

## THE STUDY OF HIGH AND LOW DOPED P-TYPE SILICON FIELD EMITTERS

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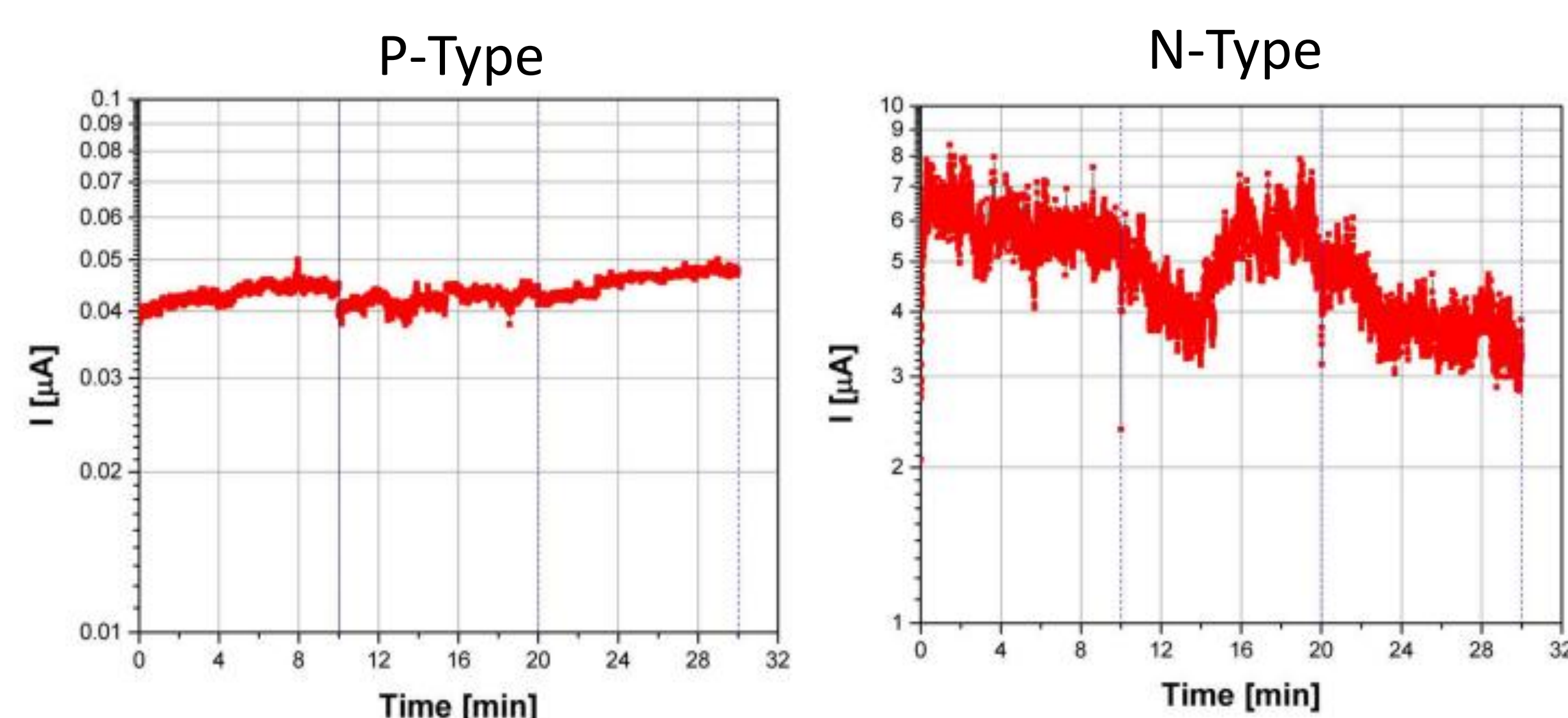
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**Abstract.** In this work, we present the results of our study on changes in occurrence of fields emission phenomenon depending on the amount of dopant in silicon wafer used in the emitter making process. Silicon tips were manufactured from both high (boron, 0.001-0.005  $\Omega\cdot\text{cm}$ ) and low (boron, 10-20  $\Omega\cdot\text{cm}$ ) doped silicon p-type wafers. In the process of making tips wet anisotropic silicon etching was used in aqueous solution of potassium hydroxide as well as photolithography using specially designed mask in order to increase the height to width ratio of the emitter. Alternatively, the laser ablation process has been used to produce the emitters. In order to have a thorough comparison the experiment was repeated for n-type silicon wafers, same technological processes and measurements methods were used in order to replicate the environment of the first experiment.

