Study of surface finishing strategies on multi-materials by additive manufacturing

Journées traitements et parachèvements de pièces issues de fabrication additive
Colmar – 30/11 & 01/12 2022

Outline

CRM Group – Aerosint

Fissel project

Introduction

- *Multi-material printing*
- *Chemical polishing*
- *Multi-material finishing strategies*

Results

- *Copper polishing*
- *316 stainless steel polishing*
- *Multi-material polishing*

Perspectives

Introduction

CRM Group

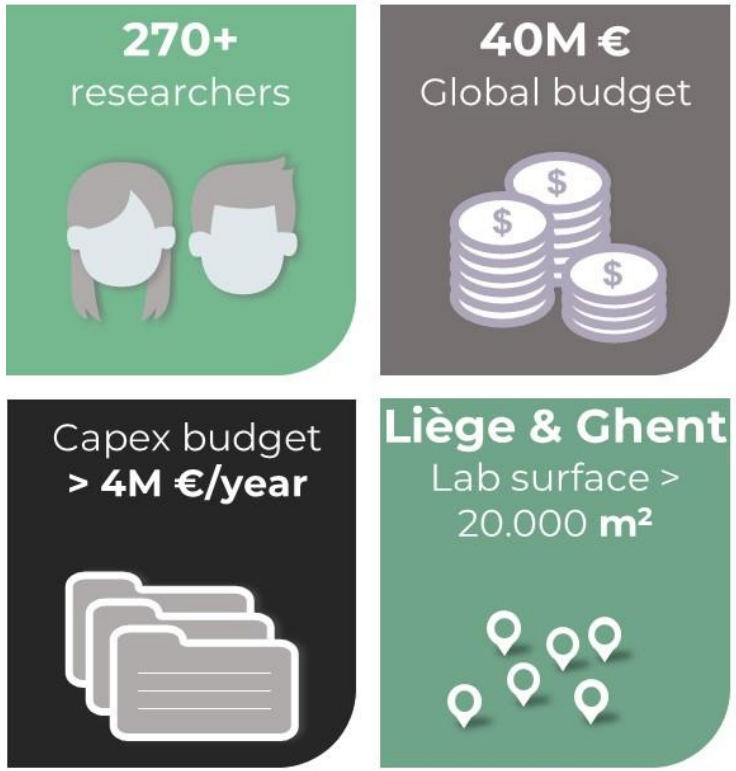
Independent research organization founded in **1948**

Product – process – application approach

From lab scale over pilot lines to industrialization

Multi-sectorial approach – cross pollinate

45 members & 350+ clients/year



Aerosint

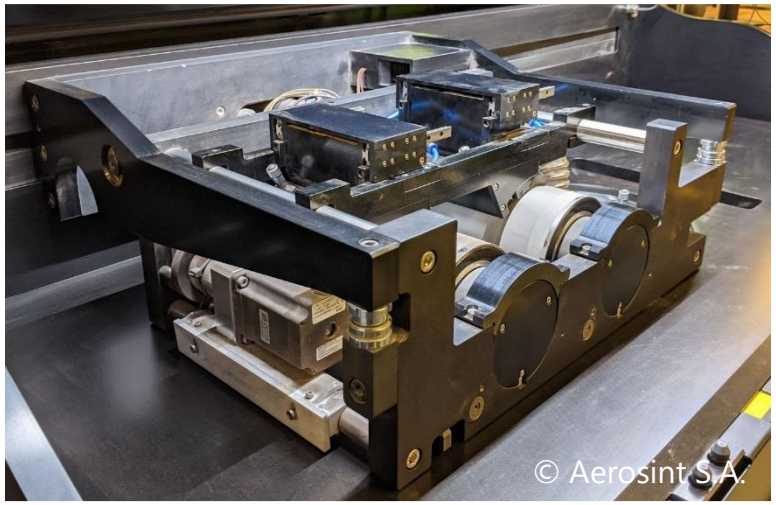
- Based in Liege region, BE
- Part of Desktop Metal family since June 2021
- Solution to **selective** powder deposition

We are #TeamDM. We exist to make production 3D printing accessible to all engineers, designers, medical professionals, and manufacturers.

Desktop Metal™

Desktop Metal | aidro | ExOne
ADAPTIVE3D | Desktop Health | ETEC
aerosint | Desktop Labs | FORUST

Selective Powder Deposition



Aerosint

Fusion Based AM

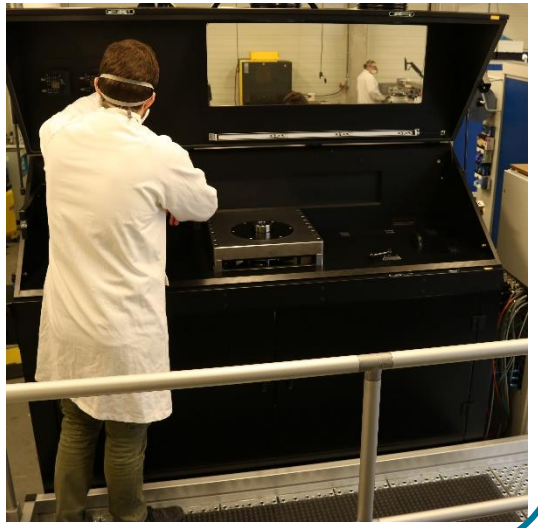
MIDI+

Micro

Sintering Based AM

P1 system

Die&Pressing

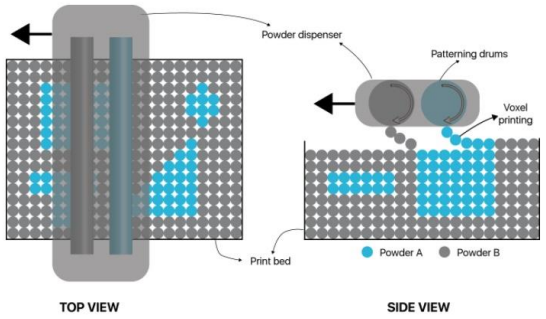


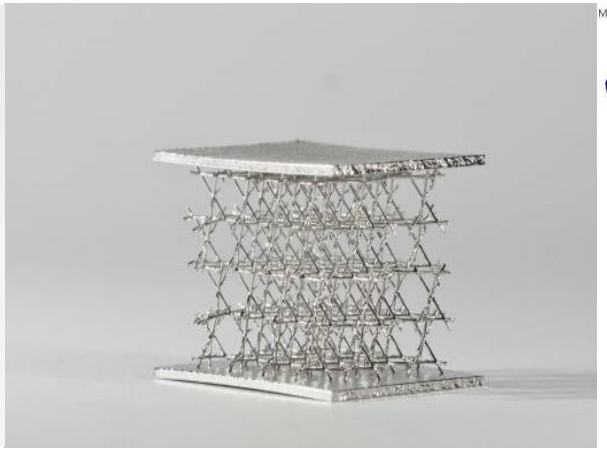
FiSSel project

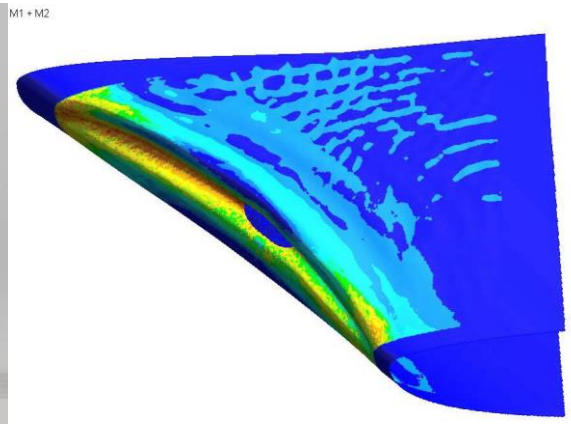
Make surface finishing of additive manufactured parts easier and more efficient

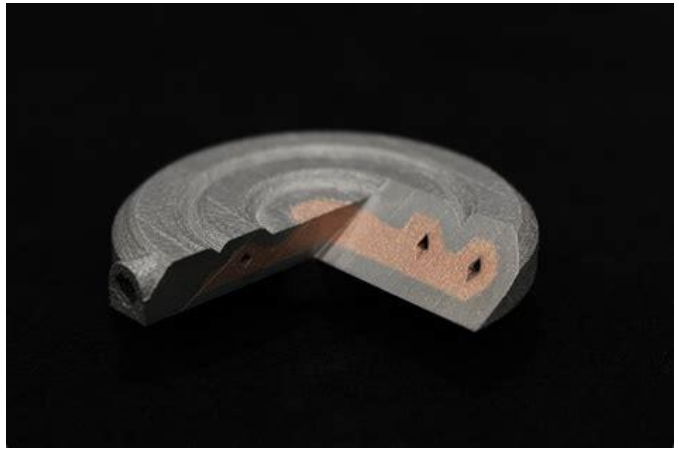
Special attention to:

- Self-limiting processes of **support structures**
- **Local** surface finishing
- **Multi-materials** finishing
- Development of **predictive tools** (simulations)









Multi-material printing

Thermal conductivity (heat exchangers, conformal cooling channels...)

