Conductively Coated 3D Printed Field emission arrays

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Outline

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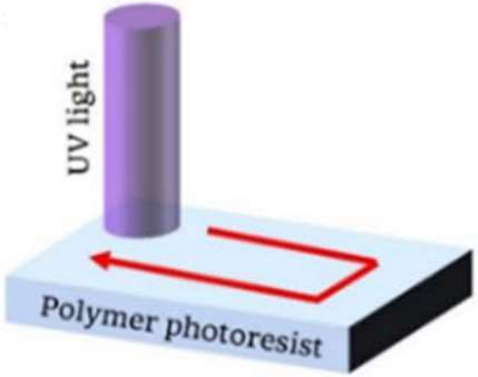
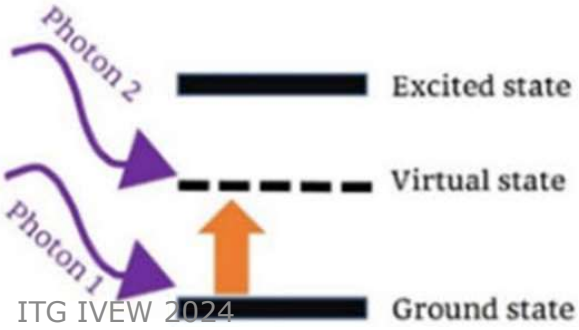
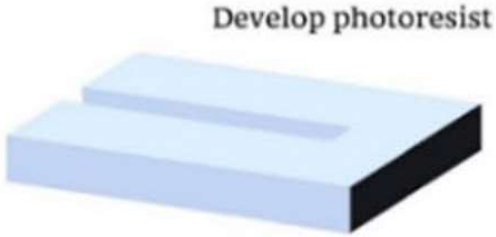
Motivation for 2PL printed FEAs – 1/2

- *„Two-photon lithography (2PL) is a novel fabrication technique which, like photolithography, utilises resist and UV light to create patterns.“*
- Generates 3d patterns by exposing the UV laser to areas called voxels
- Changing the laser intensity adjusts the dimension of the pattern.
- Resolution up to 50 nm IQS Nano 3D printer







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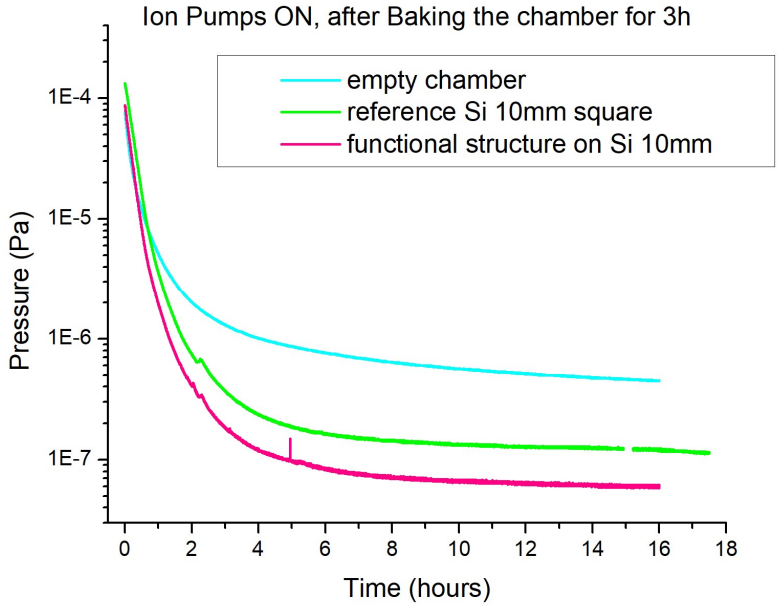
Motivation for 2PL printed FEAs – 2/2

- Fast development
- Reasonable printing speeds compared to other techniques
- Affordable material cost of resin
- Resin compatible with

chemical treatment, ie. $H_2C=O$ resistant

- Ultra-high vacuum compatible



D. Burda et al., "Conductively Coated 3D Printed Emitters for Electron Devices," 2024 IEEE 37th International Vacuum Nanoelectronics Conference (IVNC), Brno, Czech Republic, 2024, unpublished.

