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MEETING FOR ADVANCED E-BEAM LITHOGRAPHY

THE OHIO STATE UNIVERSITY

DisCharge: A Perspective on Charge Dissipation Layer Testing for Non-Conductive Substrates

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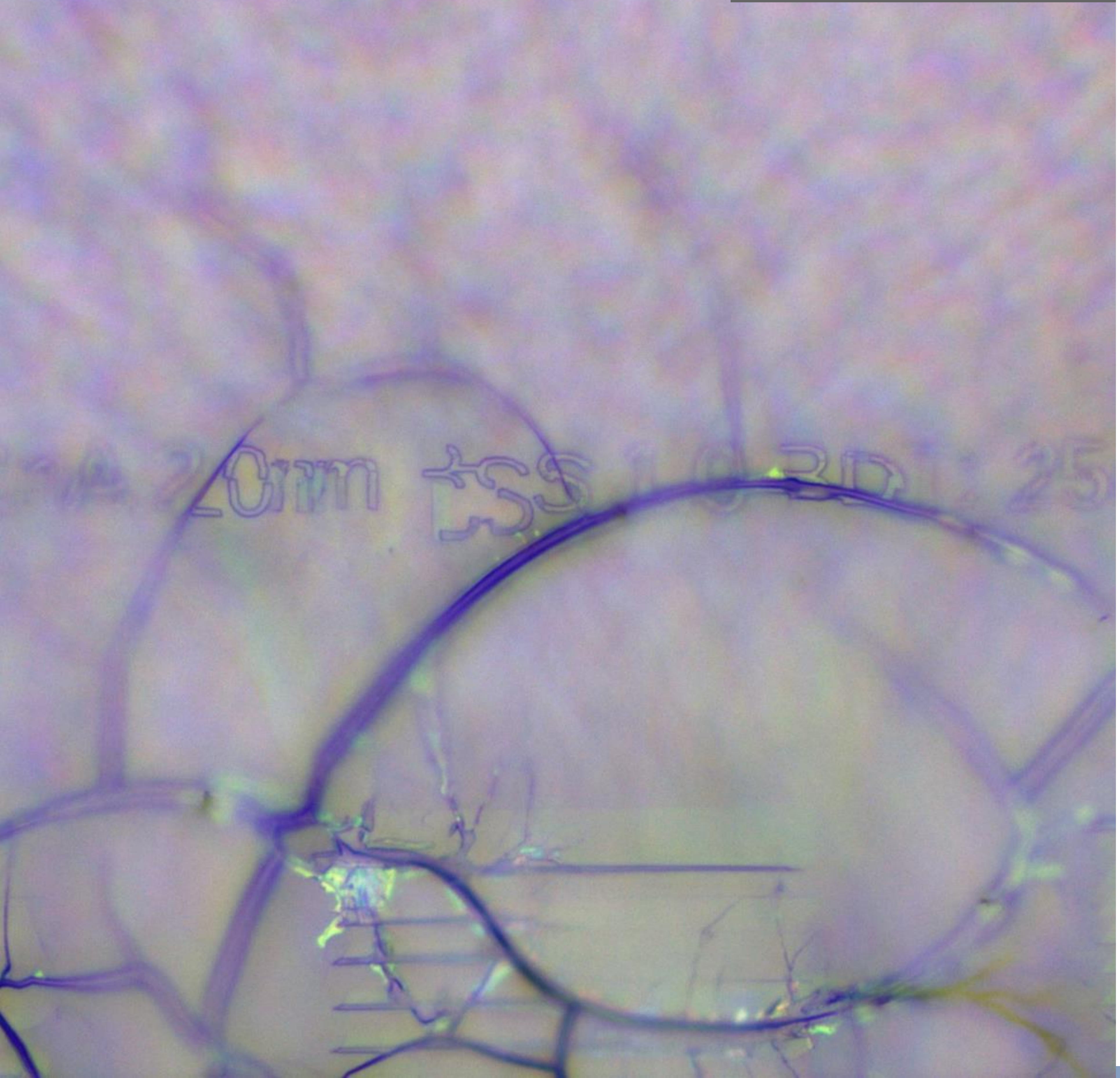
- Networking platform for the electron beam lithography (EBL) community
- Time fully dedicated to talk about standing issues in EBL devoid of conference formality and trade show exhibition
- April 6-7, 2020, at Caltech
- www.maebl.org

Motivation



Control: 300 nm PMMA 950 A4 / PDMS

Non-Conductive Substrates

- Fused Silica (Quartz)
- Glass
- Diamond
- PDMS

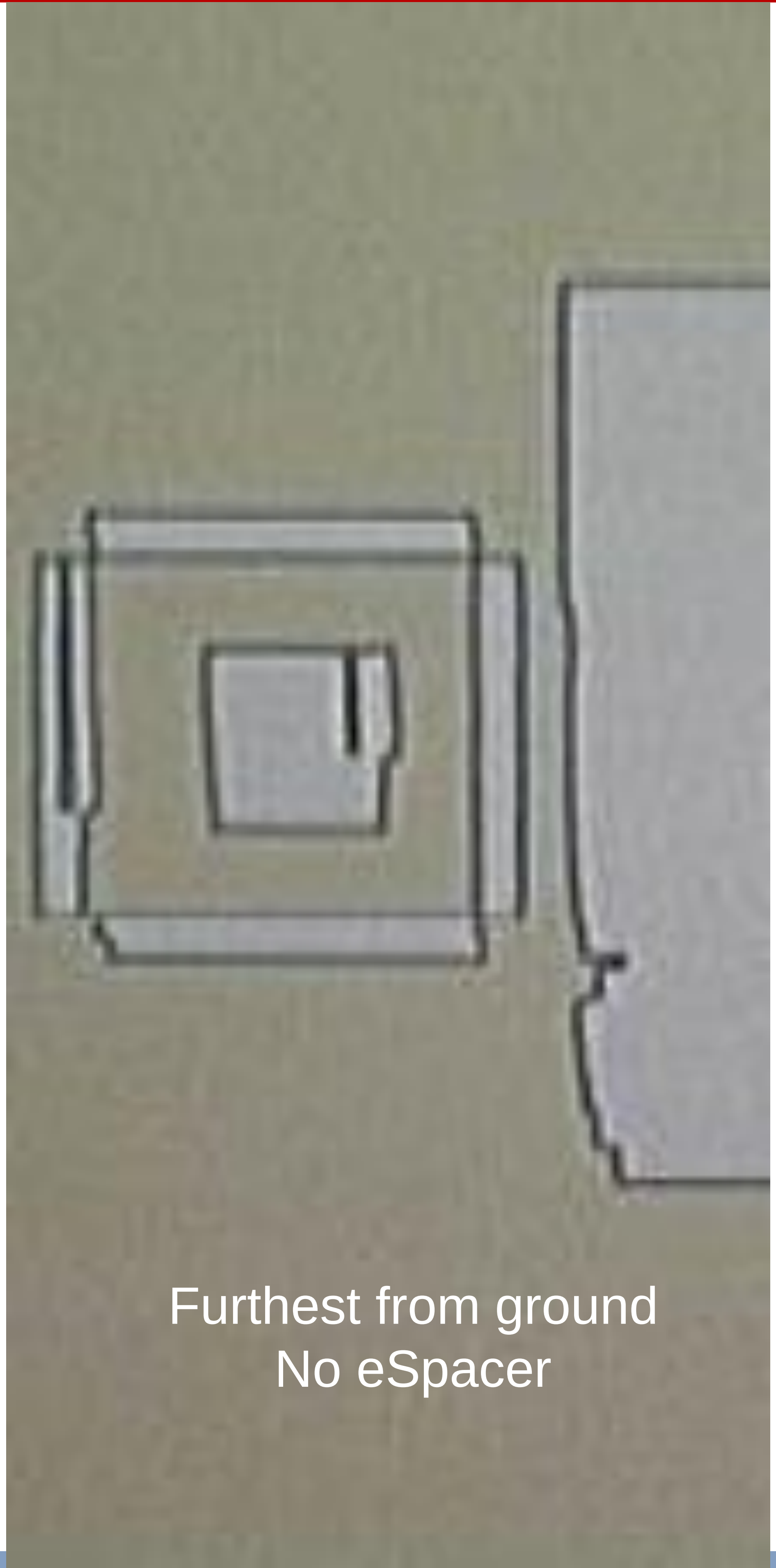
Charging Concerns:

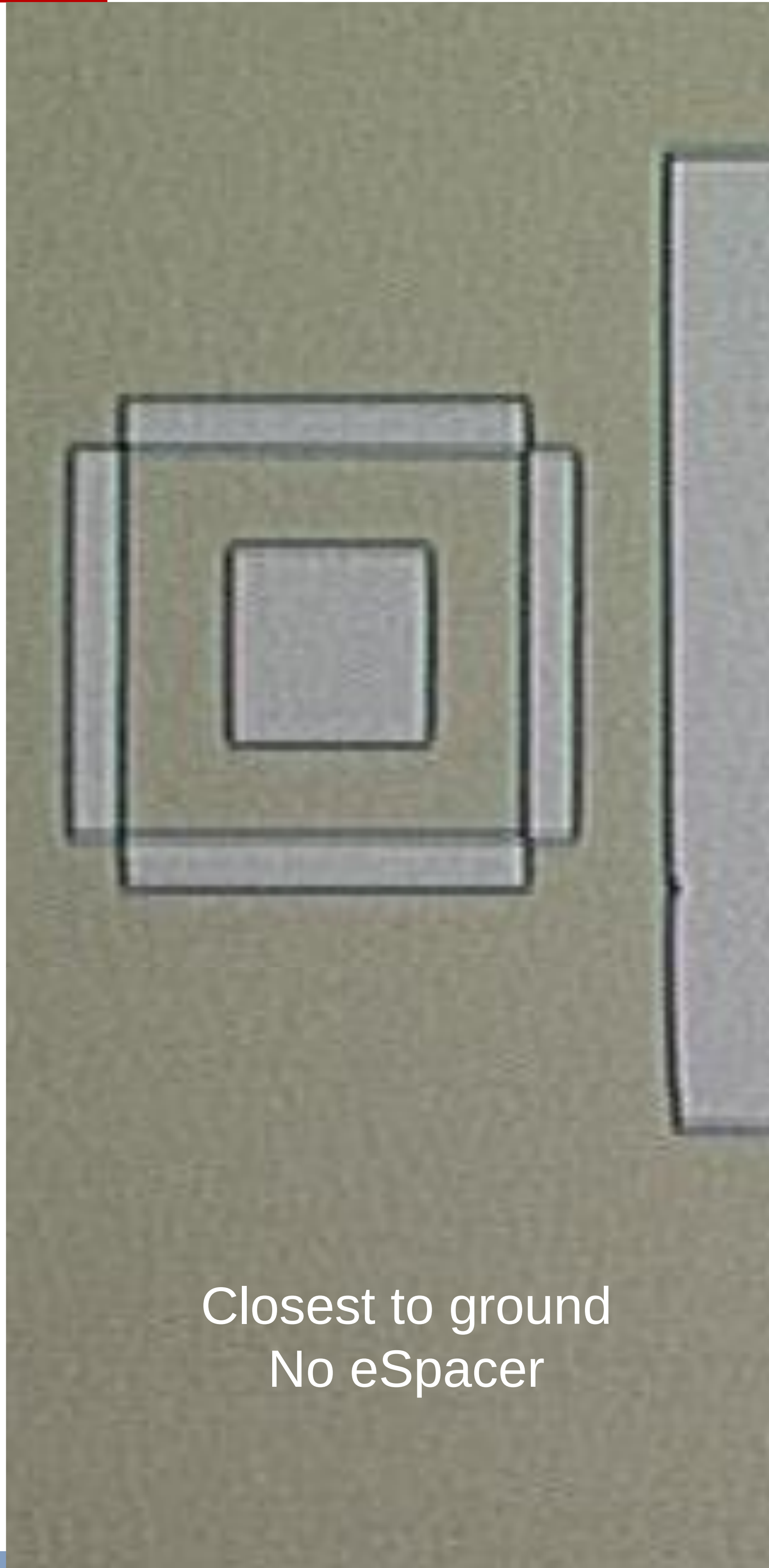
- Pattern displacement
- Distortion
- Poor overlay
- Stitching error