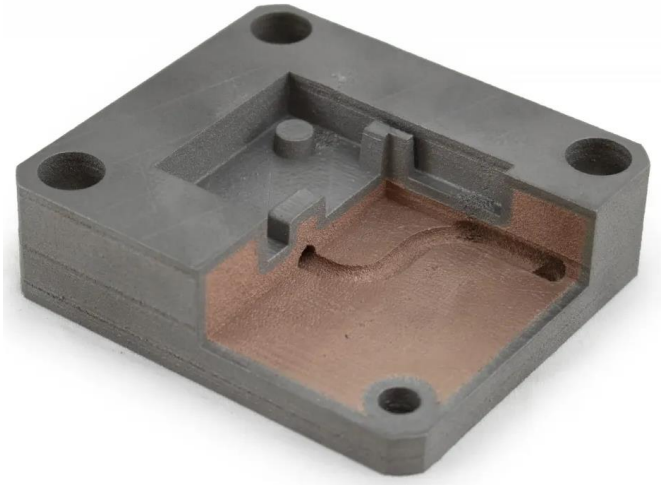
Electrical conductivity (battery connectors, satellite power transfer)

Resistance (wear, abrasion, corrosion)

Magnetic performance (motors, actuators)

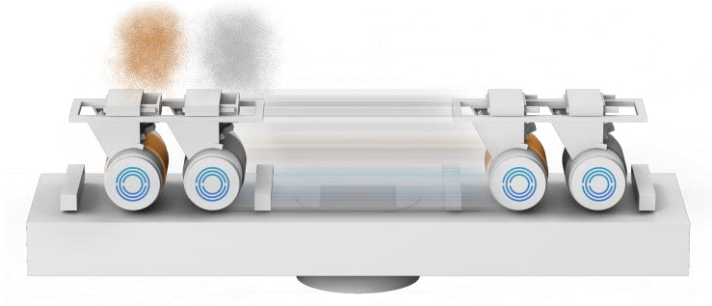
Aesthetic (luxury applications, sports accessories...)

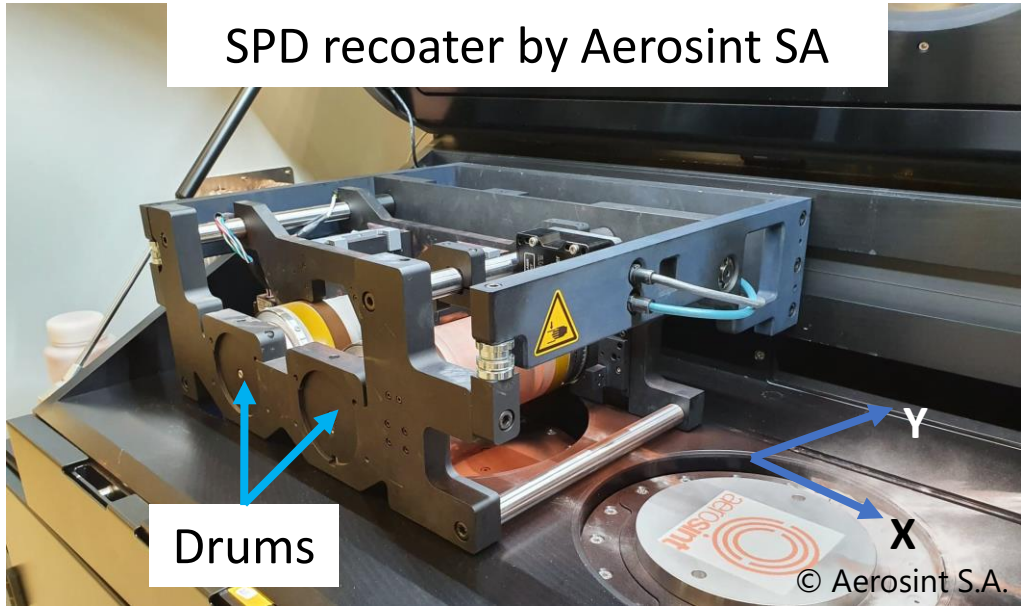
...



Manufacturing process: selective powder deposition

I. Selective Powder Deposition

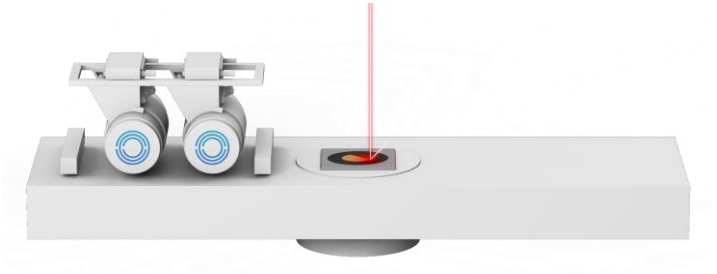




- *Integrated in Aconity MIDI+ and Micro*
- *Pixel size: 0.5 mm (X-Y plane)*
- *Powder bed dimension: Y = max. 96 mm*
- *Recoating speed: 15 mm/s (upgradable)*
- *No. of materials: 2 or 3*
- *Powders: metal, ceramic, (polymer)*

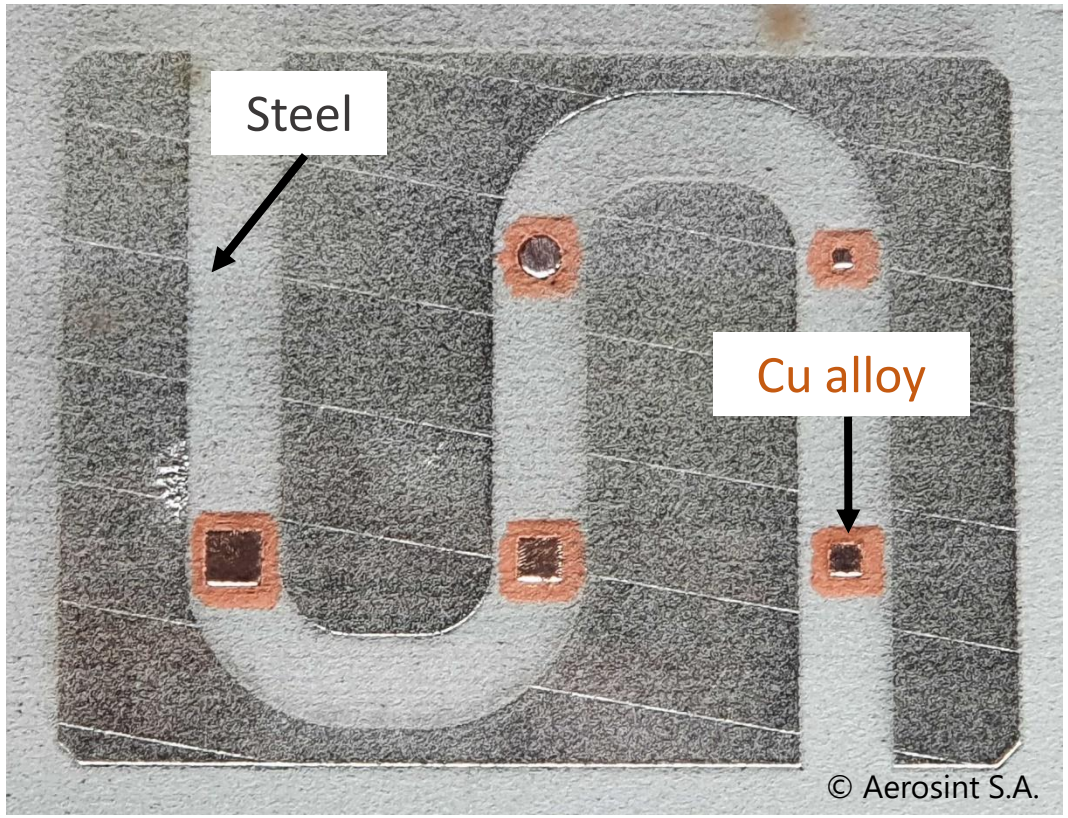
Manufacturing process: selective laser melting

II. Selective Laser Melting



Processing of dissimilar materials

- *Selected materials: Steel & Cu alloy*
- *Simultaneous deposition of two powders*
- *Dual material powder bed*
- *Separately scanned*
- *One set of parameters for each material*



Process video is available on Youtube.

