Si Tip Field Emission Electron Source for Applications in Ionisation Vacuum Gauges

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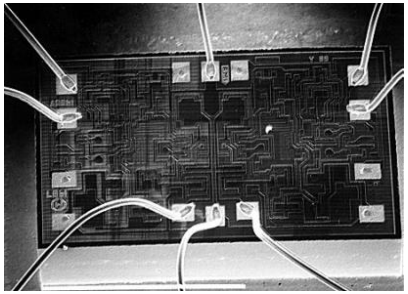
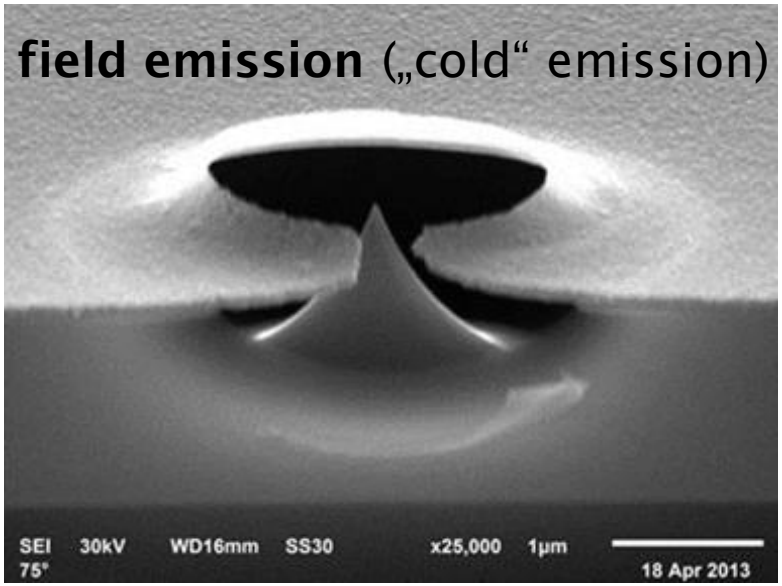
1. Motivation: Vacuum nanoelectronics

Thermionic emission
in electron tubes
(T > 1000°C)



Si-technology



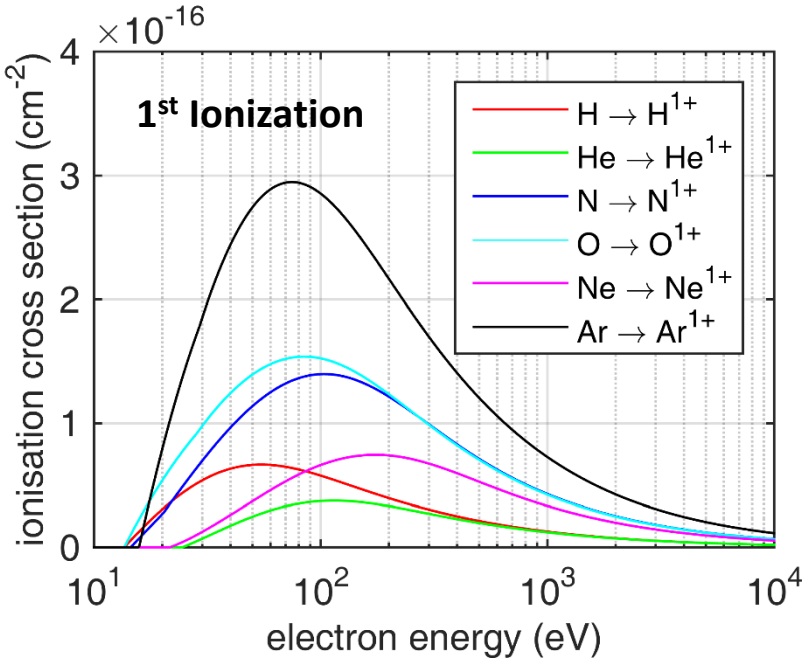
New possiblities of
vacuum nanoelectronics:
Fabrication of miniaturized field emission cathodes

1. Motivation: Vacuum nanoelectronics

Application: Ionization vacuum gauge

Ionization process is most efficient for rather low electron energies

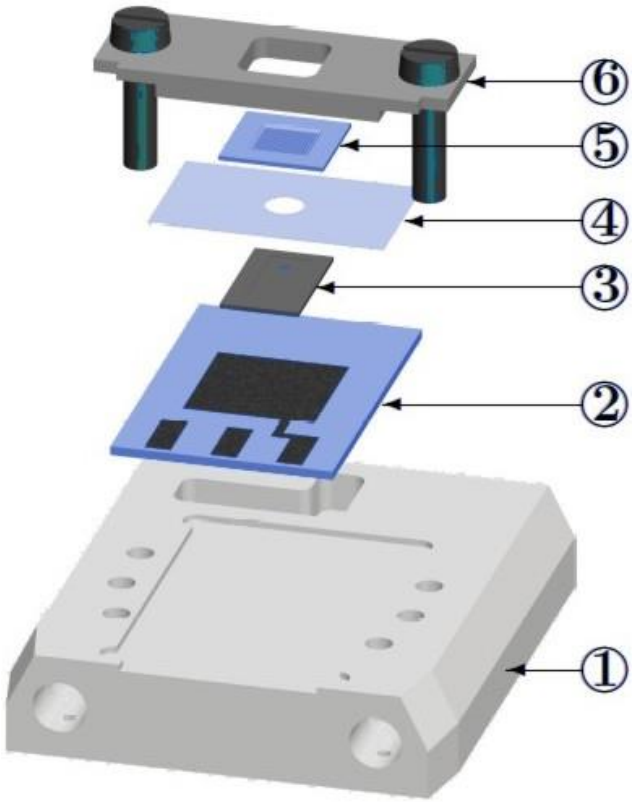
Ionization cross section vs. electron energy:



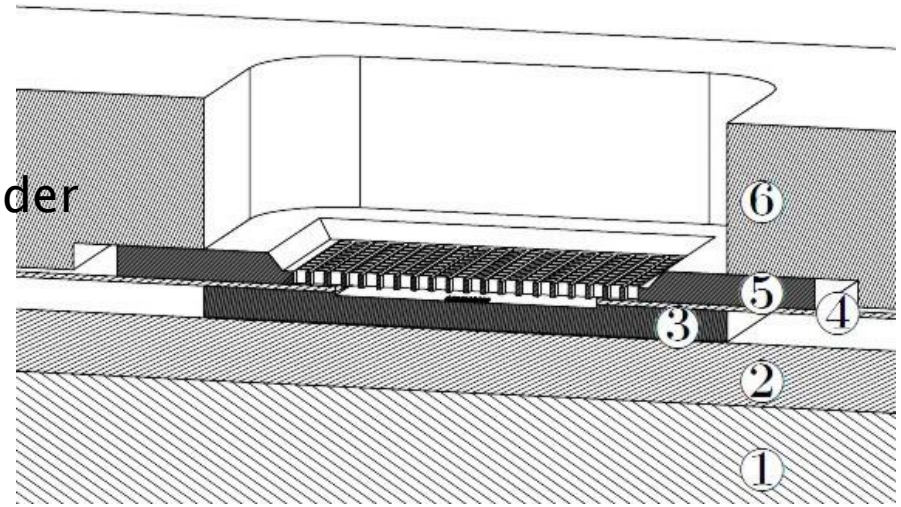
Requirements for the application:

- low operation voltage
- high emission currents
- stable, homogeneous and low-noise emission

2. Setup of the field emission electron source

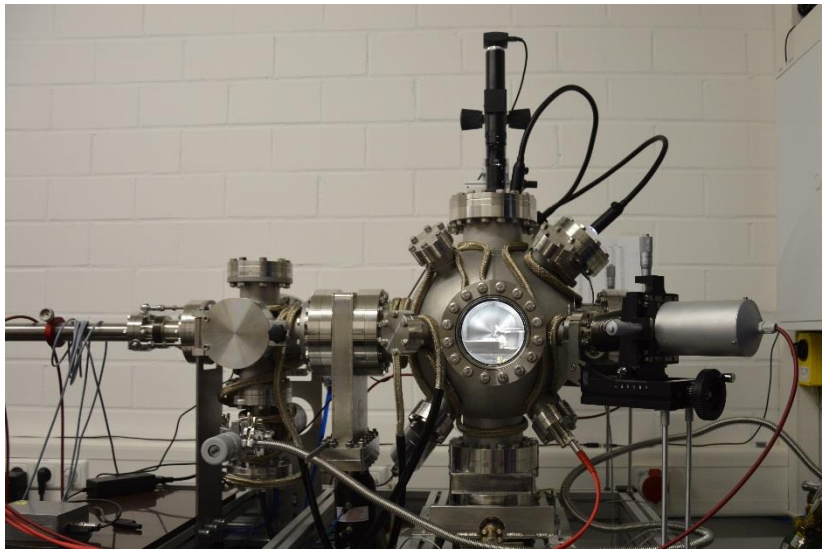


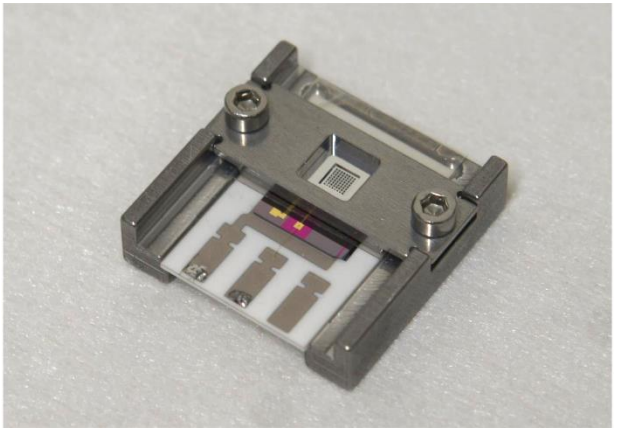
⑥ Emission window
⑤ Extraction anode
④ Spacer
③ Field emission cathode
② Ceramic substrate
① Sample holder