Approach

- Charge dissipation layer above or below resist.
- Exposure strategy.
- Easier said than done sometimes …

"Interlayer and Intershot Charging Induced Pattern Distortion on GaAs Substrates Exposed with a High Throughput Shaped Beam Electron Beam Lithography System", A. Bross, R. Davis, T. Toyama, and J. Beene, Proceedings of the 2004 Conference on Compound Semiconductor Manufacturing Technology, Miami FL (2004)





Charge Dissipation Options

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Approach	Specifics	Pros	Cons	Other
Water Soluble Conducting Polymers	eSpacer, AquaSave	• Straightforward on PMMA/ZEP • Water removal	• EXPENSIVE • Short shelf life (3 months) • Generates particles	
Metal Coatings	Au, Al, Cr	• Readily available • Inexpensive • Straightforward	• Alters resist profile • Dose • Mixes with HSQ • Peeling at high beam current/doses • Process complexity	Must use thermal evaporator or sputterer.
Exposure Strategy	Tool specific	No additional processing	SLOW	

DisCharge by DisChem

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- Contains a class of conductive quaternary ammonium compounds (QAC)
- Unique Properties
  - Remains permanently cationically charged independent of pH
  - Are often water soluble
  - Offer extended shelf life at room temperature
  - Tolerate acids and oxidizers

DisCharge Four Point Probe Characterization

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Goal:

Study the conductivity of DisCharge H2O at different anti-charging-layer thicknesses

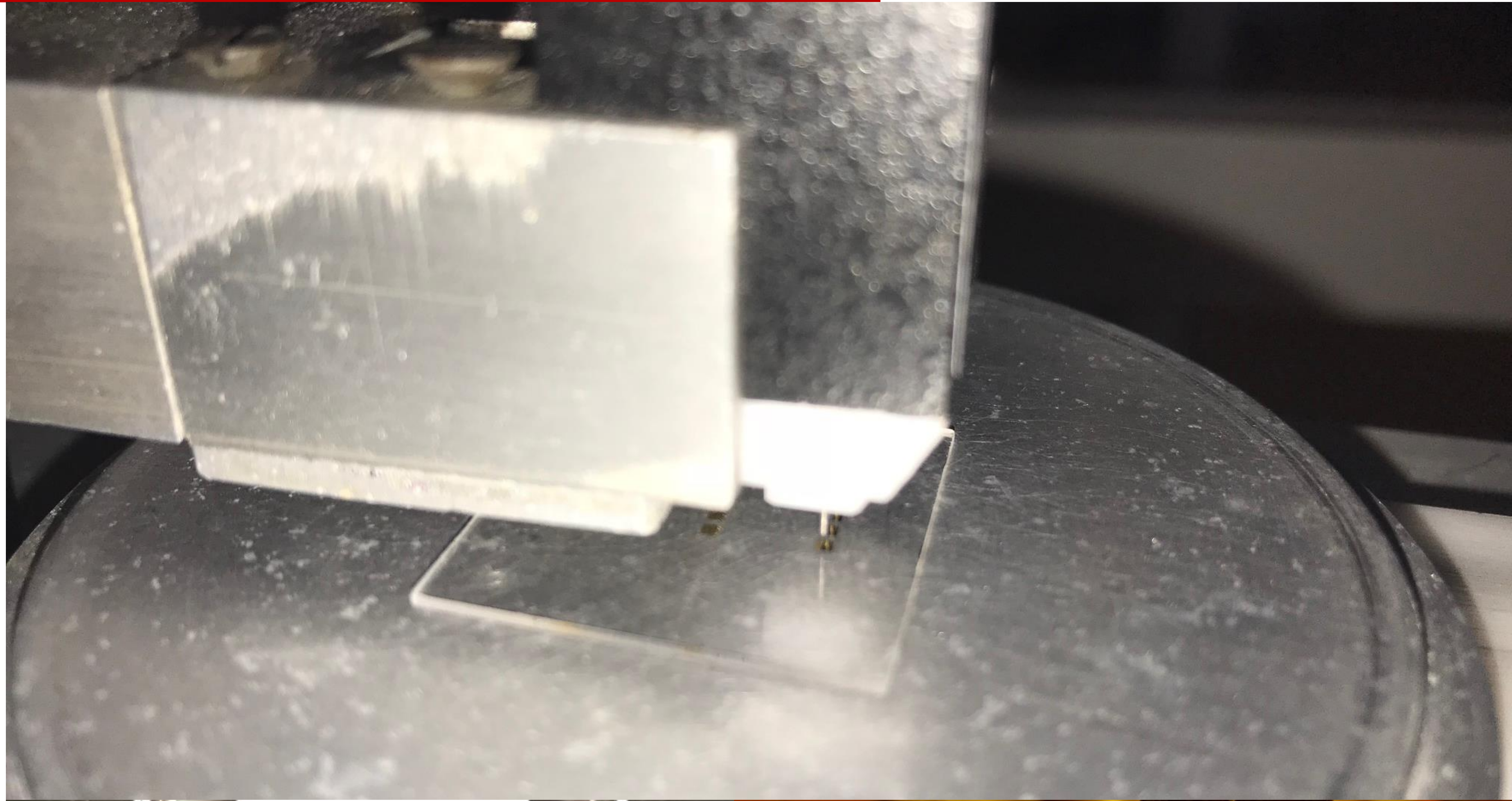
Methodology:

1. Create a test vehicle to test the conductivity
2. Test sheet resistance of DisCharge H2O at various RPMs for different concentrations

DisCharge Four Point Probe Characterization

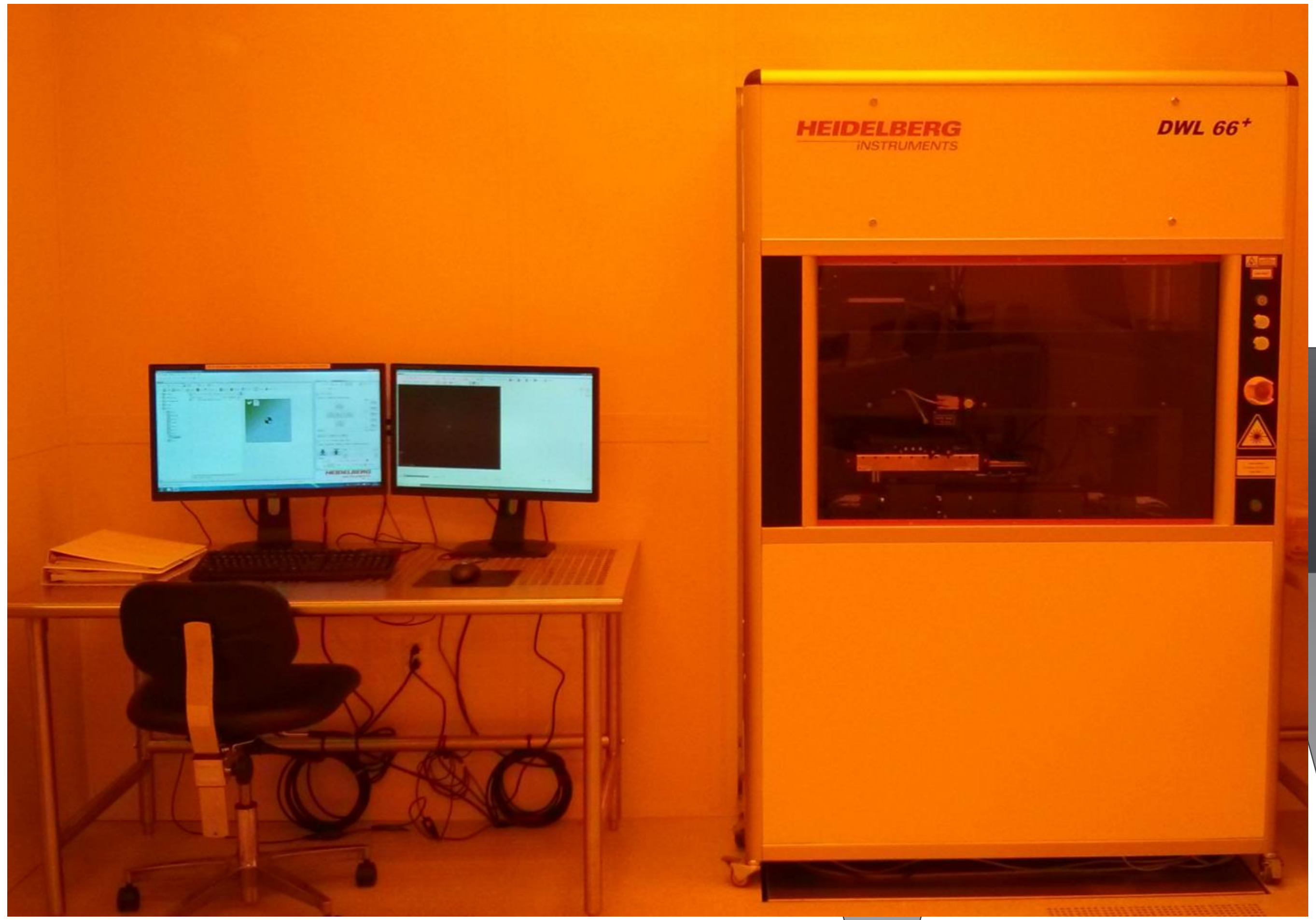
Process:

1. AMI clean of 25 mm^2 fused silica (four samples)
2. Spin on S1813 positive resist at 3000RPM
3. Soft bake 115°C
4. Write box pattern on Heidelberg DWL66+ (10mm WH, 50% filter, 200mW LP)
5. Develop MF319, 60s w/ manual agitation, water rinse, N2 dry
6. Deposit 44 nm Au (Lesker PVD75, e-beam evap, 2 Å/s)
7. Liftoff with Microposit Remover 1165 (60°C w/ sonication)
8. Spin DisCharge H_2O at 1000, 2000, 3000, and 4000 RPM
9. Ensuring that probes are contacting the Au pads, measure current and voltage with a four point probe



