TECHNISCHE UNIVERSITÄT
CHEMNITZ

Professorship Micromanufacturing Technology
Institute for Machine Tools and Production Processes
Faculty Mechanical Engineering

SuperSurfer – Meeting

Project overview: CavityPeP

Wuppertal, June 16th, 2025

Project goals

Realization of prototype setup for Plasma electrolytic Polishing (PeP) of surfaces of Quadrupole Resonators (QPR) and superconducting radiofrequency (SRF) cavities

- Process windows for Nb and Cu with fluorine-free electrolytes
- Realization of a uniform and reproducible surface, Ra < 1 µm
- Simulation-assisted design of a prototypic setup
- Process for PeP of functional cavity surfaces with more complicated, cylindrical, convex and concave features

Gantt chart

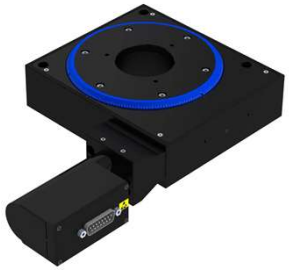
Work packages (WP) and milestones (MS)	2024		2025				2026				2027	
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
WP 1: Realization of a laboratory setup for targeted PeP treatments	**x**	**x**	**x**	**x**	**x**	**x**						
WP 1.1: Evaluation of PeP process parameter adaptions on surface deviations	x	x										
WP 1.2: Implementation of process energy source and rotary drive	x	x	x	x								
WP 1.3: Integration of process-specific measurement equipment		x	x	x	x	x						
WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes			**x**	**x**	**x**	**x**	**x**	**x**				
WP 2.1: Investigation of a PeP process window for niobium			x	x	x	x						
WP 2.2: Investigation of a PeP process window for copper			x	x	x	x						
WP 2.3: Investigation of thermal influences on the polishing results					x	x	x					
WP 2.4: Investigation of the influence of working distance variations on polishing results						x	x	x				
WP 2.5: Analyses of influences of electrolyte kinematics on the PeP process							x	x				
WP 3: Functional cathode and processing strategies for PeP of SRF cavity features							**x**	**x**	**x**	**x**	**x**	**x**
WP 3.1: Modeling of physical interactions and iterative derivation of cathode design							x	x	x	x		
WP 3.2: Realization of a functional cathode for partial cavity geometries									x	x	x	x
WP 3.3: Proof of functionality on partial SRF cavity features										x	x	x

Description of Work

WP 1: Realization of a laboratory setup for targeted PeP treatments

- **WP 1.1:Evaluation of PeP process parameter adaptions on surface deviations**
- **WP 1.2: Implementation of process energy source and rotary drive**
- **WP 1.3: Integration of process-specific measurement equipment**

Process energy source EA-PSI 10000 3U [Datasheet EA Elektro-Automatik]



Precision rotary-drive M-062.DG [www.physikinstrumente.de]

Oscilloscope Siglent SDS2354X PLUS [www.siglent.eu]

Description of Work

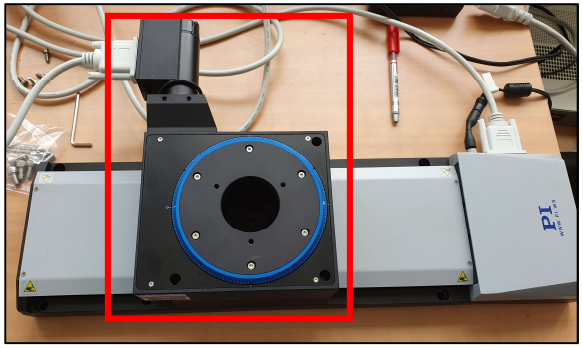
WP 1: Realization of a laboratory setup for targeted PeP treatments

- **WP 1.2: Implementation of process energy source and rotary drive**

  - Oscilloscope and rotary-drive were delivered (February 2025)
  - LabVIEW implementation is currently in progress

  - Process energy source was delivered (June 2025)

