OSTBAYERISCHE TECHNISCHE HOCHSCHULE REGENSBURG

Studies and Optimization of Field Emission from Si Nanowires on Microtubes

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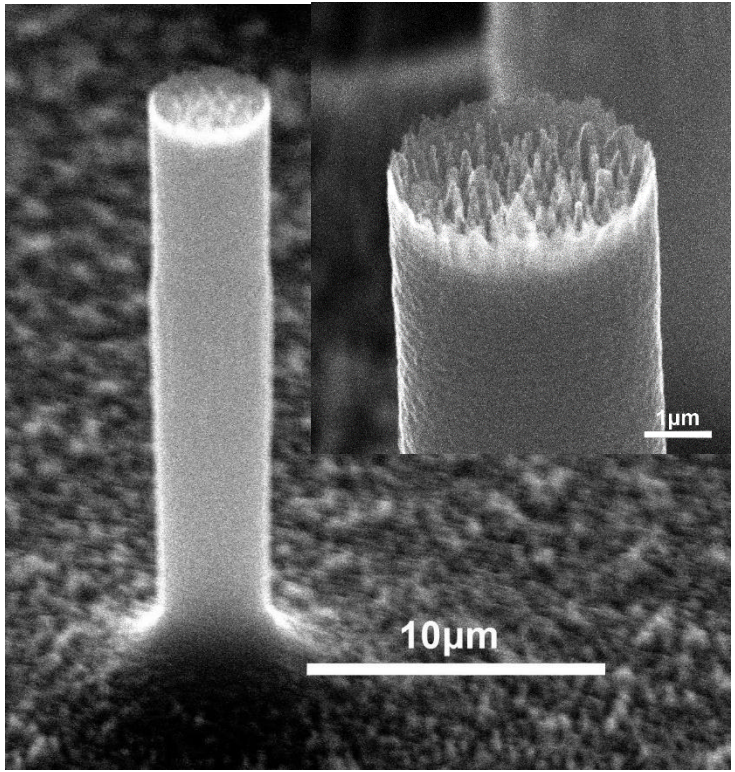
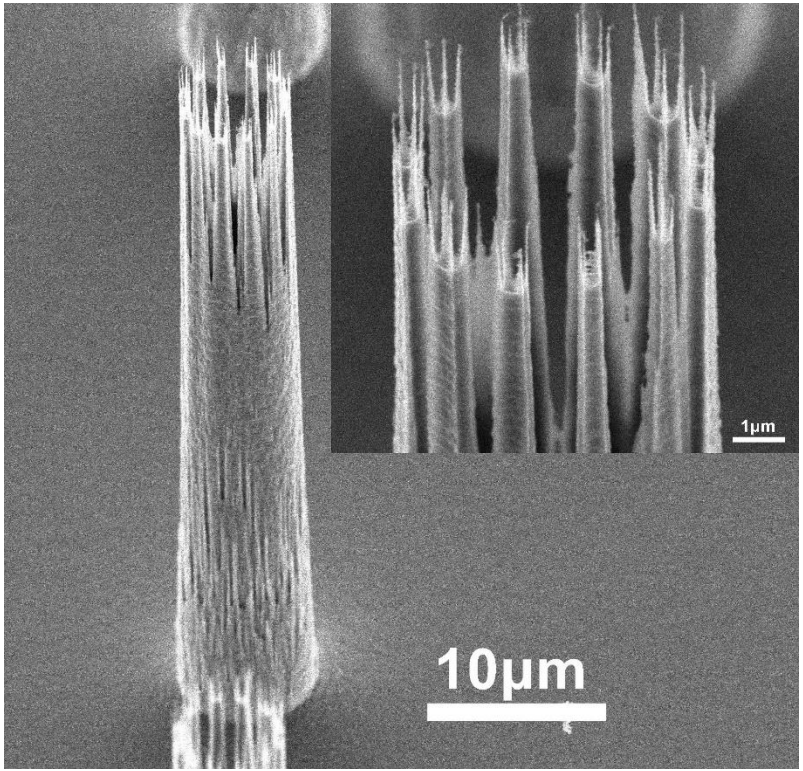
- Reference and samples
- Manufacturing
- Measurement
- Comparison of reference and new samples
- Longtime performance
- Degradation
- Conclusion