Chemical polishing

Polishing by redox reaction

- Material removed by etching, polishing and coarsening/pitting
- Insoluble product→ complexing agent needed
- Faster dissolution at the surface peaks than in the valleys

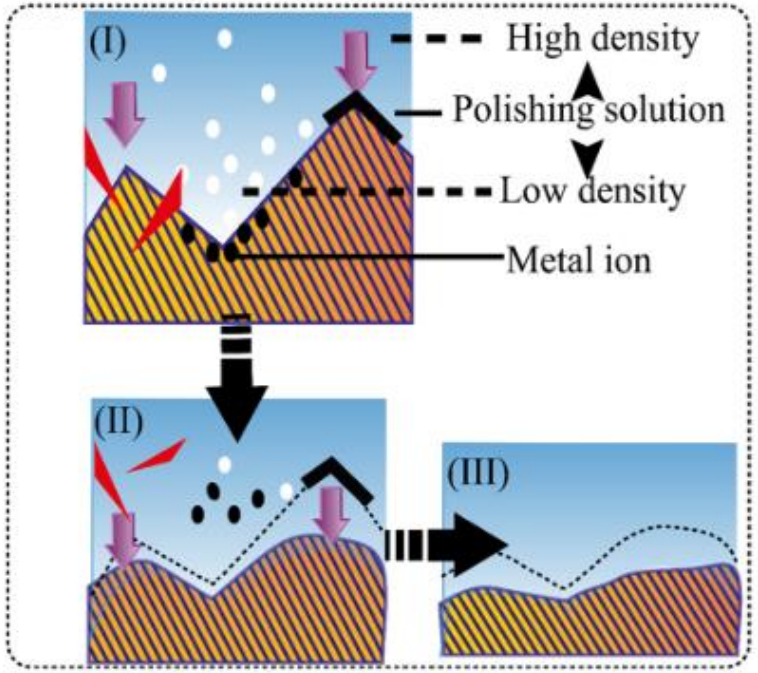
Etching rate → choice of chemicals, immersion time, temperature and viscous layer on the surface

Advantages

- On the entire surface, including internal parts of complex surfaces
- Removal rate is linear → following and prediction

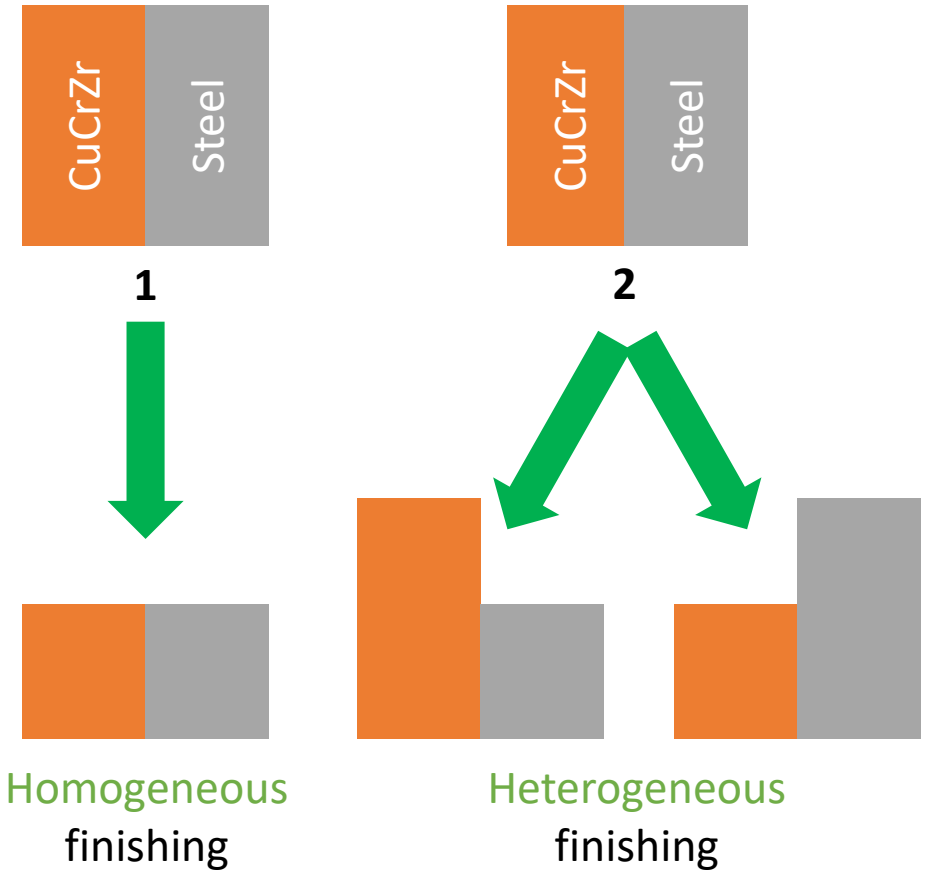
Disadvantages

- Reagents, limit of roughness decrease, homogeneity, operating parameters, flow in hollow surfaces (gas or warm-up) and gas emission



Basha, M. M., et al. *Additi. Manuf.* (2022): 103028.

Multi-material finishing



1: Homogeneous surface finishing → Conditions for homogeneous finish for both materials by mechanical & chemical means

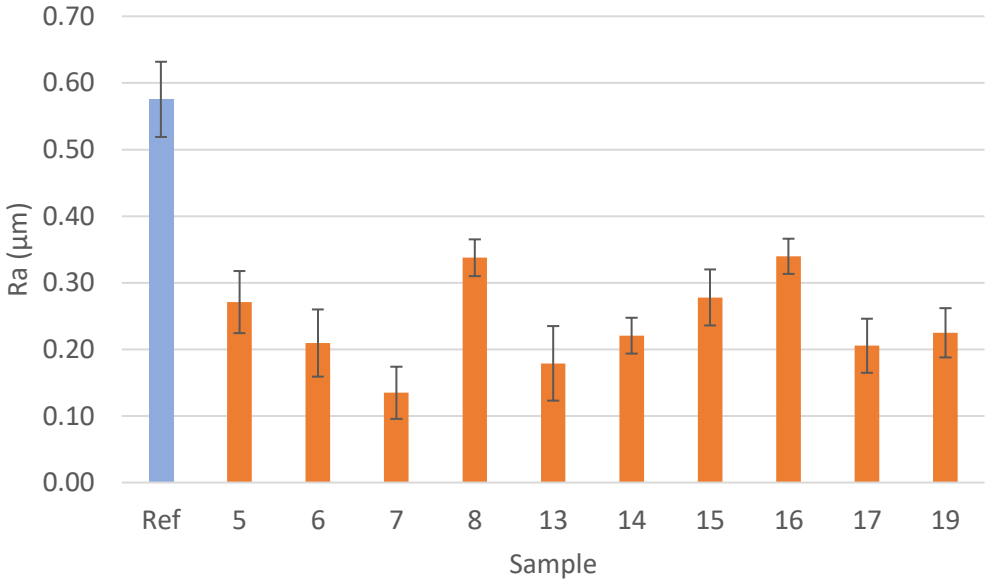
2: Heterogeneous surface finishing → Conditions for selective dissolution of each of the materials with respect to the other by chemical polishing

Strategy: Evaluation of removal rates on each of the materials separately, with different techniques and conditions, investigation of inhibitors and accelerators (depassivating compounds)