Fabrication for Anti-Charging Test Vehicle

HEIDELBERG INSTRUMENTS



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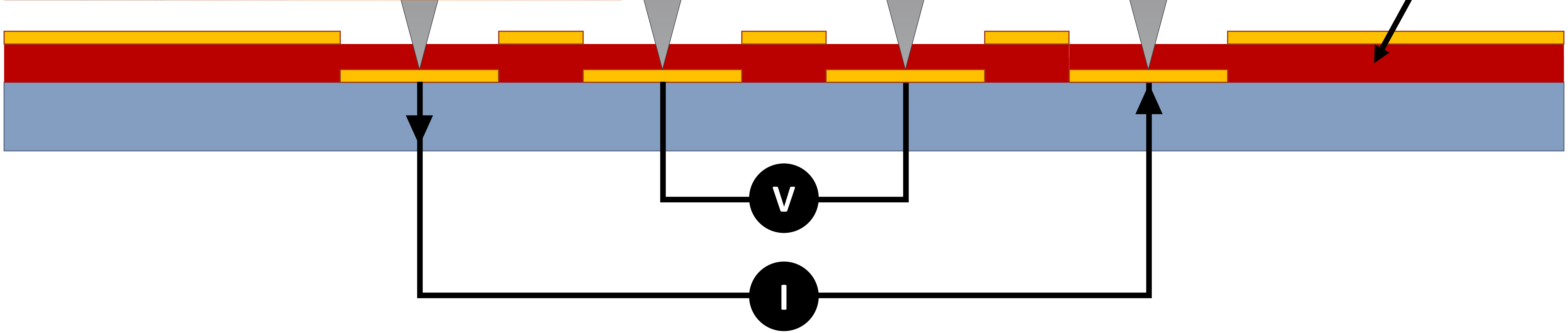

Preliminary Results for DisCharge H_2O

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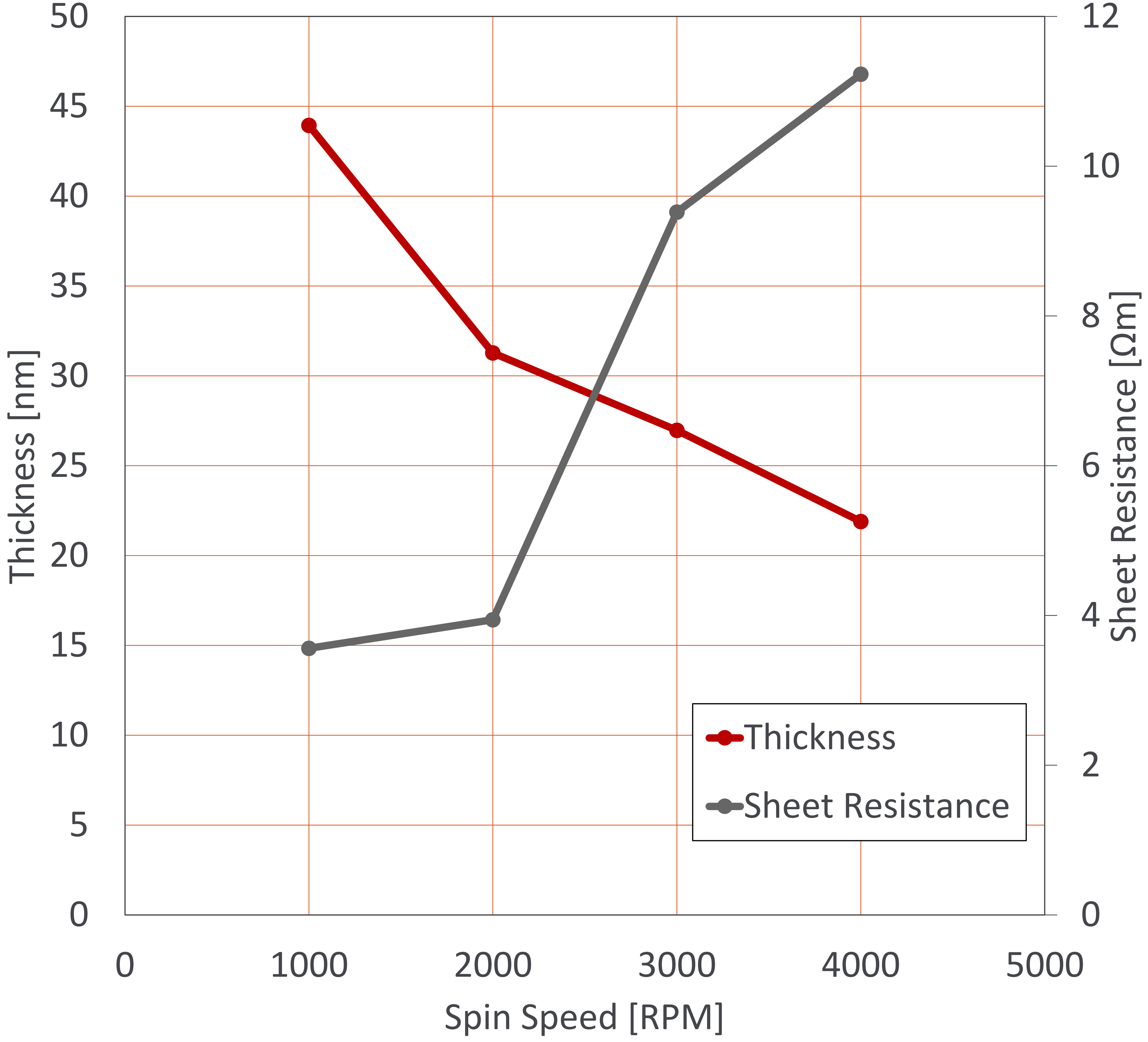

Using four point probe thin-sheet approximation:
(t < probe spacing)

$$\rho = \frac{\pi}{\ln(2)}\left(\frac{V}{I}\right)t = 4.532\left(\frac{V}{I}\right)t$$

Thin-film Sample	Sheet Resistivity (Averaged)
Au	5.525×10^{-8} Ωm
DisCharge 1000 RPM	3.562 Ωm
DisCharge 2000 RPM	3.944 Ωm
DisCharge 3000 RPM	9.388 Ωm
DisCharge 4000 RPM	11.230 Ωm

Sheet Resistance

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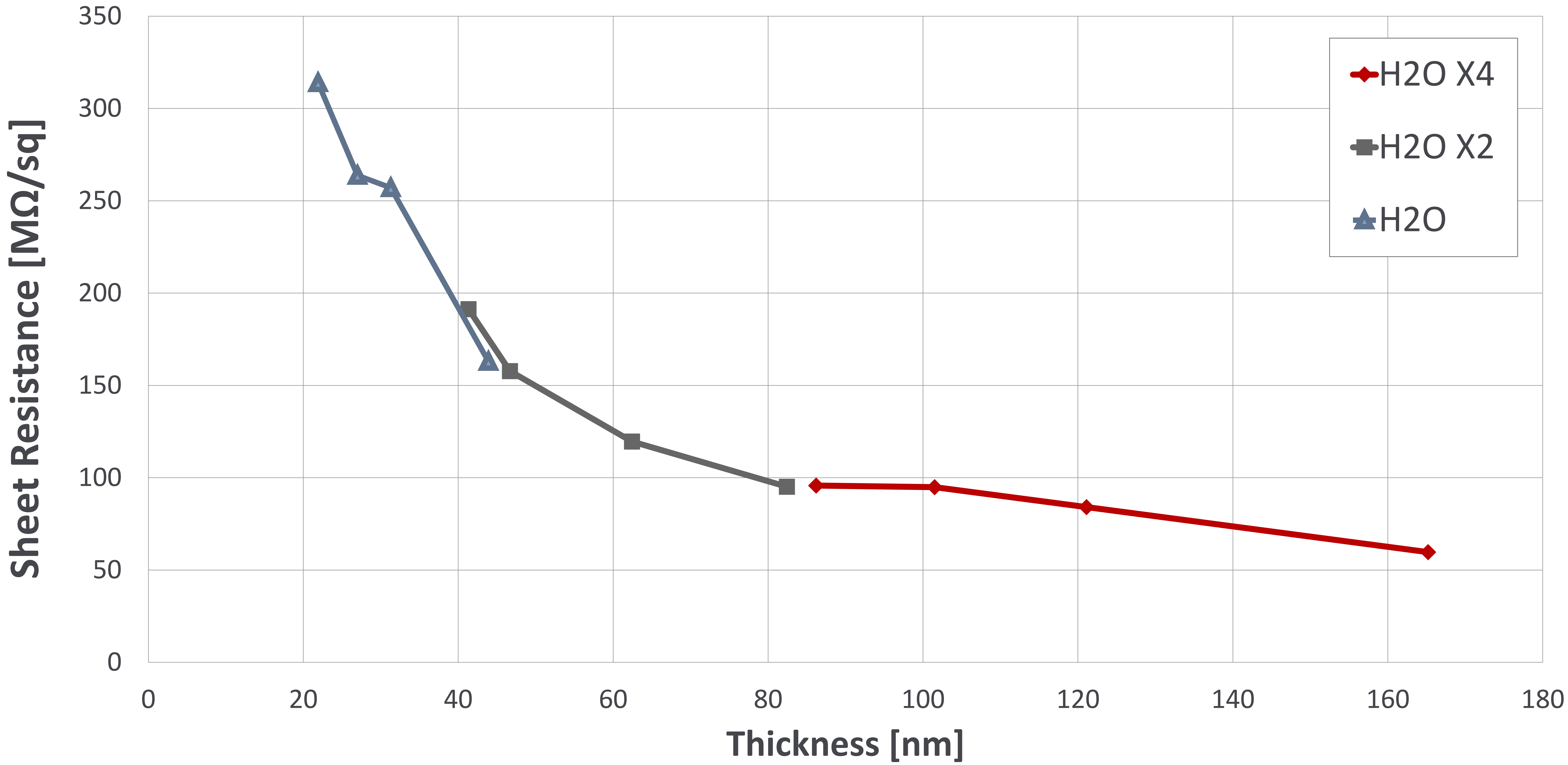
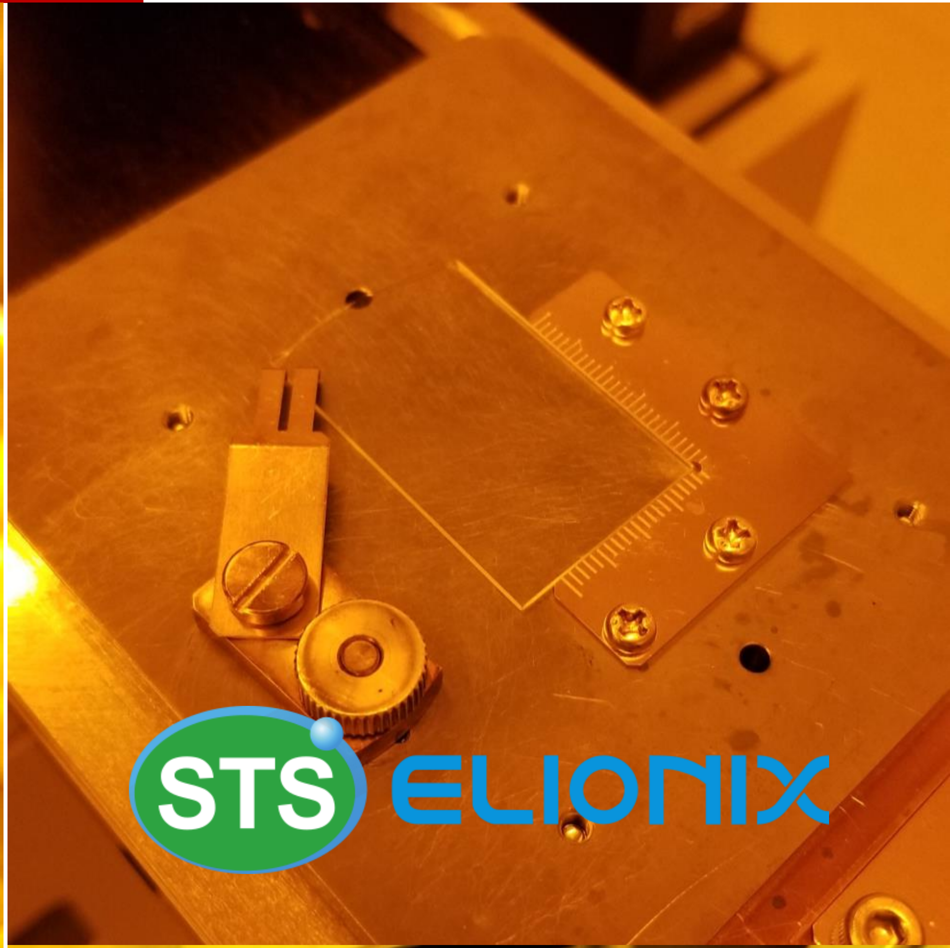
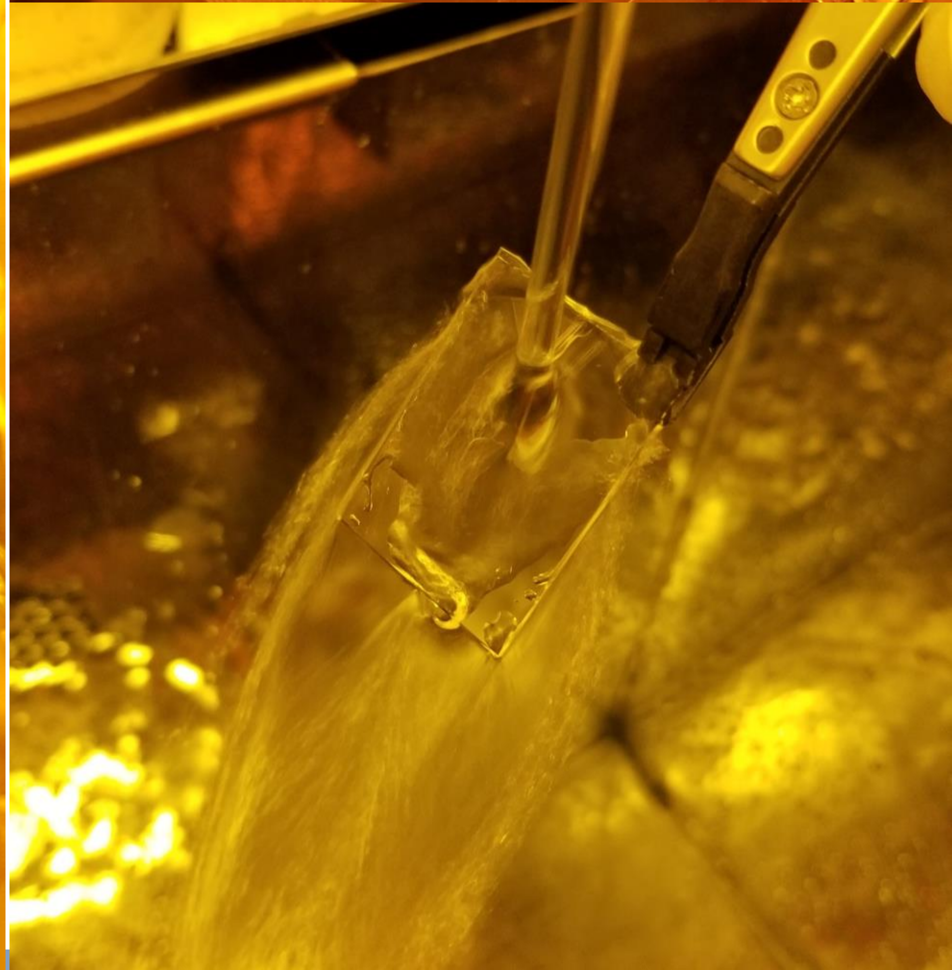


