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ANU HIAF 14UD

High Voltage Performance Degradation of the 14UD Tandem Accelerator

Linardakis P., Lobanov N., Tunningley T., Tsifakis T., Battisson S., Graham B., Bockwinkel J,. Heighway J.

HIAT 2018 – Lanzhou, China

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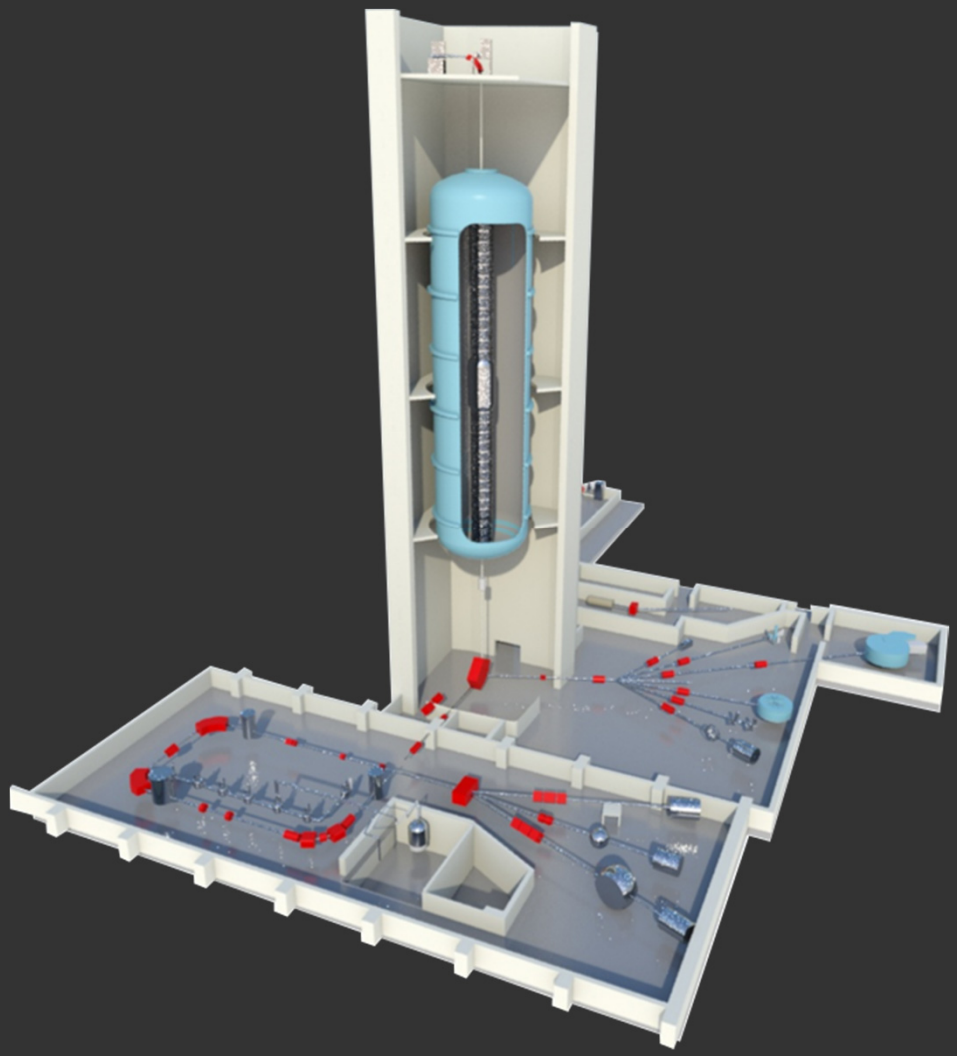

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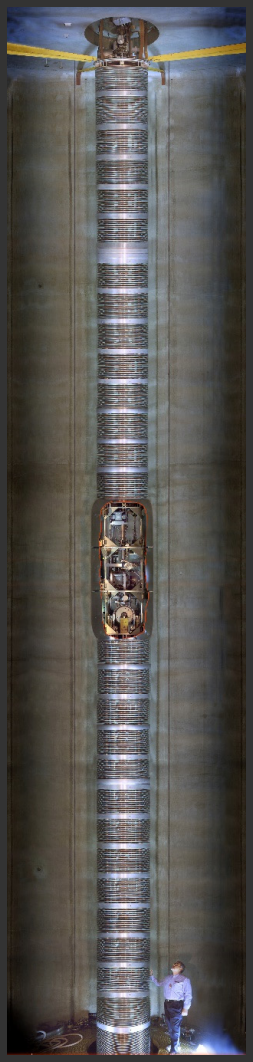

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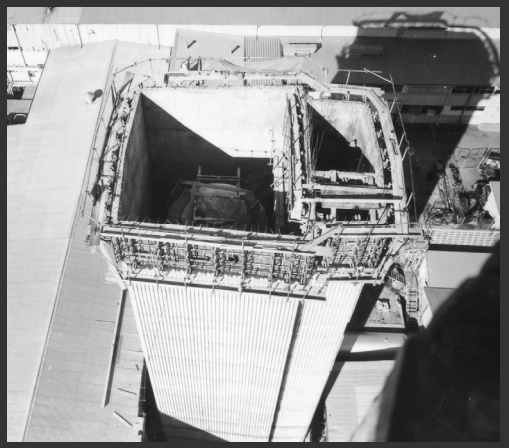
- 1971: pressure vessel complete
- 1972: 14UD assembly began
- 1973: first beam
- 1974: first experiment
- 1975: acceptance tests complete



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14UD voltage records

- Conditioned to 14.8MV in 1983 (with corona points)
- Upgrade to “compressed geometry” and resistors in ~1990
  - Conditioned to 16.7 MV
  - Experiments at 15.5 MV
- Now at 14.5 MV max for experiments

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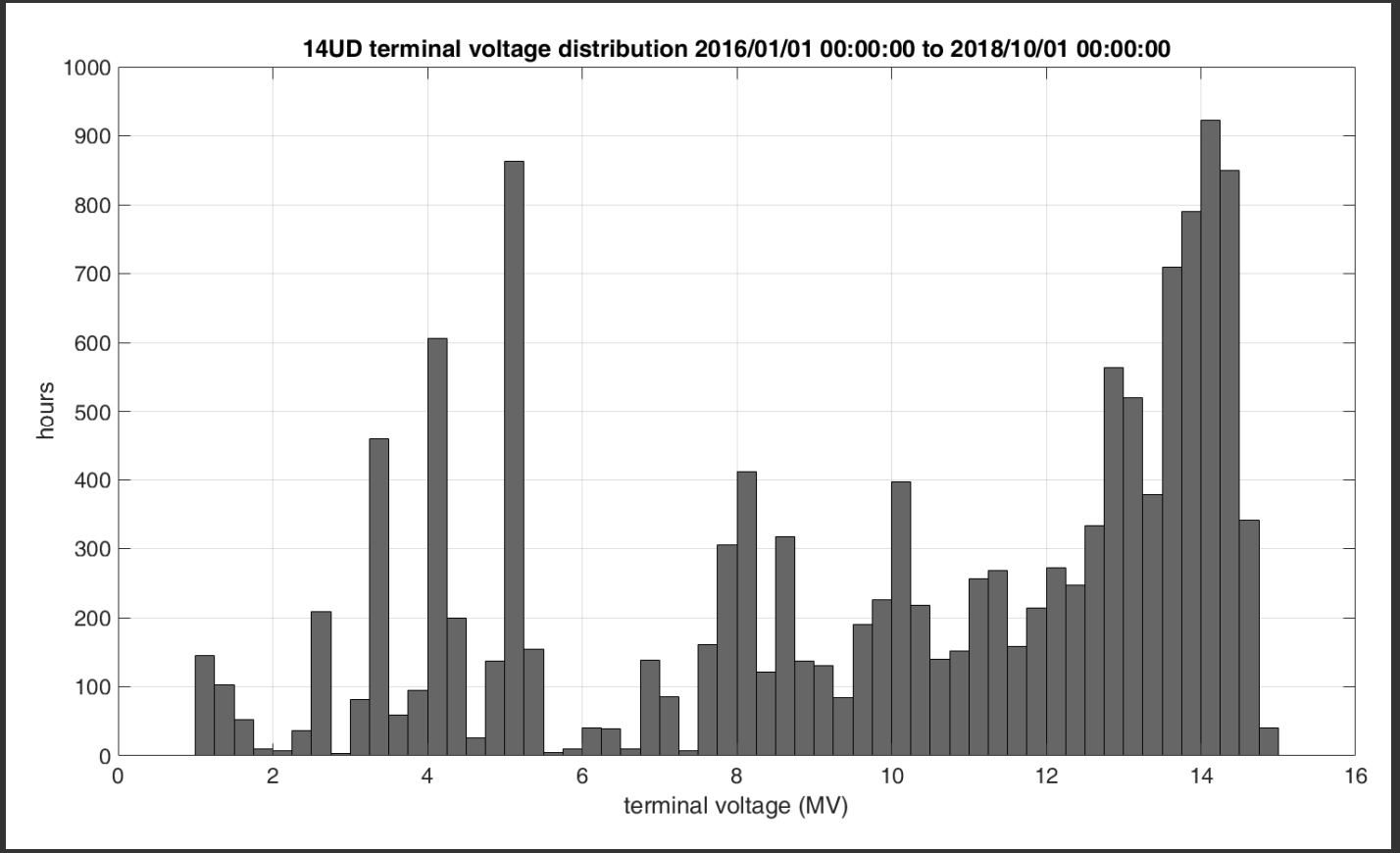
14UD voltage records

Since January 2016:

- Running for 56% of the total time
- Accelerator downtime for maintenance for 16% of the total time (both scheduled and unscheduled)
- Above 13.5 MV for 27% of time with terminal volts.