Reference and new Samples

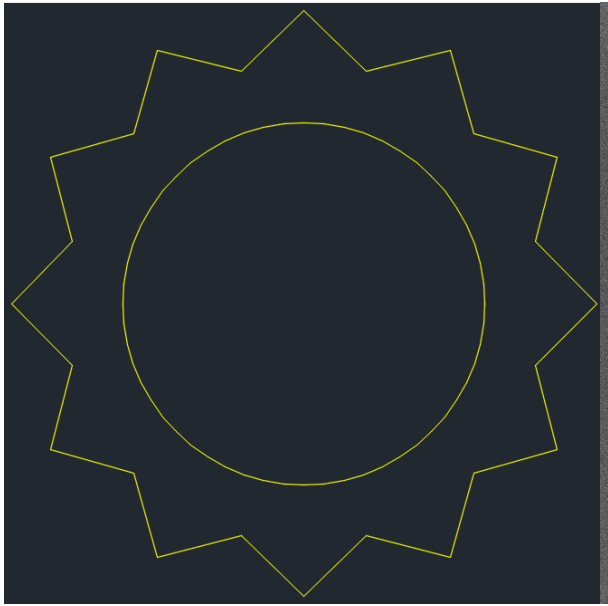
b-Si reference

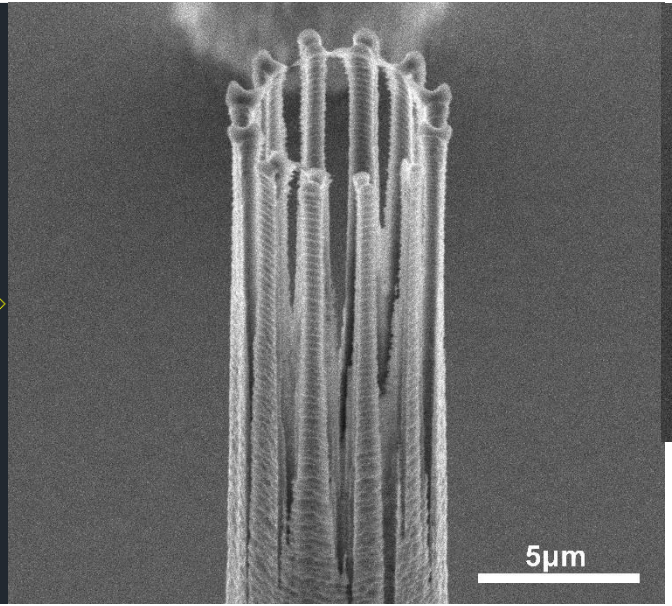


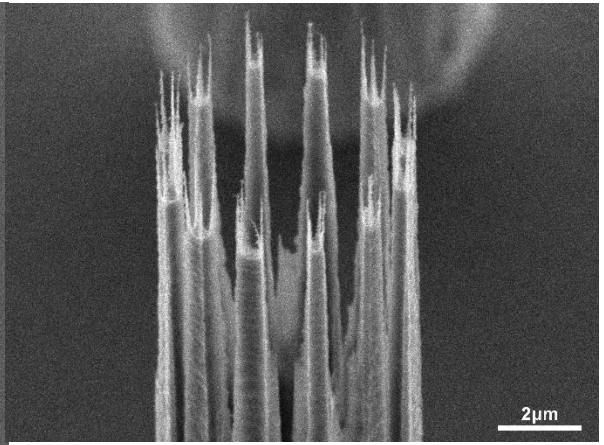
new geometry



Manufacturing







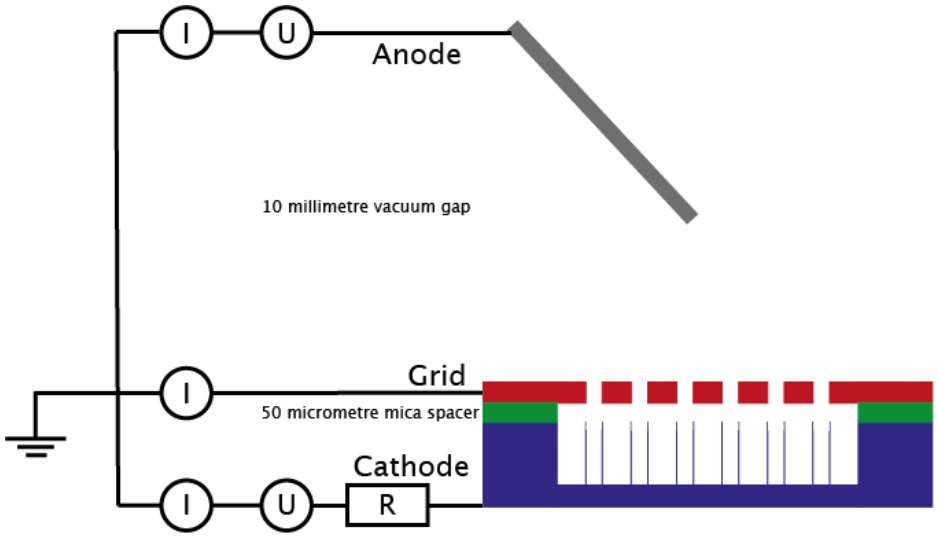
Emitter structured by a four step process:

- generating an irregular photoresist ring
- anisotropically etching the silicon
- removing the photoresist
- repeating the etching step

Two types of silicon used:

- n-Type (Ph), <100>, 1-10 Ωcm
- n-Type (Ph), <100>, <0.005 Ωcm

Measurement



- Measured at a pressure of 10^{-9} hPa
- Shortcheck before and after characterisation

- Measured in 100V increments from 400V to 1000V
- Anode voltage 1000V

- For each voltage the sample was activated for one hour
- For each voltage three up- and downsweeps in 5V steps