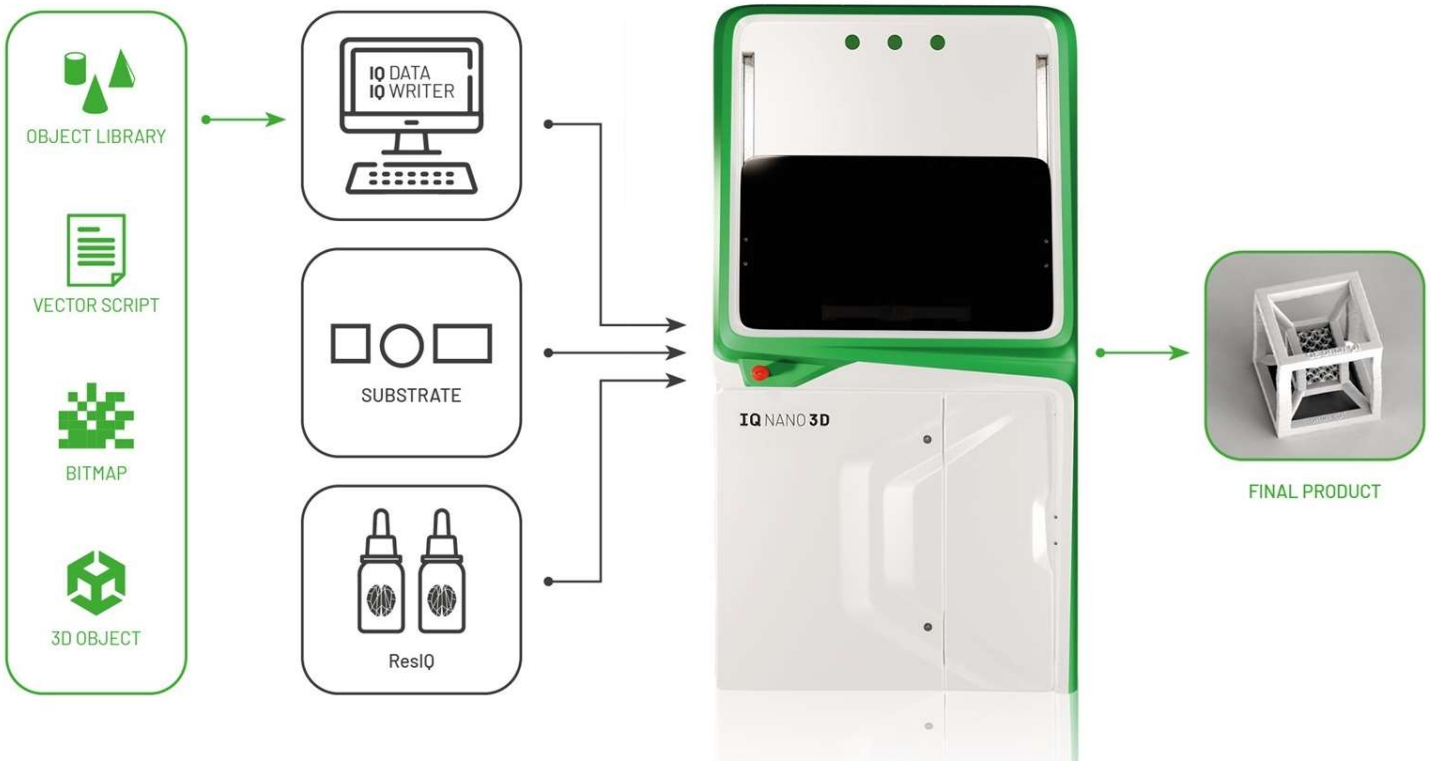
Instrumentation – 1/2

- 2PP 3D printer
  - Acousto-optic beam deflection system

  -> Very fast printing speeds

- Variable voxel size printing strategy

- Bitmap vs. Vector printing



IQS Nano 3D, https://iqsnano.com/3d-nano-printer/

Instrumentation – 2/2

- RIE (PlasmaPro, Oxford Instruments)
  - O2 Plasma thinning, 10s, ICP 1500W, CCP 10W

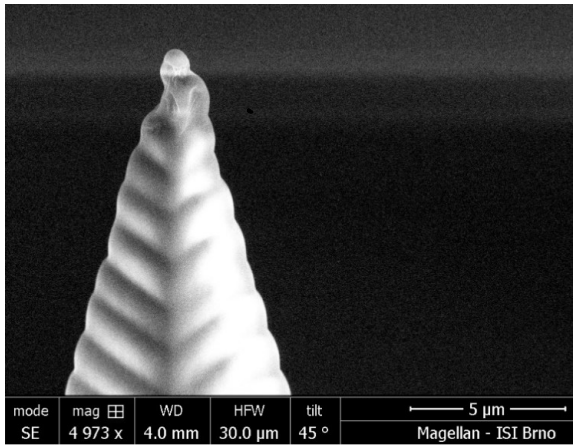
- Metallic coating
  - Magnetron Sputtering (Q150T ES, Quorum)
  - Up to 40 nm of thickness
  - Au, Cr