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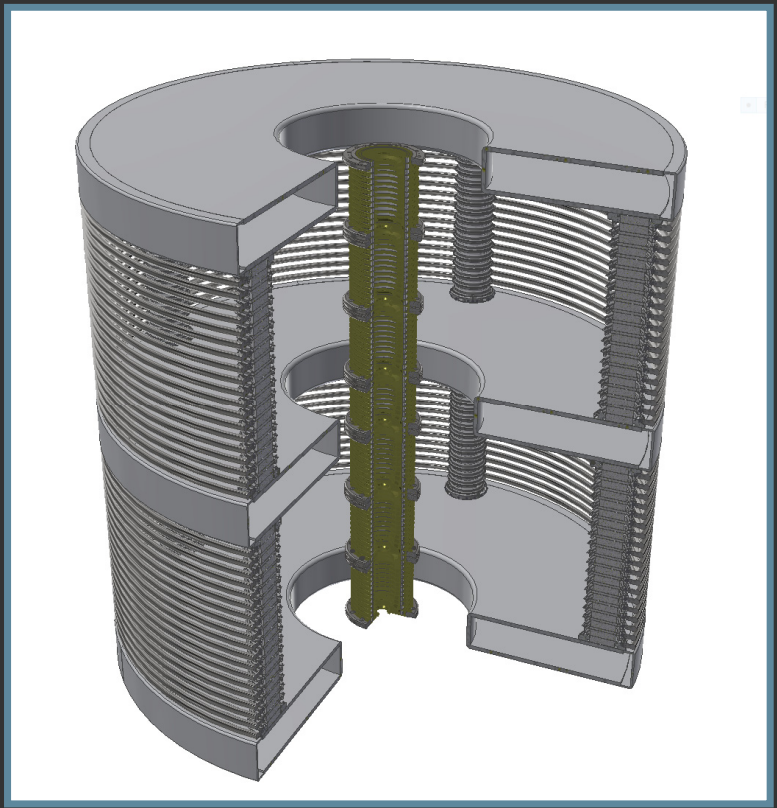
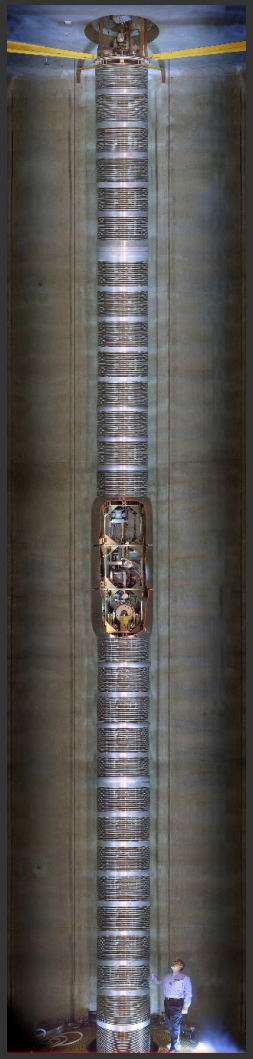
Voltage breakdown





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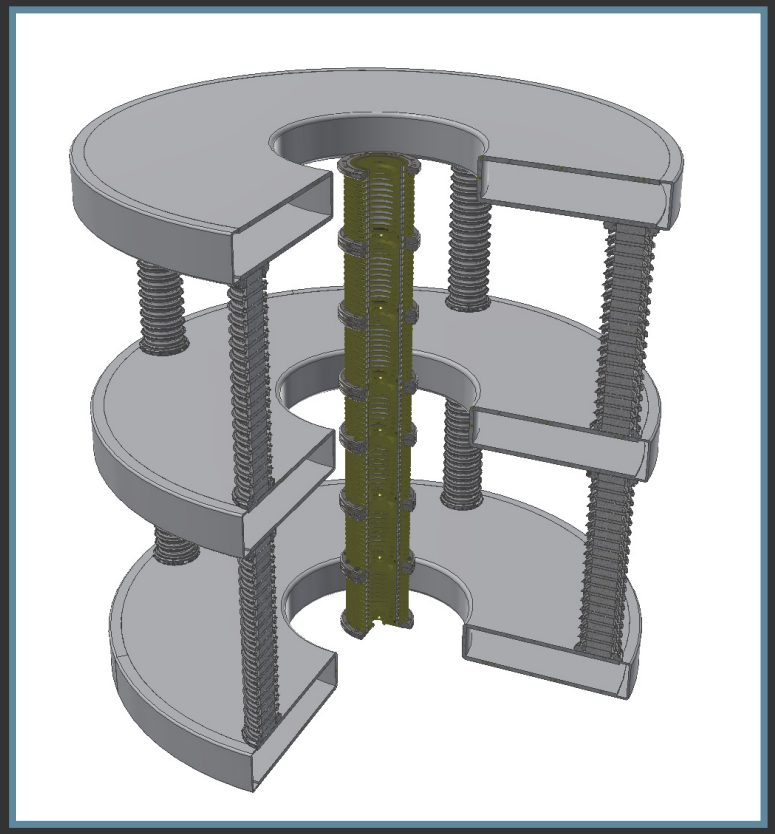
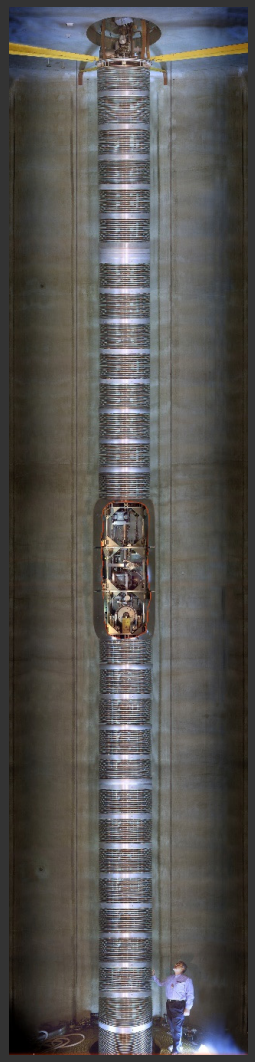
Voltage breakdown





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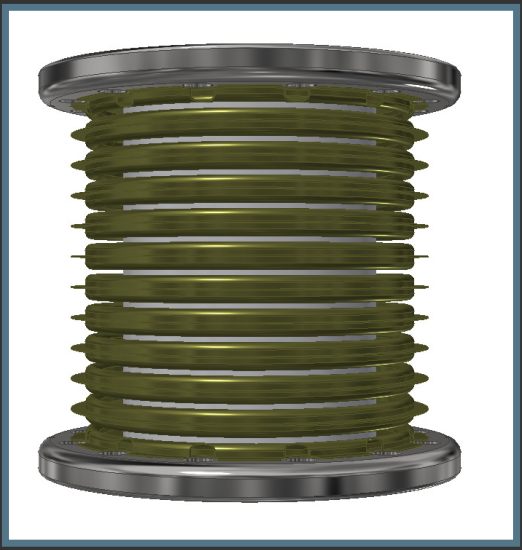
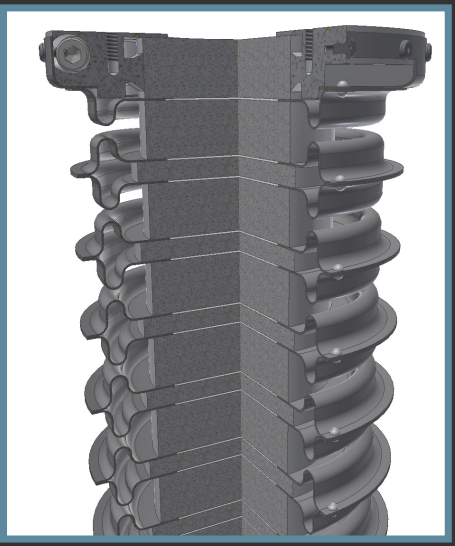
SF_6 breakdown

- $SF_6 \rightarrow SF_4 + 2F$
- $SF_4 + H_2O \rightarrow SOF_2 + 2HF$
- $SOF_2 + H_2O \rightarrow SO_2 + 2HF$
- $2F + M \rightarrow MF_n$ (where M is any metal)





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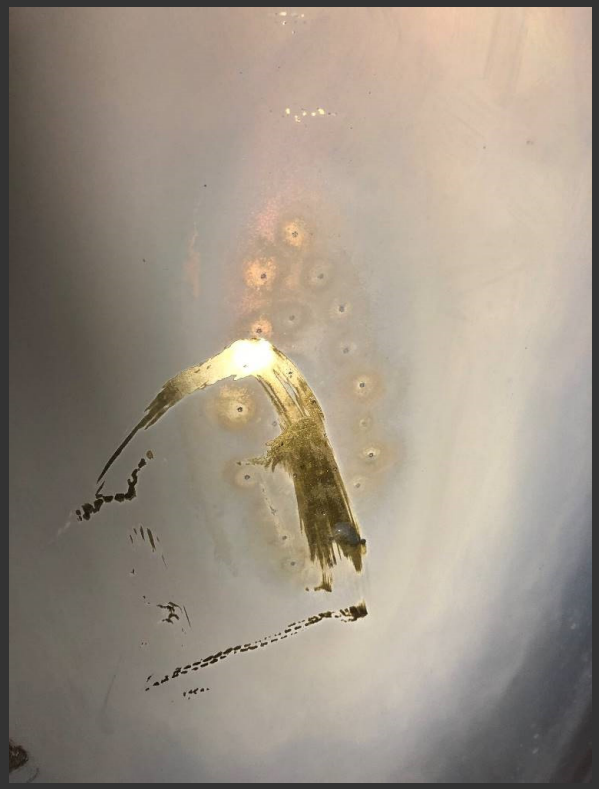
SF_6 breakdown



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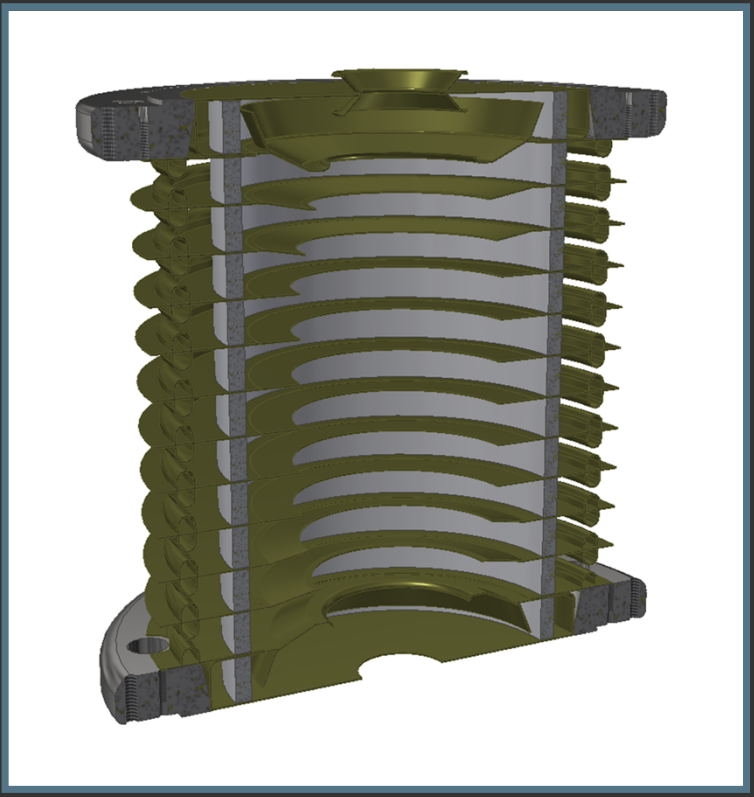
Vacuum breakdown

- Vacuum breakdown triggers:
  - field emission from protrusions on electrode surfaces, either from manufacture or previous discharges;
  - field emission from foreign particulates embedded in the electrode surfaces;
  - ionisation of gas or other low vapour pressure contaminants desorbed from electrode surfaces that then cause micro-discharges;
  - hot field emission from impacting particles that deform the electrodes and;
  - ionisation of metal vapour from high-energy particle impact.