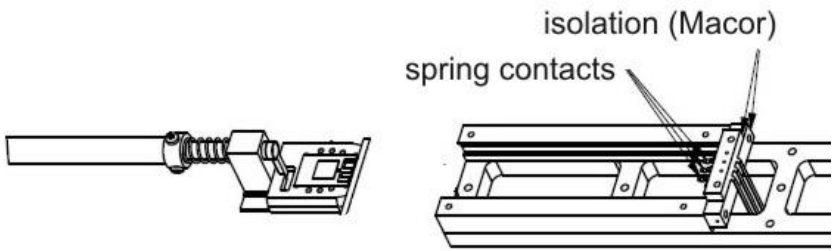


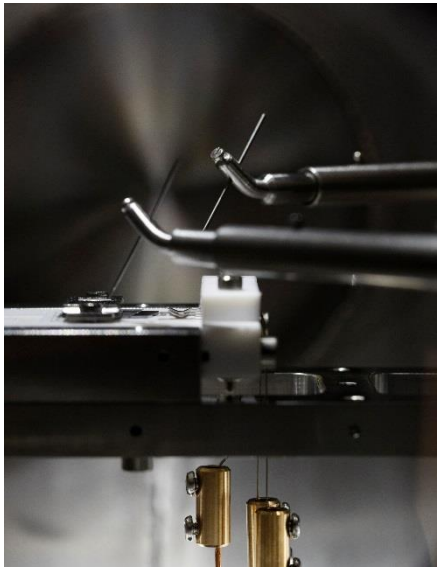
2. Setup of the field emission electron source

Vacuum measurements









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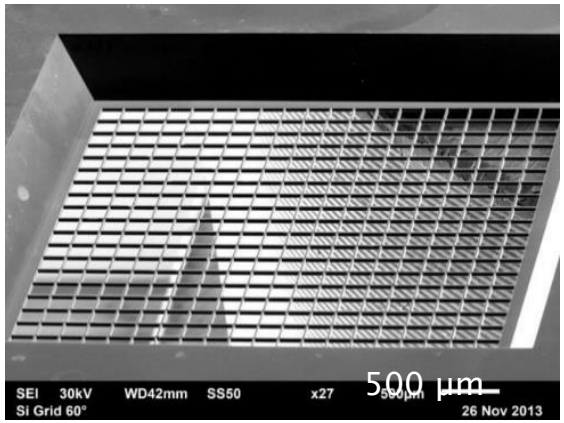
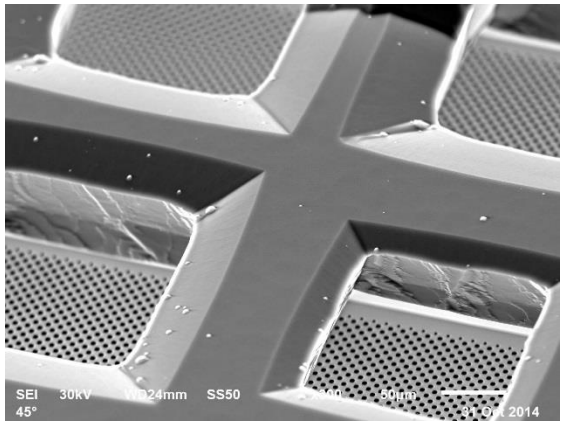
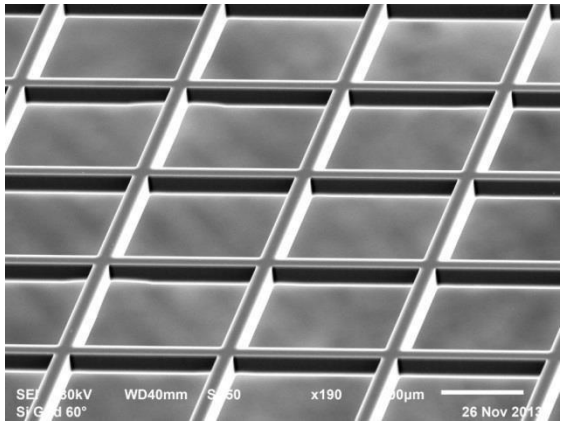
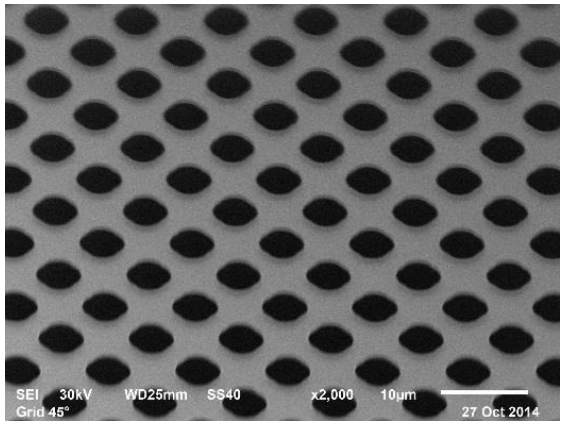