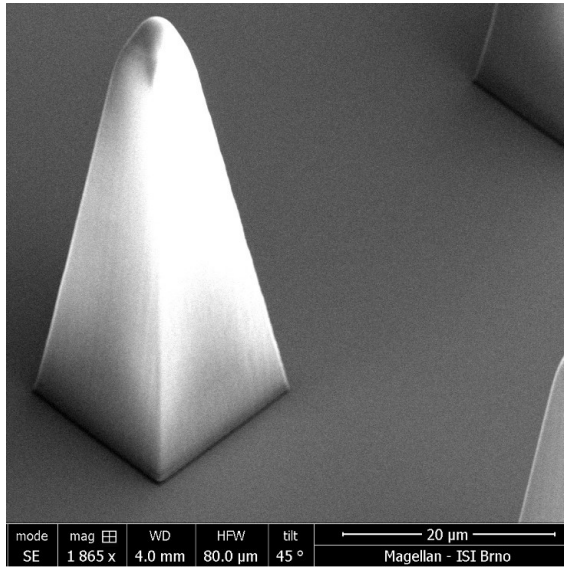
Characterization – 1/2

- Vector 2PP printing:
  - ✓ Significantly smoother side walls
  - ✓ More stable/rigid by better layer-by-layer adhesion than BMP

- BMP 2PP printing:
  - ✓ Yields sharper apexes of the structures

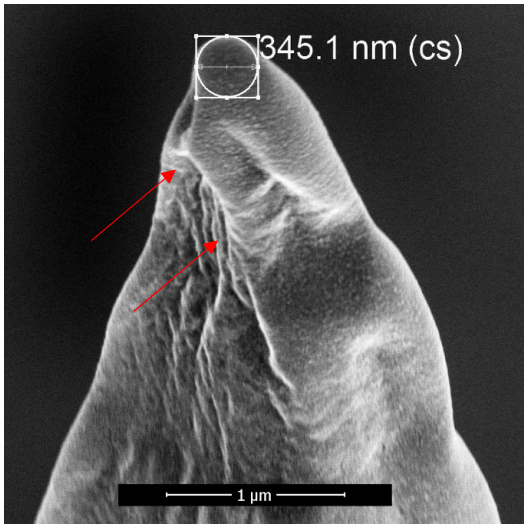
- Optimization of writing strategy of the very tip yields better results – top voxel (*subvoxel*) optimization
- Resulted radius of 100 nm