  —> Further explanation on next slide

- UI-curves generated by averaging the sweeps

Measurement

- Shortcheck before and after measurement by reversing polarity between cathode and extraction grid
- If a reverse current is measured before or after the measurement the sample is rejected

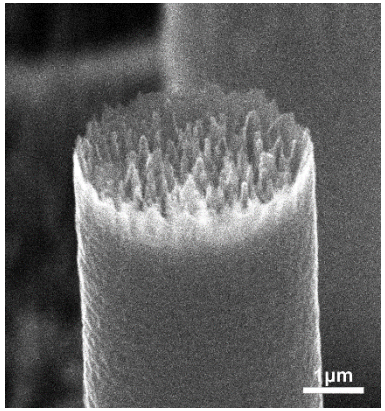
- One hour of burn in and activation time before the characteristics are recorded

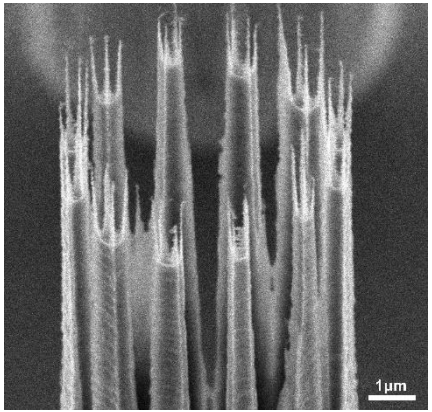
- Each characteristic is repeated three times
- UI-Plots are generated by averaging 6 datapoint for each voltage value (Upsweep and downsweep with three repititions)

- Once a extraction voltage of 1kV is reached this step is repeated at least for times to establish data on longtime performance (highlighted green)