### Focus of study

- The proper operation of electron microscopes requires maintaining a stable electron beam [1].
- Current fluctuations in N-type emitters adversely affect beam coherence, in turn requiring additional stabilisation.
- When subjected to a voltage exceeding the threshold voltage, P-type emitters enter the saturation, which is characterized by reduced current fluctuations [2].
- GOAL: Investigation into the effect of minor current fluctuations in P-type emitters on electron beam stability, and it's correlation with amount of dopant.**



Emission current in time for P-type and N-type silicon emitters

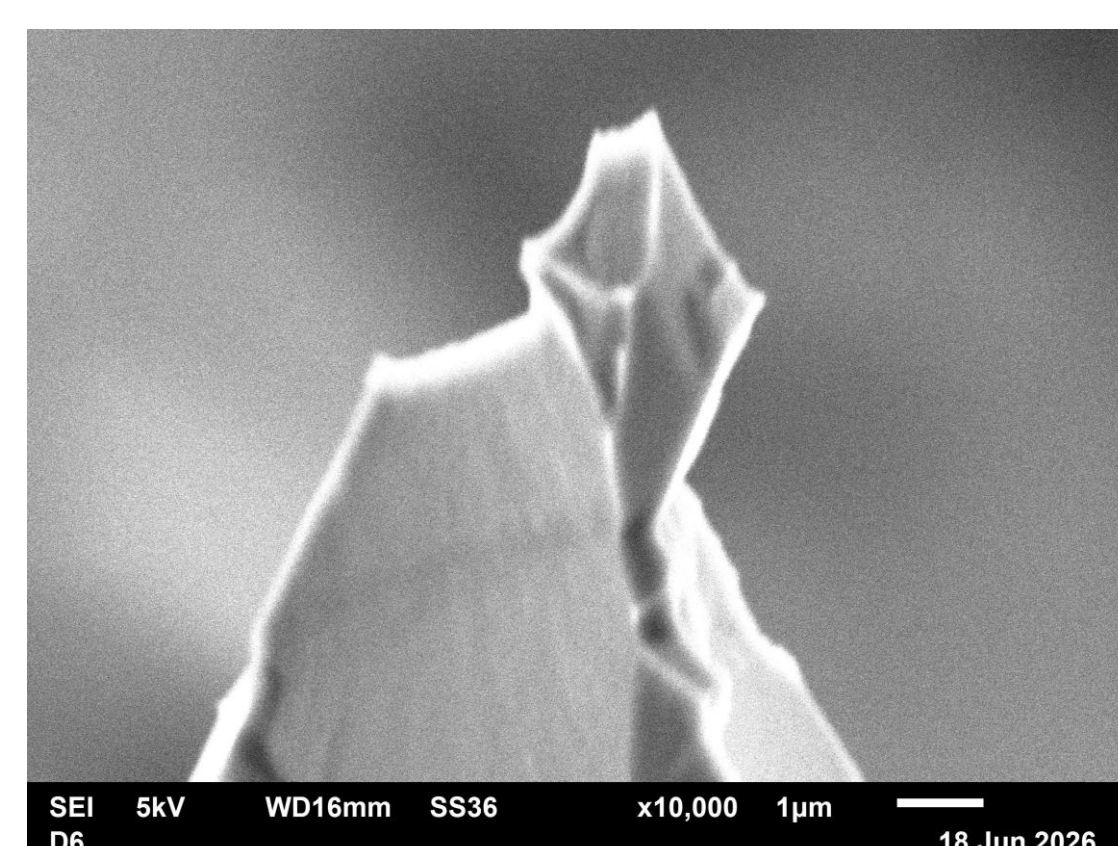
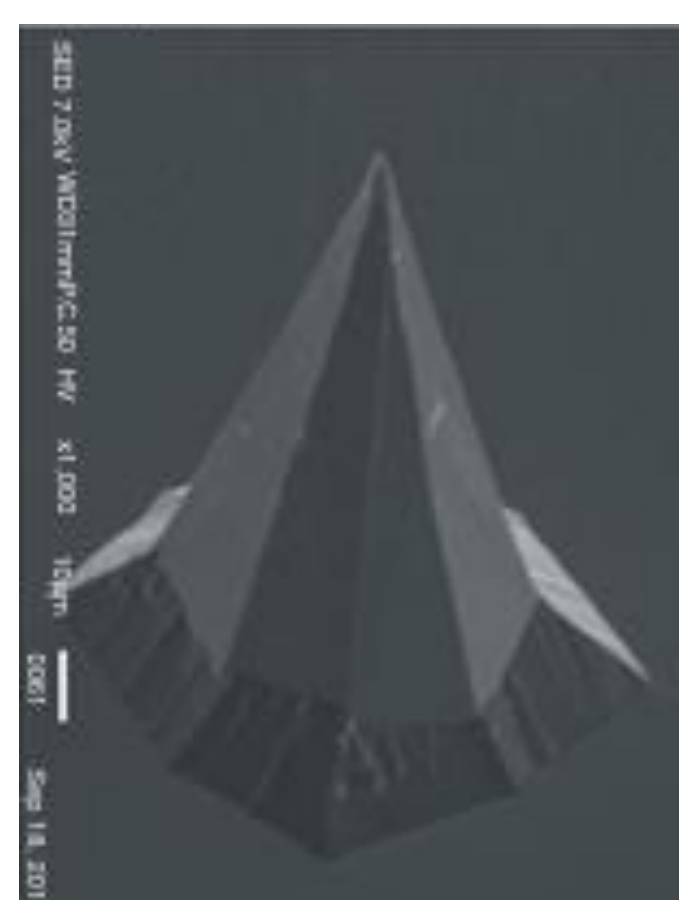
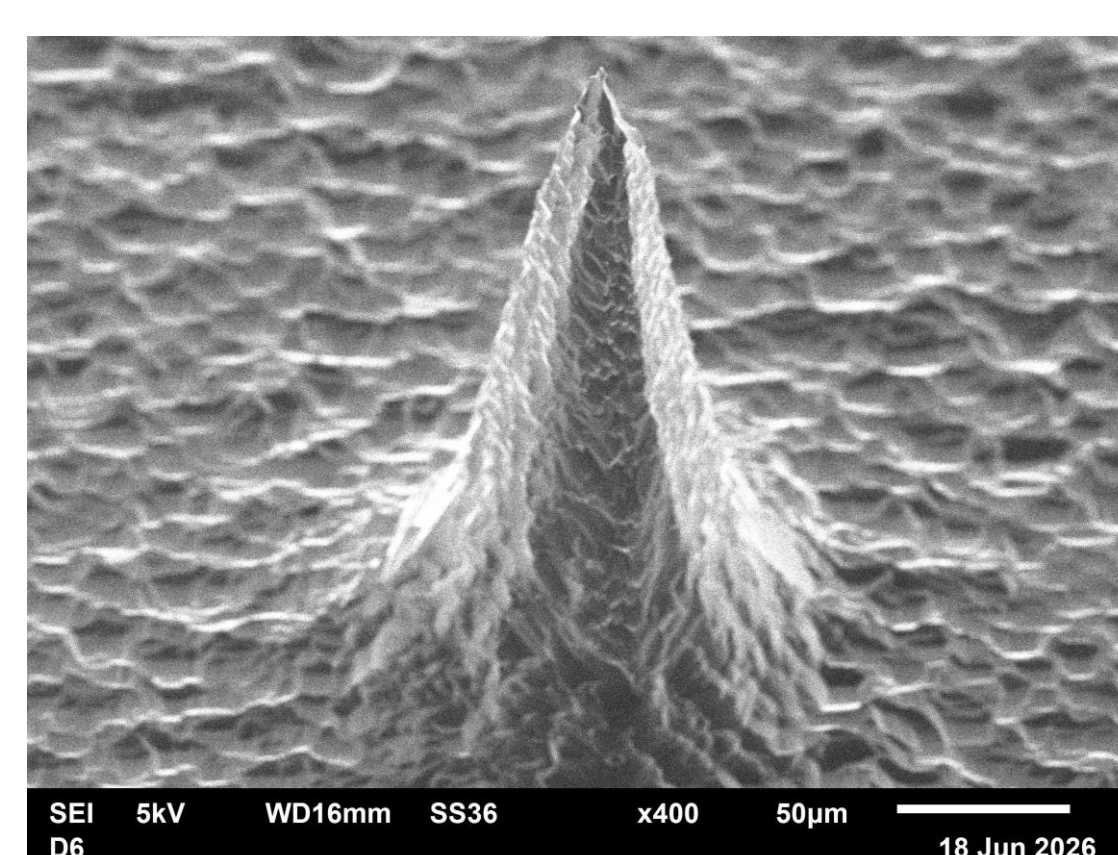
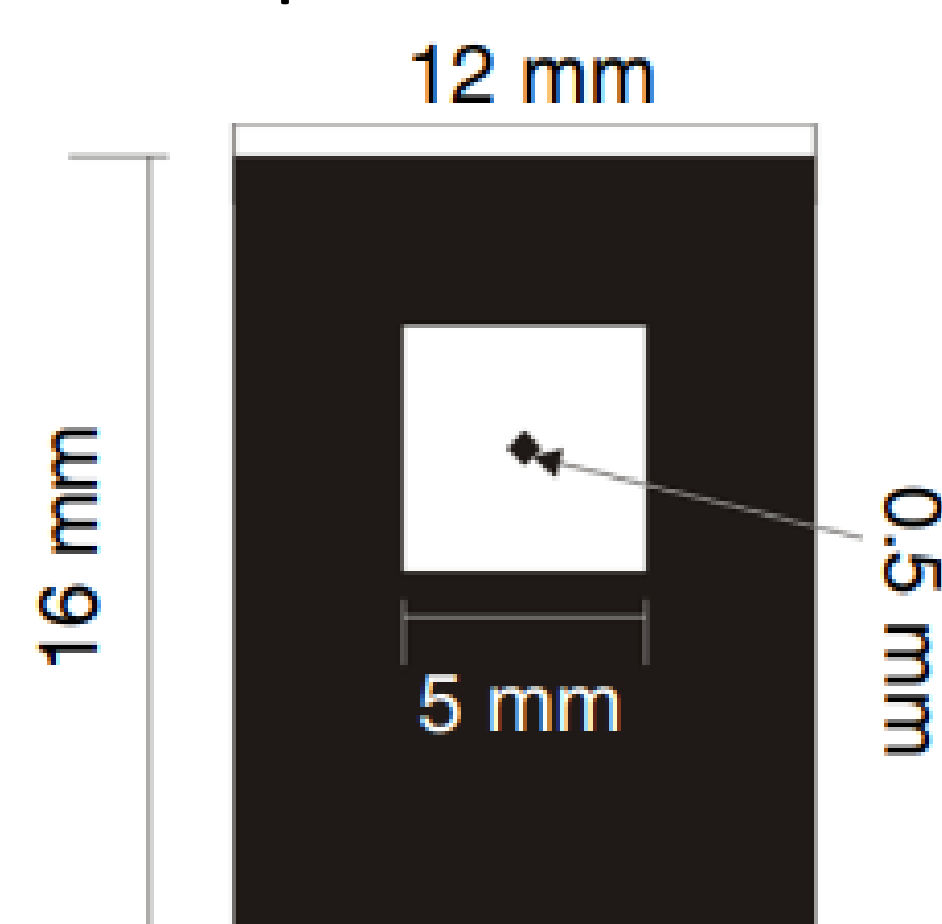
### Fabrication steps