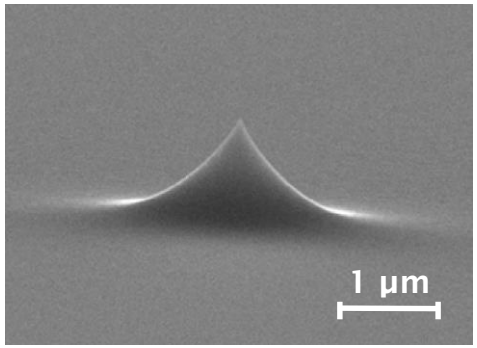
High transmission

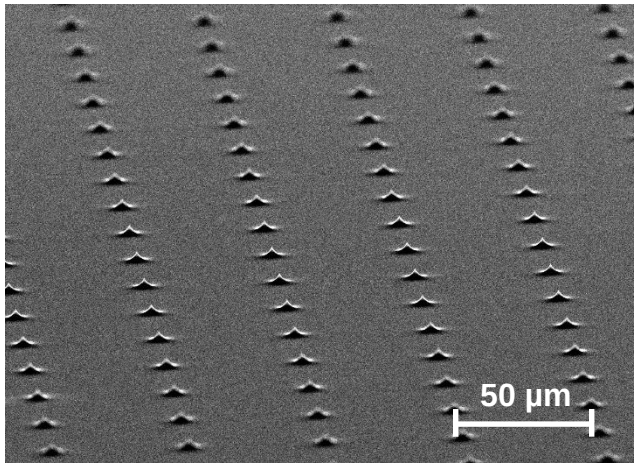
Homogeneous field distribution

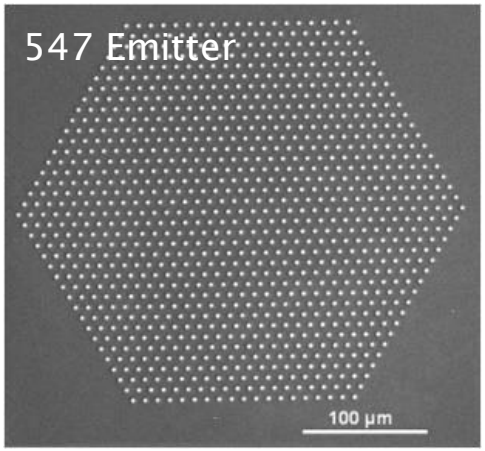
3. Si-based field emission cathodes

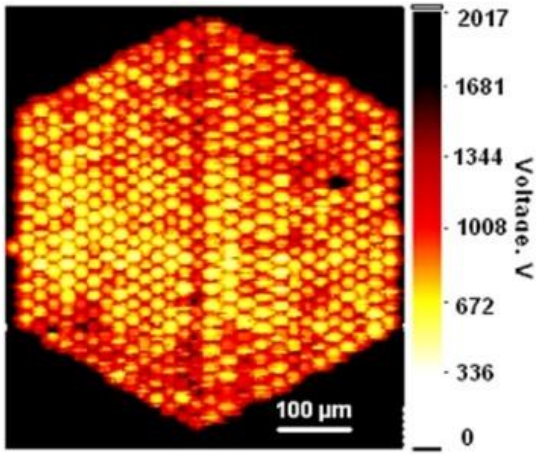
Conventional p-type Si tip Arrays

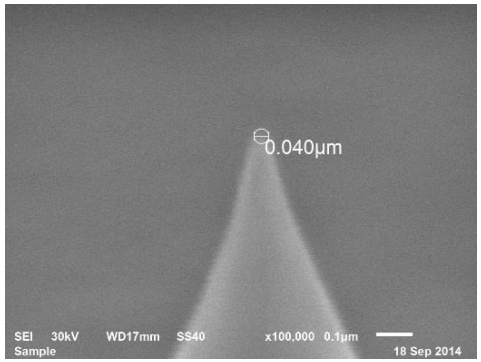
h = 1 µm, 1 nA, $Z_0 \approx 8$ µm, $\emptyset_{anode} = 3$ µm