Process Integration

1. Spin coat and pre-bake resist per protocol
2. Allow wafer/sample to cool to room temperature
3. Spin coat *DisCharge H2O*. No soft bake required.
4. Remove *DisCharge H2O* film using one of the following methods:
   - **Spin Rinse Removal:** While spinning at 3000 RPM for 60 seconds, rinse with DI water or IPA
   - **Sink Rinse Removal:** Rinse with running DI water for 30-60 seconds
   - **Solvent Rinse Removal:** Rinse with steady stream of IPA for 30-60 seconds
5. Dry sample using N_2 blow dry
6. Develop resist as normal





300 nm PMMA 950 A4 on 1mm PDMS on bulk Si

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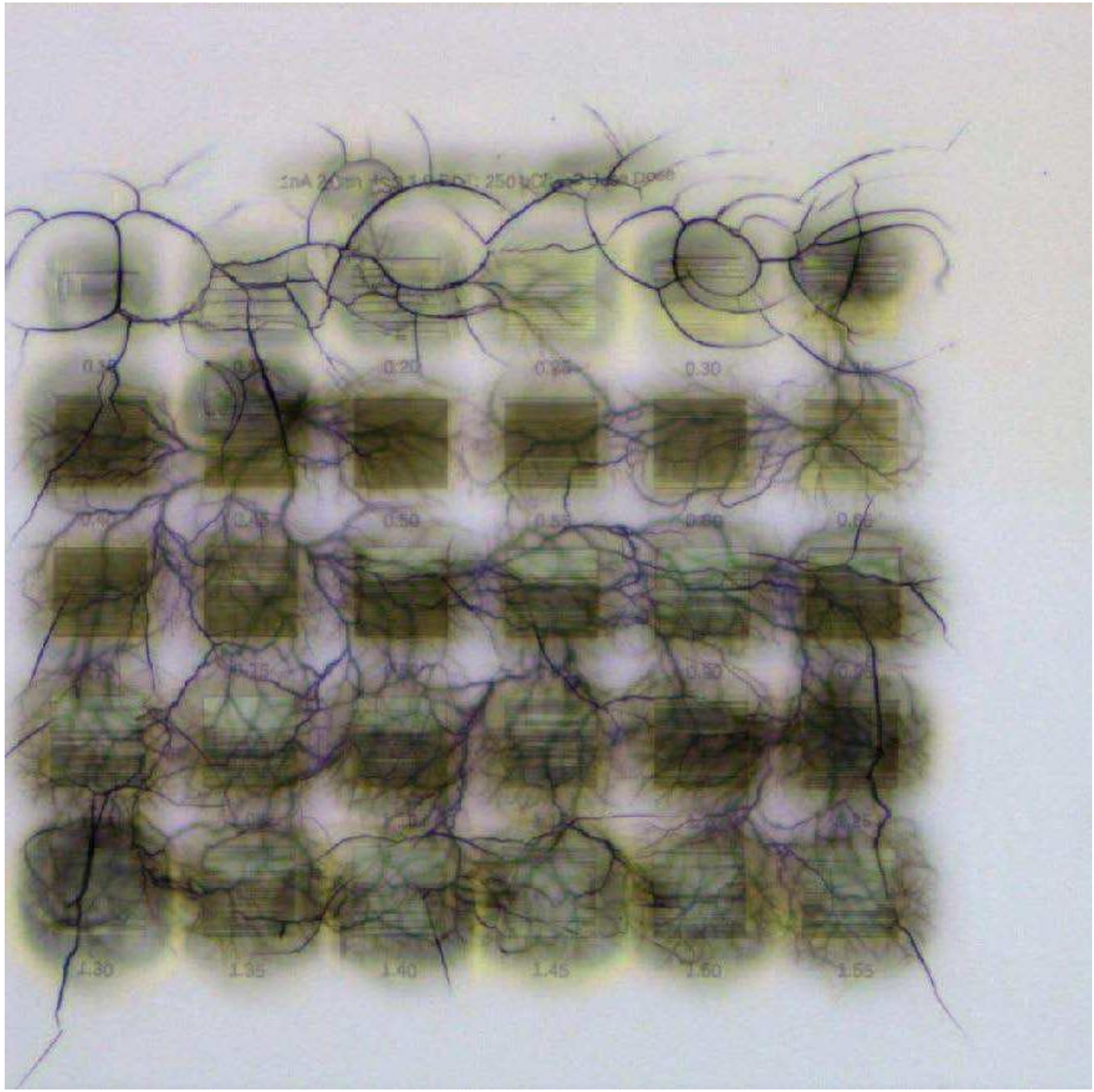
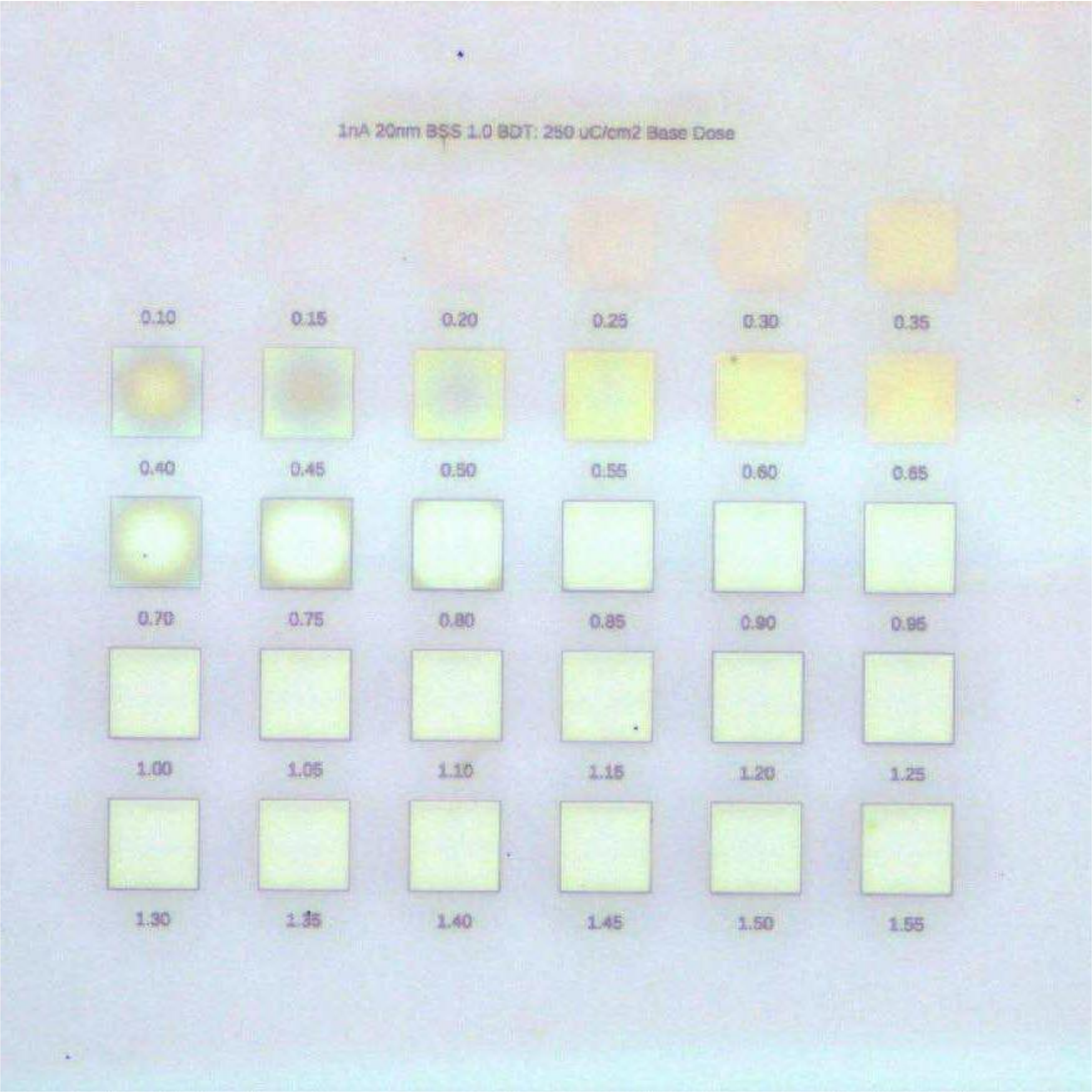
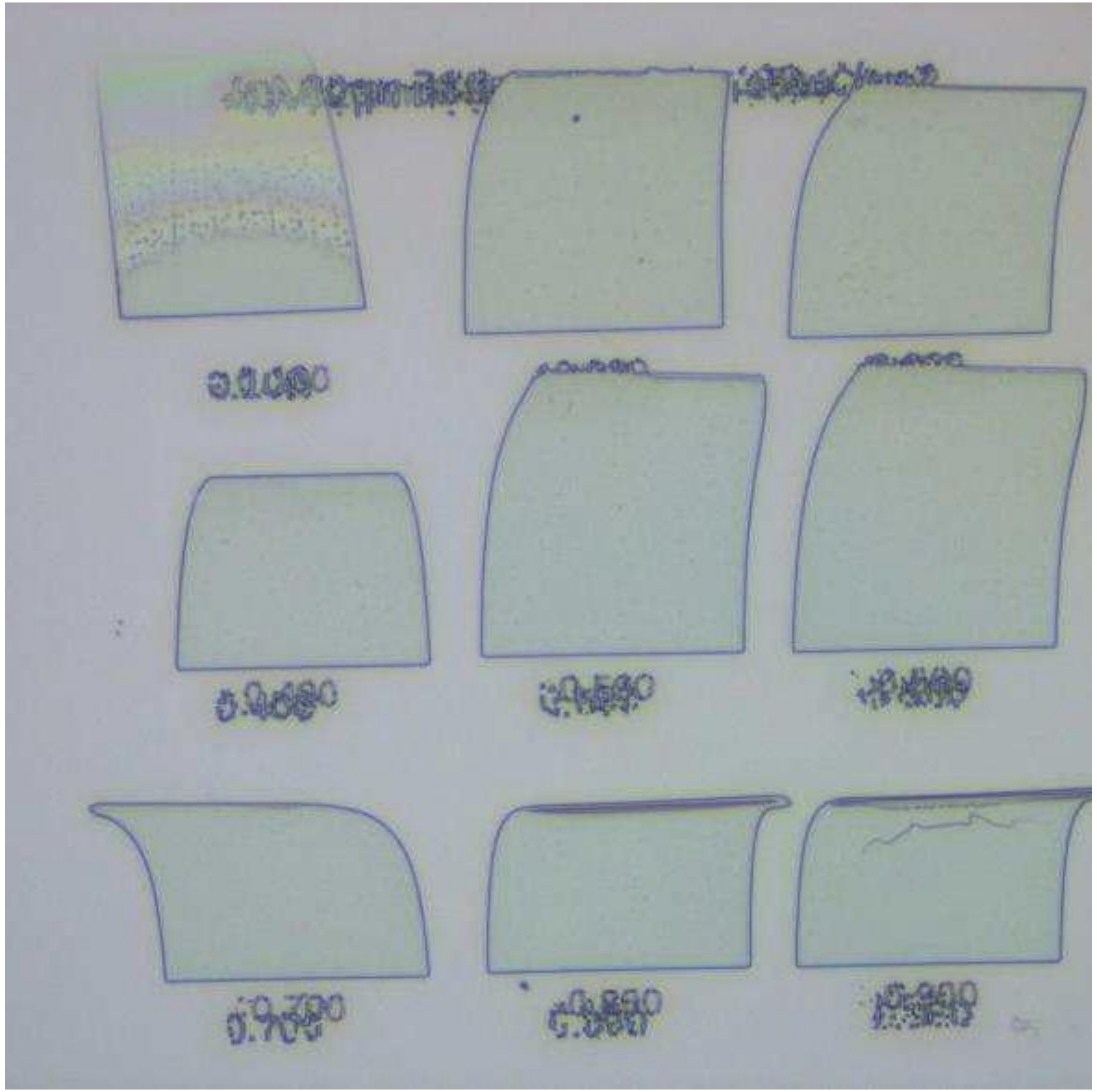
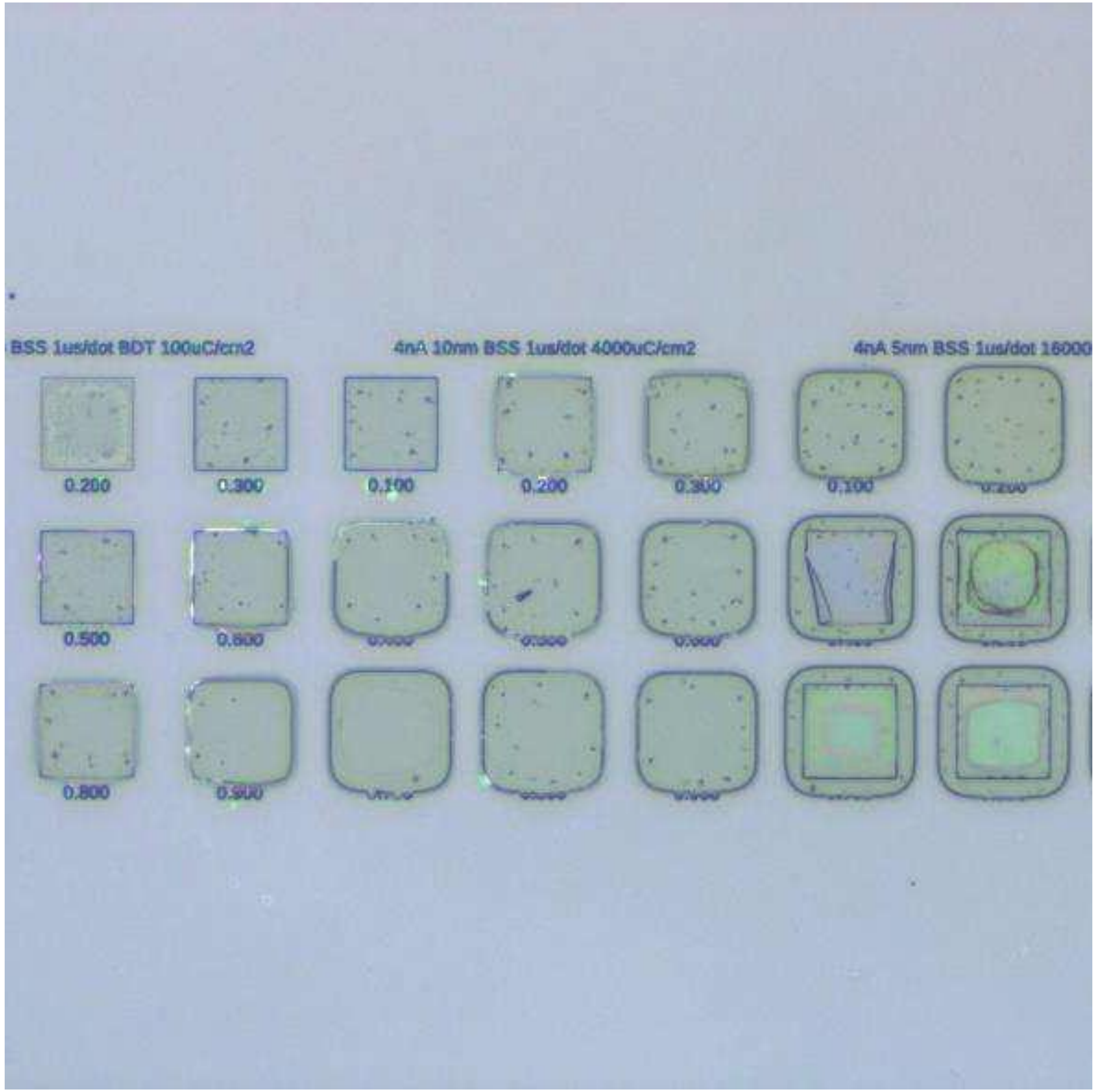




