SCALE UP OF ELECTROPOLISHING PROCESS FOR TITANIUM PARTS PRODUCED BY ADDITIVE MANUFACTURING

01/12/2022 - Colmar

CONFIDENTIAL CONTENT

Journées Traitements et parachèvements de pièces issues de fabrication additive (A3TS & Association française du titane)

Martin MARCELET / Salomé PARRIAUX

IRT M2P
Institut de Recherche Technologique
Matériaux Métallurgie et Procédés

Institut UTINAM

Context

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Institut de Recherche Technologique
Matériaux Métallurgie et Procédés

CONTEXT

NEMO : **NE**xt al**M** finishing pr**O**cesses

Goals

- Development and increase in maturity of different finishing processes for parts resulting from additive manufacturing.
- Treatment of technological samples (TRL4) and demonstrators (TRL6).
- Industrial transfer of finishing processes.

Duration & Budget

- 01/01/2022 – 31/12/2025 (4 years)
- 4 973 k€ (of which 55% are industrial)

Consortium

- 21 industrials & 3 academic laboratories

Donneurs d'ordres

AIRBUS, SAFRAN, LIEBHERR, Collins Aerospace, stryker, NAVAL GROUP, arianeGROUP

Fabricants de pièces ALM

lisi AEROSPACE, we are, VOLUM-e 3DComplexProduction, AddUp

Applicateurs TS

auchlin, CHROME DUR INDUSTRIEL, Satys surface treatment, GIT Galvanoplastie Industrielle Toulousaine, MINITUBES

Porteurs technologiques

ABC SwissTech, MICRONX Fabricant d'Energie Positive, INEOSURF, Be2Sim, temisth

Laboratoires académiques

Institut UTINAM, CENTRALELYON ENISE, CENTRALE NANTES

Work Packages

- Influence of the manufacturing conditions of ALM parts
- Finalization of the R&D work resulting from After ALM*
- Exploration of innovative technologies **
- Help in dimensioning
- Finishing for WAAM parts
- Recycling & ACV
- Transversal work

Link to A3TS presentations

*Maturation and industrialization of the chemical polishing process for base, Ti, Al, Ni or Fe alloys (J. Frayret; L. Exbrayat; J. Rolet).

*Electrolytic plasma polishing: developments for the finishing of metallic additive manufacturing parts (S. Parriaux; L. Exbrayat).

*Scale-up of an electro-polishing process for titanium alloy parts from additive manufacturing (S. Parriaux; M. Marcelet).

**New tribofinishing solutions applied to ALM parts (J. Rolet; S. Chagnard).

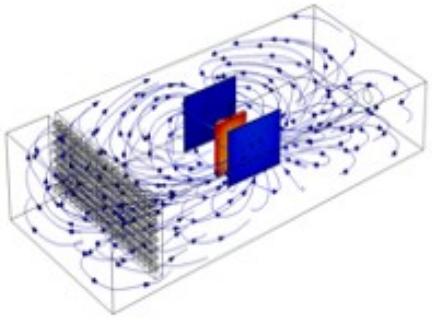
UTINAM boasts several years of experience in electropolishing

Pequignet

MOMEQA **(2014-2018 BPI France)** : innovation in mechanical watch manufacturing. Tasks dedicated to tin alloys and 316L stainless steels after mechanical pre-treatment electropolishing. PhD C. Rotty

Volum-e®

AFTER ALM **(2017-2021 IRT M2P)** : chemical polishing assisted by ultrasound - levelling coatings - electropolishing. PhD E. Drynski, post-docs C. Rotty and F. Roy - 3 part-time engineers

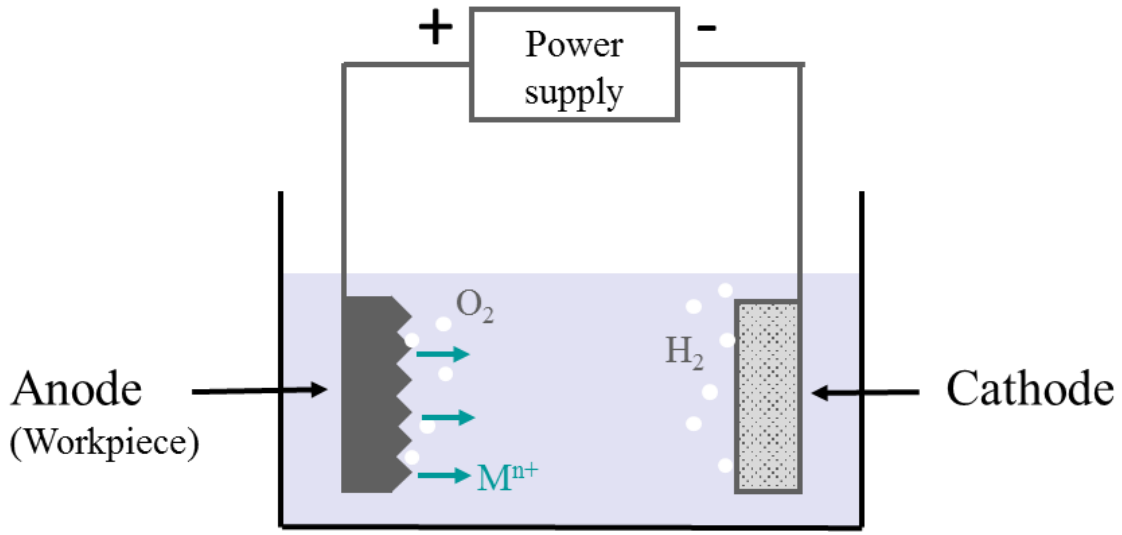


ELECTROPOLISHING SIMULATIONS **(2020-2023)** : ALM parts in stainless steel and inconel. PhD A. Boucher

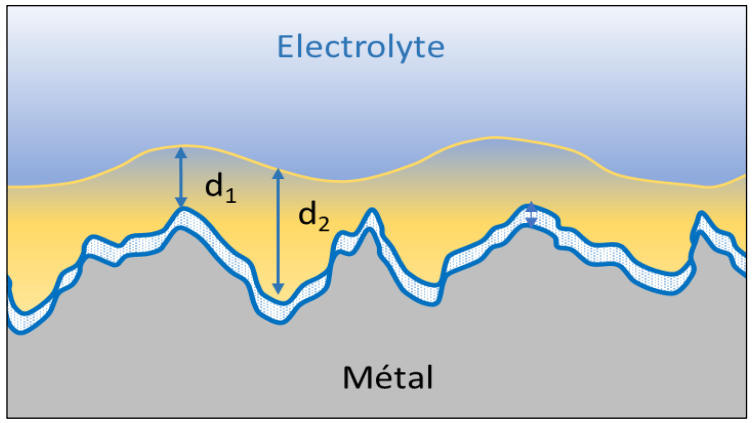
ELECTROPOLISHING OF PRECIOUS METALS **(2021-2024)** : gold and gold alloys. PhD J. Rodriguez

The **electropolishing process** is an electrolytic **ultra-finishing** process widely used in the industry consisting in the :

Controlled anodic dissolution of a metal to reduce roughness and increase brightness



Electropolishing only possible for a **particular material/electrolyte combination**



viscous layer

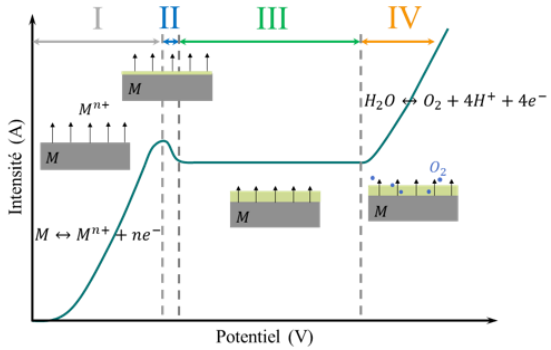
compact film

Formation of a **viscous/passivation layer** induces **preferential dissolution** of peaks over valleys