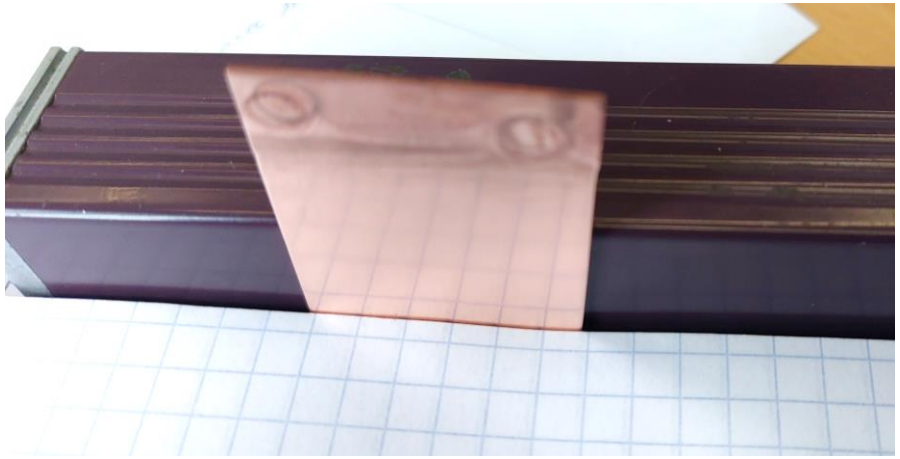
Results

Copper polishing

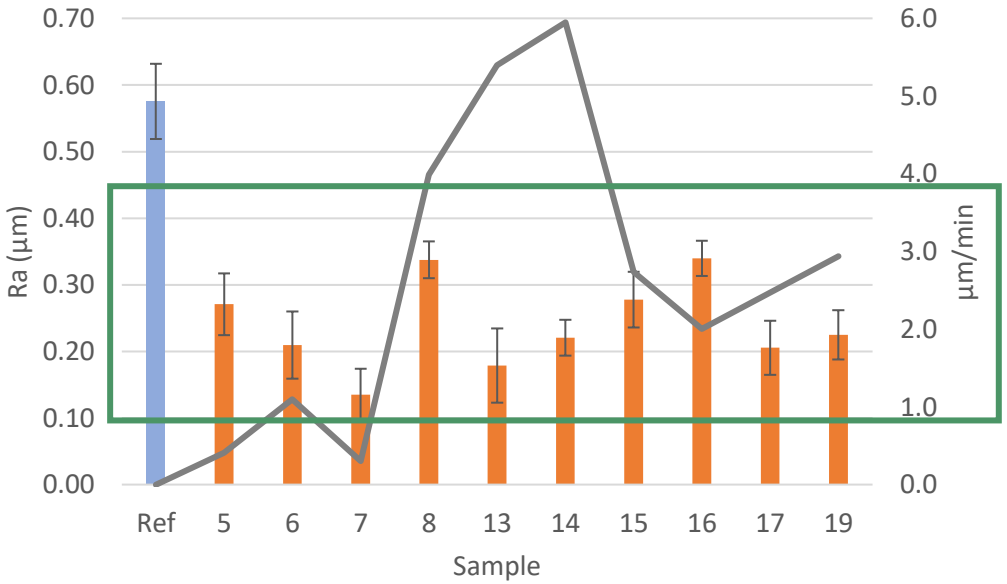
- Polishing trials with baths from the literature
- Brushed copper plates
- Optimization of polishing conditions (temperature, agitation) and bath concentrations



Before polishing



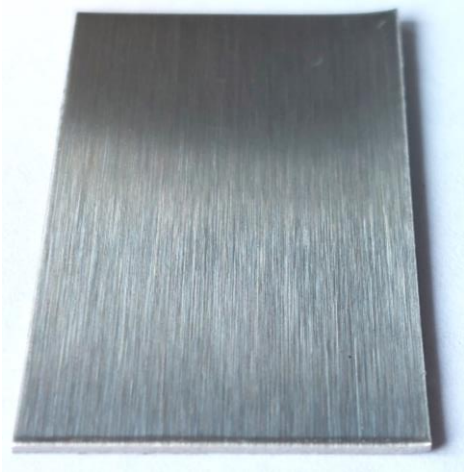
After polishing



Stainless steel polishing

- Polishing trials with baths from the literature
- Brushed stainless steel plates

- Modification of the concentrations (3 components bath)
- Factors: roughness, material removal rate, appearance



Sample before polishing

Bath	A (vol. %)	B (vol.%)	C (vol. %)
1	**10**	5	8
2	**15**	5	8
3	**20**	5	8
4	**30**	5	8
5	15	**1**	8
6	15	**3**	8
7	15	**7**	8
8	15	**10**	8
9	15	5	**1**
10	15	5	**3**
11	15	5	**7**
12	15	5	**10**
13	15	5	**15**

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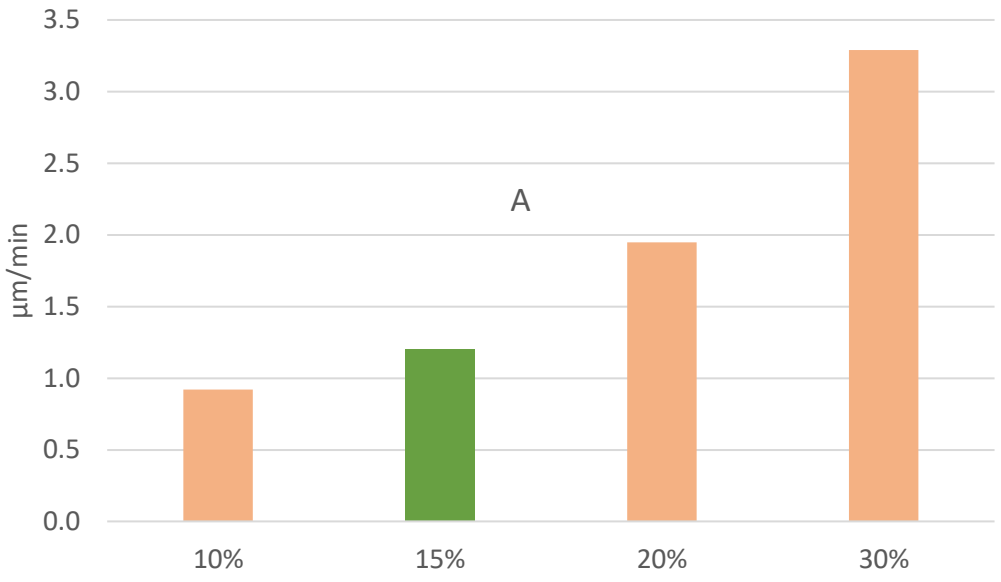
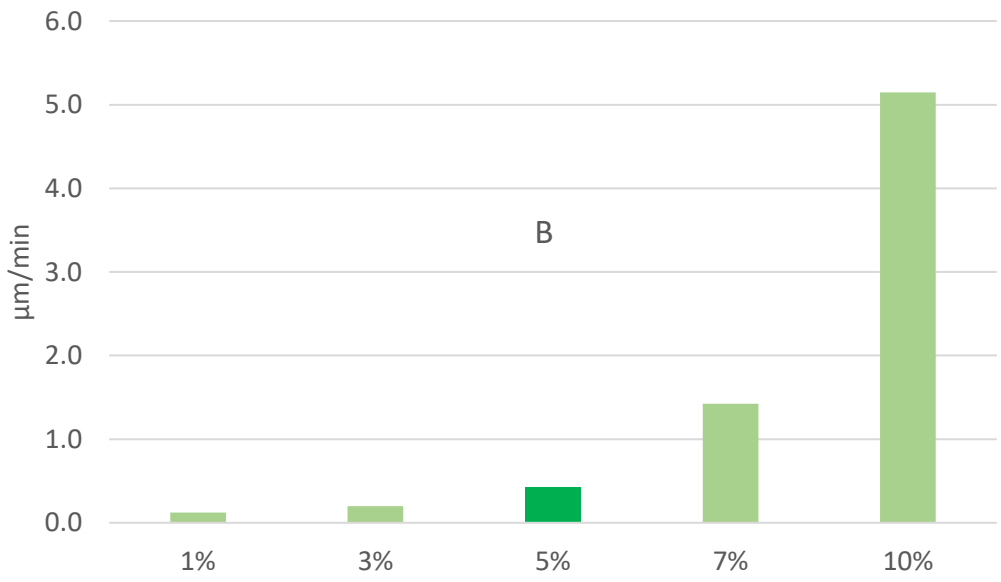
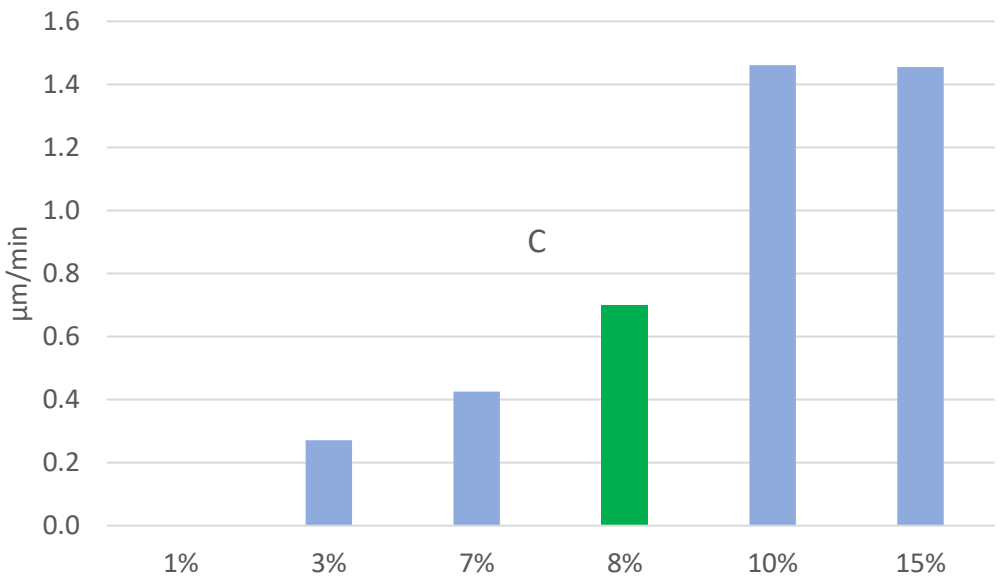
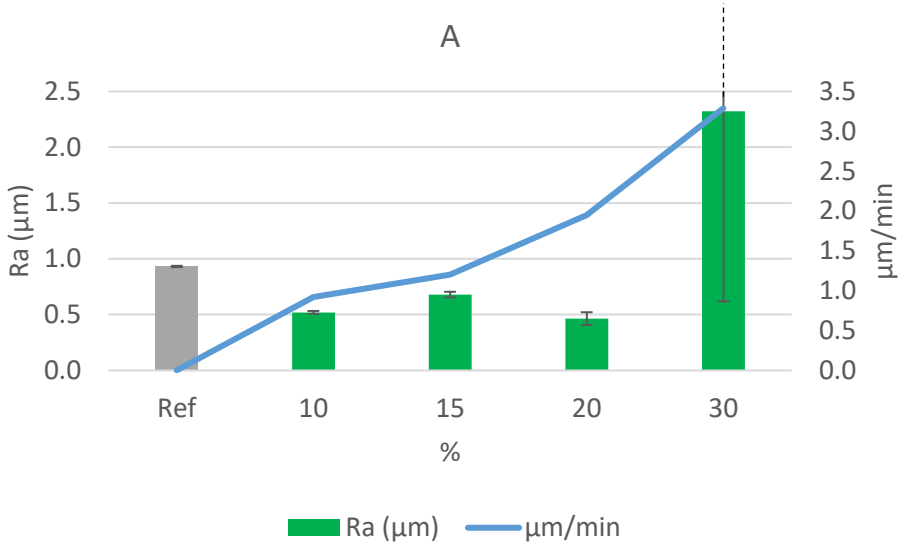