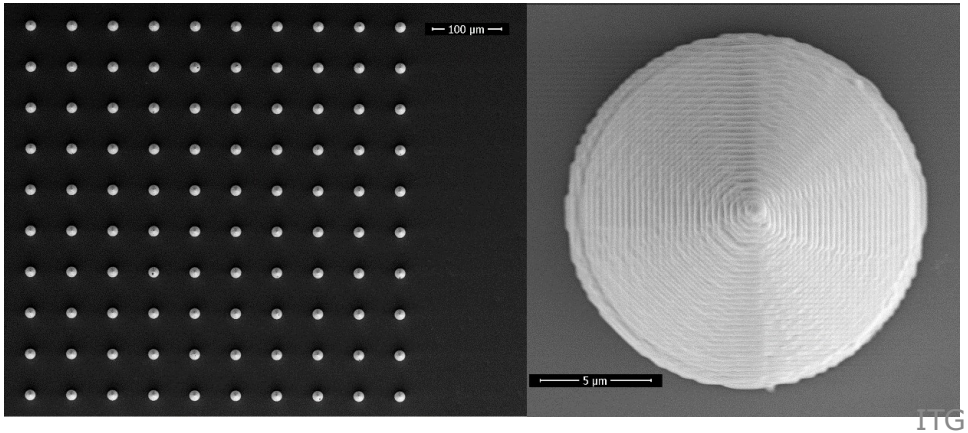


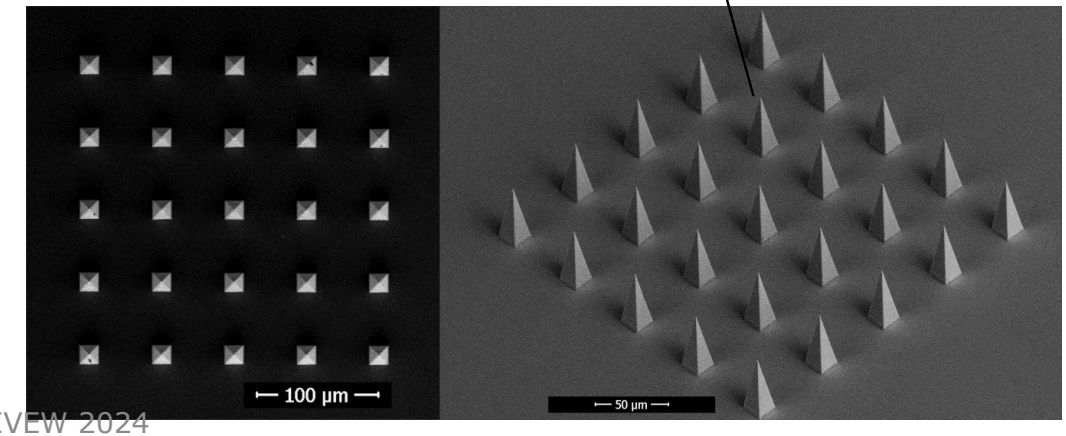


Characterization – 2/2, Coating

Magnetron sputter coating Au or Cr
- melting of the sample
- Introduces damage to the structures due to elevated temperature

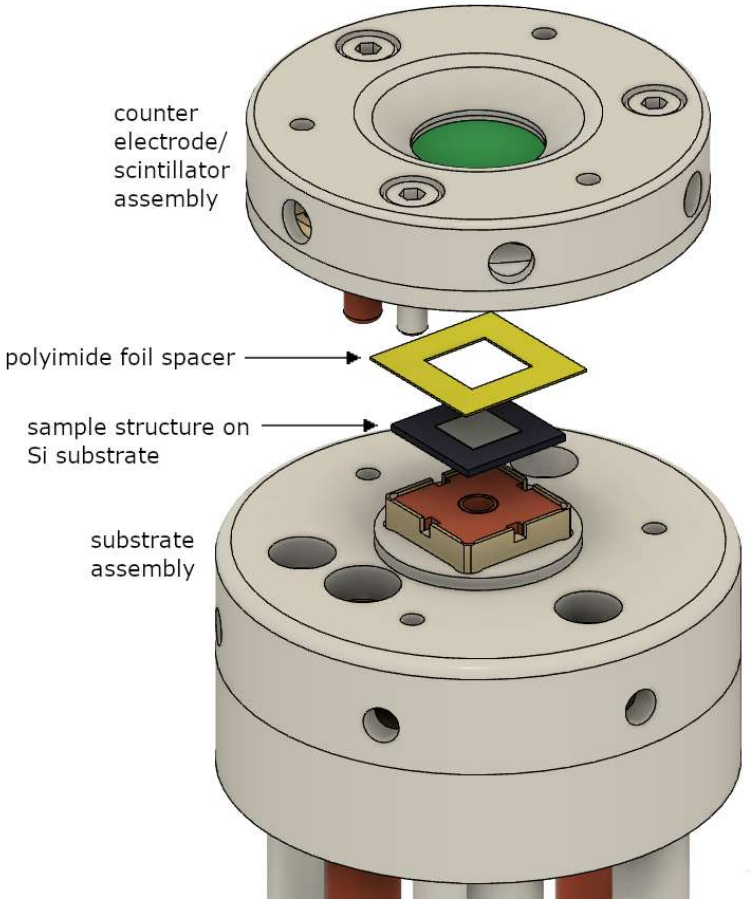






FE Experiment – 1/3

- UHV compatible sample holder
  (designed by L.Dupák, ISI Brno)
- Array of 10 x 10 square pyramids on 8 x 8 mm Si chip
- Mounted in Diode configuration
- An 80 μm thick polyimide sheet spacer separates the chip from the counter electrode.
- The counter electrode/scintillator - Ce:YAG scintillating monocrystal coated with a 30 nm conductive Al layer, connected to picoammeter