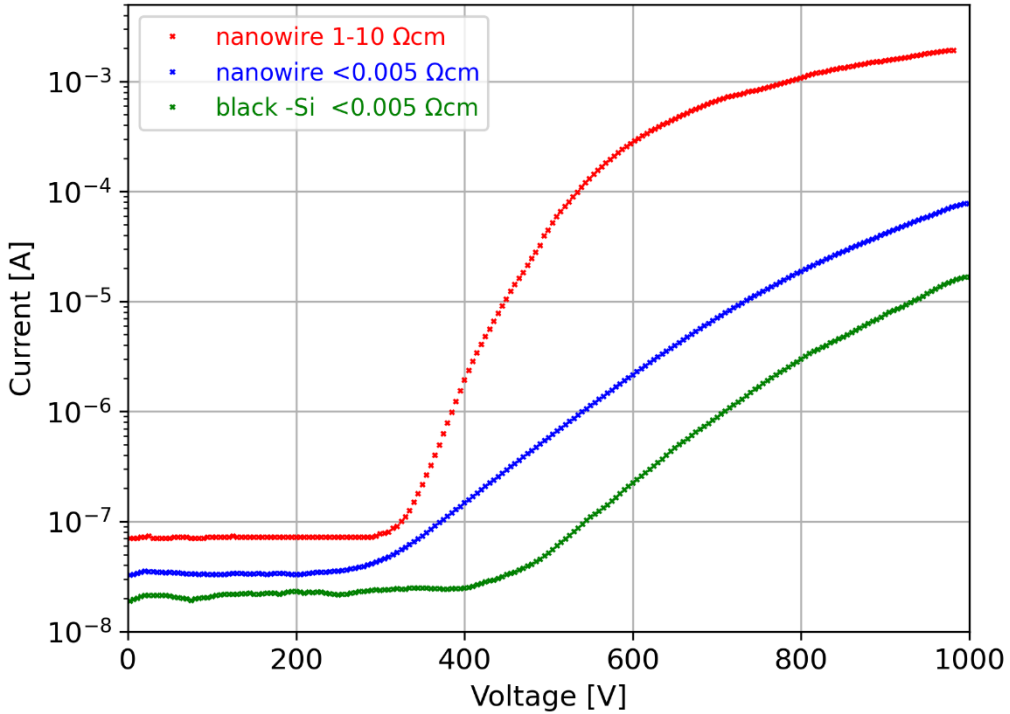
Comment	Repeats	U_A	U_C
Short Check	1	1kV	0…-100…0…+100…0V
Activation	1	1kV	400V (1h)
Characterisation	3	1kV	0…400…0V (5V steps)
Activation	1	1kV	500V (1h)
Characterisation	3	1kV	0…500…0V (5V steps)
Activation	1	1kV	600V (1h)
Characterisation	3	1kV	0…600…0V (5V steps)
Activation	1	1kV	700V (1h)
Characterisation	3	1kV	0…700…0V (5V steps)
Activation	1	1kV	800V (1h)
Characterisation	3	1kV	0…800…0V (5V steps)
Activation	1	1kV	900V (1h)
Characterisation	3	1kV	0…900…0V (5V steps)
Activation	1	1kV	1000V (1h)
Characterisation	3	1kV	0…1000…0V (5V steps)
Short Check	1	1kV	0…-100…0…+100…0V

Comparison



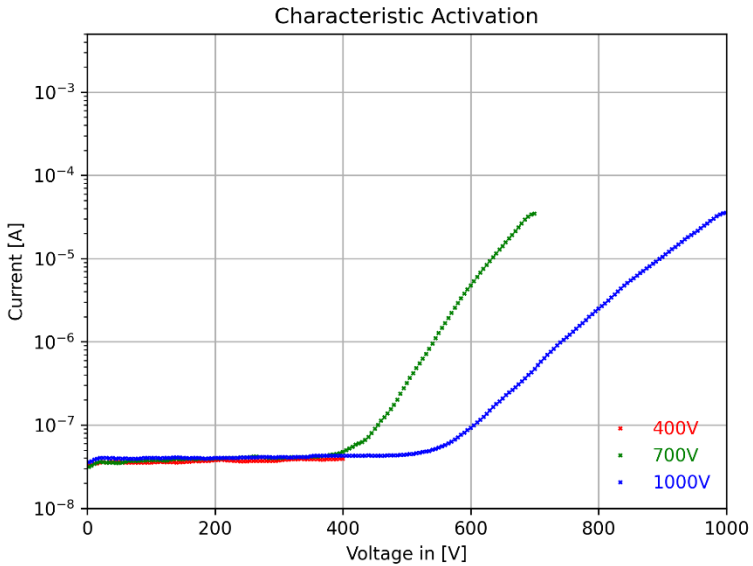


- Nanowire emitters start emitting at lower voltage due to lower shielding and higher field enhancement
- Changing the doping leads to even greater emission current