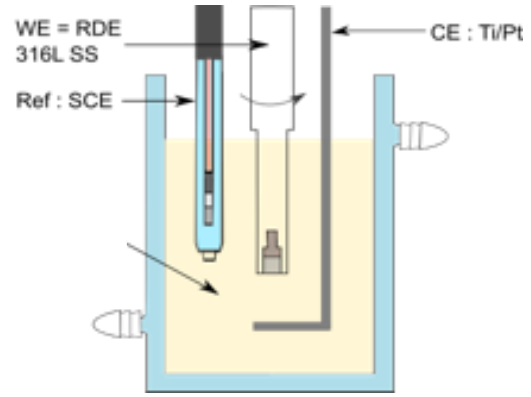
CONTEXT
PREREQUISITE KNOWLEDGE FOR TITAN ELECTROPOLISHING SCALE-UP

Two PhD works (C. Rotty and E. Drinsky) realized on **316L stainless steel** as reference material

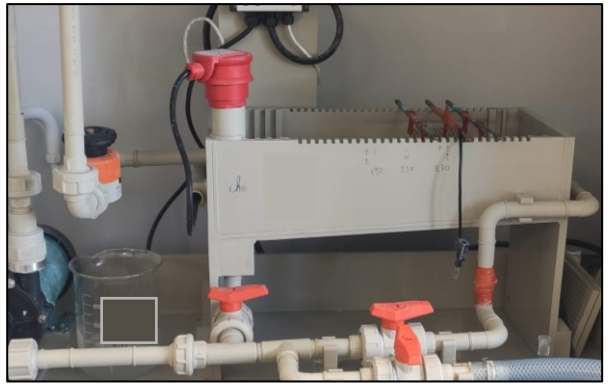
From electrochemical studies to pilot scale electropolishing



Electrochemistry

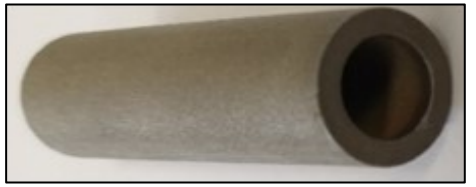


Laboratory scale

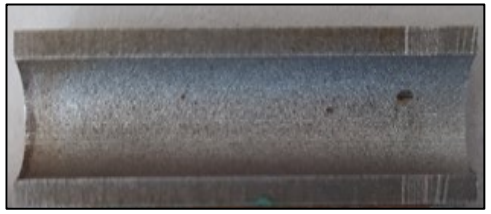


Pilot scale (4 to 15 L)

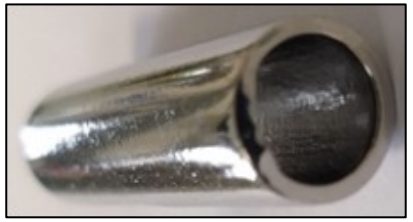
Studies of **pulsed potentials** to improve the preservation of the geometric integrity



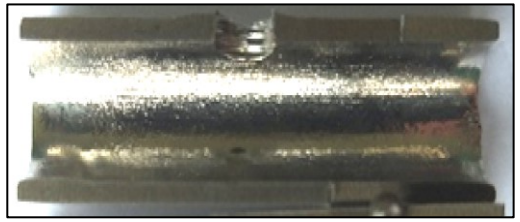
Ra = 8,93 µm



Ra = 8,84 µm



Ra = 0,65 µm



Ra = 1,23 µm

AFTER-ALM project

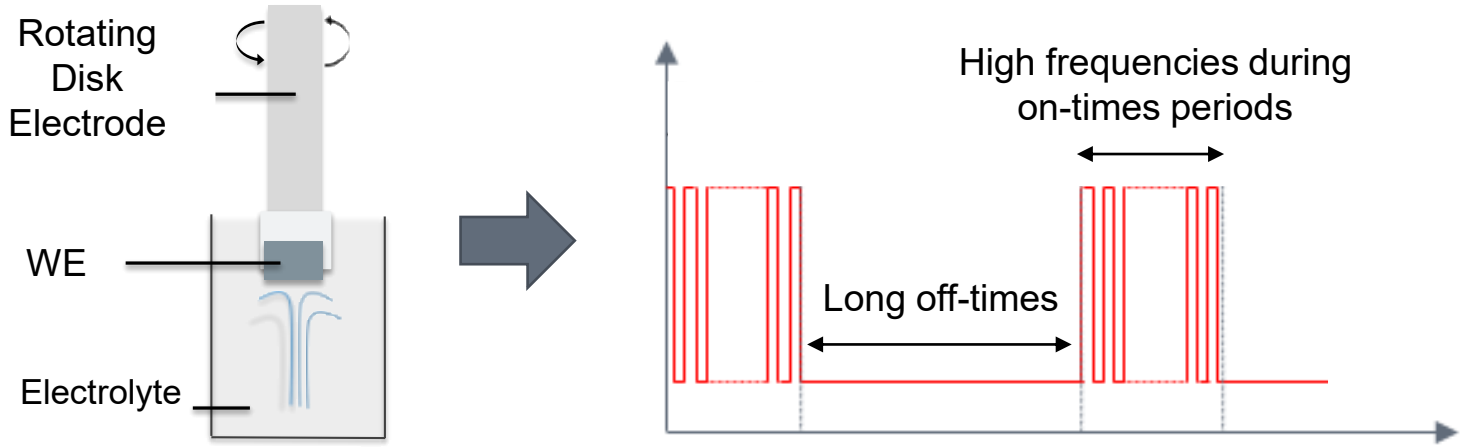
F. Roy **post-doctorate** realized mainly on **TA6V** (also on Inconel, aluminum alloys and 316L stainless steel)

TA6V electropolished plate

Encouraging results making a **scale-up conceivable**

AFTER-ALM project

Work done on RDE allowed to find **complex sequences of pulsed potentials** that were used for scale-up



- **High frequencies** during the pulse sequence reduce the impact on the **geometry**
- **Long off-times** control the thickness of the viscous layer and the **homogeneity**

AFTER-ALM project

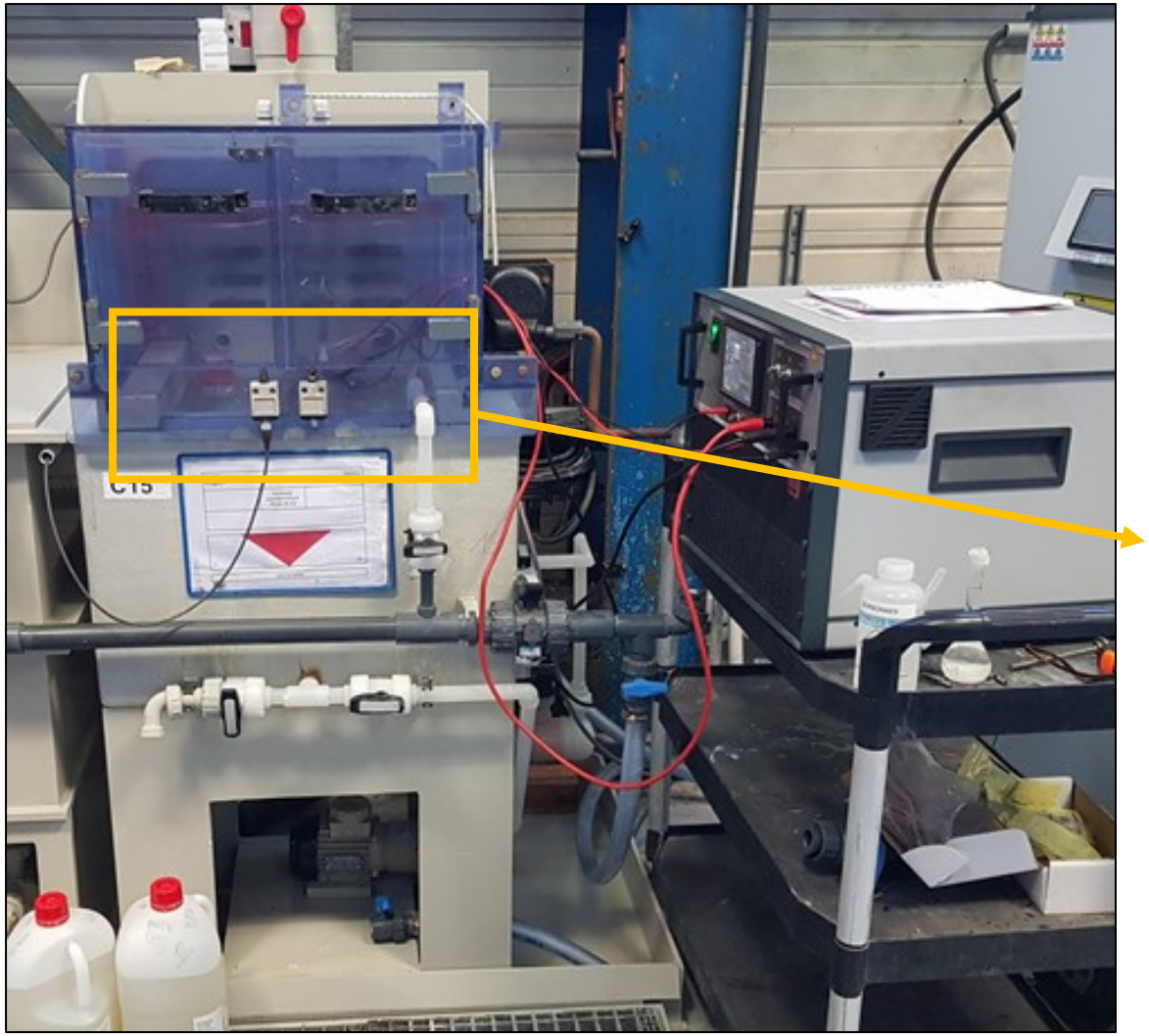
Scale-up of electropolishing process for TA6V parts