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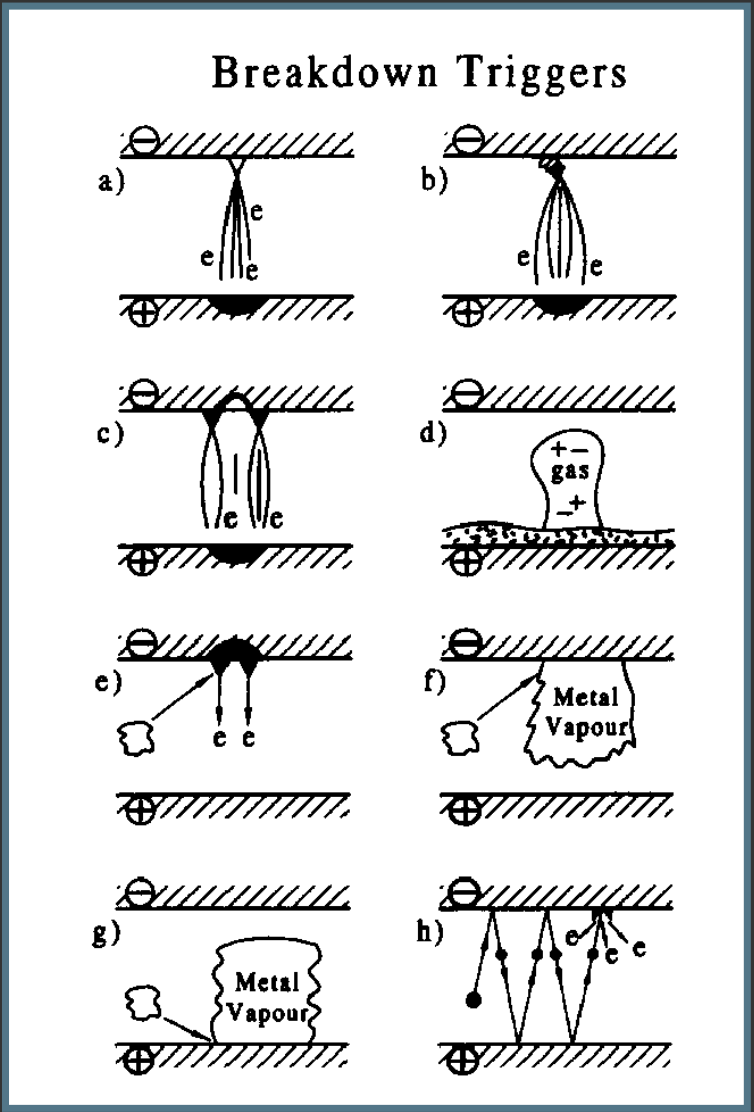

Morrow & Weisser 96

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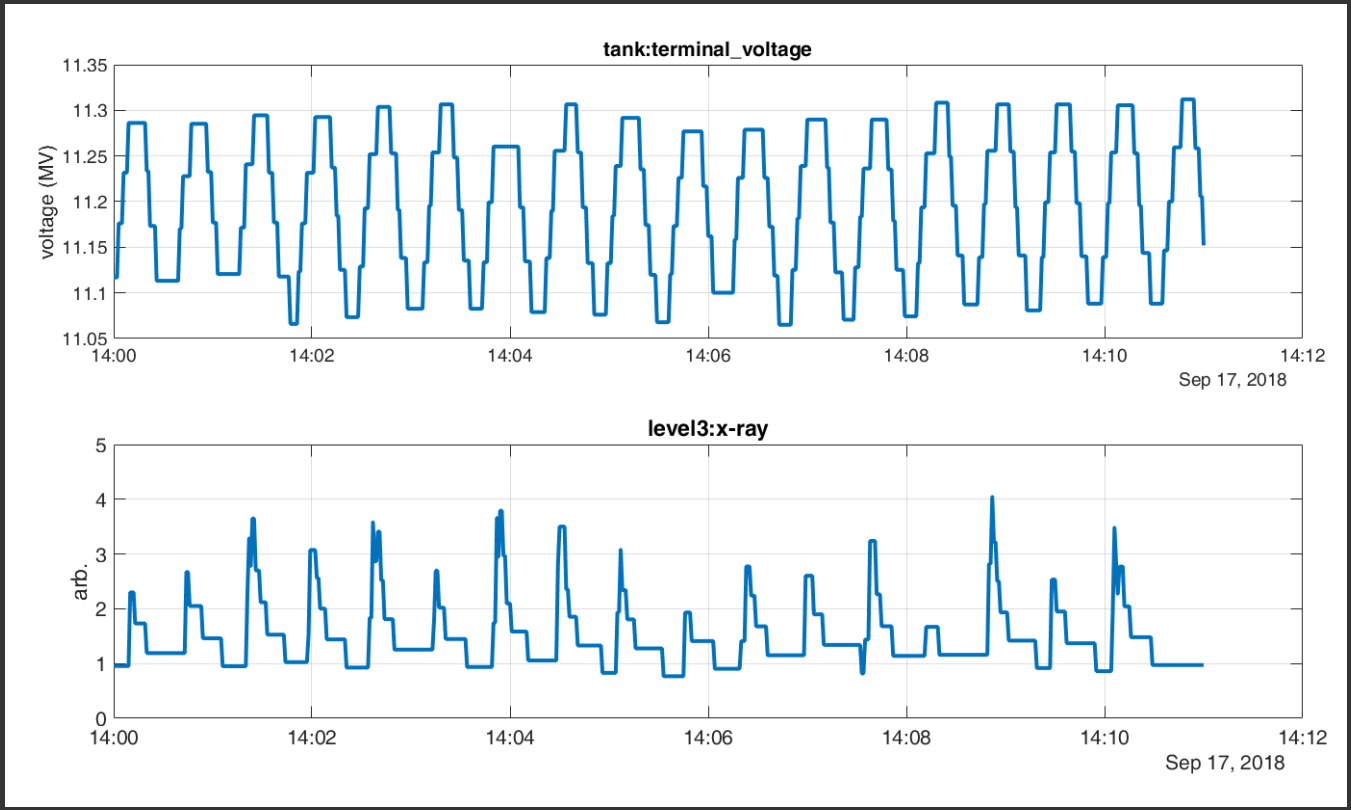
Vacuum arcs

- Electrode surface conditioning
- In-situ cycling of terminal voltage with a gradual increase over time
- Vacuum and x-ray emission used to guide level of conditioning



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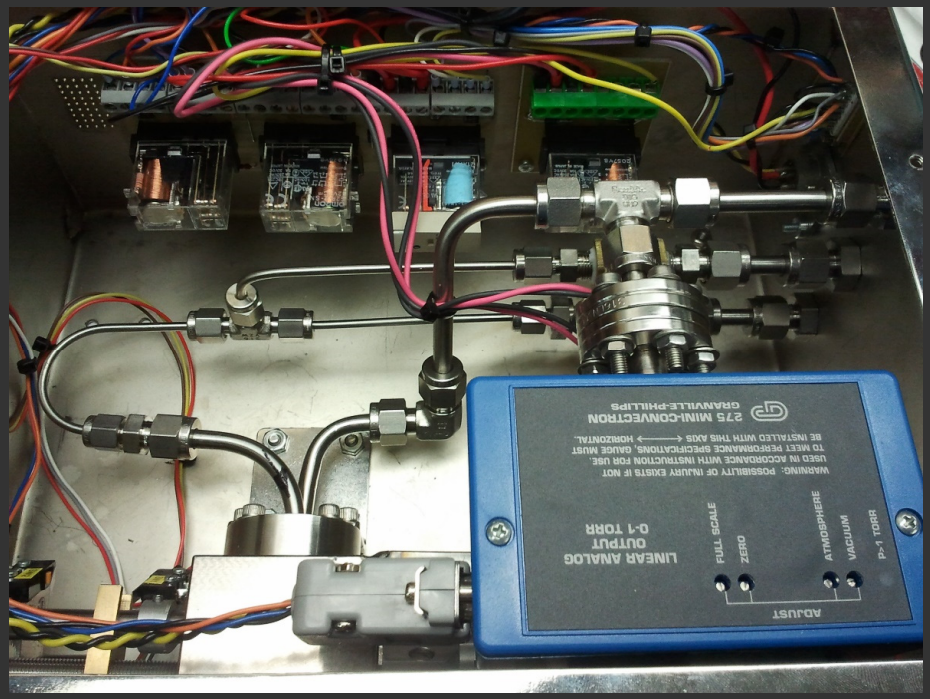
SF_6 ingress into vacuum