Oscilloscope Siglent
SDS2354X PLUS



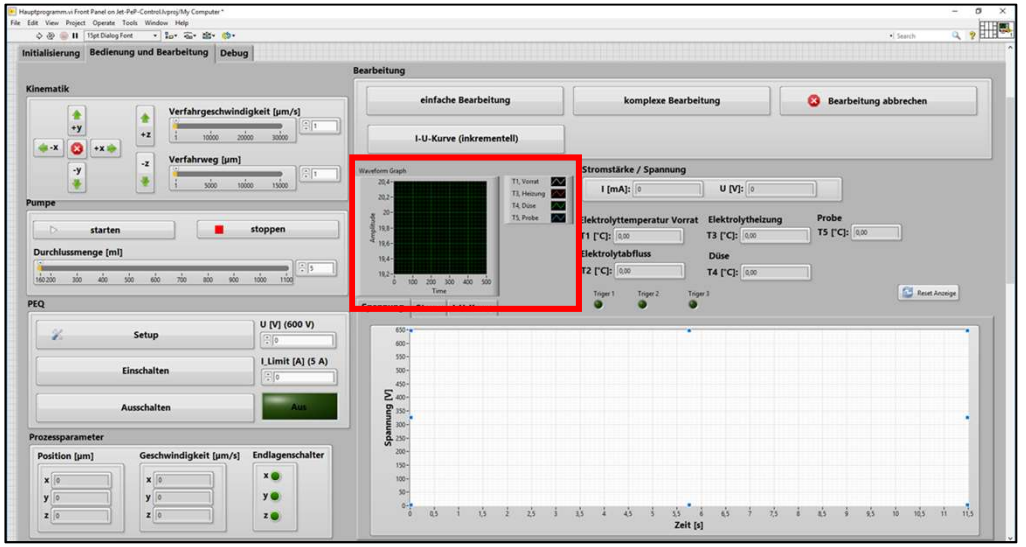
Precision rotary-drive M-062.DG
mounted on PI axis

Process energy source
(during assembly)

Description of Work

WP 1: Realization of a laboratory setup for targeted PeP treatments

- **WP 1.3: Integration of process-specific measurement equipment**
  - Temperature sensor (thermocouple typ K) was selected and integrated
  - Control software based on LabVIEW
  - Adjustment of the measurement loop is required



Screenshot of the control software of the setup

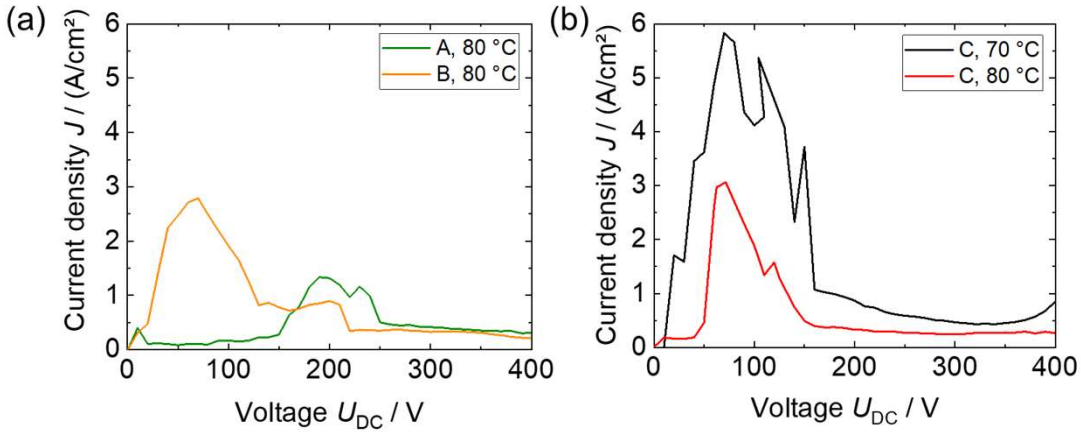
Description of Work

WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes

- **Goals:**
  Suitable electrolyte,
  Surface roughness of Ra < 1 µm

- **WP 2.1: Investigation of PeP process window for niobium**

  - Nb samples provided by Uni HH
  - 3 different electrolytes were investigated
  - Recording of electric current and voltage
  - Electrolyte C is suitable for polishing