Stainless steel polishing: A compound



Increase in concentration does not affect Ra decrease

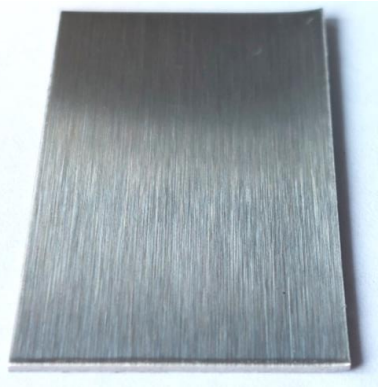
Higher concentrations lead to higher removal rate

- Weak etching

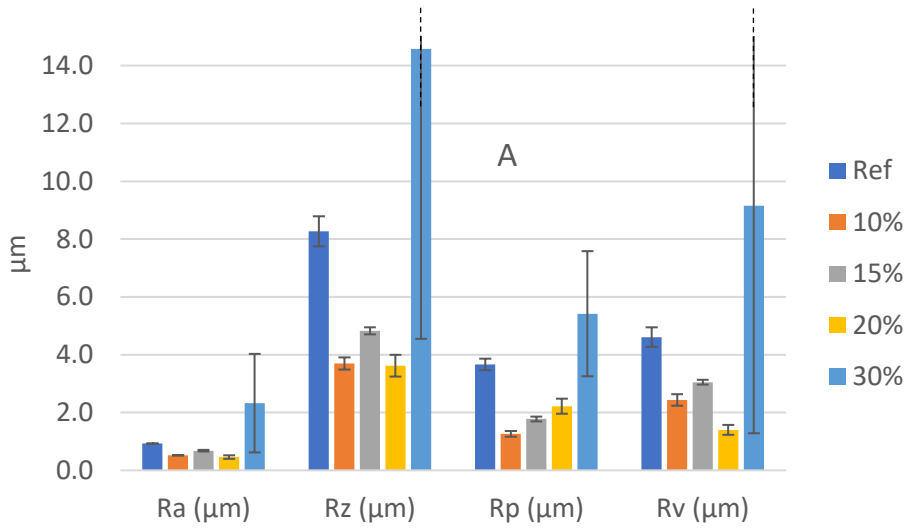
Shiny samples from 10 – 20 %

At 30 vol. %, sample is dull/matt and pitted → Ra ↗

- Change of viscosity



Stainless steel polishing: A compound

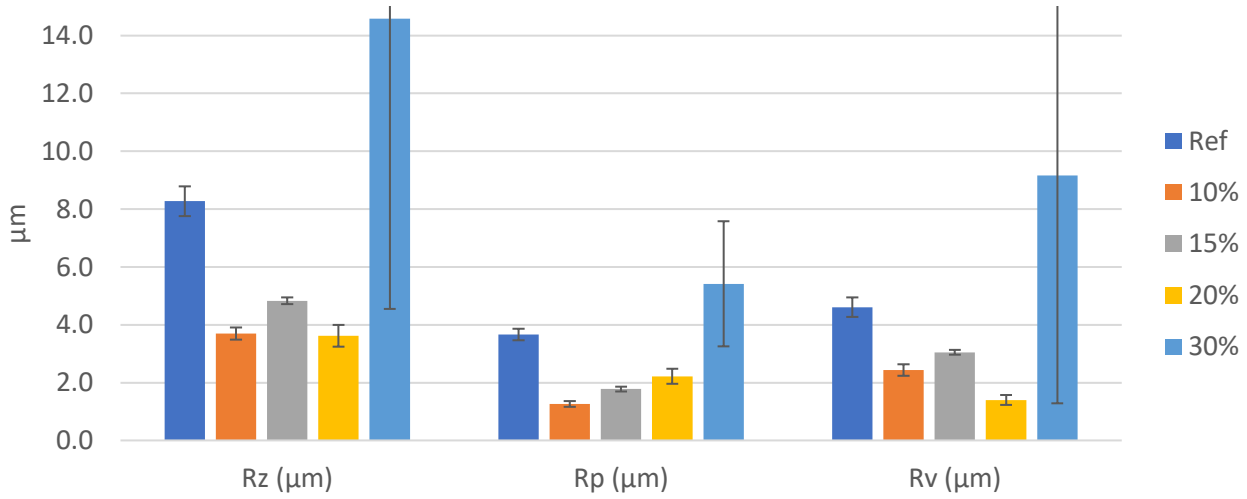


Rp ↗ with increasing concentration

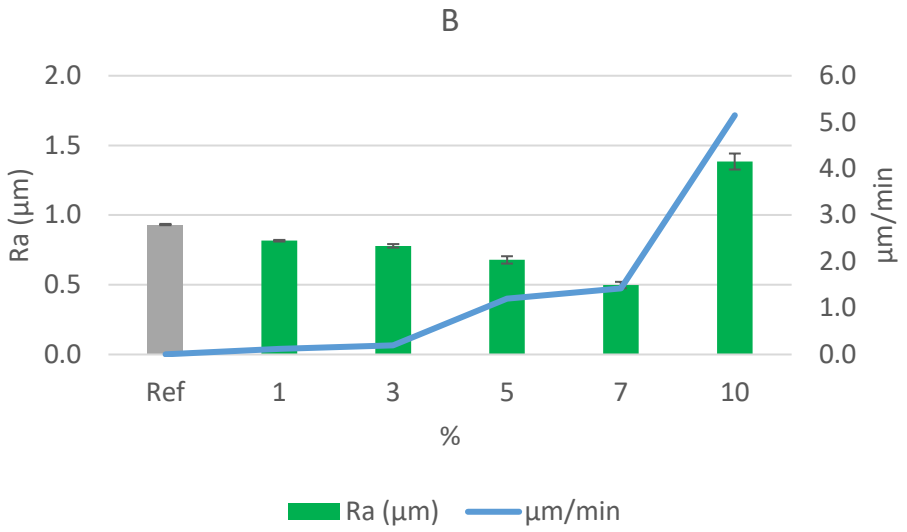
- Thicker viscous layer

Rv is affected to a lesser extend

Pitting of the 30 % sample causes the parameters to rise significantly



Stainless steel polishing: B compound



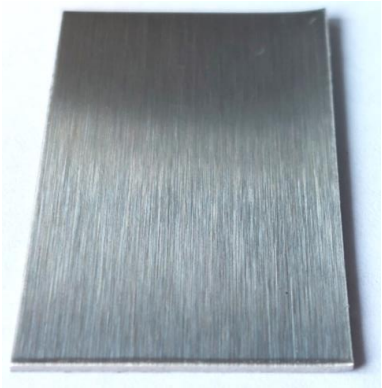