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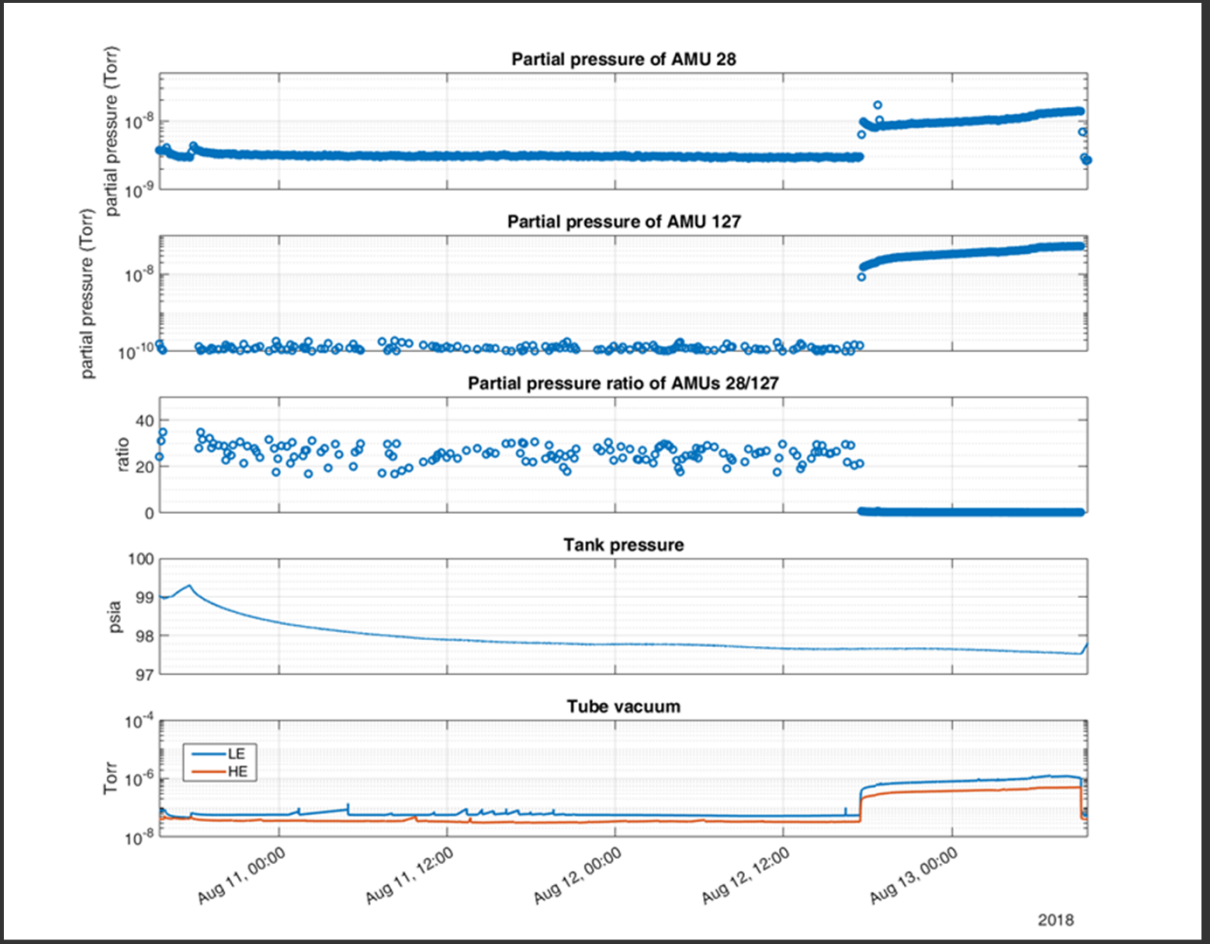
SF_6 ingress into vacuum

- RGA search for SF_6
  - Sudden leak while idle



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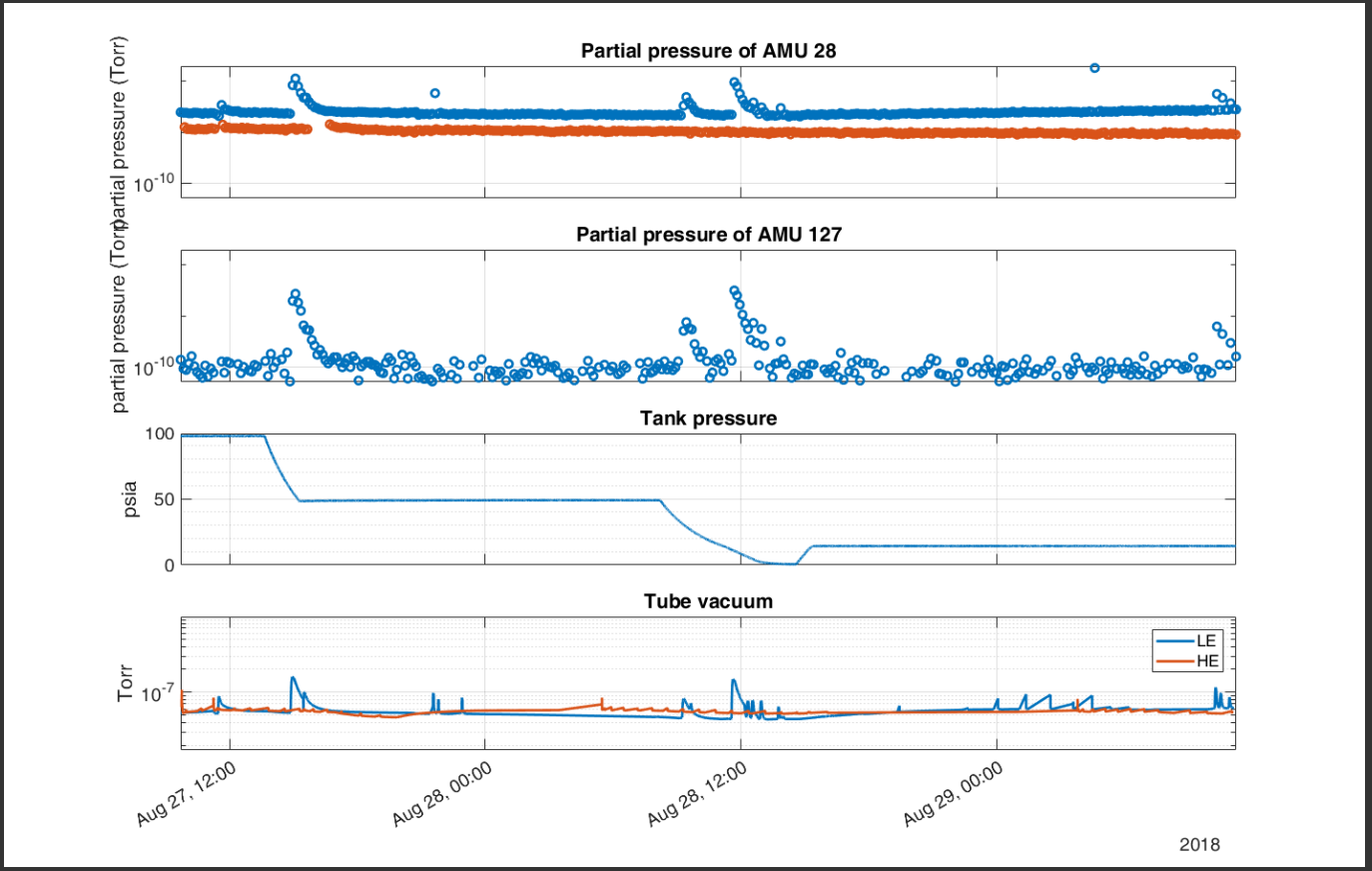
SF_6 ingress into vacuum

- RGA search for SF_6
  - Small “burps” while pumping SF_6 from pressure vessel



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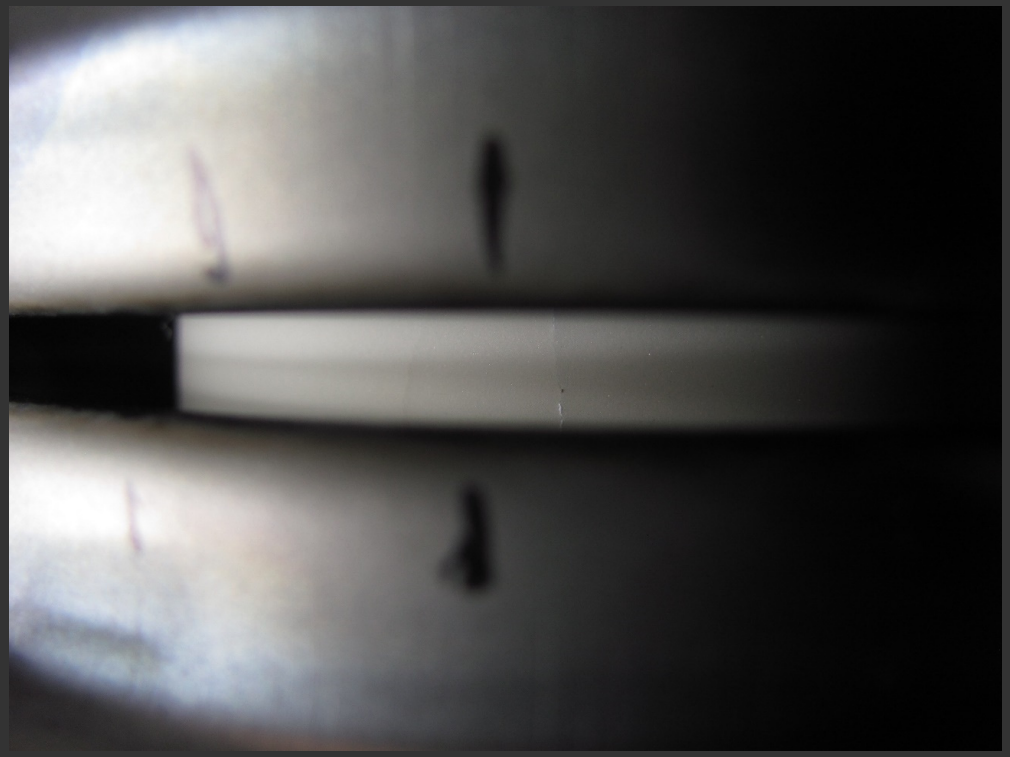
Ceramic insulators