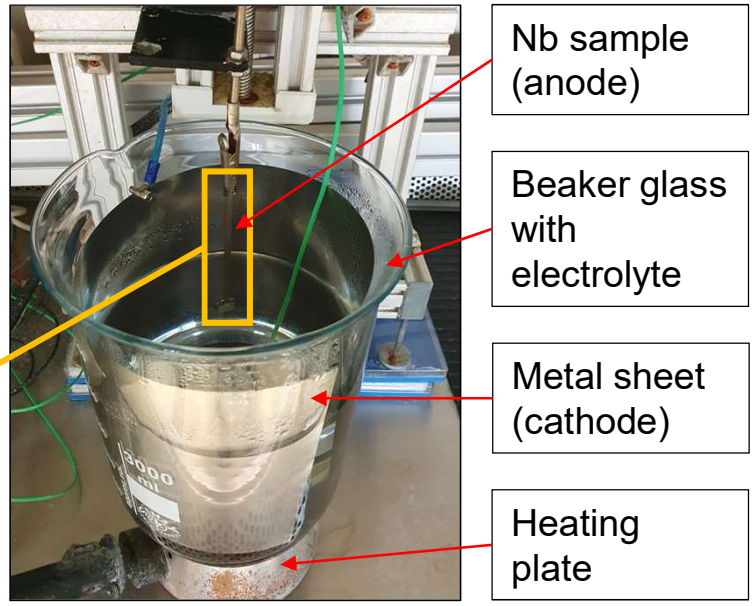
Current density as a function of applied voltage for different electrolyte (a) A, B and (b) C (at different temperature)

Description of Work

WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes

- **WP 2.1: Investigation of PeP process window for niobium**
  - Experiments were carried out with different parameters
  - Electrolyte temperature: (70, 80) °C
  - Applied voltage: (200, 220, 250, 280, 310) V
  - Polishing time: 60 s

Sample geometry



Setup for immersion based PeP

Description of Work

WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes

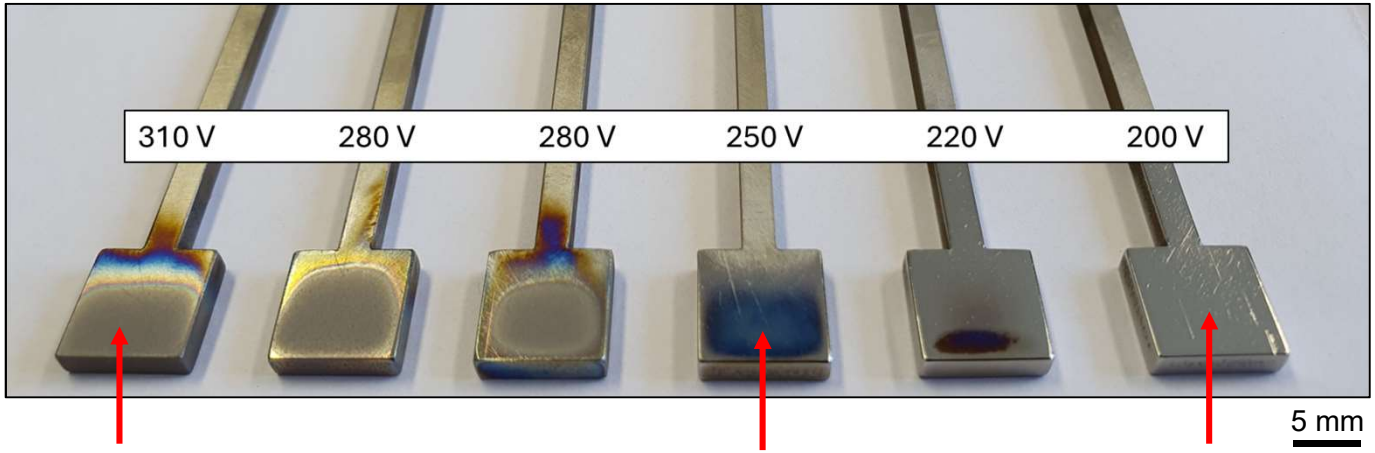
- **WP 2.1: Investigation of PeP process window for niobium**
  - Characterization of the surface with laser scanning microscope (Keyence VK-9700)
    - Roughness (Rz, Ra), Defects
  - Characterization of the chemical composition with EDS (SEM Zeiss EVO 25)

Laser scanning microscope VK-9700

Description of Work

WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes

- **WP 2.1: Investigation of PeP process window for niobium**
  - Different surfaces were created for each parameter (roughness, gloss level, chemical composition)