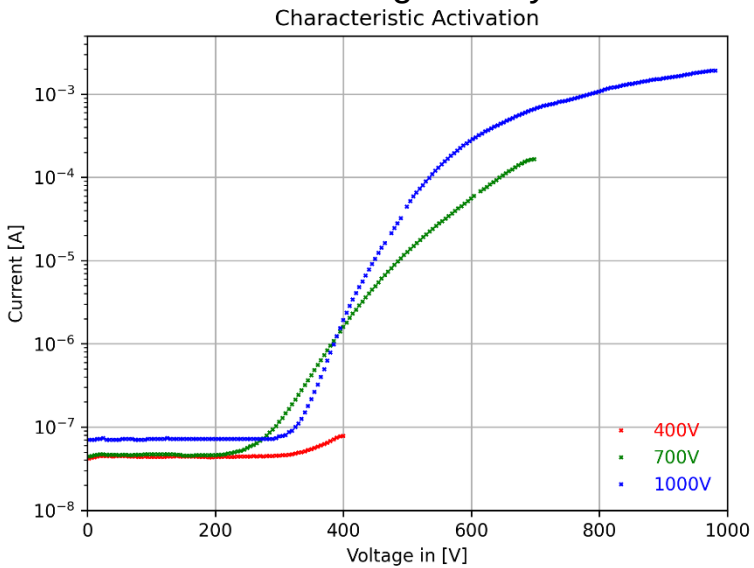
Degradation

b-Si reference



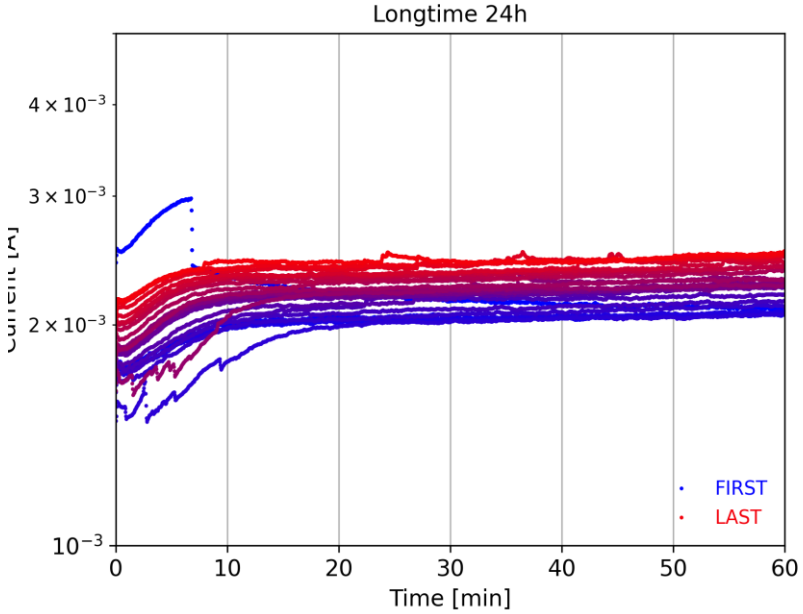
- Reference sample shows no emission current at 400V
- For higher voltages the onset Voltage rises significant due to degradation