300 nm mr-PosEBR on Glass Slide





200 nm ZEP520A on Glass Slide

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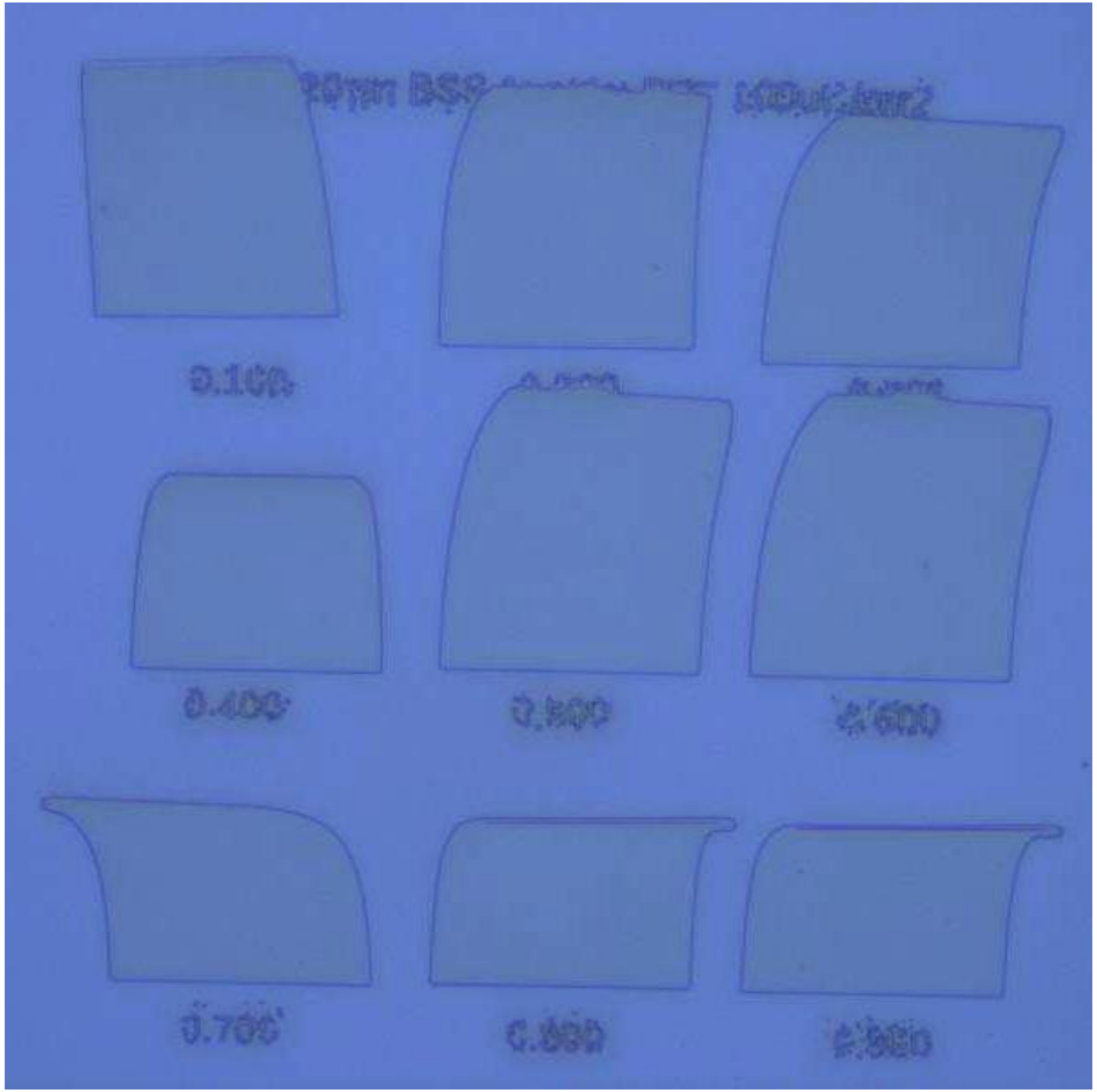
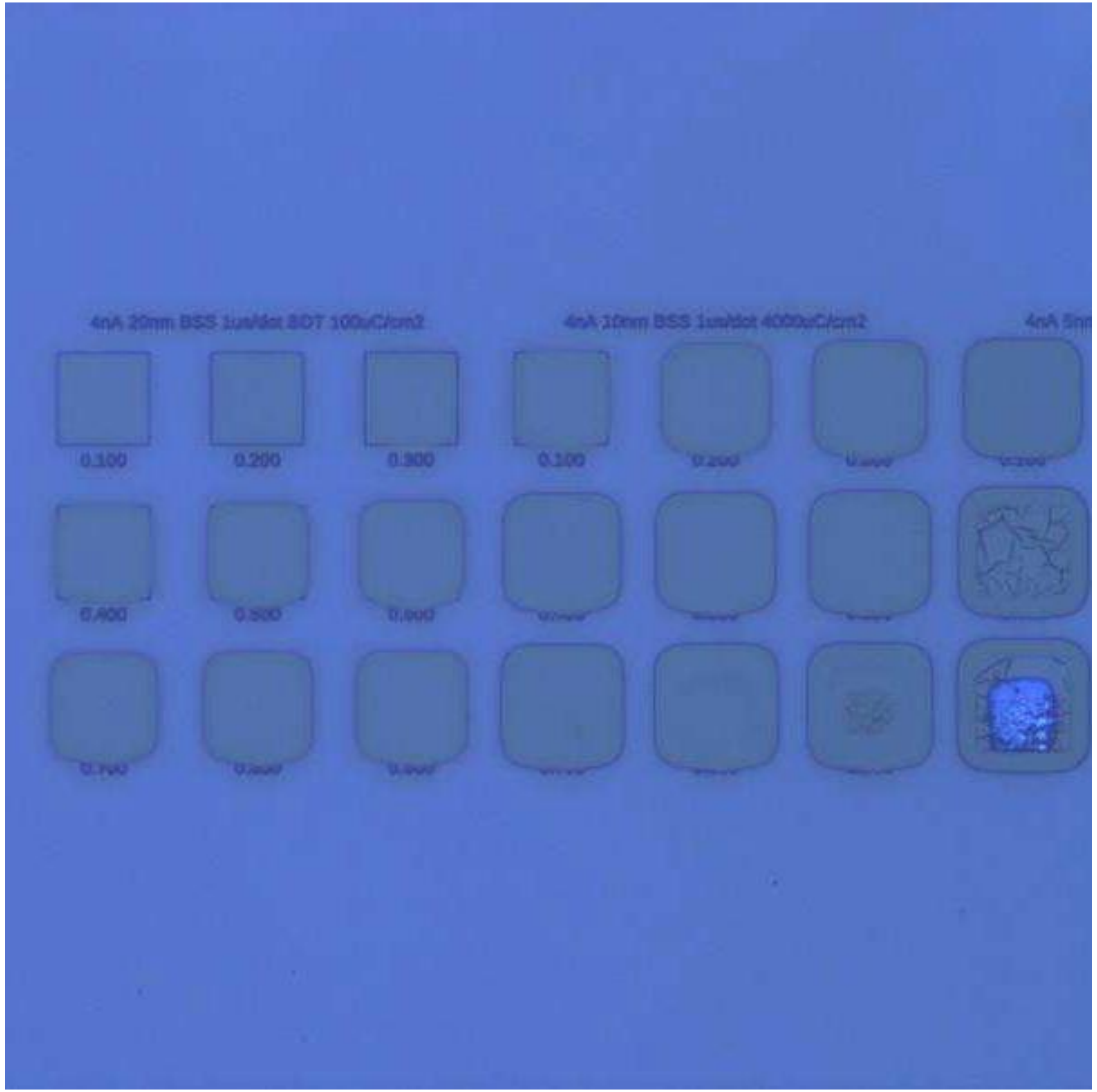
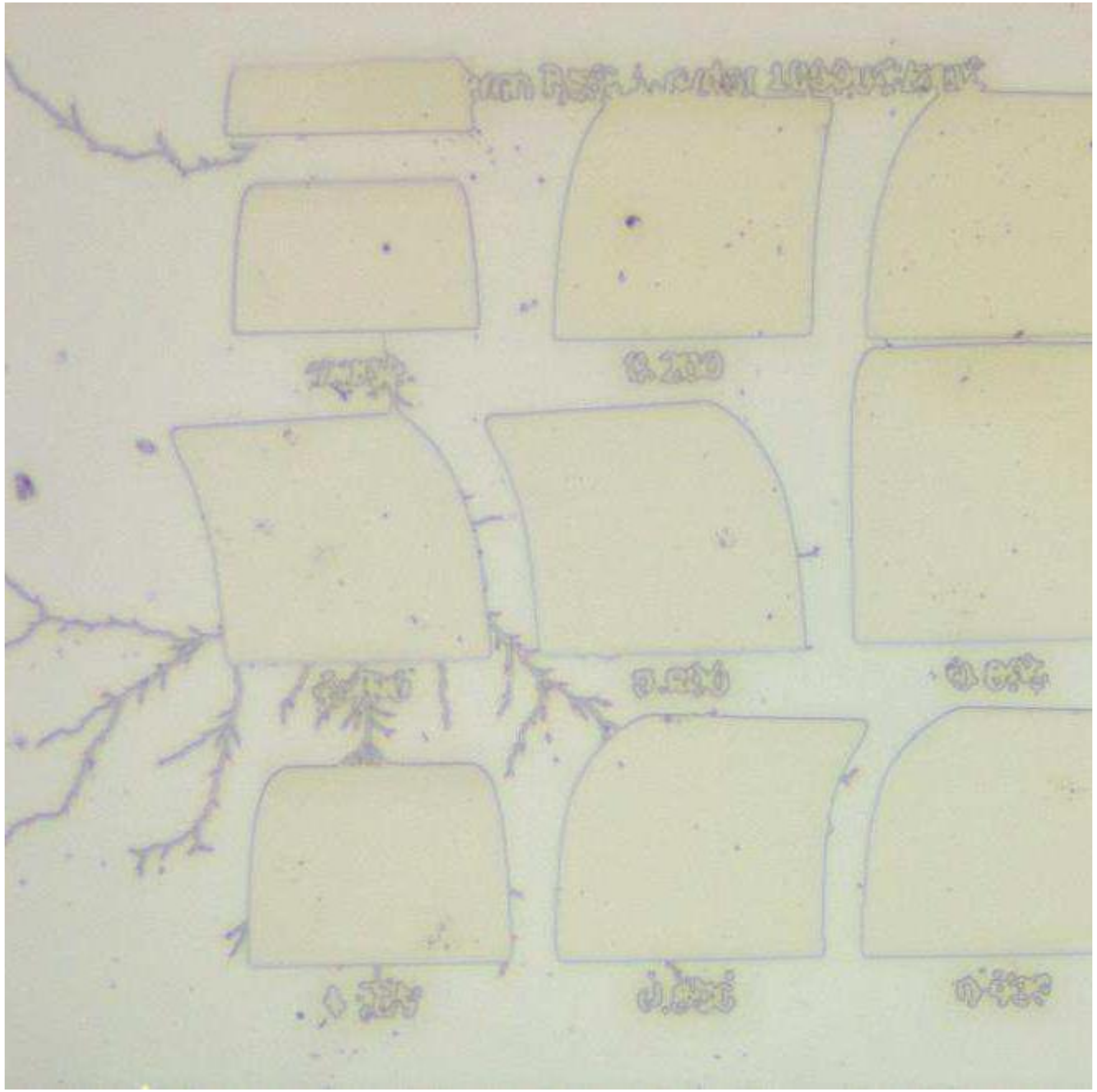
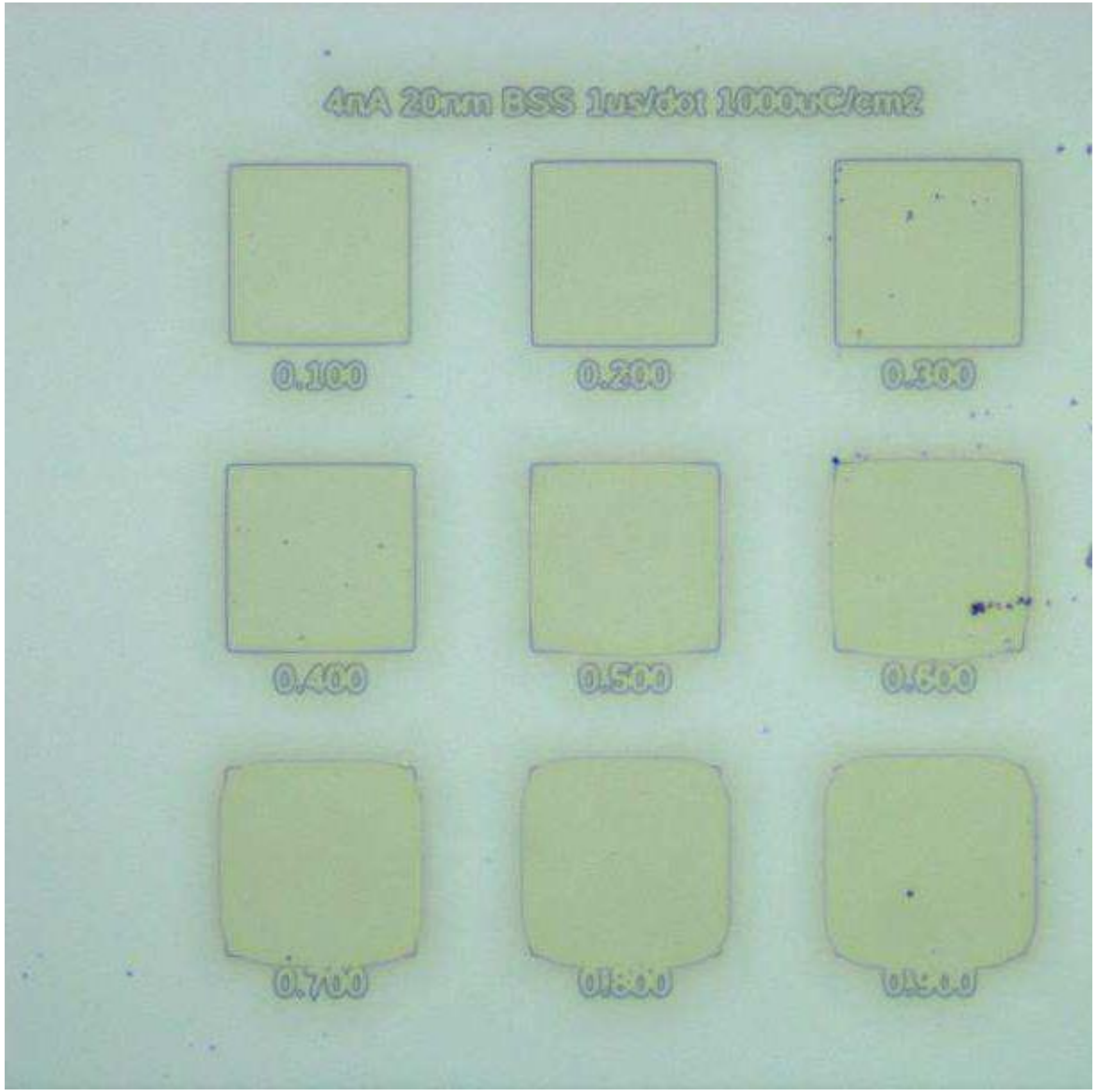