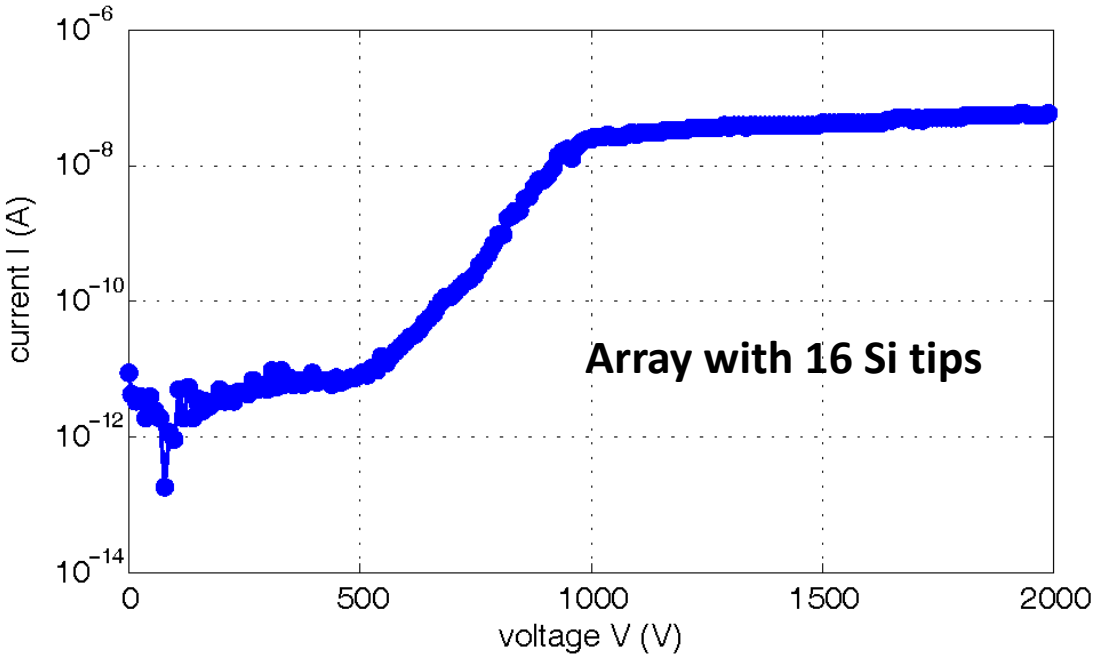




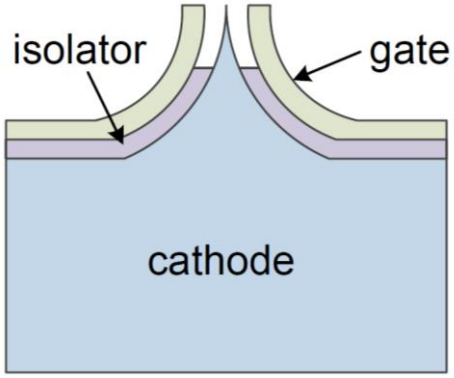
Homogeneous emission over large areas

3. Si-based field emission cathodes

Conventional p-type Si tip Arrays



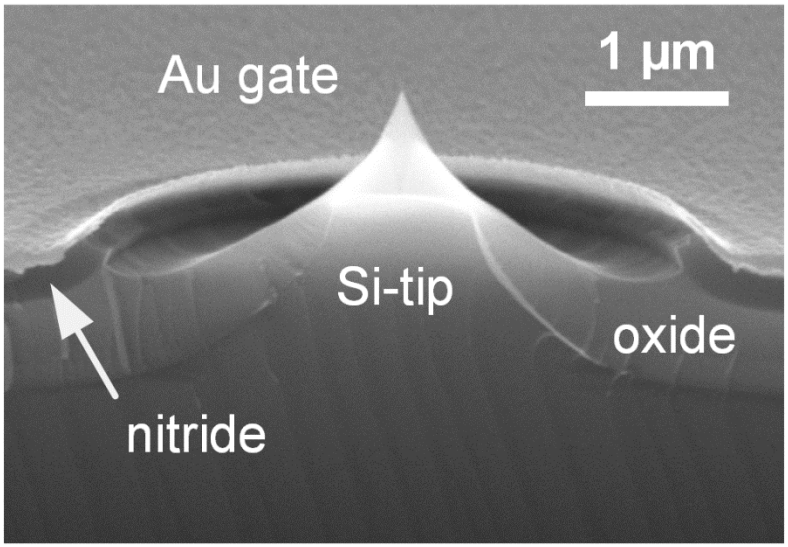
- high operation voltage
- p-doped Si shows a saturation region