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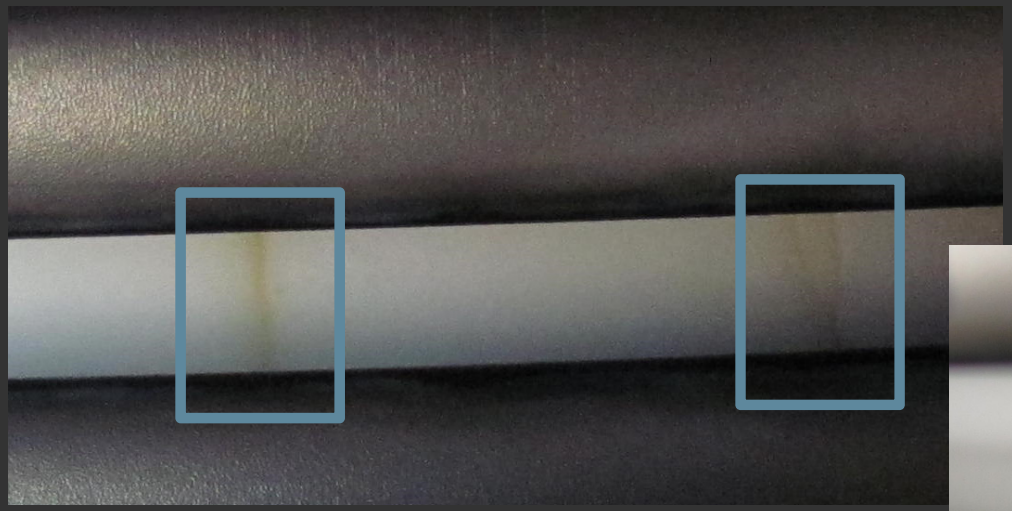
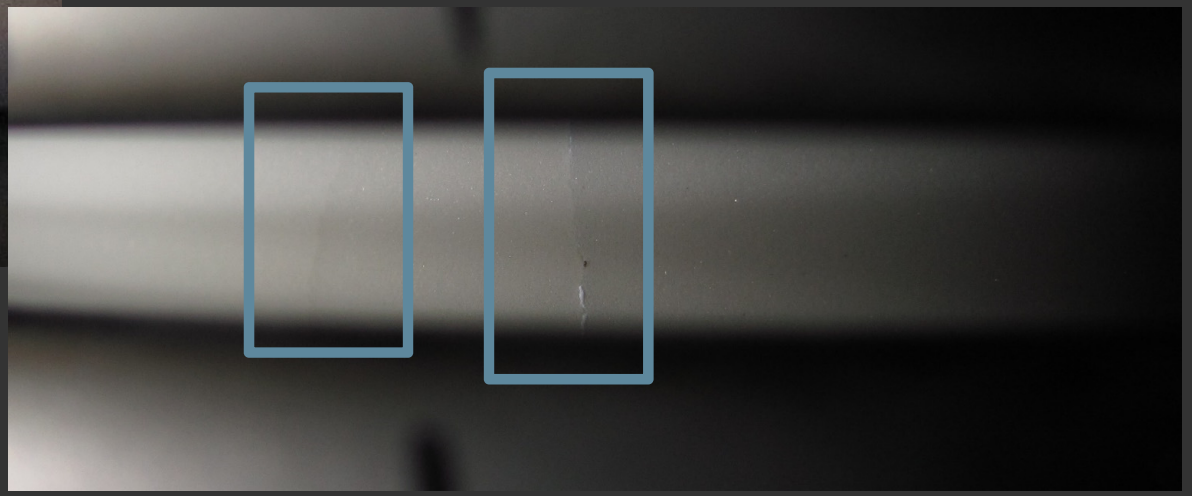
Ceramic insulators





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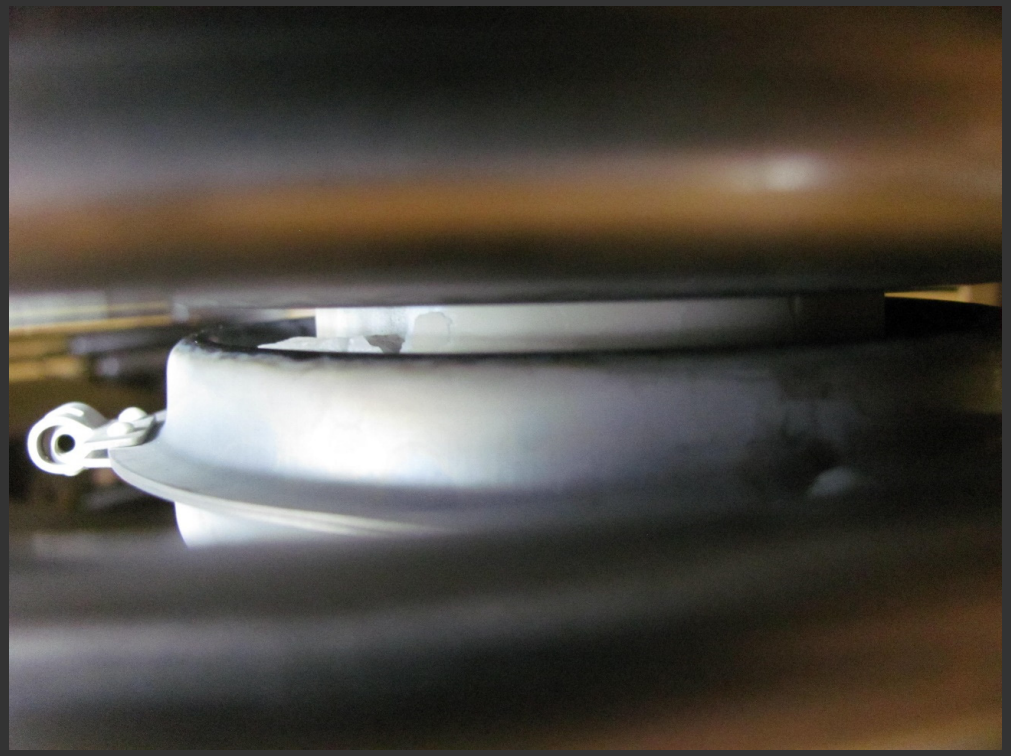

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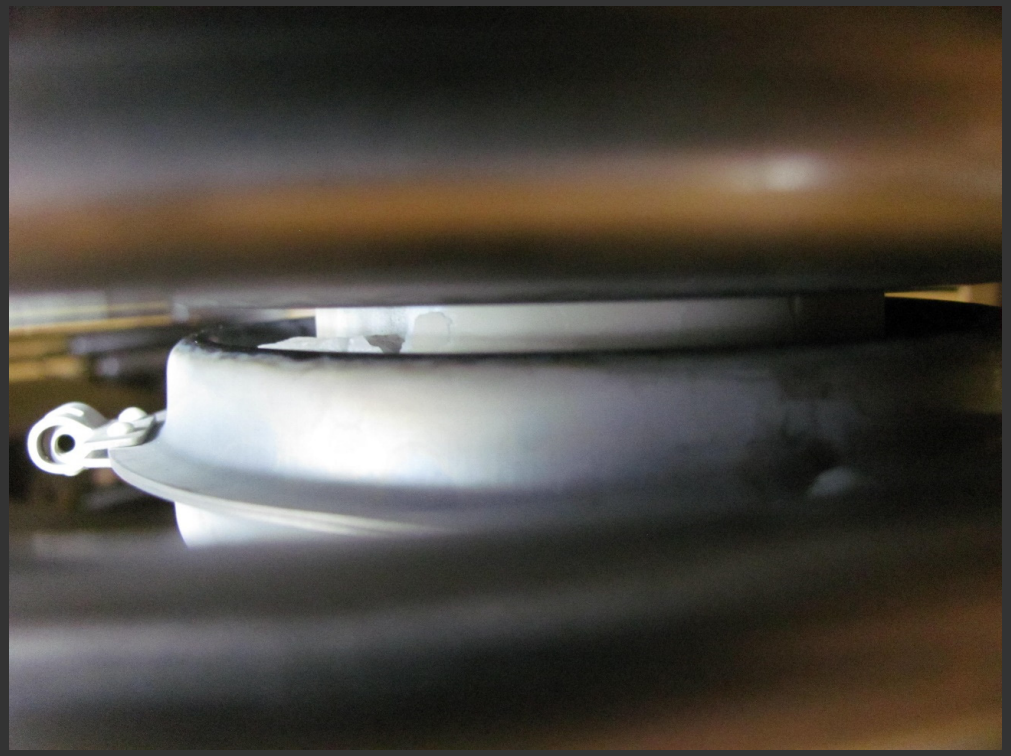

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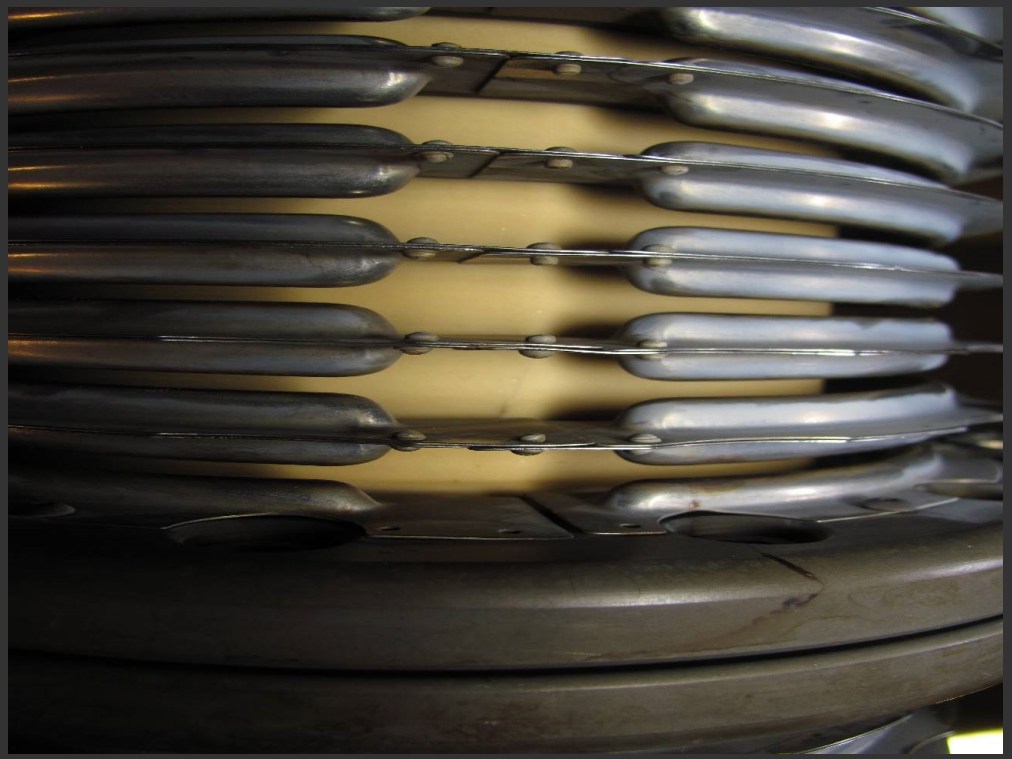
Ceramic insulators