Photograph of the Nb samples after the experiments

Nb: 73.08 wt.-%
O: 26.92 wt.-%

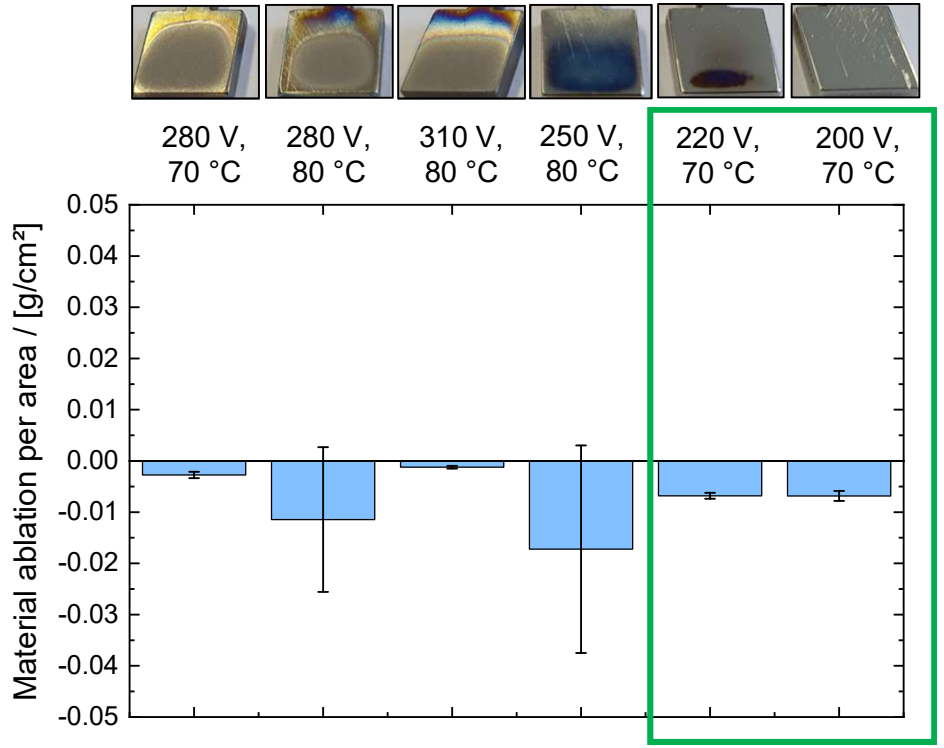
Nb: 86.76 wt.-%
O: 13.24 wt.-%

Nb: 99.02 wt.-%
O: 0.98 wt.-%

Description of Work

WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes

- **WP 2.1: Investigation of PeP process window for niobium**
  - Measurement of the sample weight with precision scale
  - Calculation of material ablation per surface area
  - 220 V / 200 V and 70 °C: 0.0068 g/cm²