Transfer from UTINAM laboratory to IRT facilities

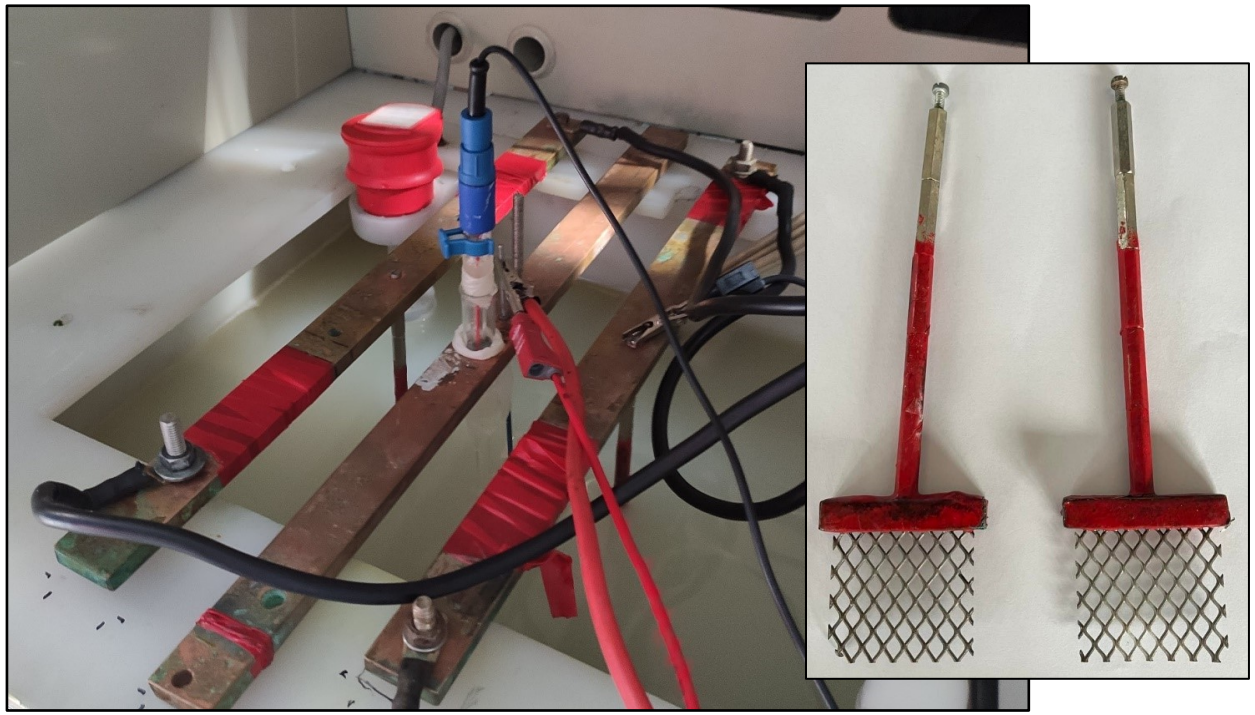
IRT M2P Institut de Recherche Technologique Matériaux Métallurgie et Procédés

SCALE-UP OF ELECTROPOLISHING PROCESS FOR TA6V PARTS

MATERIAL AND METHODS



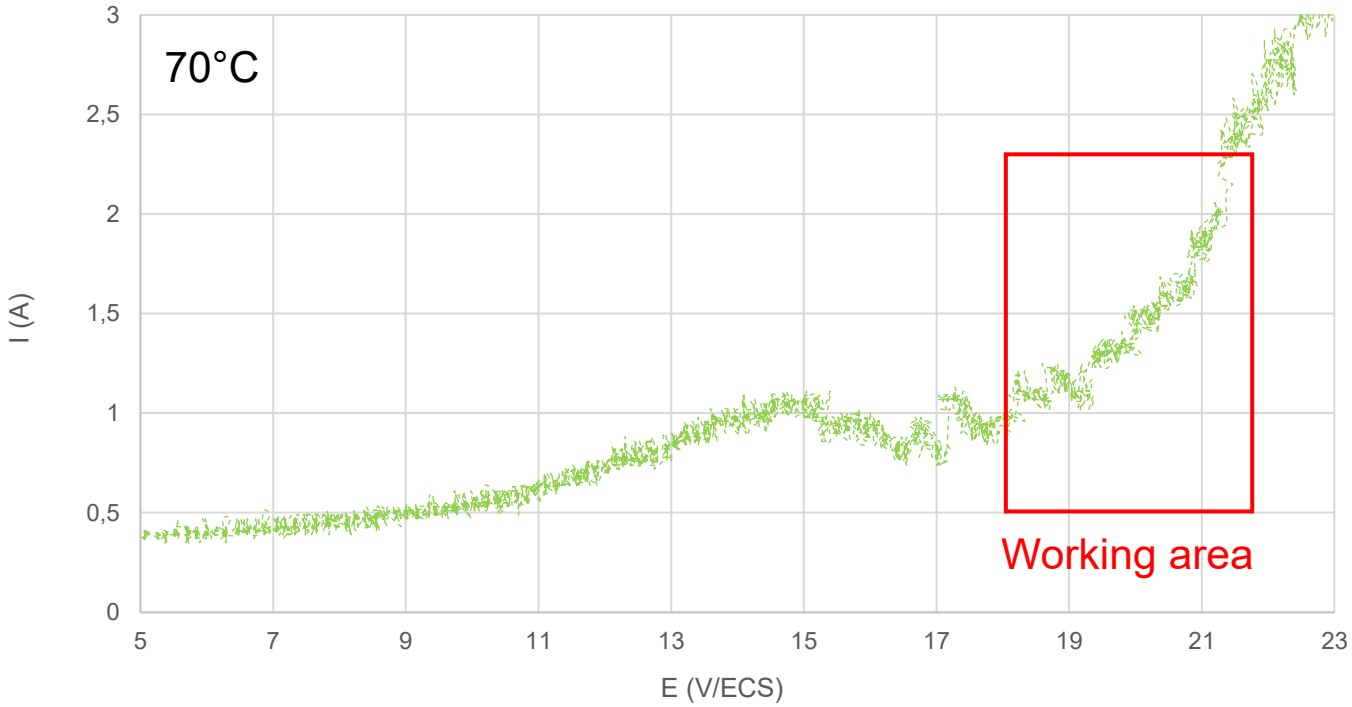
- **Electrolyte :** deep eutectic solvent (DES)
- **Tank** : 65 L
- **Generator** : 60 V / 40 A
- **Reference electrode** : SCE
- **Cathodes** : platinum-plated titanium grids



SCALE-UP OF ELECTROPOLISHING PROCESS FOR TA6V PARTS

ADAPTATION OF ELECTRICAL PARAMETERS TO THE EQUIPMENT USED

First step : draw **intensity-potential curve(s)** to **adapt the electrical parameters** to the change of scale