Correlation between Ra and removal rate for 1 – 7 %

- Higher concentrations lead to higher removal rates and lower Ra
- Both etching and polishing effect

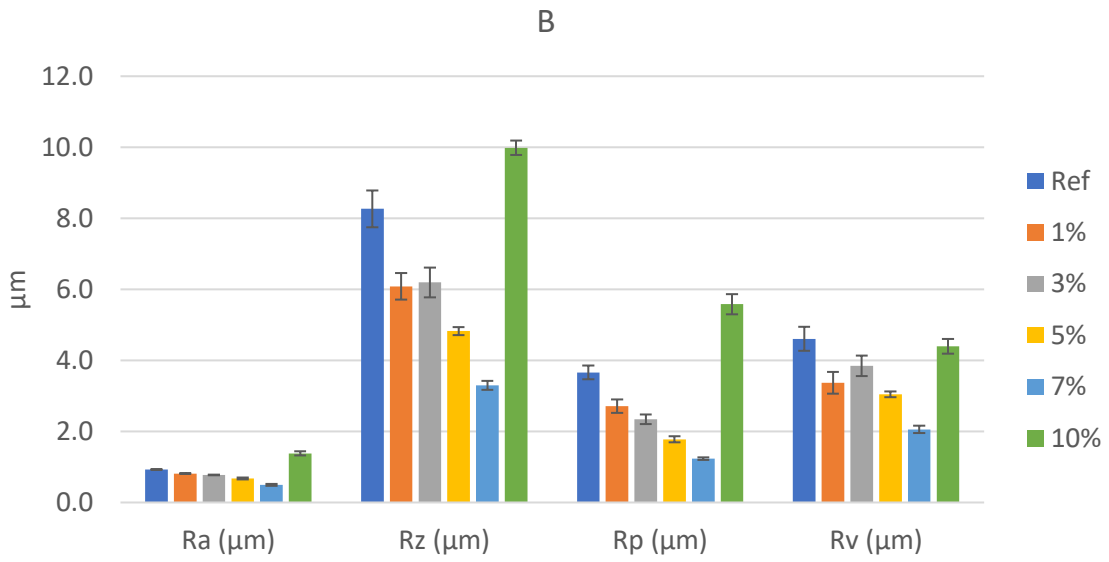
Shiny samples from 1 to 7 %

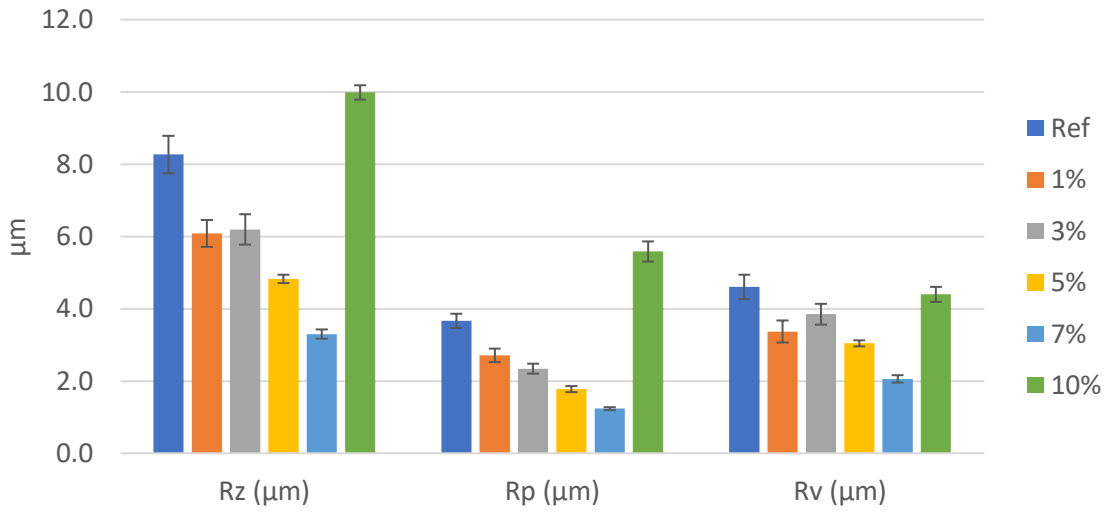
At high concentrations, bright etching until pitting

At 10 %, the sample is dull/matte with pitting



Stainless steel polishing: B compound





Below 5 %, material removal rate is low

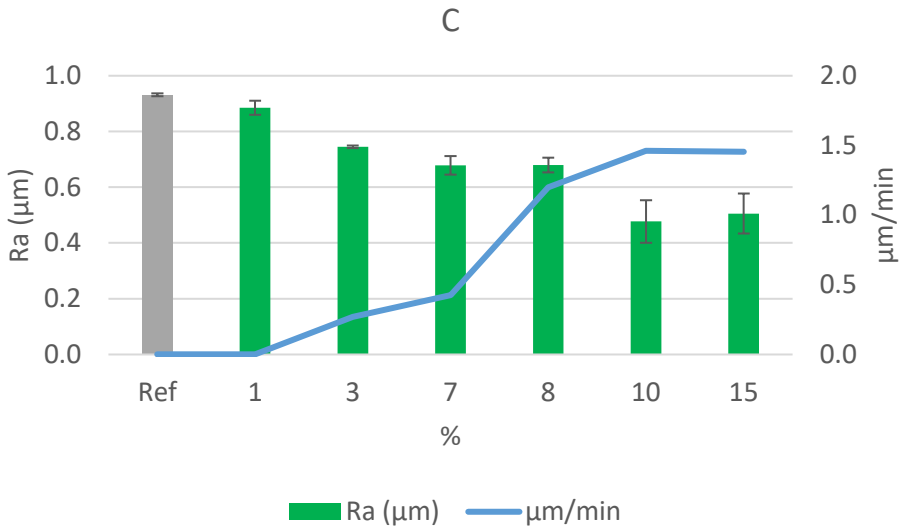
- Decrease of Rp → preferential dissolution at the peaks → increase of shininess
- Rv similar for 1, 3 and 5 %

Similar material removal rate for 5 and 7 %

- At 7 %, decrease of Ra, Rp and Rv

Pitting at 10 % leads to a rough surface with higher Ra and Rp than for the reference