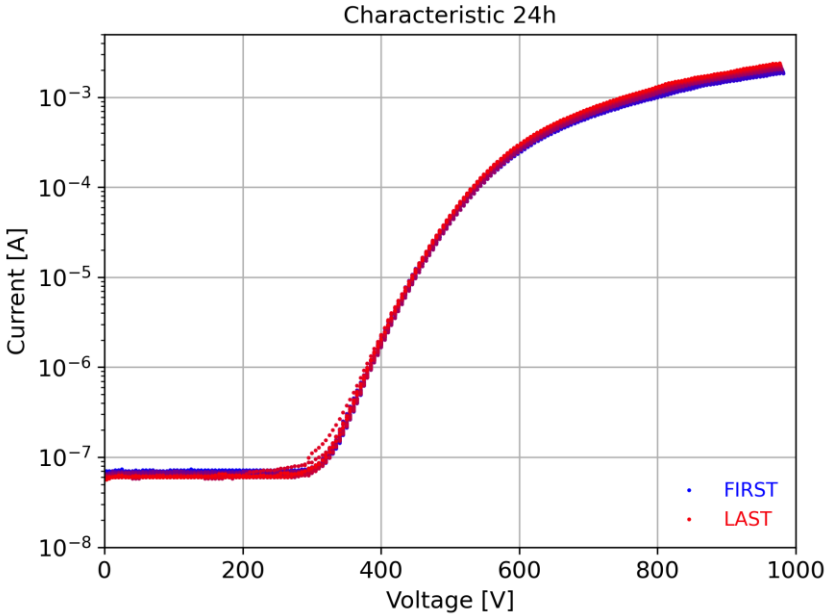
new geometry



- Reference sample shows emission already at 400V
- For higher voltages the onset Voltage does not rise
  —> no or lower degradation

Longtime Measurements

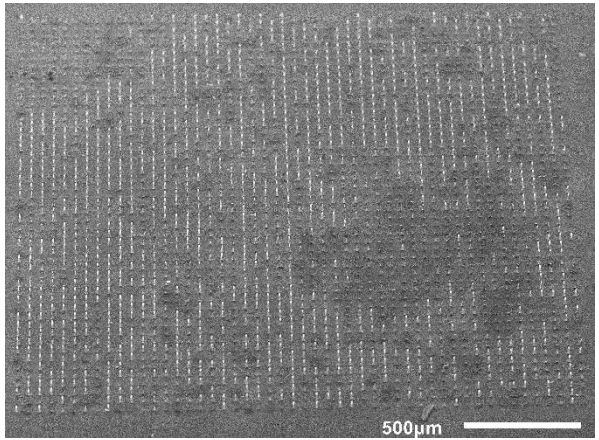




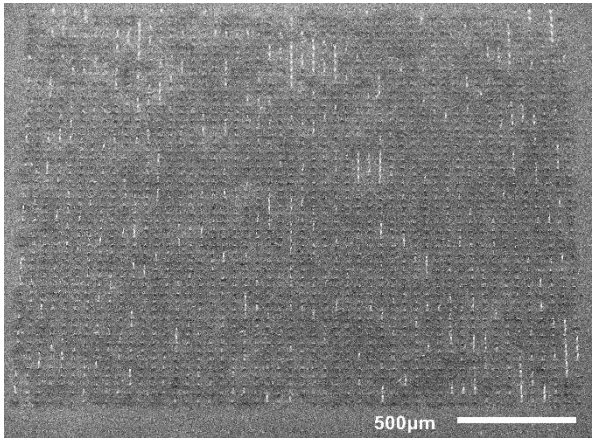
- 24h longtime measurements at 1000V for the new emitter show no degradation

After Measurements

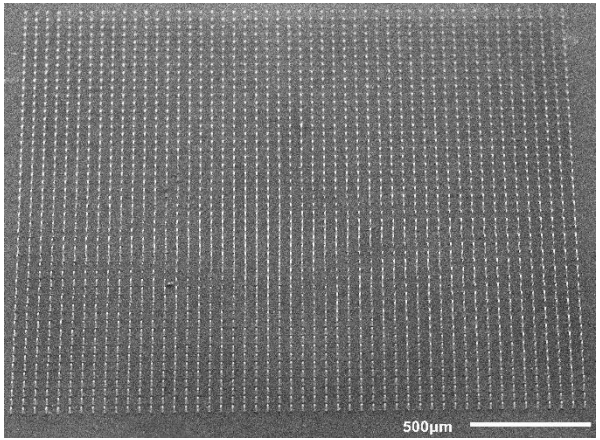
b-Si reference



new geometry (high doping)