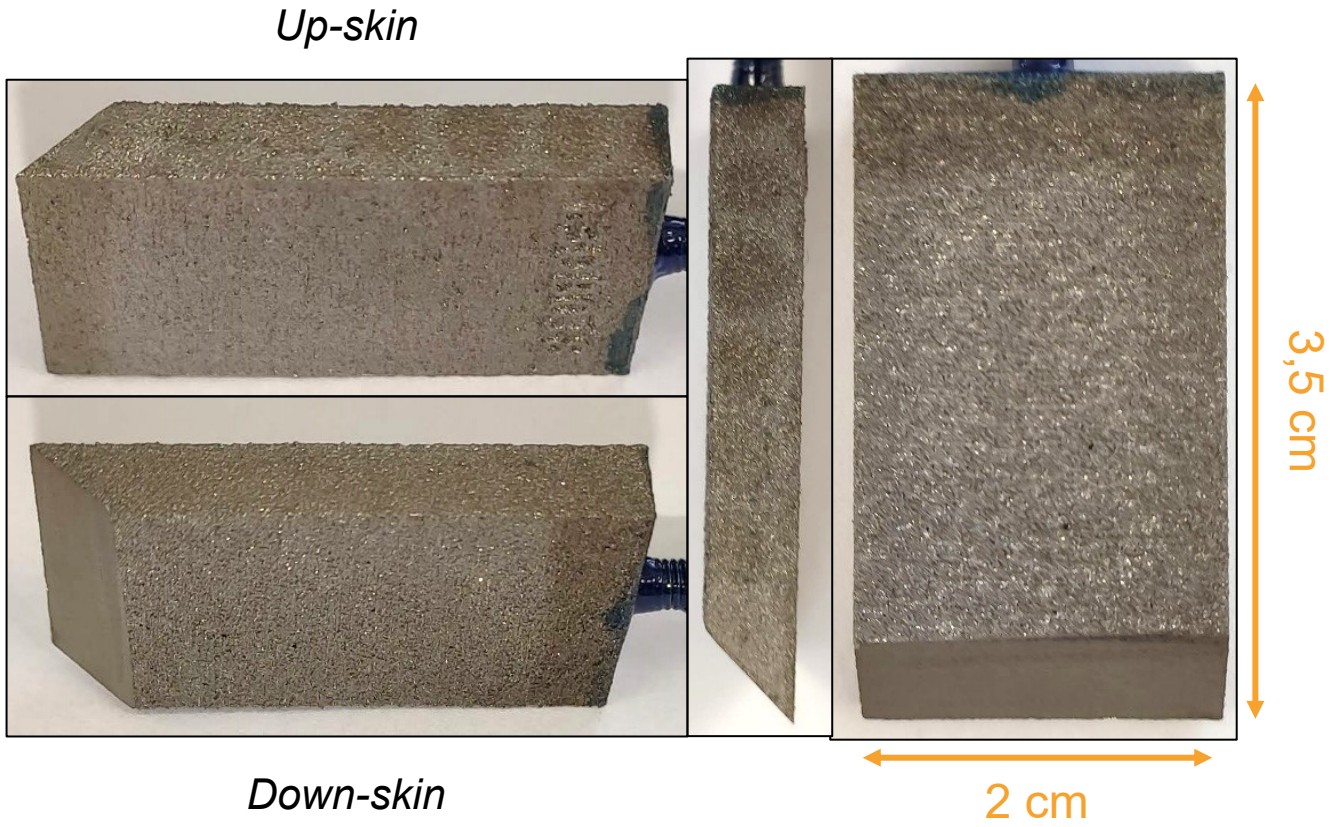
- Provides **optimum electrical parameters** with **minimal testing**
- Curves can be drawn directly on the generator (Micronics)

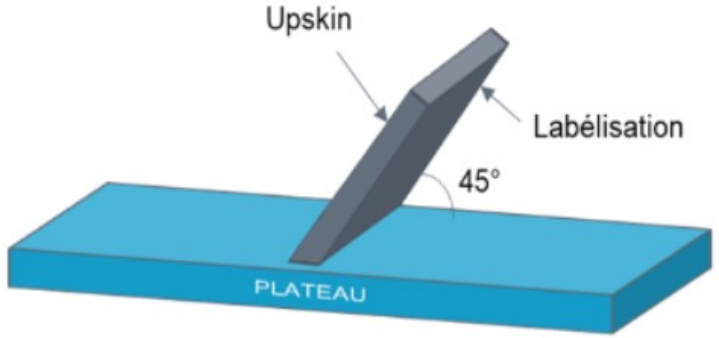
MicronX
Fabricant d'Energie Positive

SCALE-UP OF ELECTROPOLISHING PROCESS FOR TA6V PARTS

PLATES FROM ADDITIVE MANUFACTURING

NEMO shared samples : **TA6V additive manufacturing plates**





- **Up-skin** : Sa = 22,7 ± 4,7 µm
- **Down-skin** : Sa = 49,7 ± 6,8 µm

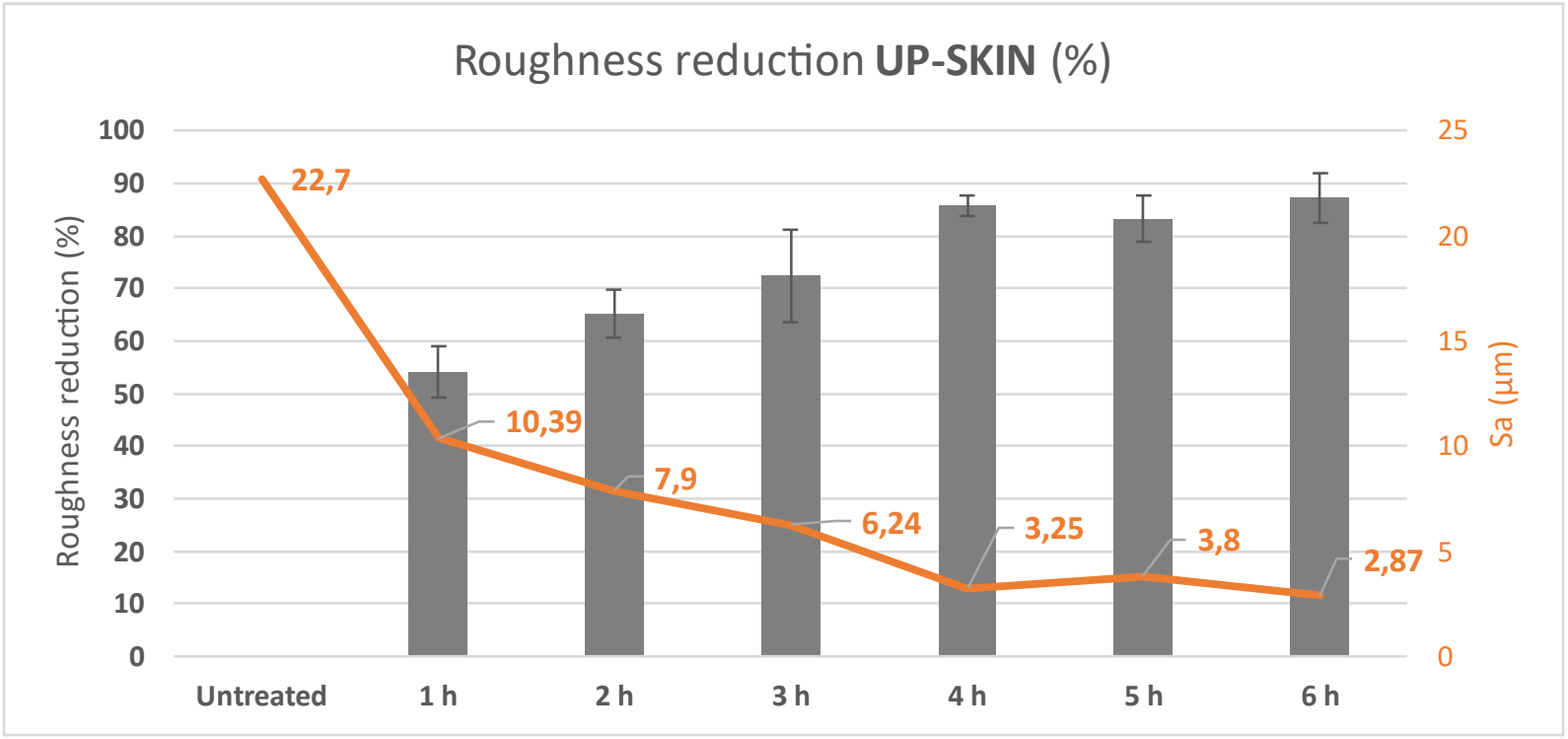
Significant initial **roughness** (worth conditions)