300 nm CSAR62 on Glass Slide





ZEP520A 300 nm Line Space Patterns atop Fused Silica

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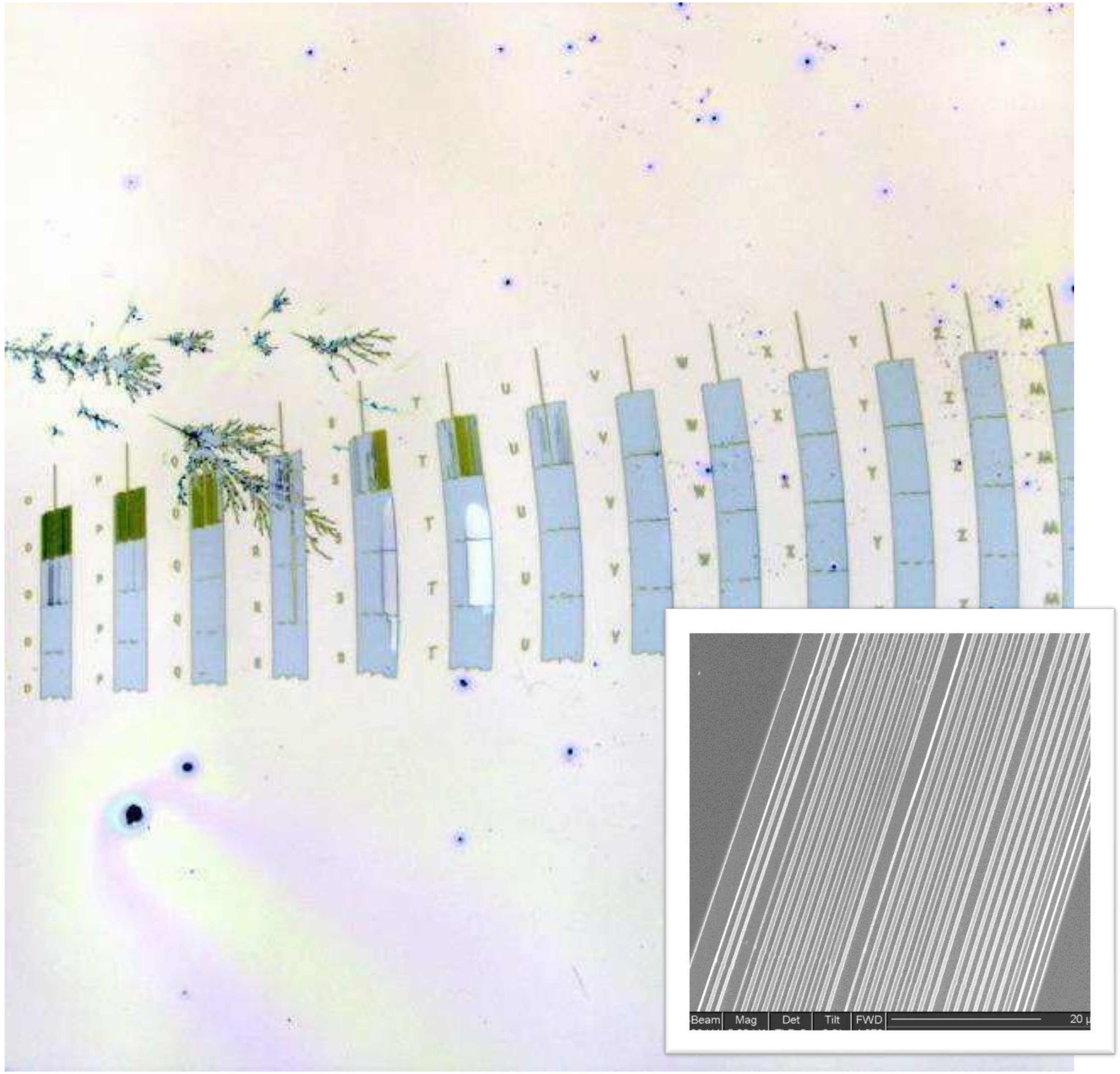
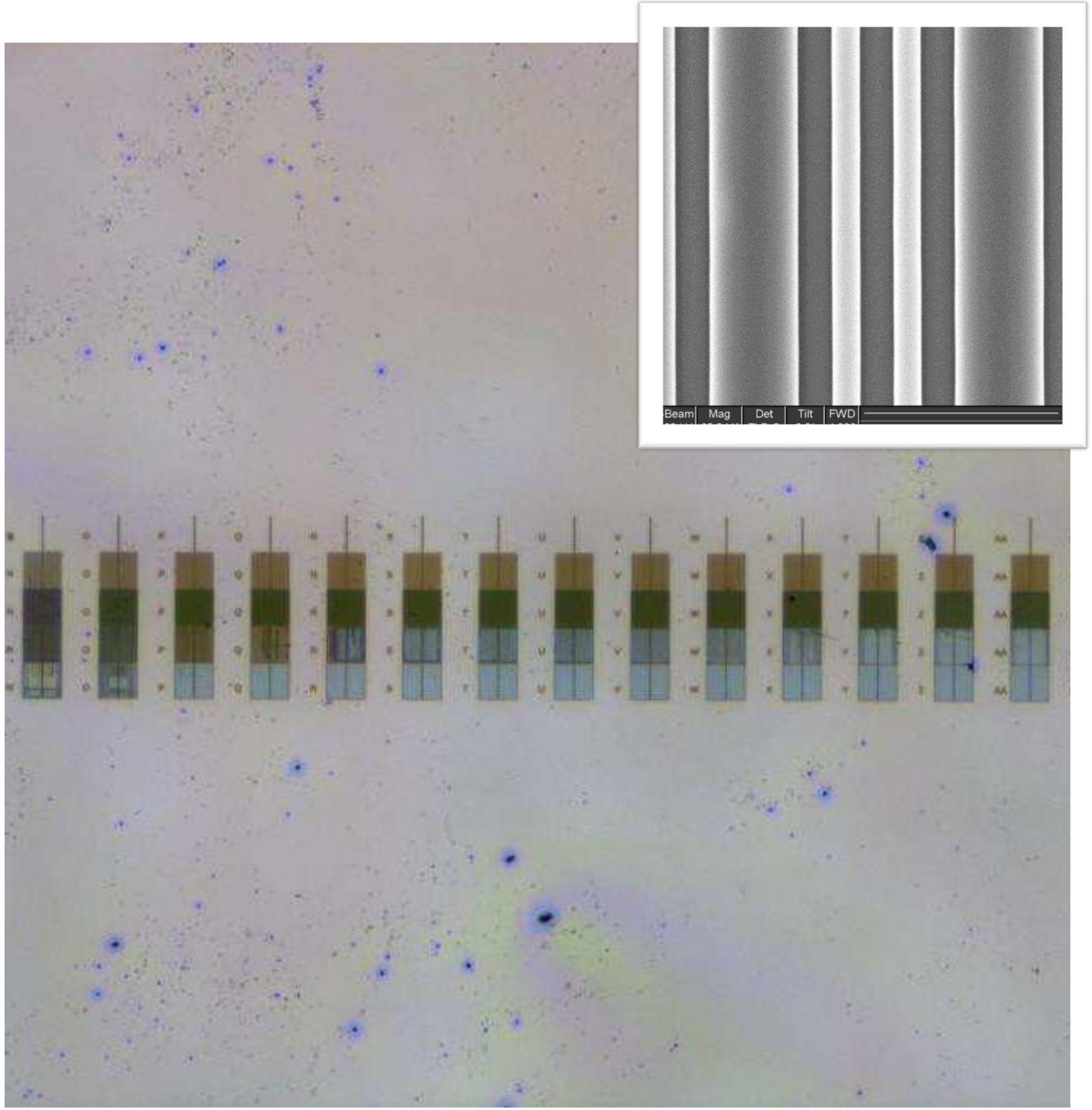
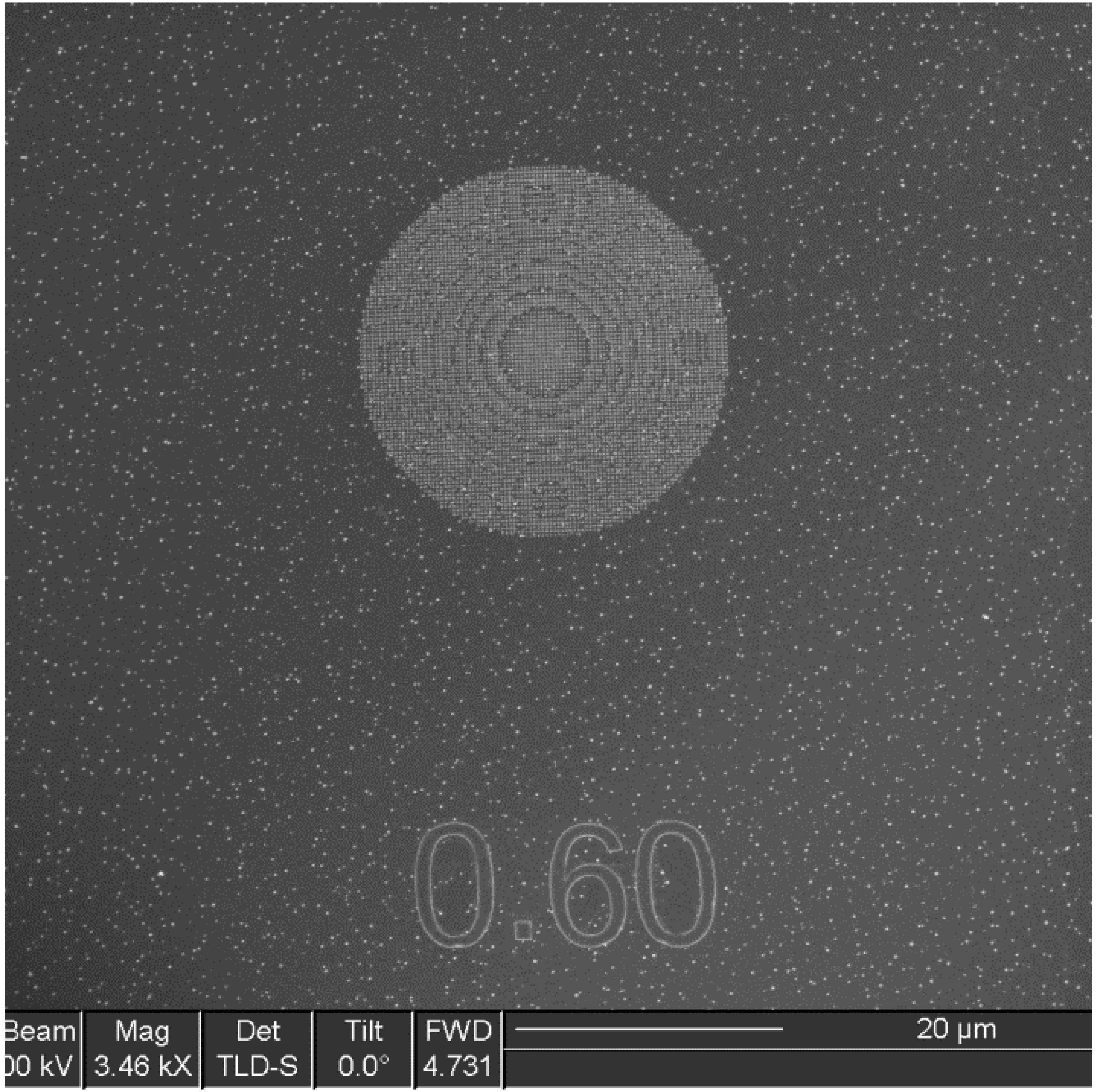
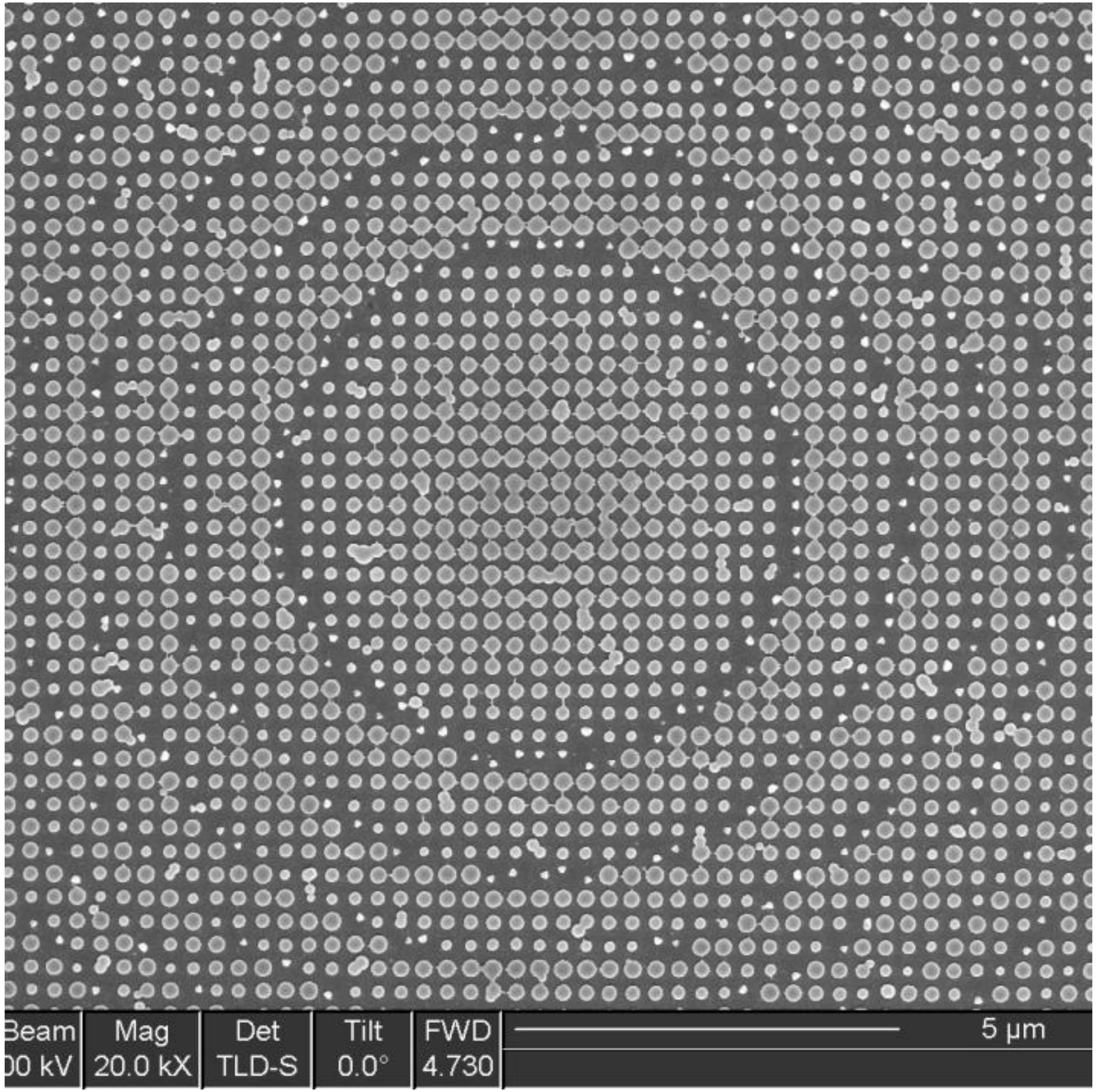