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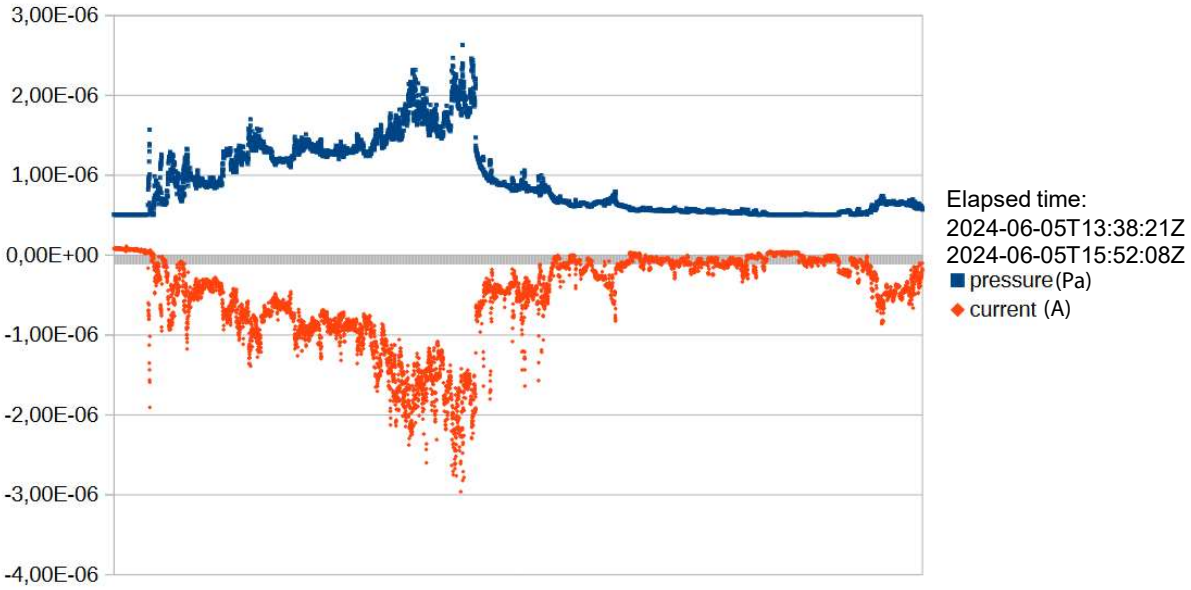
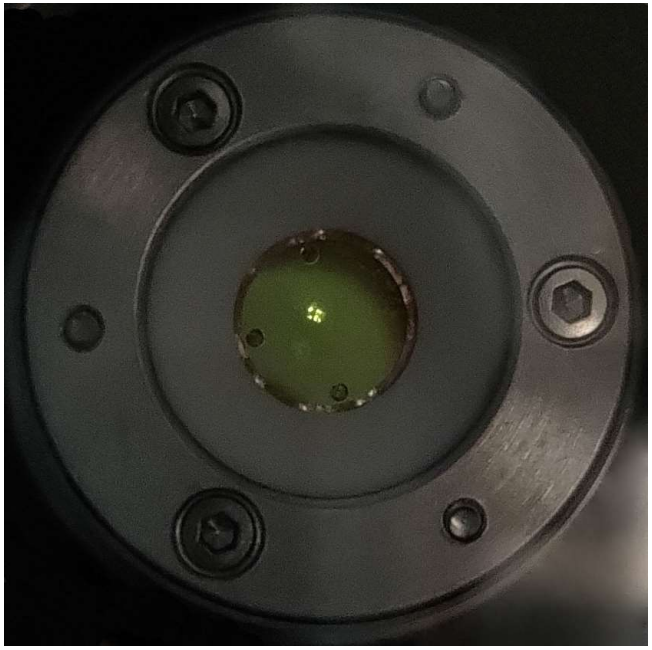
FE Experiment – 2/3

- Au 20nm/ 10 x 10 square pyramids
- Value of workfunction ϕ_{Au}=5.1 eV
- UHV pressure prior experiment: $5 \cdot 10^{-7}$ Pa
- The distance between the tips of the array and the counter electrode is 25 to 30 µm.

FE Experiment – 3/3

- Au 20nm/ 10 x 10 square pyramids
- Switching of emission centres observed
- Fluctuation of current
- Suspecting micro discharges





Future modifications

- Study of RIE thinning
  - To improve the overal sharpness of the structures

Seeking replacement for more suitable coating method:

- 2PP compatible with conventional photolithography

  - Electroforming

Electroless plating

Conclusions

- Planar 3D structures as a platform for future development
- Integration into other 3D printed devices: electrodes, octupoles, etc., ***for newest development see IVNC2023 & IVNC2024***

- Emission occured at high applied voltage,
- Micro discharges lead to decrease in performance

- 2PL resin compatible with Ultra-High Vacuum
- 2PL resin compatible with agressive chemicals

- Magnetron sputtered metallic coating -> erosion, melting
- Future: Electroless plating/Conductive oxide deposition (ALD), 2PL+Electroforming

Thank you for your attention

https://www.isibrno.cz/en

https://iqsnano.com/