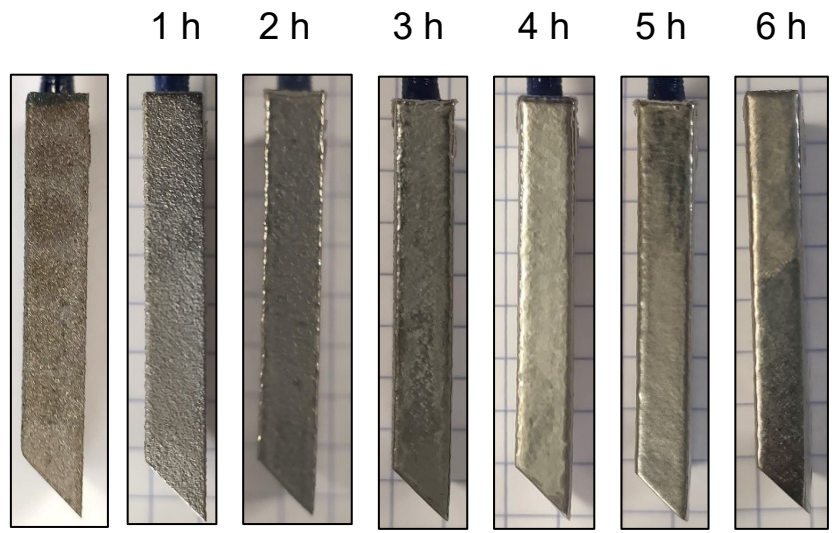
Presence of a **bevel** whose fine end is **sensitive to deformation** due to its sharp edge

SCALE-UP OF ELECTROPOLISHING PROCESS FOR TA6V PARTS

PLATES FROM ADDITIVE MANUFACTURING

Evolution of surface profiles vs treatment duration





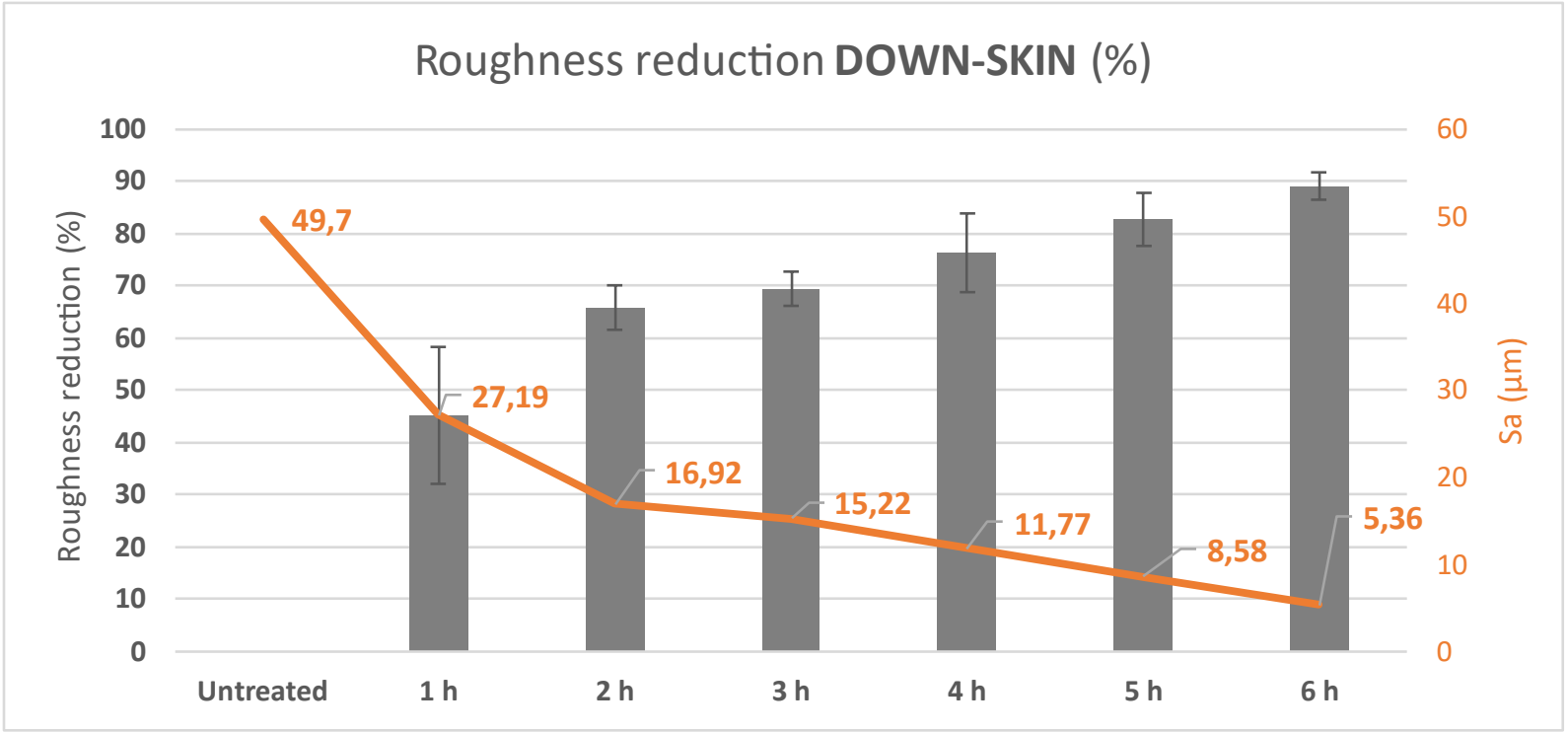
Increasing deformation (still limited)

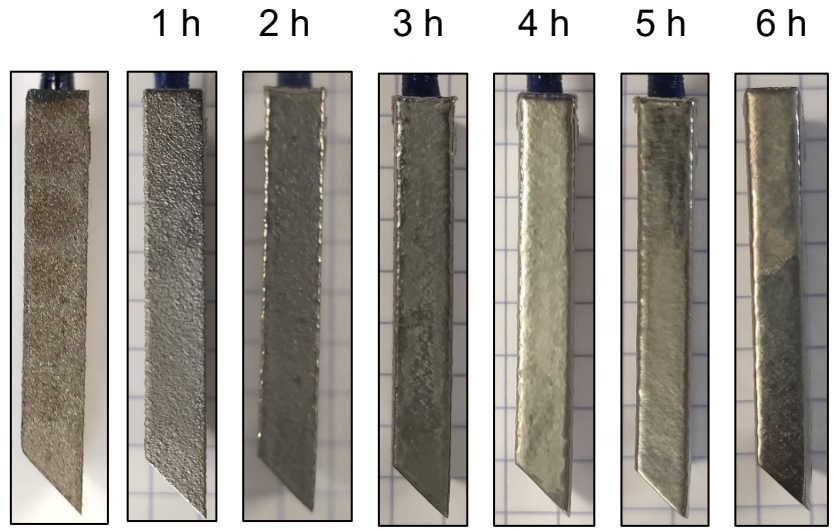
- **Reduction of the roughness slows down after 4 hours** but continues to decrease