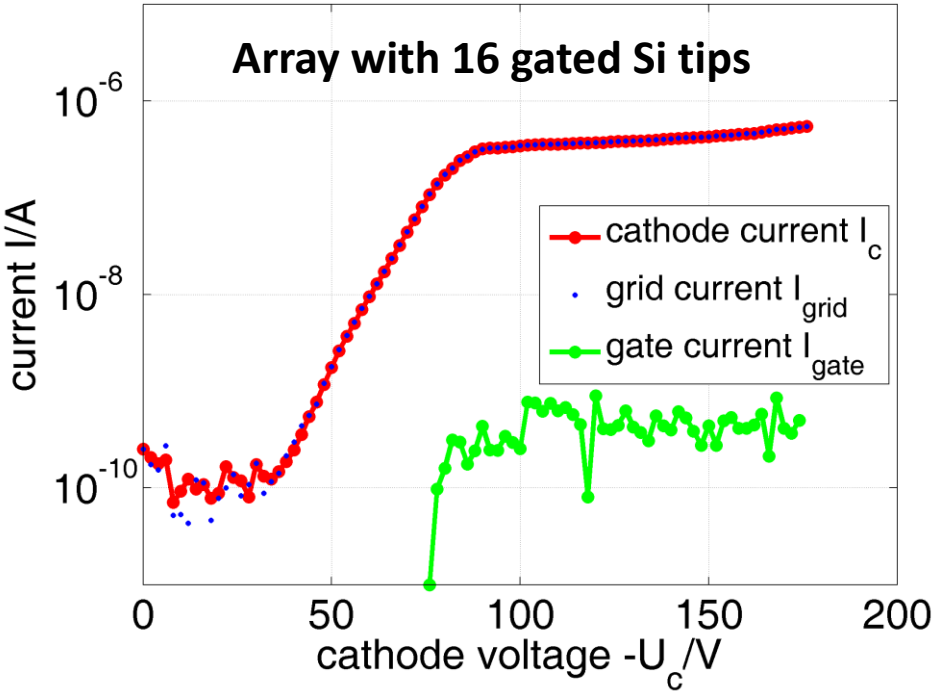


-> Integration of a gate-electrode close to Si-tip structure

3. Si-based field emission cathodes

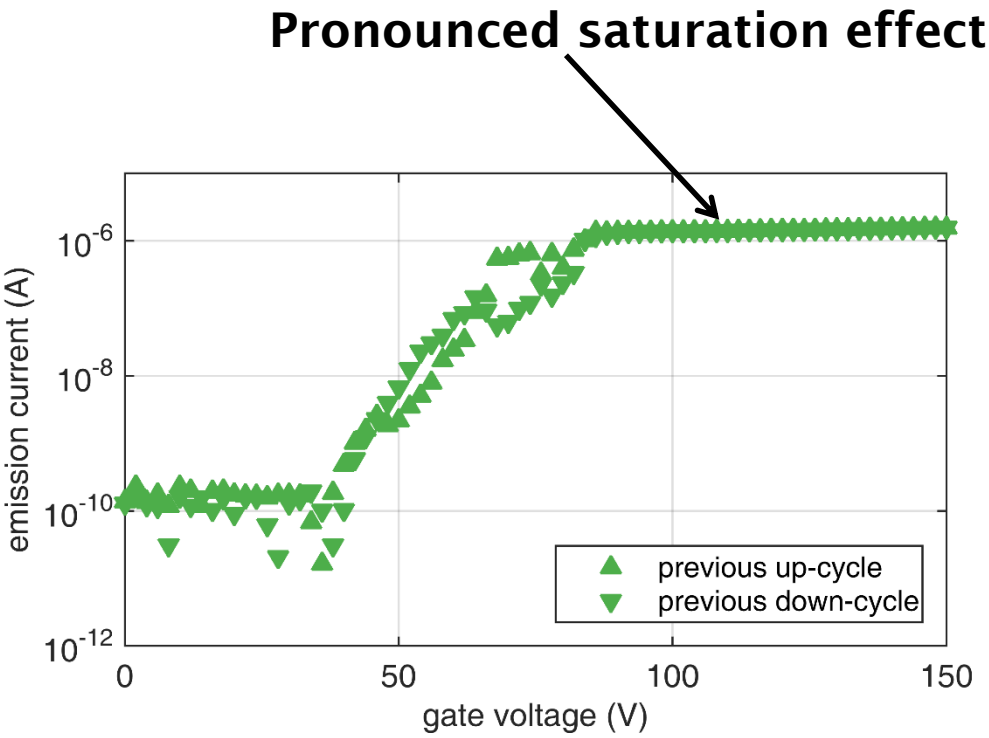
p-type Si tip Arrays with integrated gate electrode

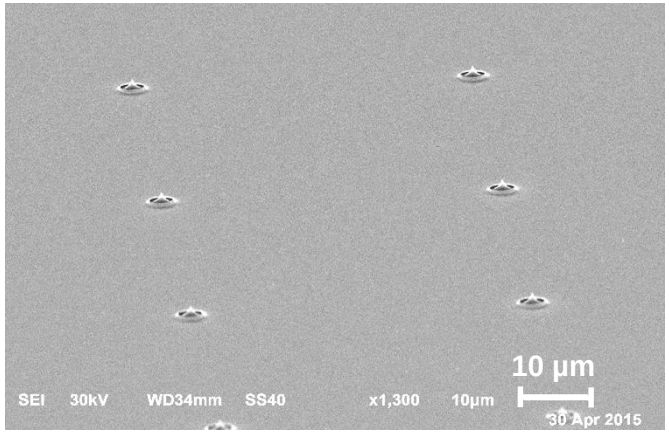




- negligible gate current I_{gate}
- nearly all e^- reaching the grid anode

3. Si-based field emission cathodes

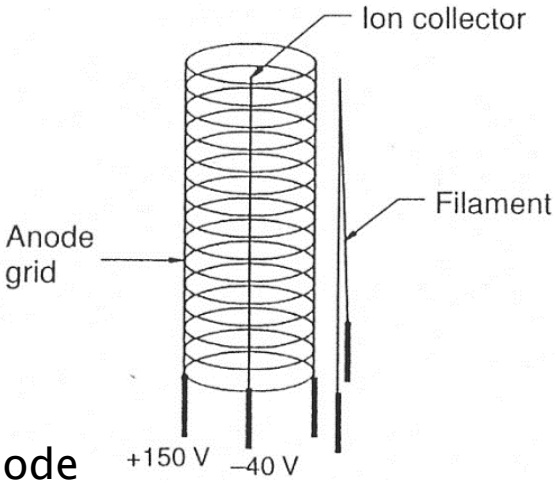


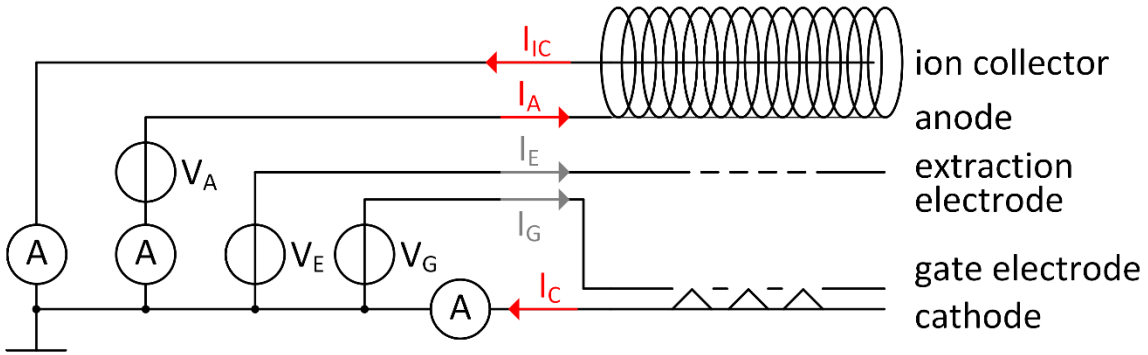


Pre-characterization:
Saturation regime at V_{Gate} > 80 V
Emission current of 1.6 µA @ 150 V