Stainless steel polishing: C compound

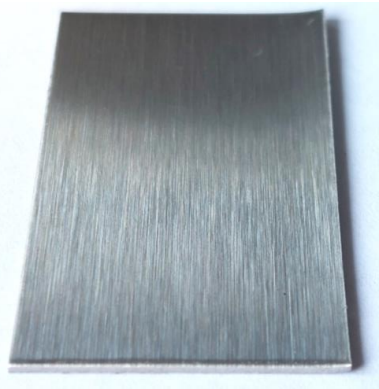


Slight decrease of Ra with increasing concentration

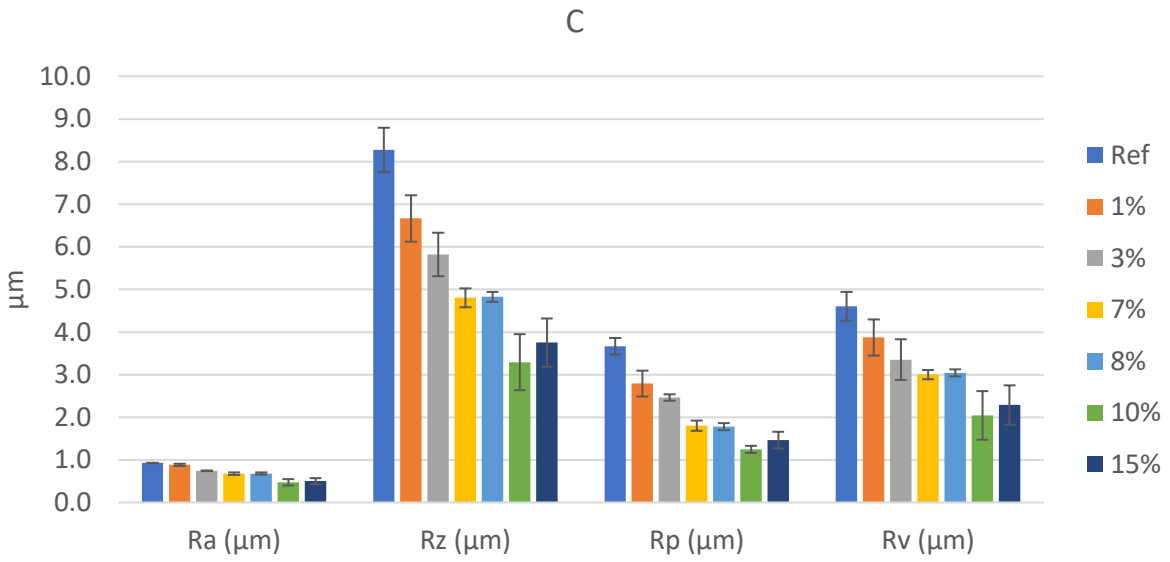
> 7 % to have significant material removal rate

Shiny samples for all concentrations

Bright etching due to adsorption on surface



Stainless steel polishing: C compound



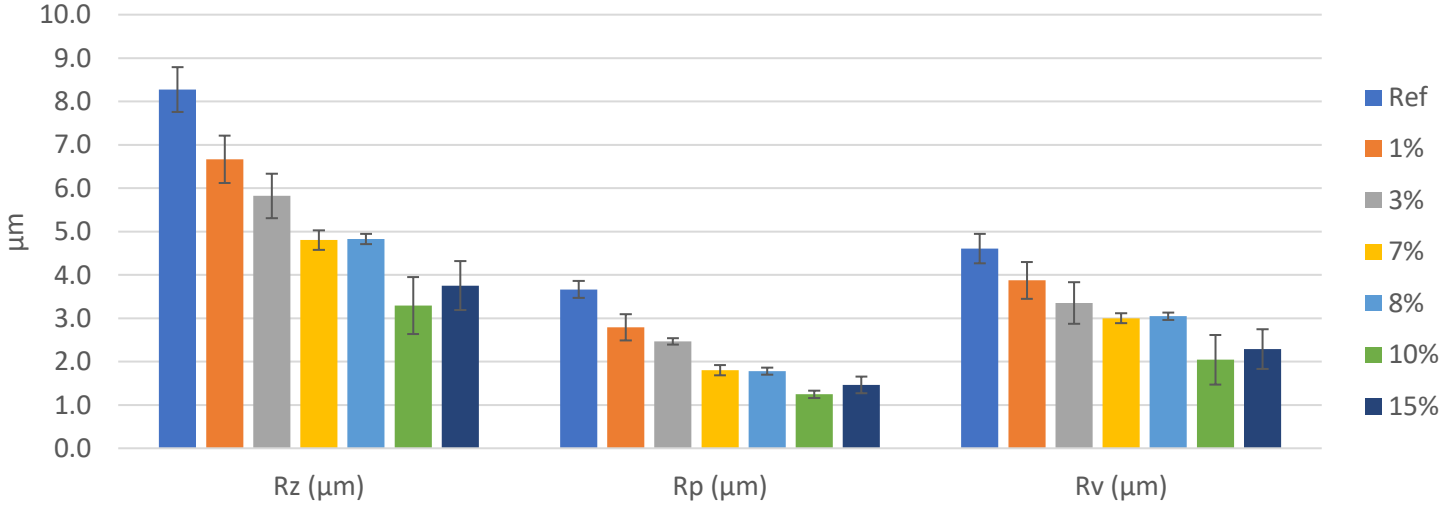
Low material removal rates below 8 % (< 0.5 µm/min)

- Slight decrease of Rz, Rp and Rv

Same removal rate for 10 and 15 %

- Similar Ra, Rp and Rv

Further increase in concentration does not improve etching/polishing



Additive manufactured parts

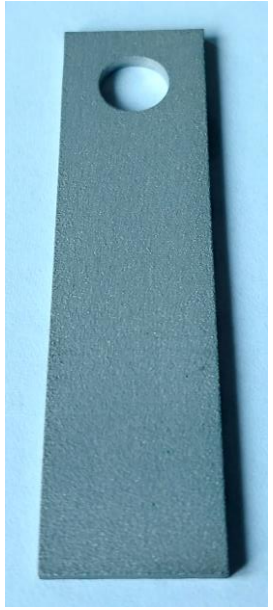
CuCrZr alloy

27.2 ± 1.3 µm Ra

Chemical polishing

8.1 ± 0.4 µm Ra

316 stainless steel



6.3 ± 0.1 µm Ra

Chemical polishing

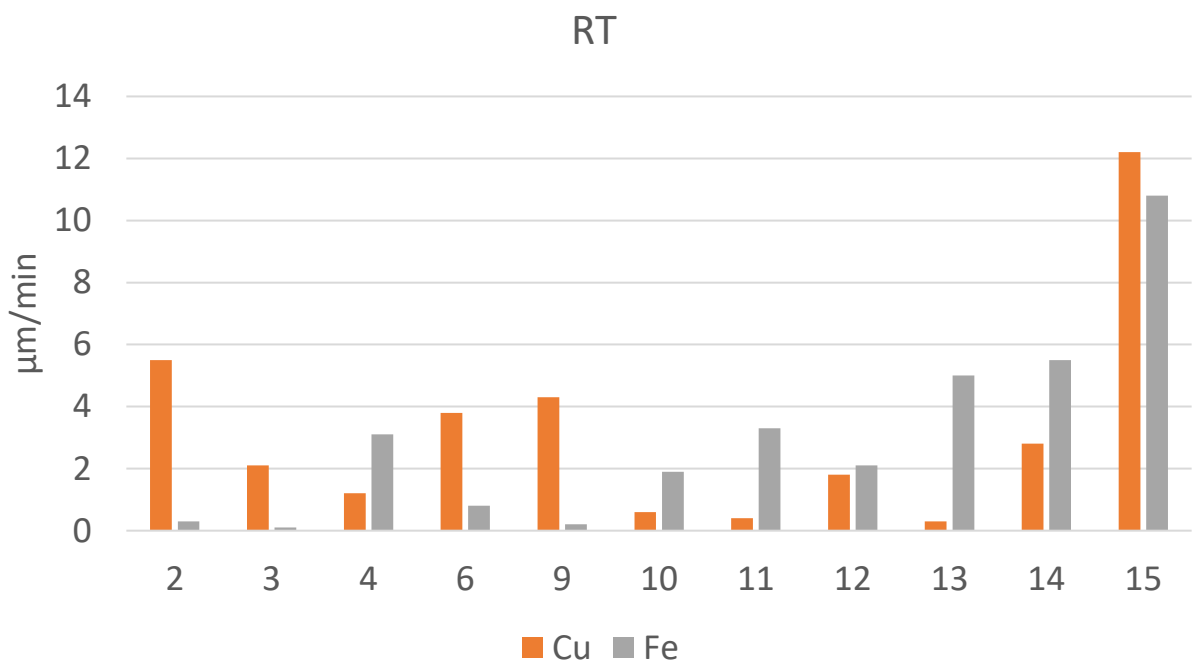
3.1 ± 0.3 µm Ra

Multi-material polishing

Multi-material polishing

Identified polishing solution for each components

- Trials on Cu with polishing baths for steel
- Trials on steel with polishing bath for Cu
- **Optimization** (temperature, agitation, concentrations)