SCALE-UP OF ELECTROPOLISHING PROCESS FOR TA6V PARTS

PLATES FROM ADDITIVE MANUFACTURING

Evolution of surface profiles vs treatment duration

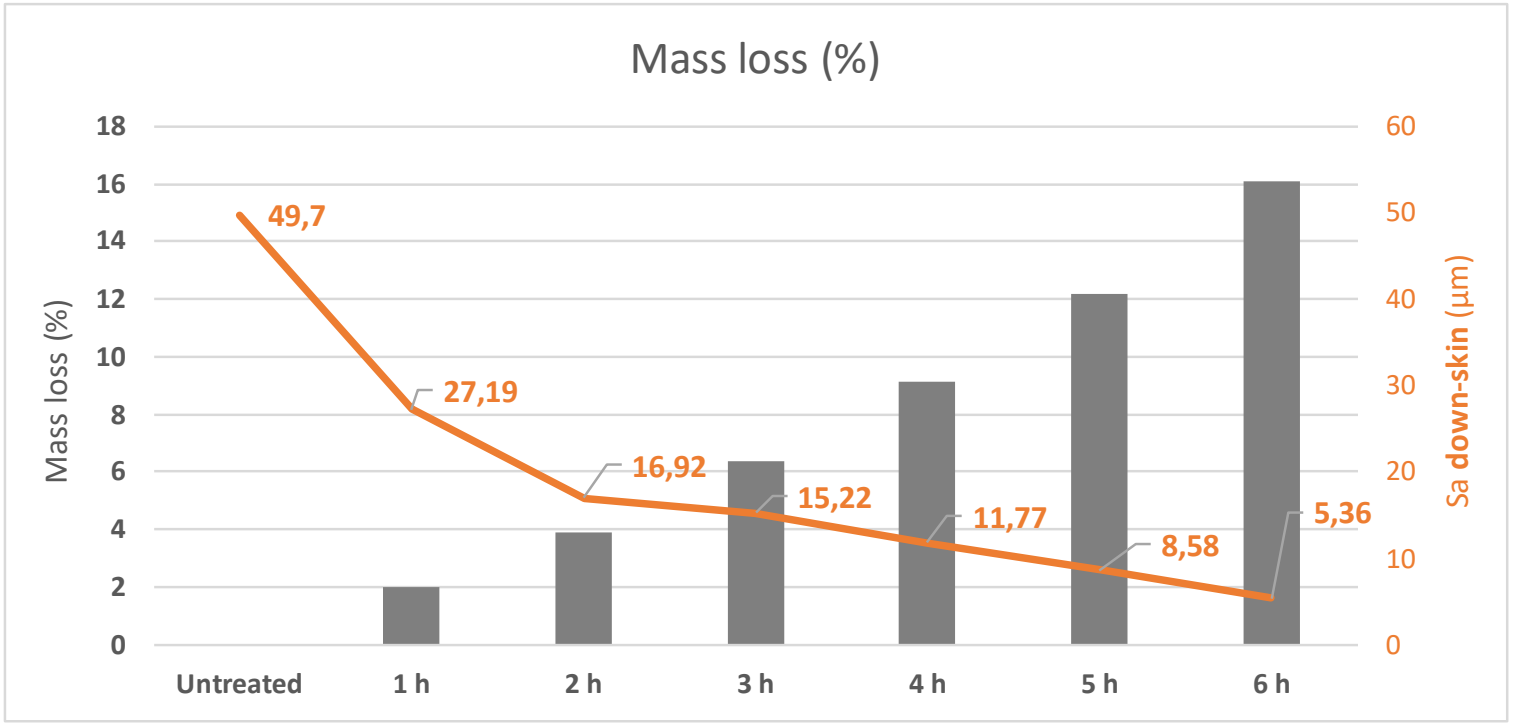


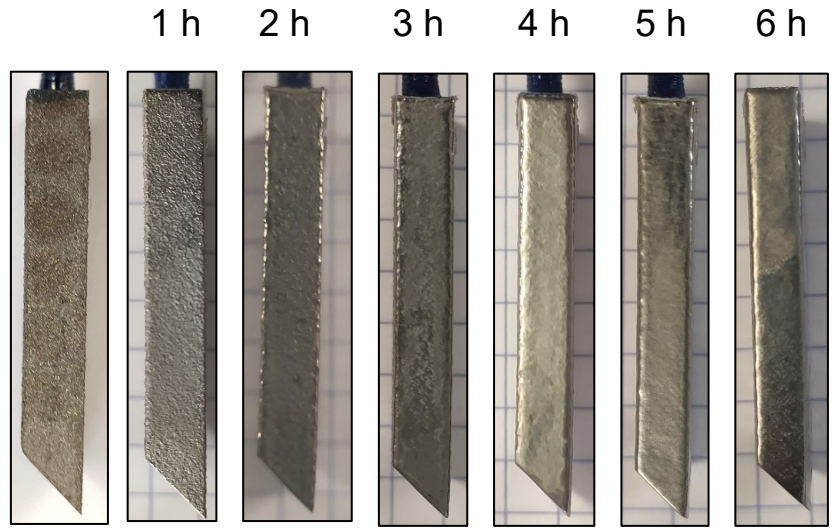


Increasing deformation (still limited)

- **Reduction of the roughness slows down after 4 hours** but continues to decrease
- Roughness reduction (%) remains constant irrespective of the initial roughness (lower initial roughness ➔ lower final values)

Evolution of surface profiles vs treatment duration





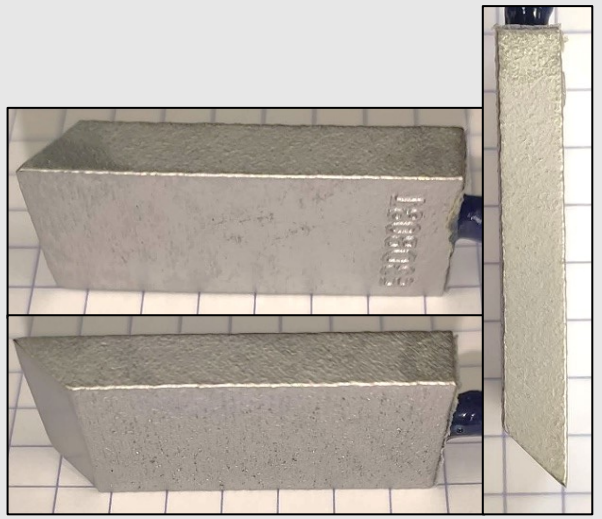
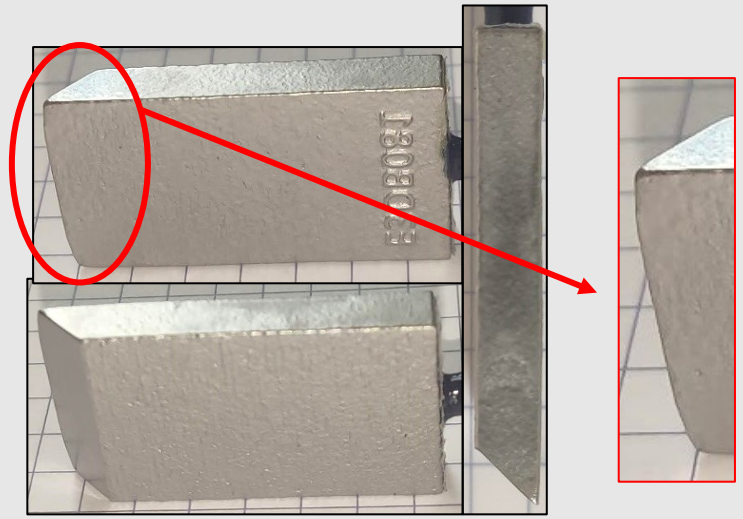
Increasing deformation (still limited)

- **Mass loss is proportional to time treatment** i.e. the current density is constant whereas the process is controlled by potential
- **Compromise** between **roughness reduction** and **deformation**

SCALE-UP OF ELECTROPOLISHING PROCESS FOR TA6V PARTS

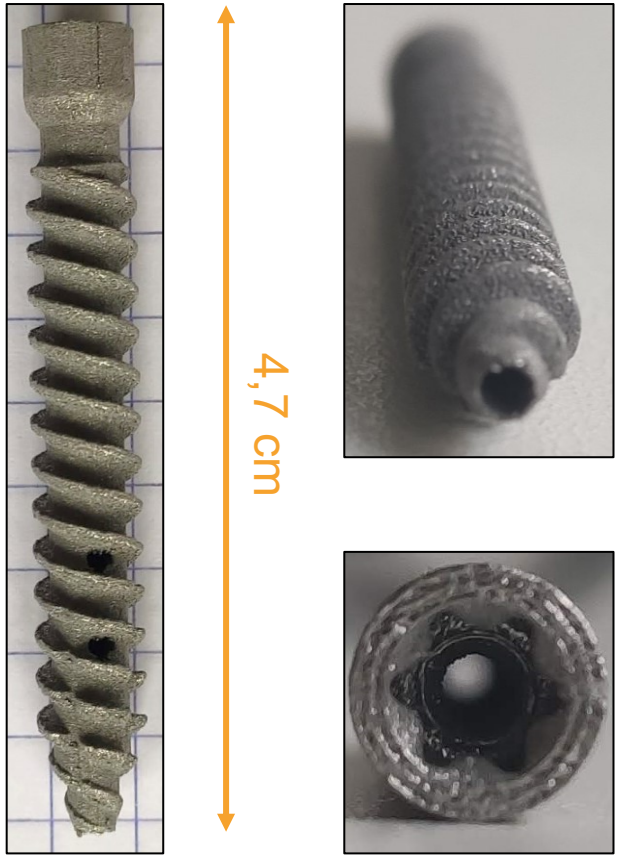
PLATES FROM ADDITIVE MANUFACTURING

Electropolishing parts with optimized parameters

	Untreated	Electropolished 3 h	Electropolished 4 h
			
Sa **UP** (µm)	**22,7** ± 4,7	**7,52** ± 0,99	**6,43** ± 0,98
Sa **DOWN** (µm)	**49,7** +/- 6,8	**16,63** ± 2,44	**10,91** ± 0,76
Mass loss (%)	0	4,4	6,9