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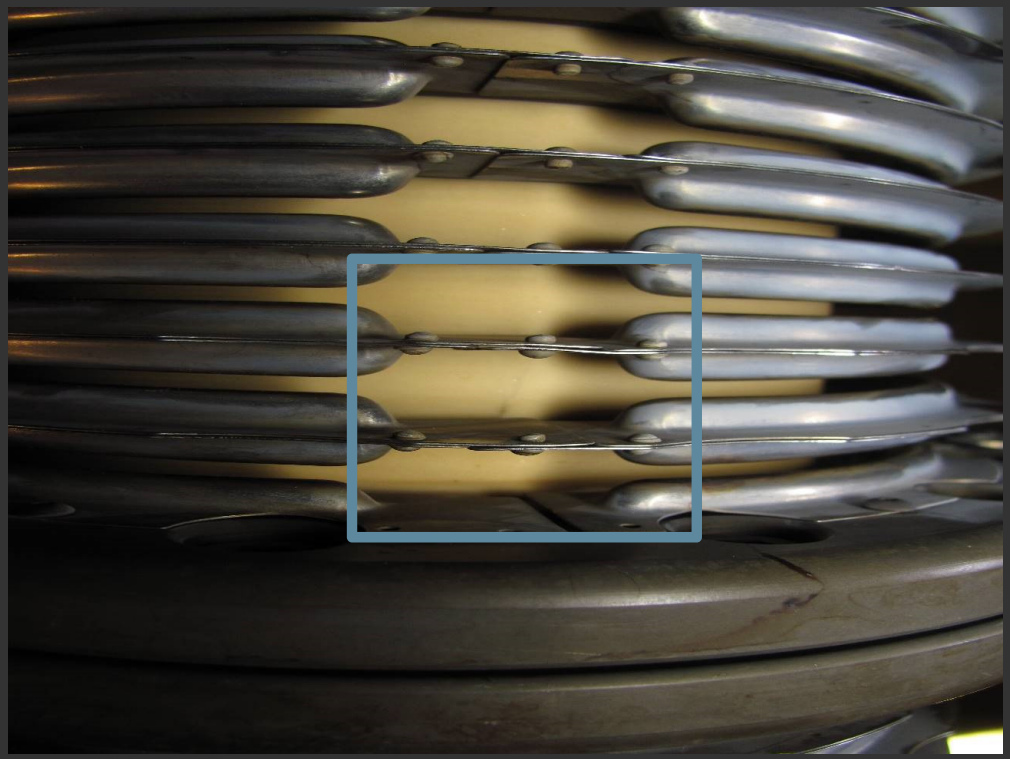

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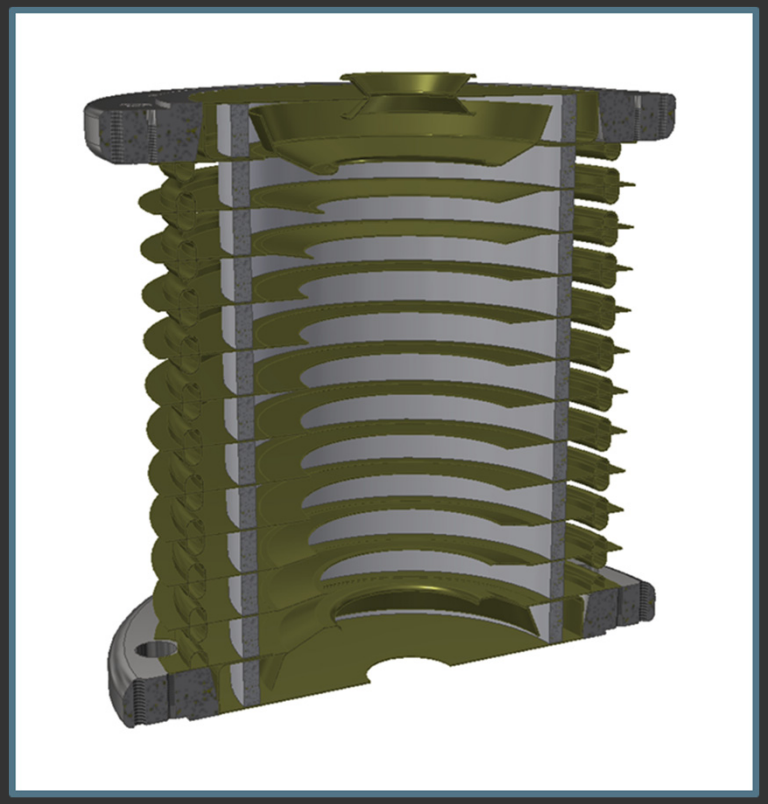

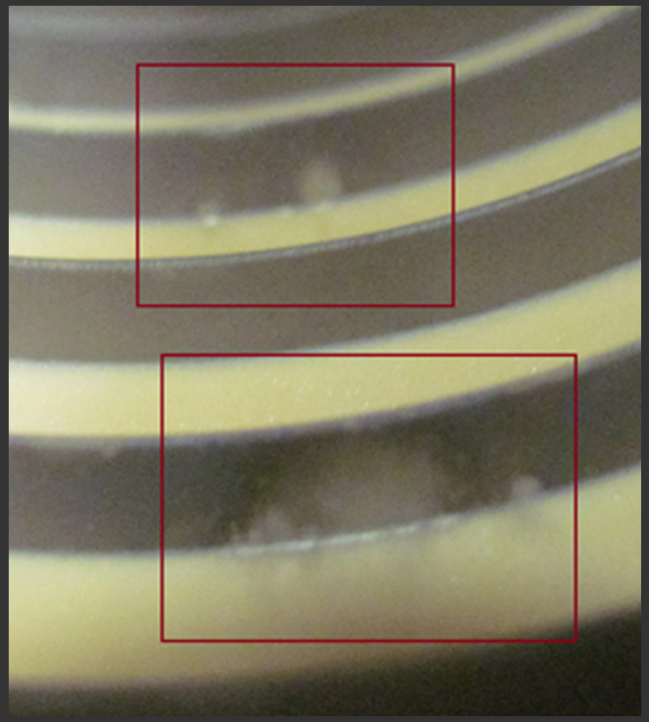

Damage arising from aluminum bonding layer between titanium and ceramic

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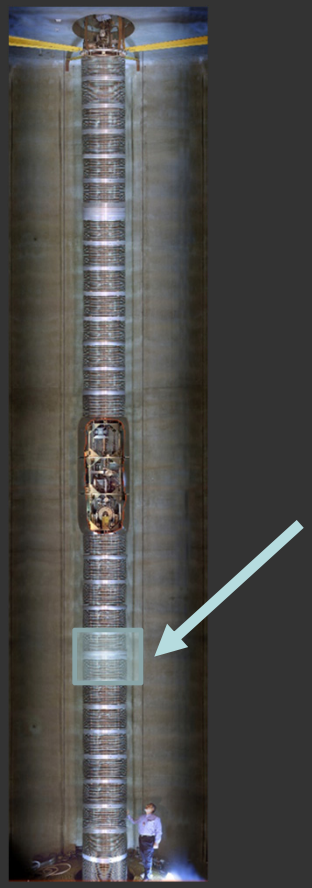
Electrode surface condition



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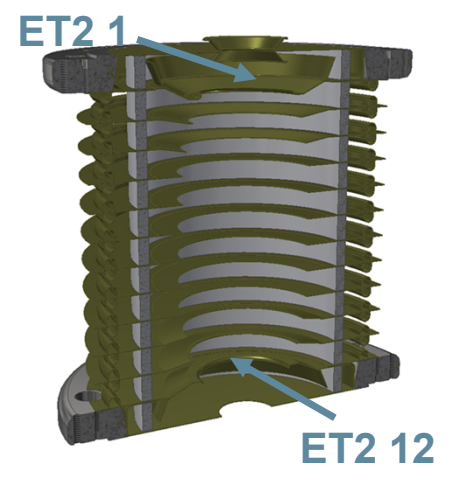
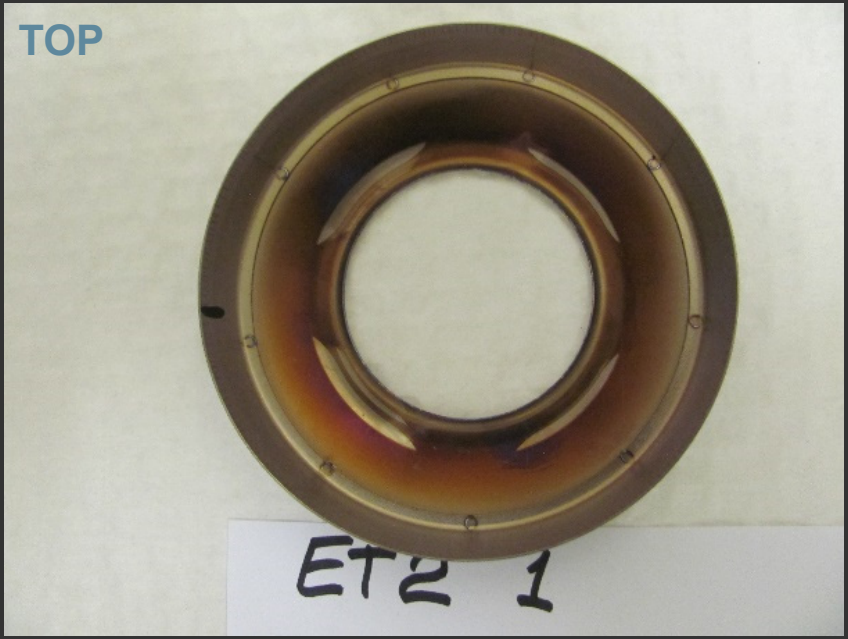
Electrode surface condition





