required for deposition



Voxel-based printing

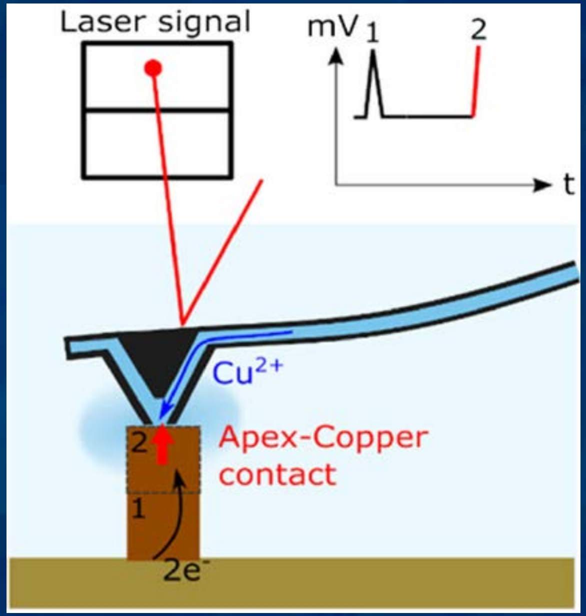


Stationary phase:

- **Probe dispenses the metallic ions**
- **Metal growth occurs at the working electrode**
- **The metallic deposit reaches the tip aperture**

Dynamic phase:

- **When deposit reaches tip → trigger**
- **A voxel is completed, retract tip**
- **Height of the voxel is now known**



Ercolano *et al.*,
Adv. Eng. Mater. 2019

Space transformer materials

- PCB FR
- μPCB
- Silicon
- Membrane (polyimide)