- Significant roughness reduction before the deformation of the sensitive area (around 70 - 80 %)
- Absolute value of the roughness still “relatively high” due to the high initial roughness

Electropolishing of a complex geometry part



Additive manufacturing screws provided by **Stryker company**

- **Screw head**: Sa = 8,45 ± 1,25 µm
- **Screw thread** : Sa = 9,96 ± 0,53 µm

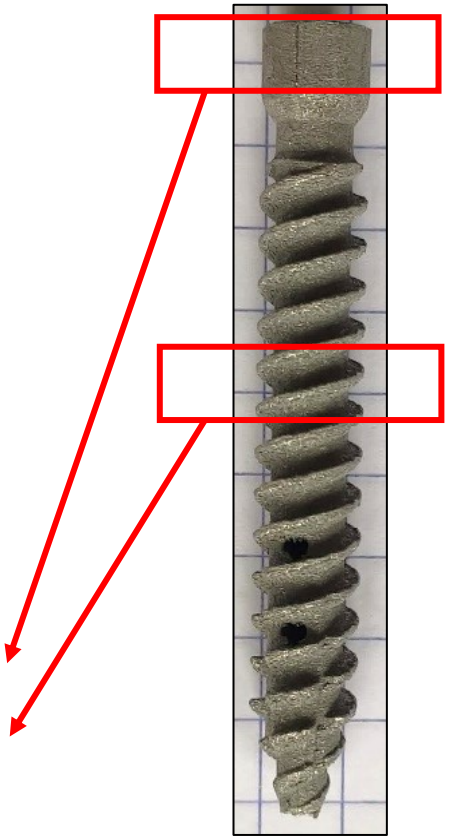
Lower roughness than the plates

The screws are **hollow all along** which induces a **very sensitive tip** (very thin thickness)

SCALE-UP OF ELECTROPOLISHING PROCESS FOR TA6V PARTS

COMPLEX GEOMETRY PART FROM ADDITIVE MANUFACTURING

	Untreated	30 min	1 h	3 h
				
Sa screw head (µm)	**8,45** ± 1,25	**2,58** ± 0,51	**1,80** ± 0,04	**0,83** ± 0,05
Sa screw thread (µm)	**9,96** ± 0,53	**3,96** ± 1,33	**2,37** ± 0,41	**1,32** ± 0,25
Mass loss (%)	0	6,1	8,9	21,6

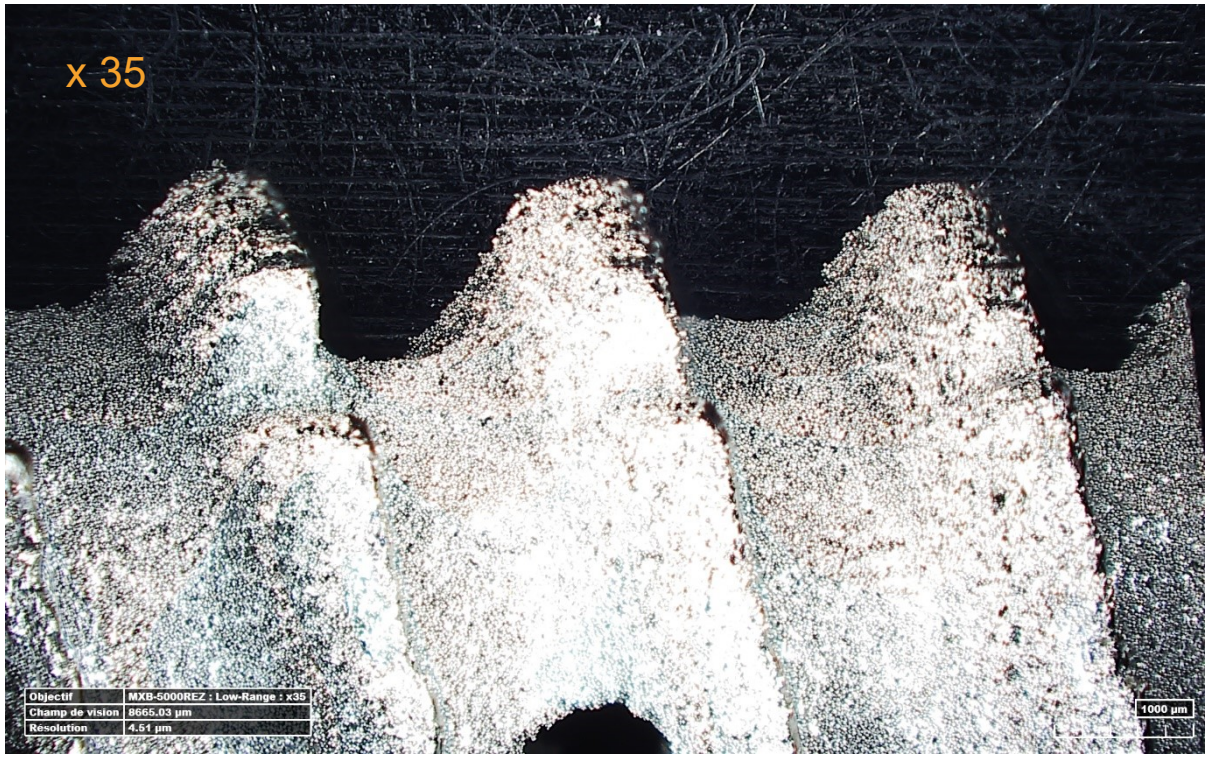


- Possibility to reach **low final roughness values**
- Need to work on a **cathode design** or **specific masks** to **avoid dissolution of the hollowed tip**