KOH method:

1. Wafer oxidation
2. Double-sided photolithography
3. Oxide removal in BOE
4. KOH etching
5. Optical quality inspection

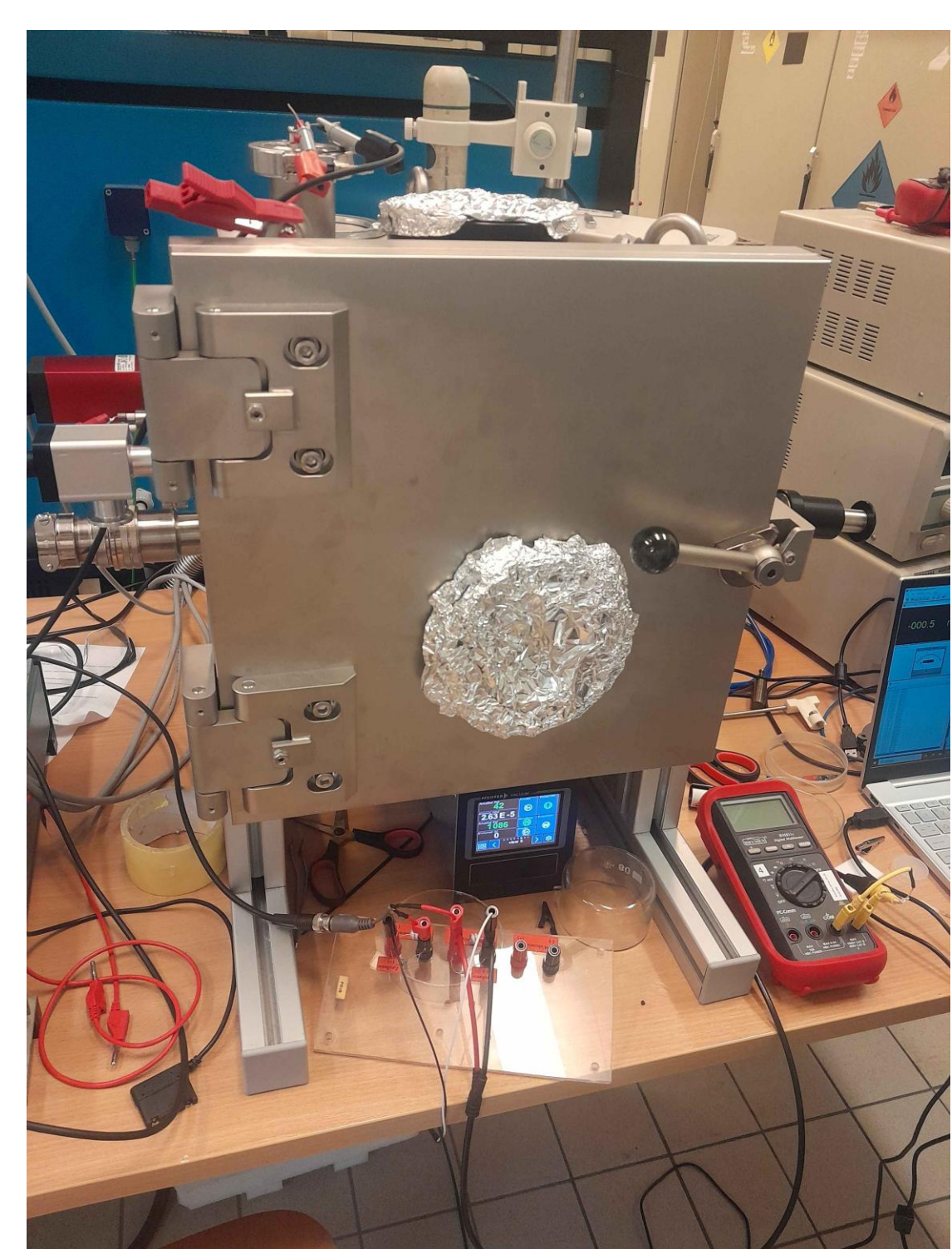