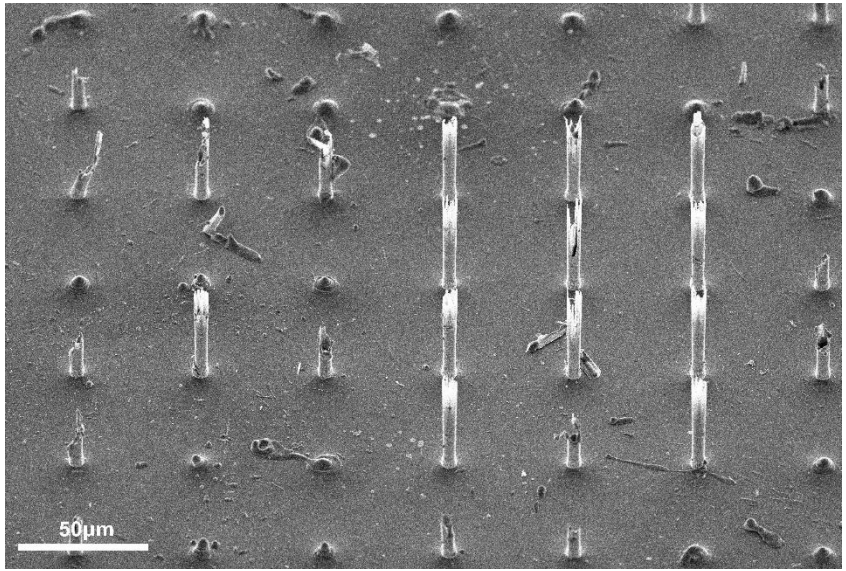
new geometry (low doping)

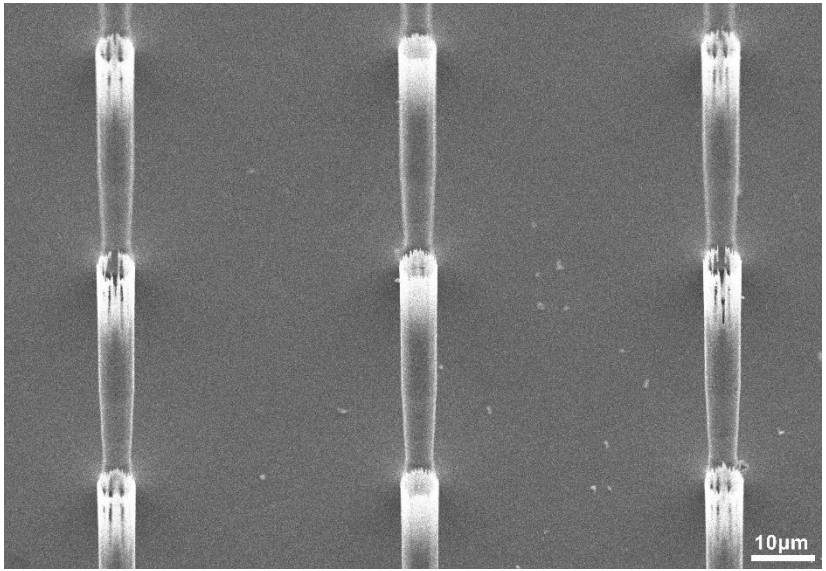


- Both samples with high doping show strong degradation
- Degradation seems to be scattered homogeneously over the whole sample

- New geometry with low doping is almost unchanged (although having completed a 24h longtime measurement at 1kV extraction voltage)