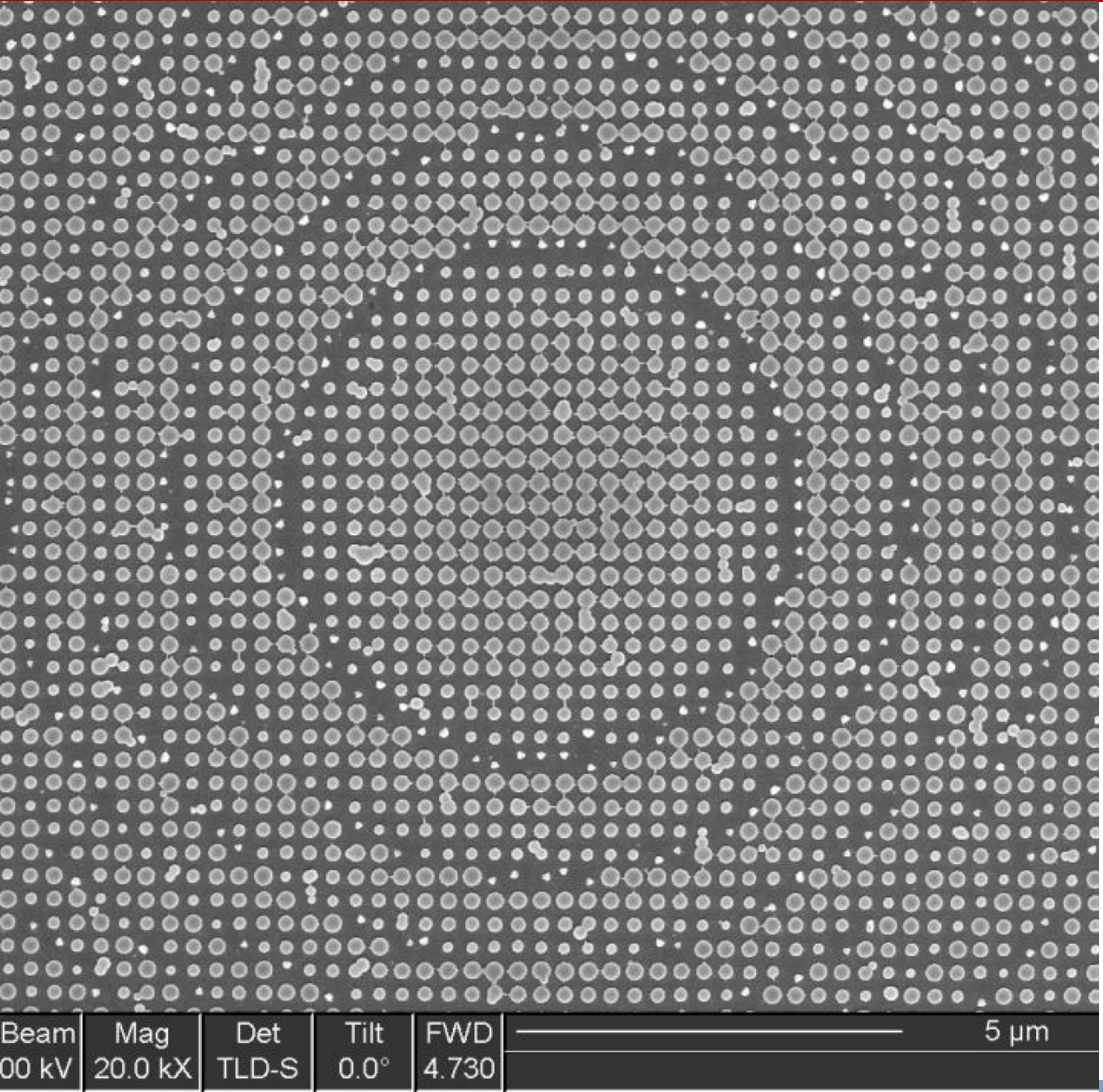


HSQ on Fused Silica





Compatibility Summary



DisCharge H2O Compatible EBL Resists

CSAR 62 (positive resist containing poly (α-methylstyrene-co-chloromethacrylic acid methyl ester), plus an acid generator in anisole solvent)
mr-PosEBR (acrylate-based positive resist in anisole solvent)
ZEP520A (positive resist in anisole solvent)
PMMA (polymethyl methacrylate positive resist)
HSQ (hydrogen silsesquioxane negative inorganic resist)

DisCharge H2O Incompatible EBL Resists

ma-N 2400 (negative organic novolak resist)

Summary

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- Presented our work on DisCharge by DisChem
- Demonstrated electrical conductivity and efficacy in charge dissipation
- Shown to be compatible with several commercially available positive resists and a negative resist (HSQ)