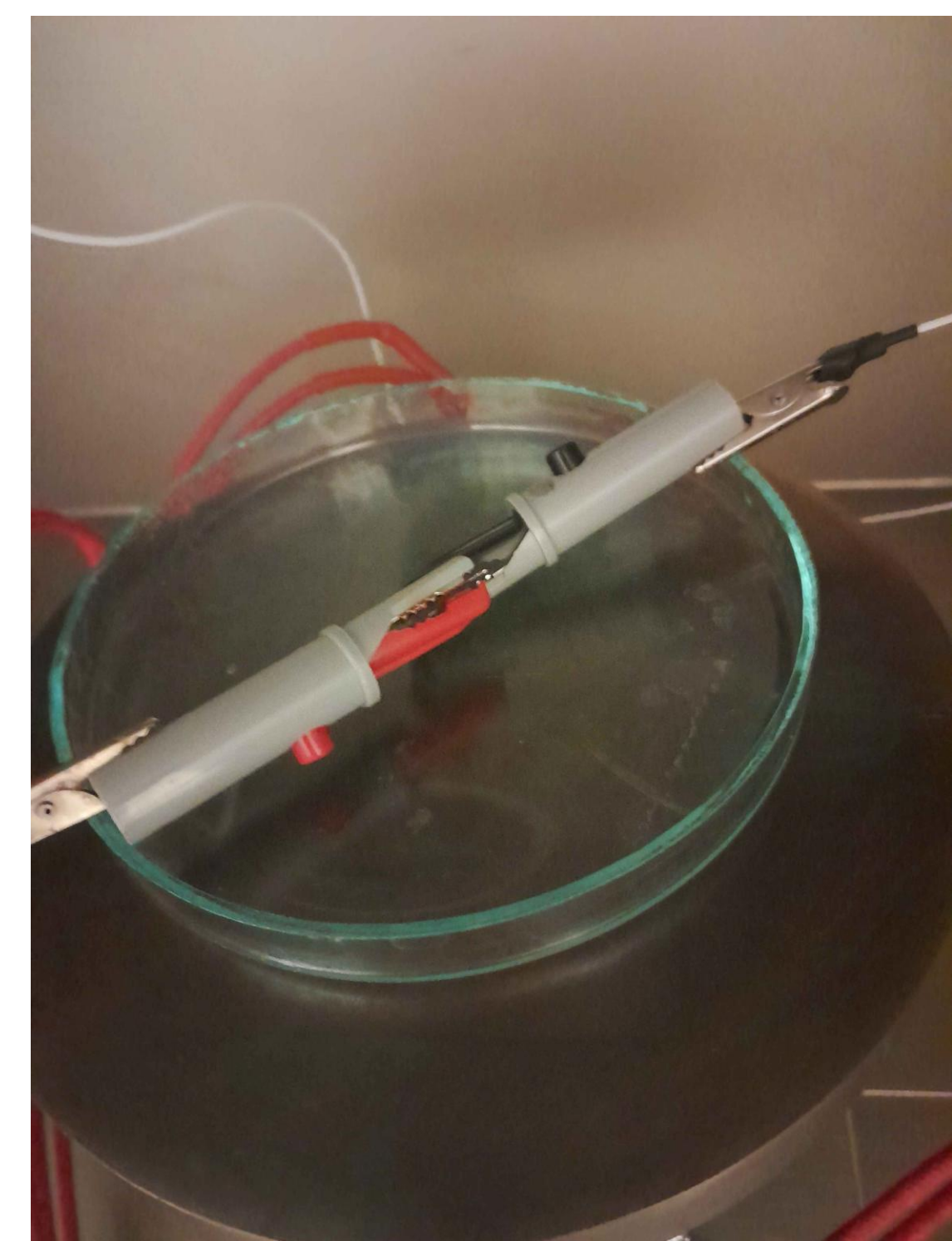
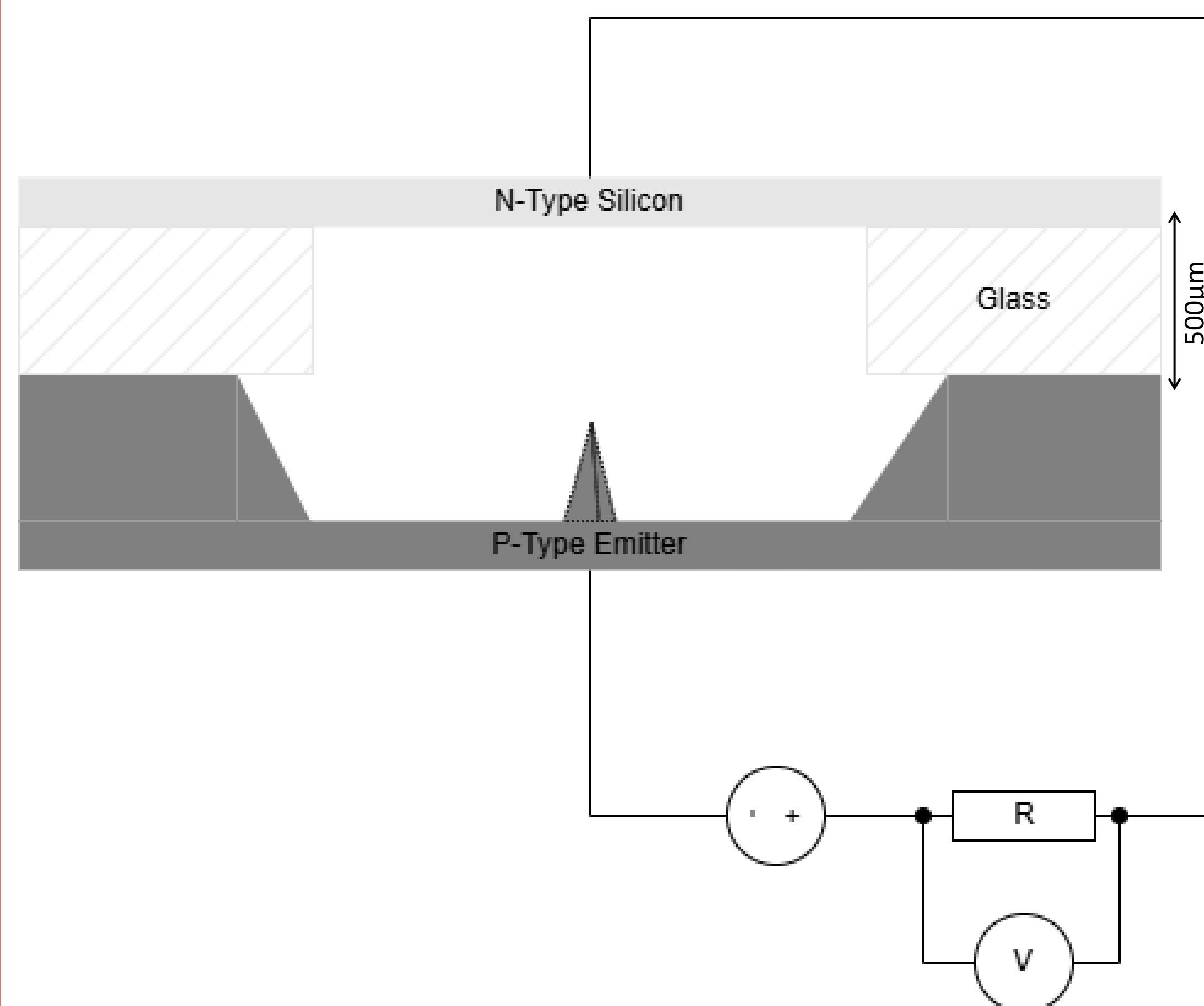
Laser ablation method:

1. Cathode contours designing
2. Laser ablation
3. Oxide removal in BOE
4. Tip sharpening in TMAH
5. Optical quality inspection



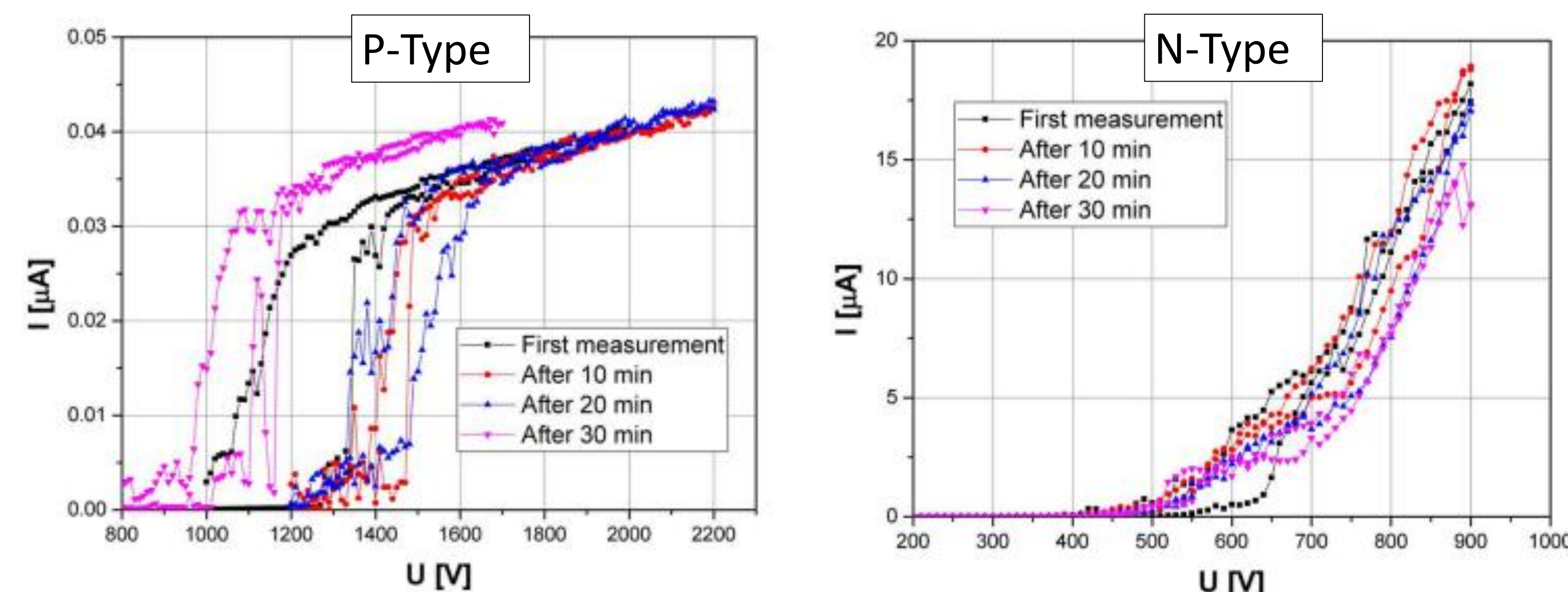
### Experimental setup

- High-vacuum chamber
- Input voltage in range of 0-2000 V
- Voltage measurement across a 10 M $\Omega$  resistor
- Glass and kapton tape used as spacer interchangeably
- Experiment repeated for low-doped and high-doped P-type emitters and N-type emitters.



### Electrical properties

- P-type emitters enter saturation, with a stable increase of current
- N-type emitters show exponential growth of current



Emission current-voltage characteristics for P-type and N-type silicon emitters

### Bibliography

1. M. Krysztof, "Field-emission electron gun for a MEMS electron microscope." *Microsystems & Nanoengineering* 7.1 (2021): 43.
2. M. Krysztof, P. Urbański, T. Grzebyk, M. Hausladen and R. Schreiner, "MEMS X-Ray Source: Electron Emitter Development," *2022 21st International Conference on Micro and Nanotechnology for Power Generation and Energy (PowerMEMS)*.

### Summary

P-type emitters are characterized with saturation region of work compared with N-type emitters. In the saturation region the emission current shows less fluctuations which can be further limited using electronic feedback loop. The emission current of P-type emitters is lower, but still enough to get sufficient signal from the samples in the miniaturized scanning electron microscope. Research on P-type field emitters may positively influence the performance of electron microscopes by reducing the amount of current fluctuations. Due to a technical malfunction of the measuring equipment, it was not possible to obtain conclusive results verifying the findings from previous years; however, the work is still ongoing.