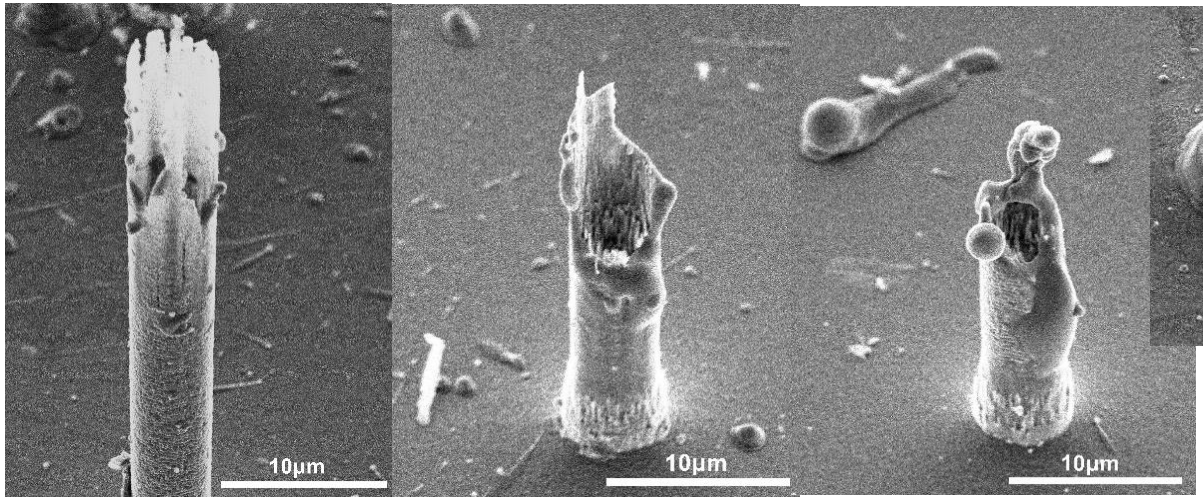
After Measurements





- SEM images after measurement show strong degradation for both low resistance silicon samples
- High resistance sample shows no virtually no degradation in SEM images after measurements

After Measurements



- High magnification SEM images of destroyed emission tubes on the sample with new geometry and high doping concentration

- Failure mode in all cases seems to be melting due to high thermal stress

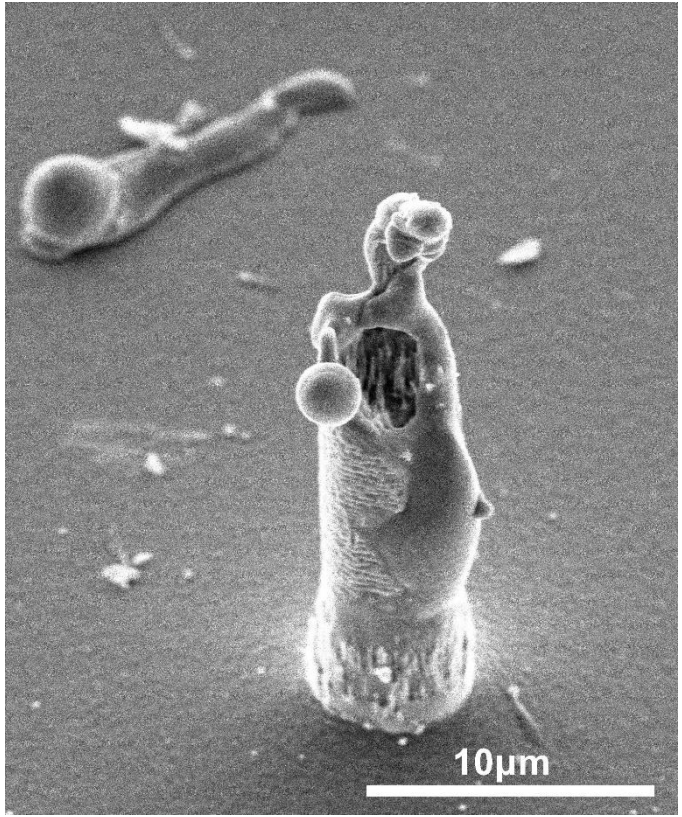
Conclusion

- New geometry shows lower onset voltage due to lower shielding due to thinned out structure and therefore higher field enhancement

- Presumed failure mode is high thermal stress while emitting
- Therefore sharper emitters are destroyed before blunter emitters start emitting

- Optimized material reduces thermal stress
- More emitters emit in parallel and increase achievable emission current

- Model calculations are being made to prove this theory



Thank you for your attention