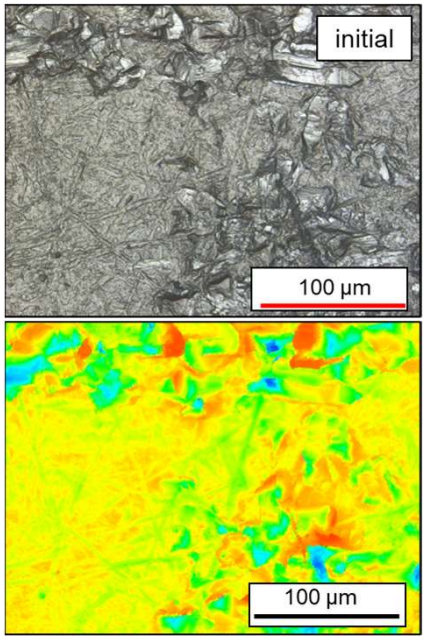


Material ablation per area for each parameter set

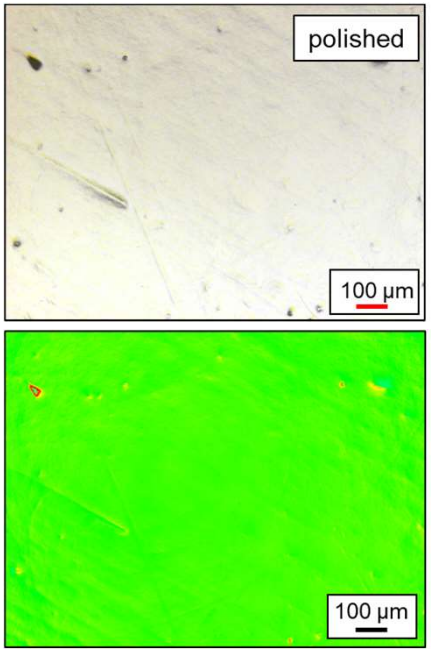
Description of Work

WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes

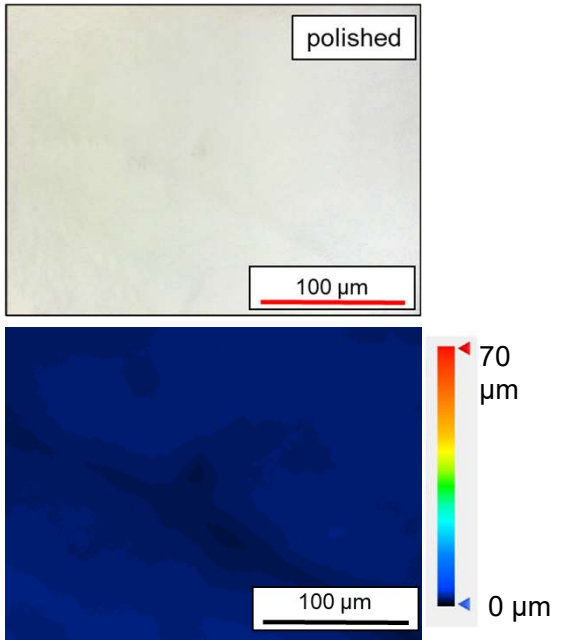
- **WP 2.1: Investigation of PeP process window for niobium**



Initial surface of Nb sample



Polished surface of Nb sample

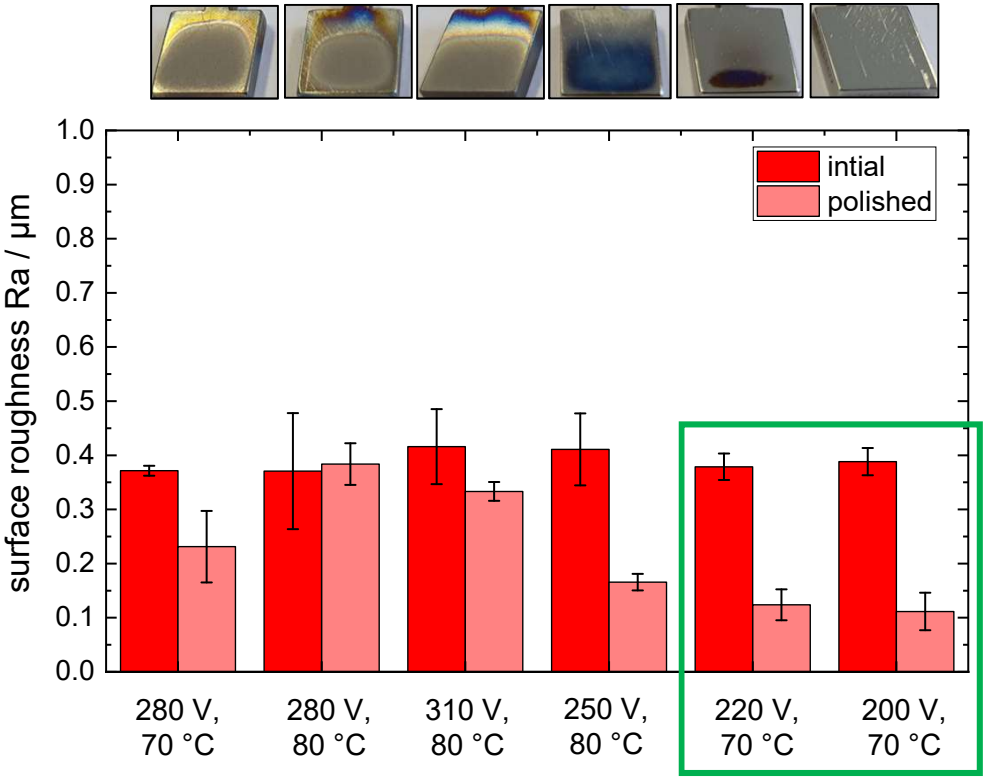


Polished surface of Nb sample (Detail)