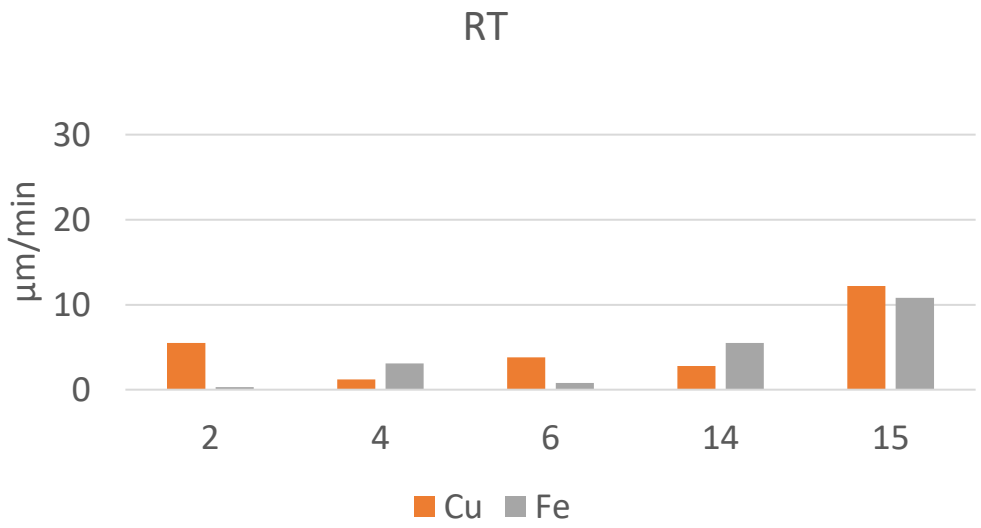


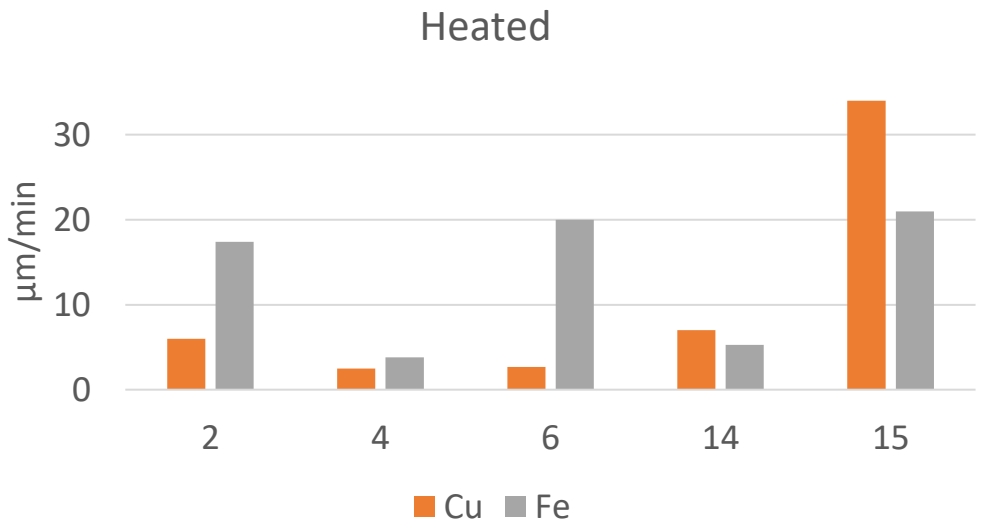
Solutions for heterogeneous polishing

- Cu dissolved, Fe unaffected (2, 3, 9)
- Fe dissolved, Cu less attacked (11, 13)

Solutions for homogeneous polishing (~ 14, 15)

Multi-material polishing

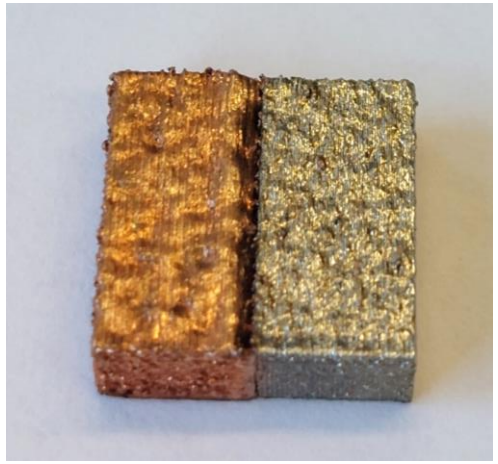




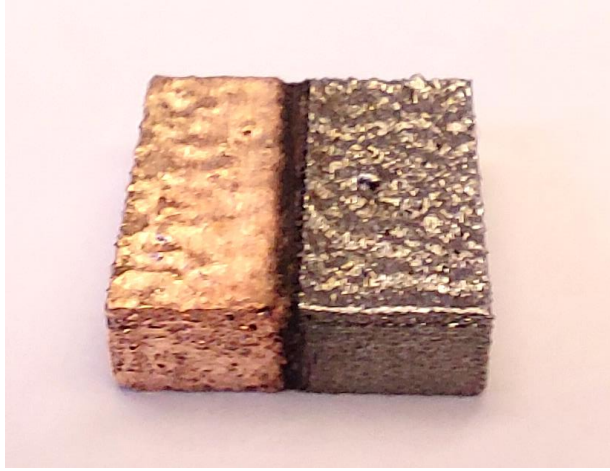
- When heated, some solutions have opposite trends (2, 6)
- Heating the solutions can lead to better homogeneous polishing (4)

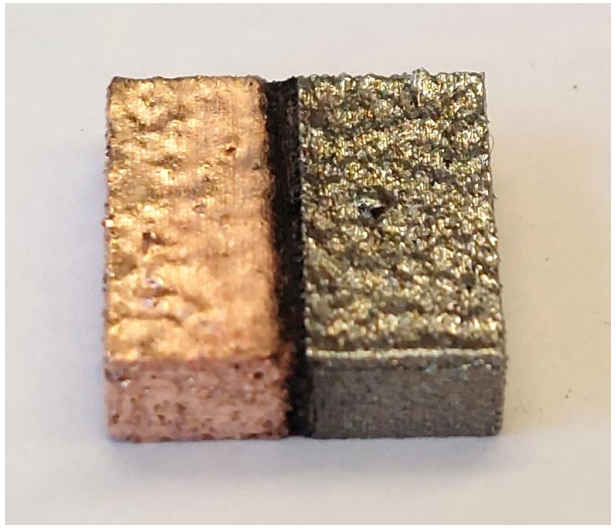
Multi-material polishing

CuCrZr – 316 stainless steel



Chemical polishing





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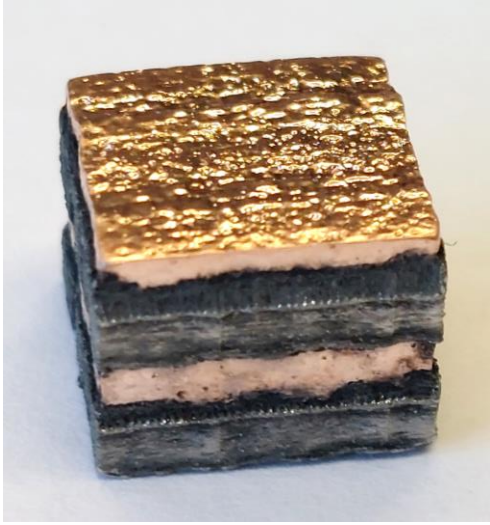
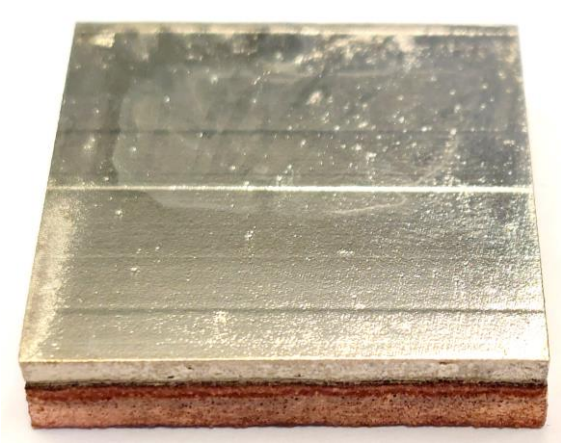


Multi-material polishing

CuCrZr – maraging steel



Perspectives

- Compare bath performances to commercial baths
- Trials on representative multi-material part
- Inhibitors/depassivating agents to have 100 % selectivity

Thank you for your attention

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