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Electrode surface condition

	HIGHEST	MIDPOINT	LOWEST
TOP SURFACE			
BOTTOM SURFACE			

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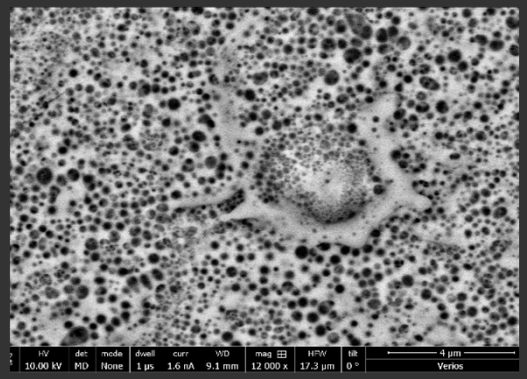
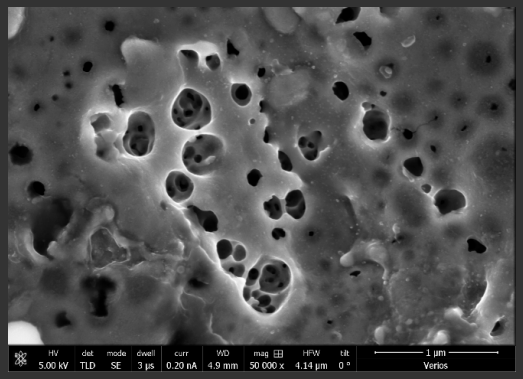
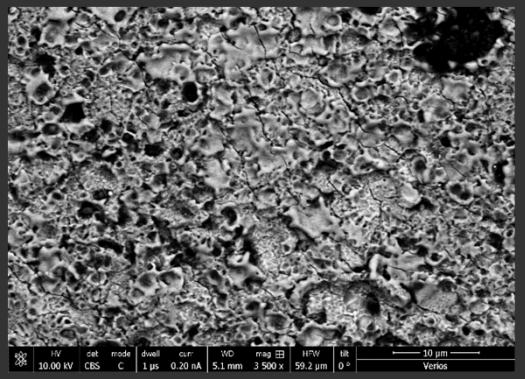
Electrode surface condition



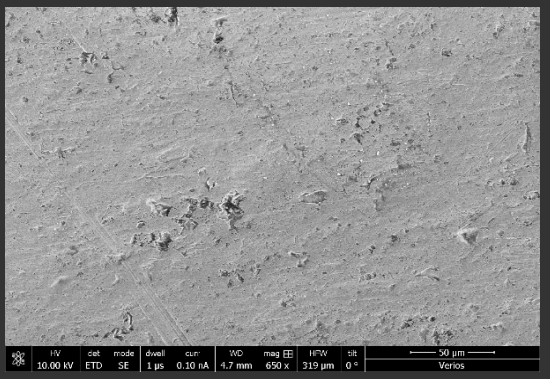
Porosity



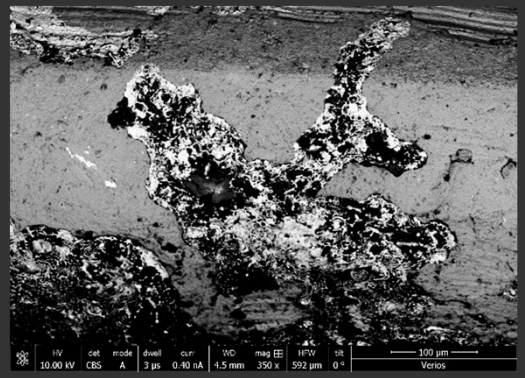
Recrystallization



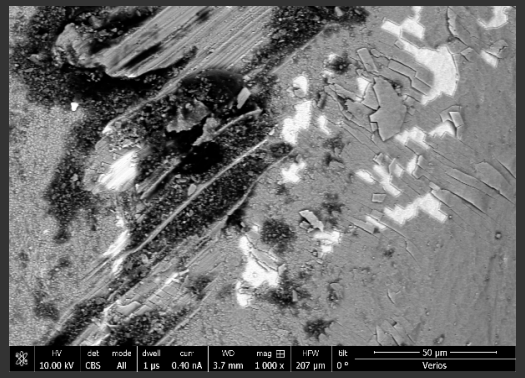
Unused Ti



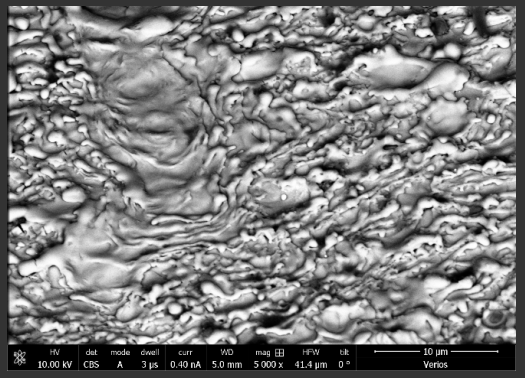
Metal vaporisation



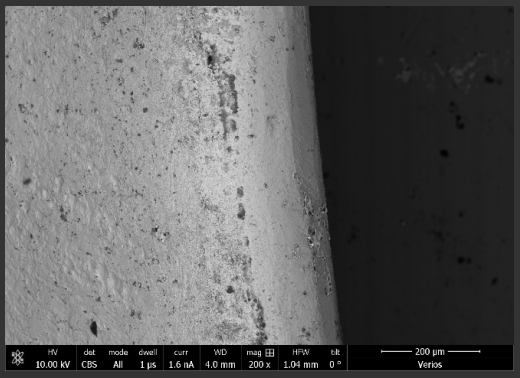
Layer build-up



Melting



Electrode edge



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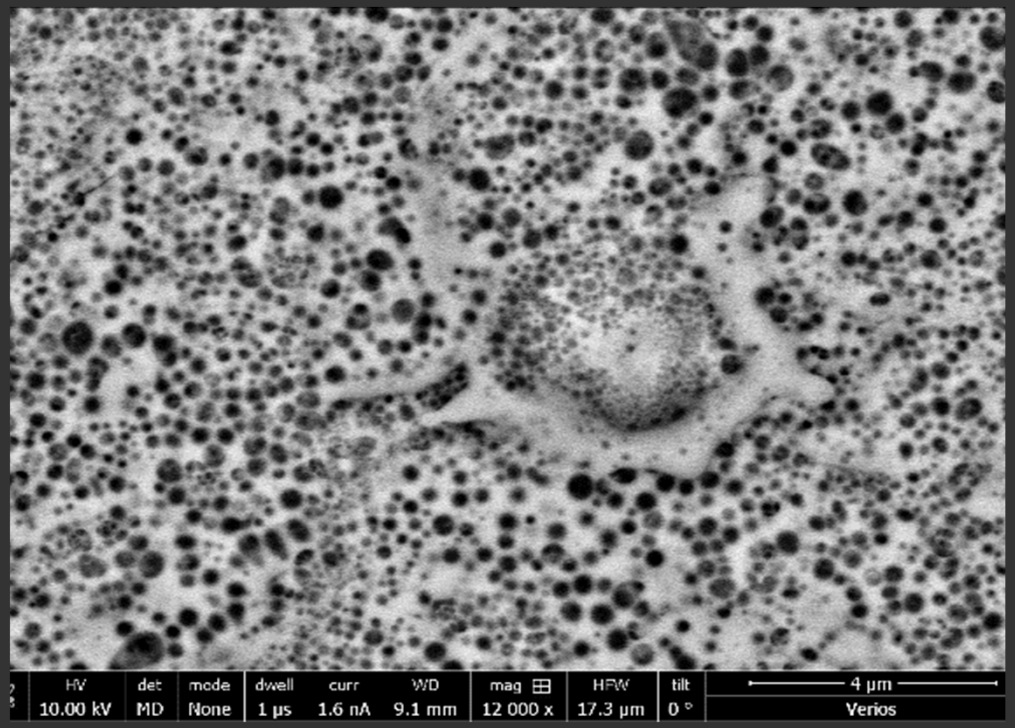
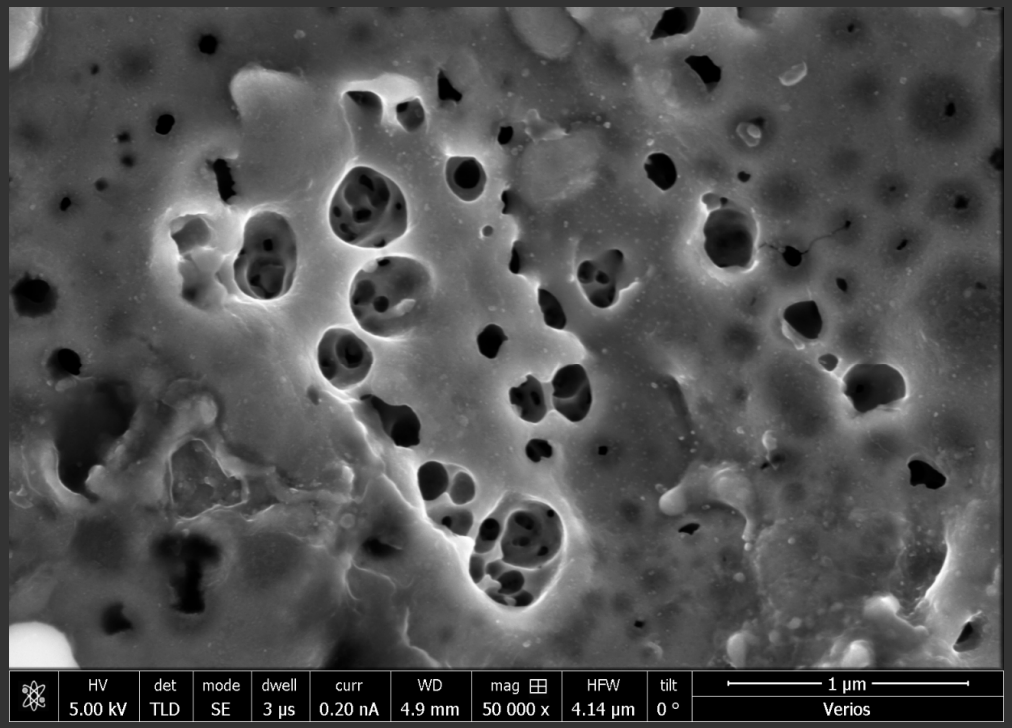
Electrode surface condition