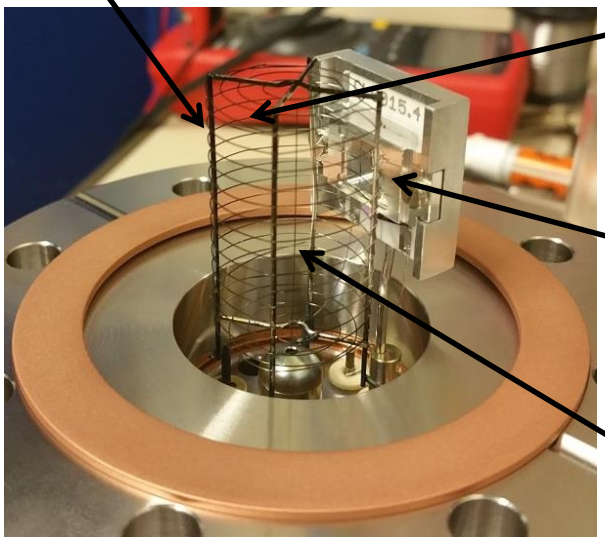
- Low operation voltages
- High emission currents
- Stable and homogeneous emission currents

4. Application in an ionisation vacuum gauge





Anode



Ionisation of the residual gas

FE electron source

Ion collector

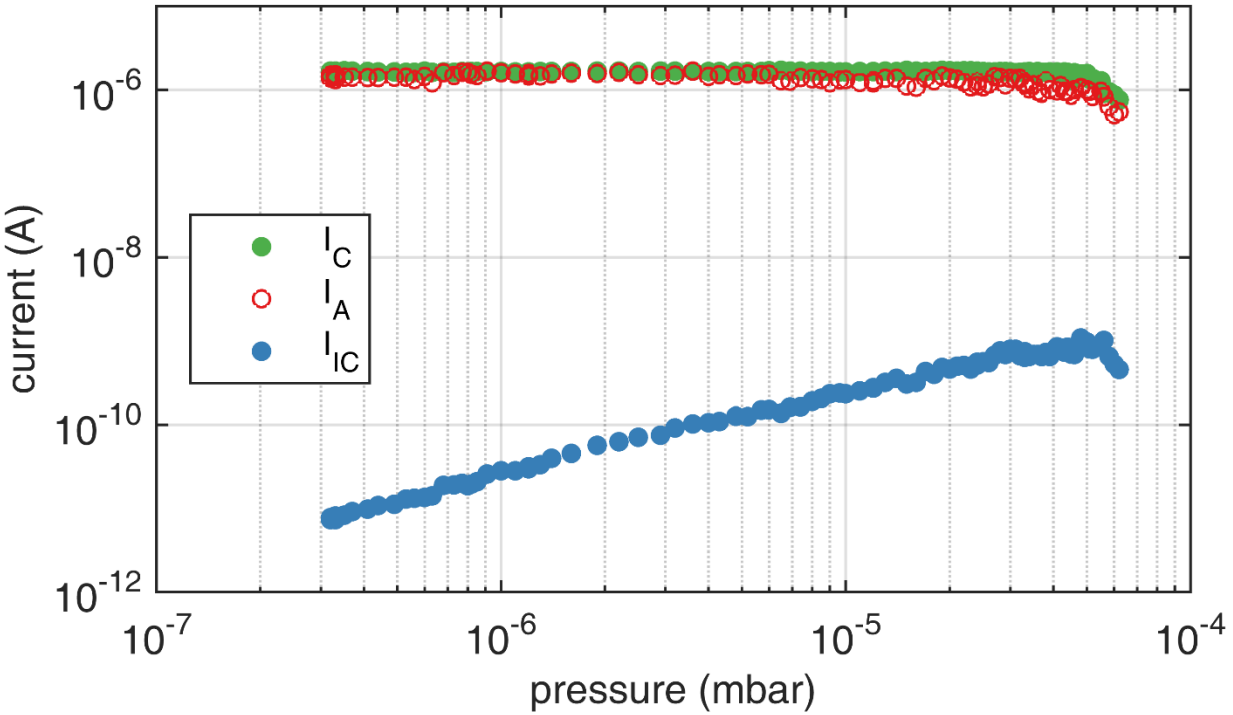
Ion collector = 0 V
Anode voltage = 500 V
Grid voltage = 400 V
Gate voltage = 150 V

FE electron source as a replacement for the hot filament

4. Application in an ionisation vacuum gauge

Measurement results

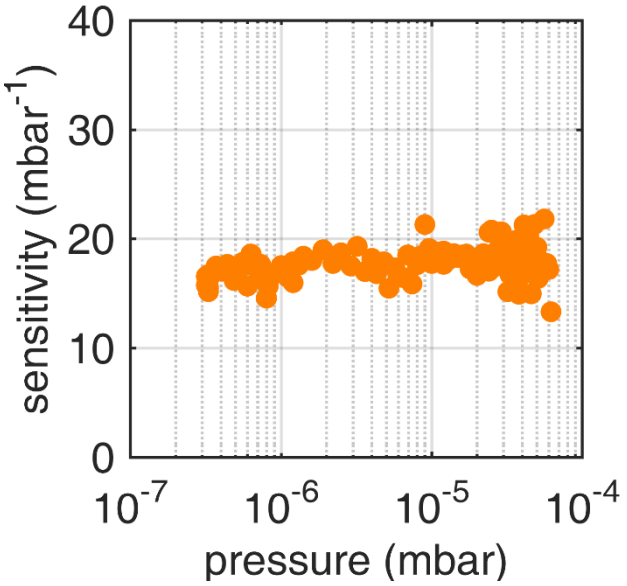
Ion collector current $I_{IC} = I_A * S * p$