Description of Work

WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes

- **WP 2.1: Investigation of PeP process window for niobium**
  - Surface roughness was measured
  - Ra was significantly reduced
  - 220 V: Ra = 0.38 µm → Ra = 0.12 µm
  - 200 V: Ra = 0.39 µm → Ra = 0.11 µm

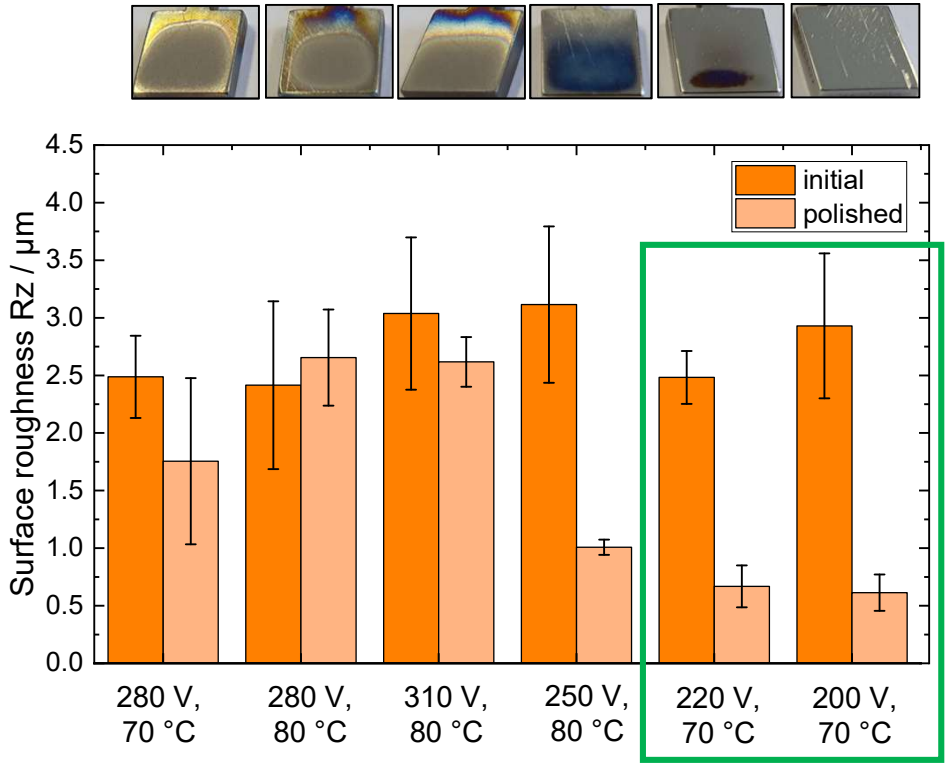


Surface roughness of Nb samples for each parameter set

Description of Work

WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes

- **WP 2.1: Investigation of PeP process window for niobium**
  - Rz was significantly reduced
  - 220 V: Rz = 2.48 µm → Rz = 0.67 µm
  - 200 V: Rz = 2.93 µm → Rz = 0.61 µm



Surface roughness of Nb samples for each parameter set

Description of Work

WP 2: Investigation of material-specific process windows for Nb and Cu parts with novel, fluorine-free electrolytes

- **Next steps:**
  - WP 2.1: Variation of the concentration of the electrolyte
    → 3 % and 10 % are planned
    → additional: variation of polishing time (3 min, 5 min)
  - WP 2.2: Investigation of the PeP process window for copper
  - WP 2.3 and WP 2.4: Q3 – Q4 2025

Organizational

Cooperation agreement

- Document was finalized

Publication

- **euspen's 25th International Conference & Exhibition**, Univ. Zaragoza ESP, June 9th – 13th 2025;
  Investigation of process parameters for plasma-electrolytic polishing of copper with an environmentally friendly electrolyte

- **International Symposium on Electrochemical Machining Technology** – INSECT, Chemnitz, November 3rd – 4th, 2025;

  Paper by Susanne: *Evaluation of a suitable electrolyte for plasma electrolytic polishing of niobium*
  Paper by André: *Plasma-electrolytic polishing of copper with low surface oxidation*

Logo of the European Society for Precision Engineering and Nanotechnology (eu**spen**) [https://www.euspen.eu/]

INSECT ELECTROCHEMICAL MACHINING ECM