Porosity

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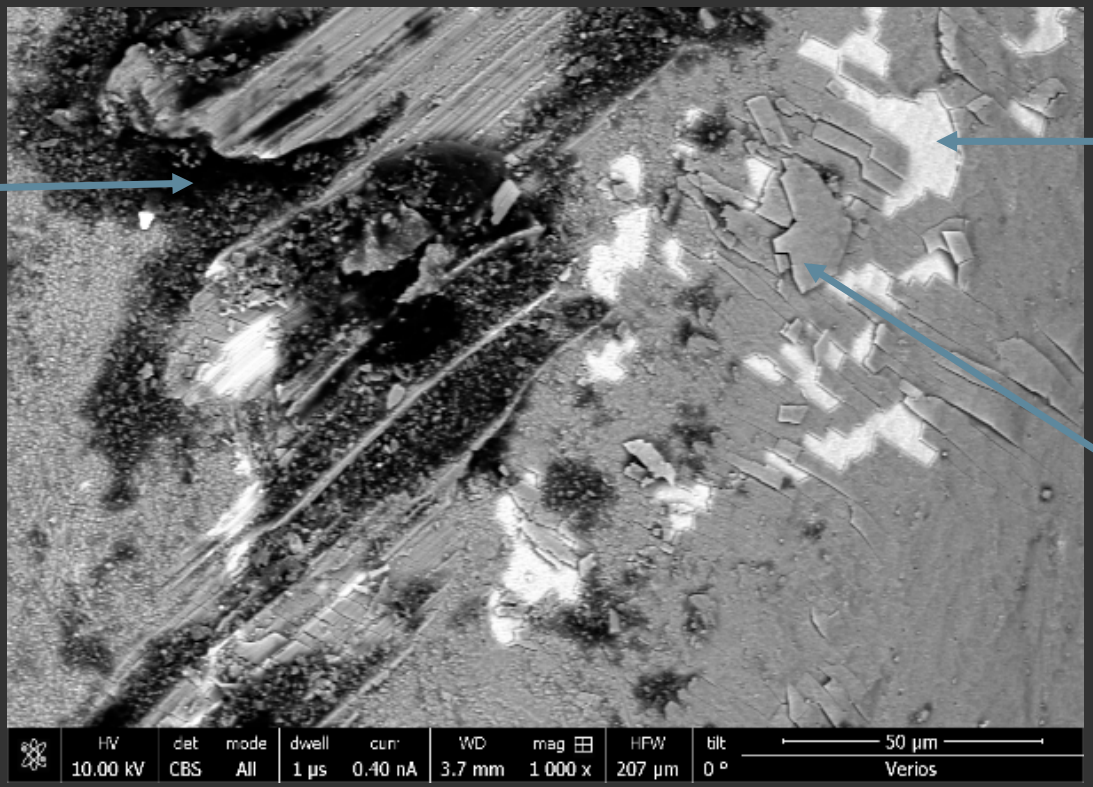
Electrode surface condition



Carbon

Titanium

Oxygen, fluorine contamination

Layer build-up

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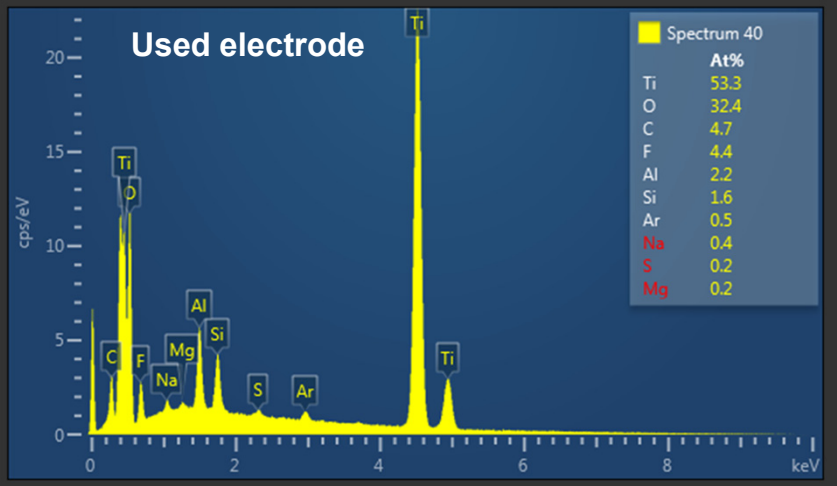
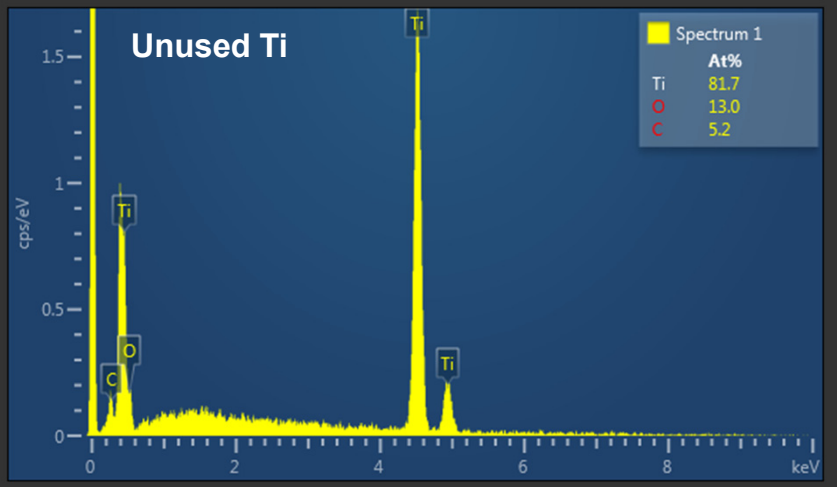
Electrode surface condition

- SEM EDX on used electrodes
  - oxygen 20 – 40%
  - carbon 10 – 20%
  - **fluorine** 3 – 7%
  - aluminium 1 – 3%
- Unused Ti
  - oxygen 10 – 15%
  - carbon 3 – 6%





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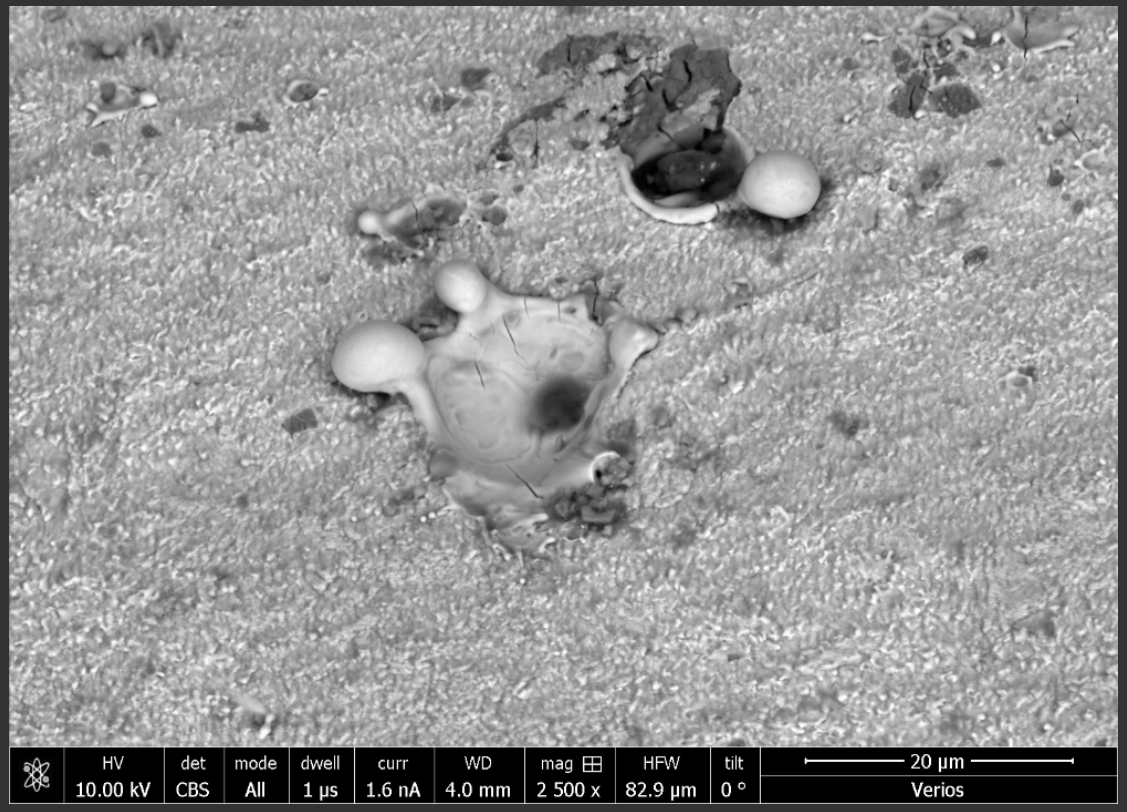
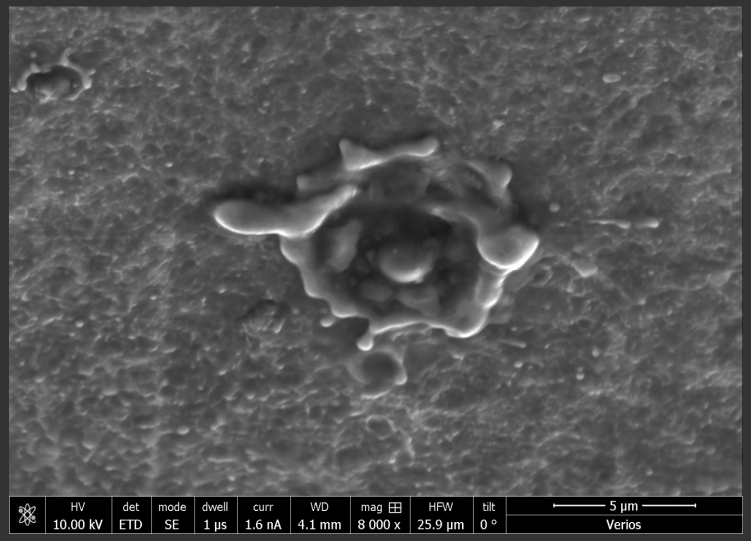


- Damaged electrodes exacerbate vacuum breakdown triggers
  - Field emission from protrusions
  - Ionisation of metal vapour



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Remediation

- New tubes
- Factory refurbishment (NEC)
- In-house refurbishment
  - High-pressure rinse
  - Electro-polishing

Thank you