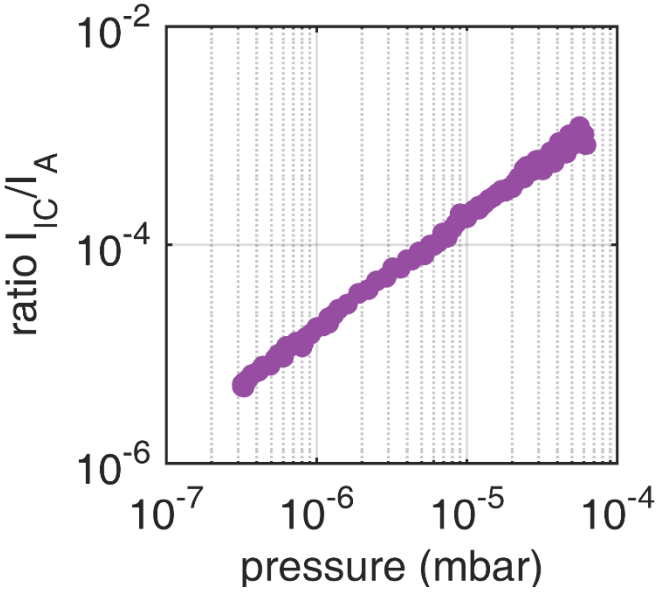
Anode current of 1.3 µA led to an ion current I_{IC} of 7 fA (@ 3 x 10-7) and of 0.8 pA (@ 4 x 10-5 mbar)

4. Application in an ionisation vacuum gauge

Measurement results



Ratio with the same slope



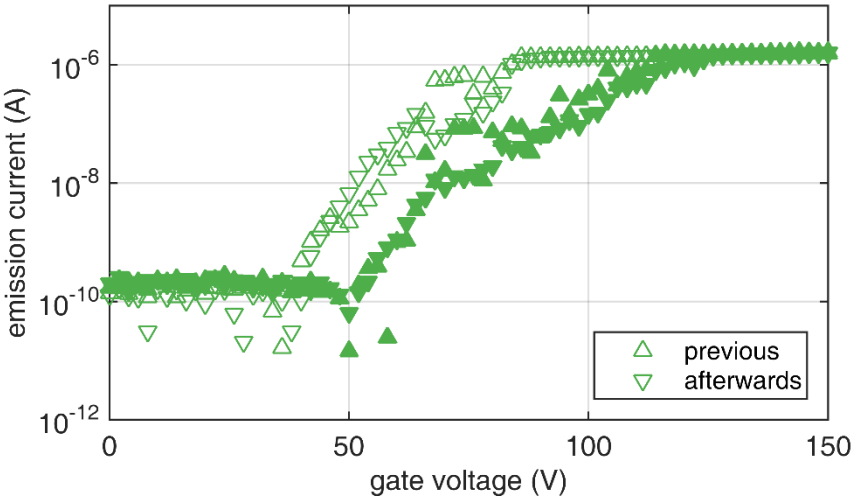
Mean value of sensitivity S of 17.6 mbar^{-1}
Good agreement with given value of 17 mbar^{-1} by the manufacturer for this ionization gauge with hot filament

4. Application in an ionisation vacuum gauge

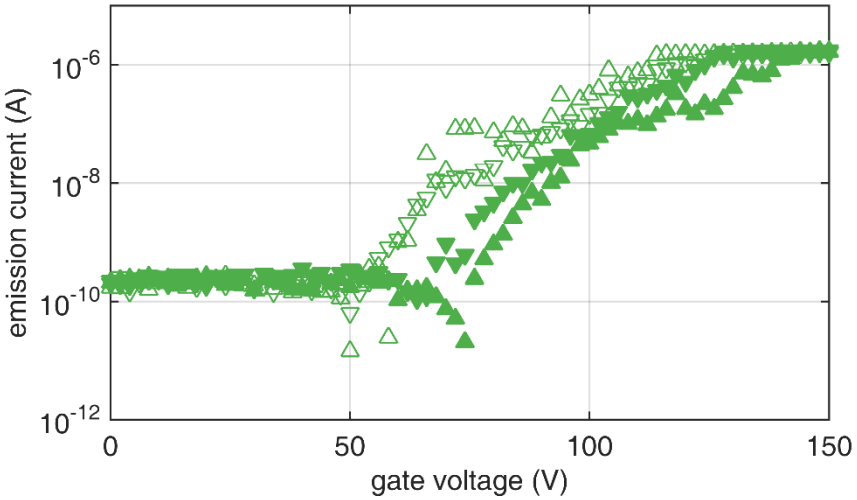
Characterization of the electron source

p up to 6 x 10^5 mbar

After 2 sweeps



After 3 sweeps



- Slightly degradation
- Saturation regime at V_{Gate} > 120 V

- Further degradation
- Saturation regime at V_{Gate} > 130 V

5. Conclusion

1. We developed a setup of a field emission electron source
2. Our conventional Si tip arrays showed homogeneous FE, but high operation voltages were required
3. A significant reduction of the operation voltage was possible with our Si tip arrays with integrated gate electrode
4. The FE electron source showed a very stable and reproducible field emission behavior and a hot filament in a ionisation vacuum gauge was replaced
5. Our electron source is applicable in a commercial BA ionisation vacuum gauge even in harsh environments (pressures up to 10^{-5} mbar)

Thank you for your attention

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