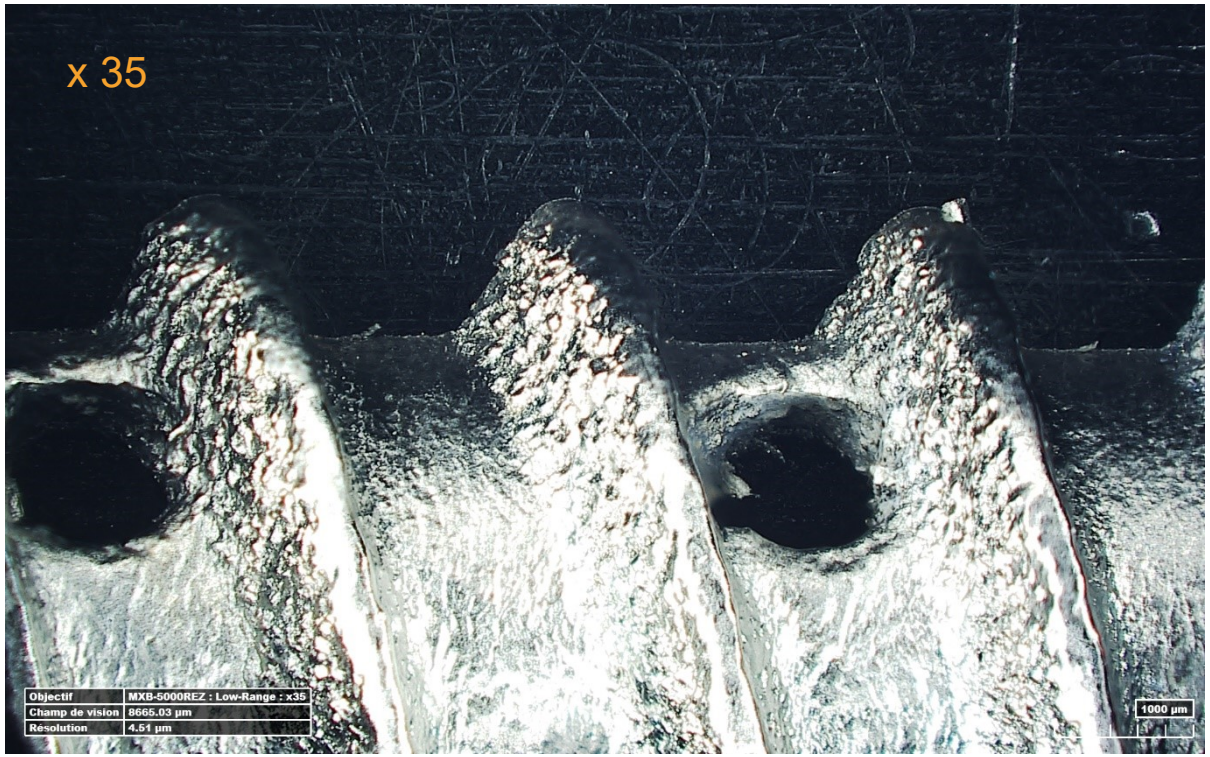
SCALE-UP OF ELECTROPOLISHING PROCESS FOR TA6V PARTS

COMPLEX GEOMETRY PART FROM ADDITIVE MANUFACTURING

Untreated



30 min



Removing unmelted particles and increasing brightness

Optical microscop (Hirox)

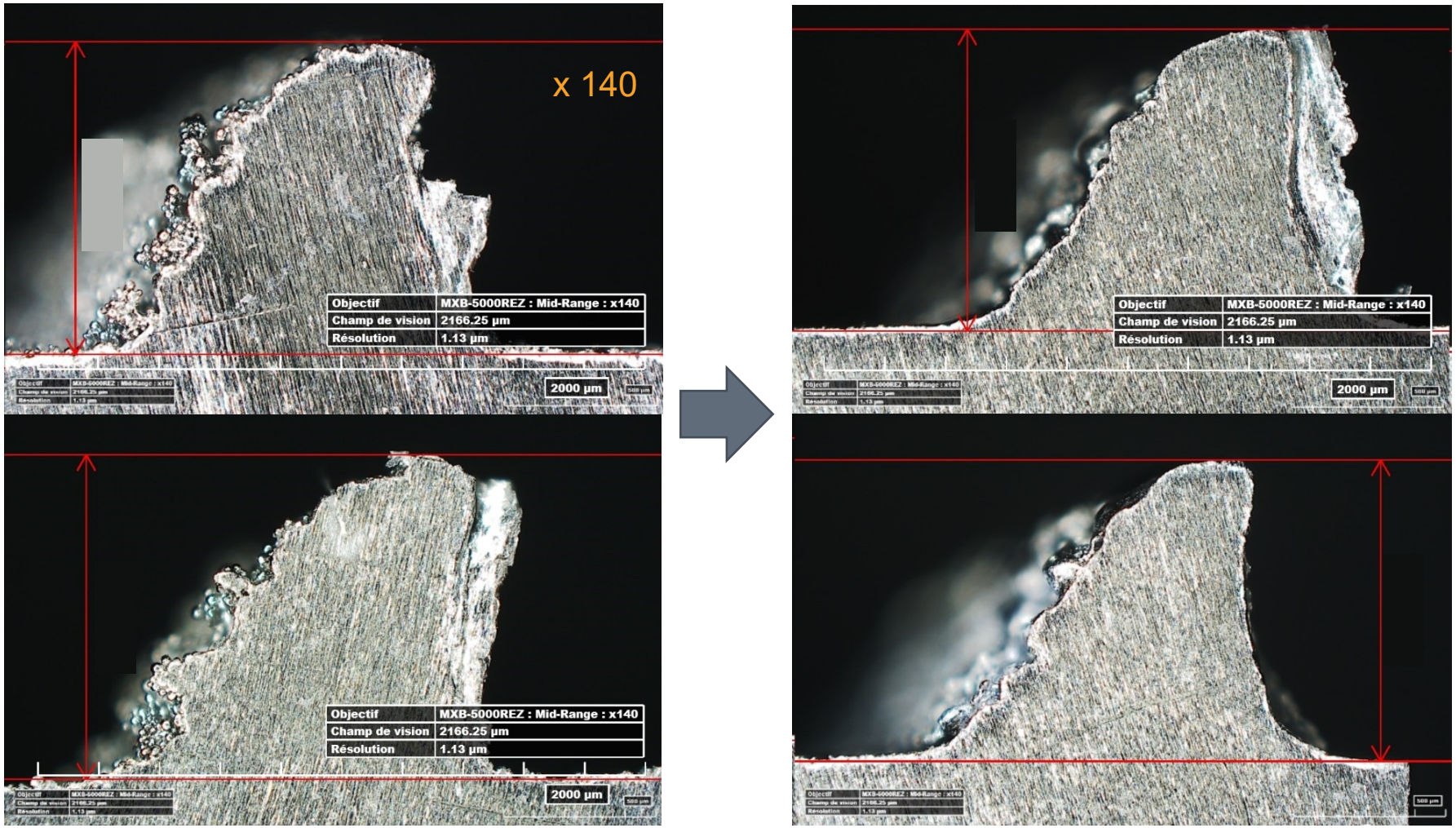
SCALE-UP OF ELECTROPOLISHING PROCESS FOR TA6V PARTS

COMPLEX GEOMETRY PART FROM ADDITIVE MANUFACTURING

Institut UTINAM

Untreated | **30 min**

Metallographic sections



In 30 minutes

- 50 / 60 % of roughness reduction
- 4 % reduction in peak height

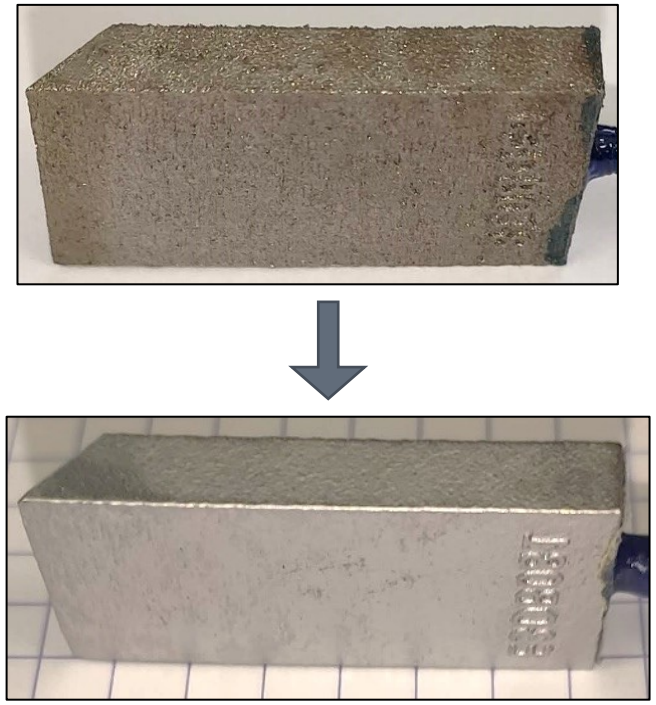
➔ Interesting roughness reduction with a limited geometric deformation

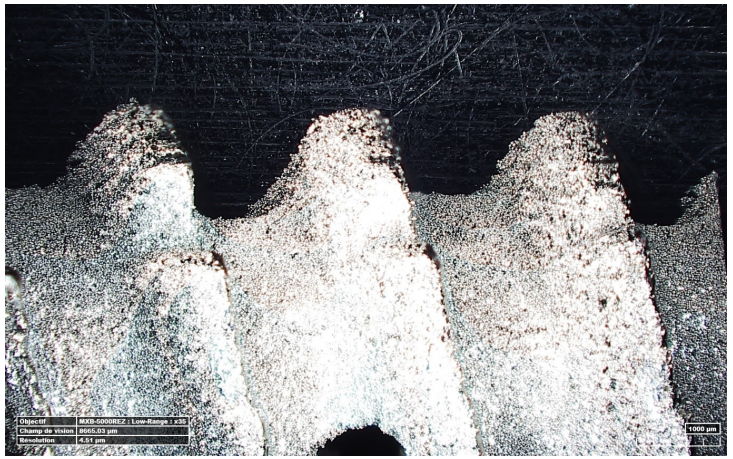
Optical microscop (Hirox)

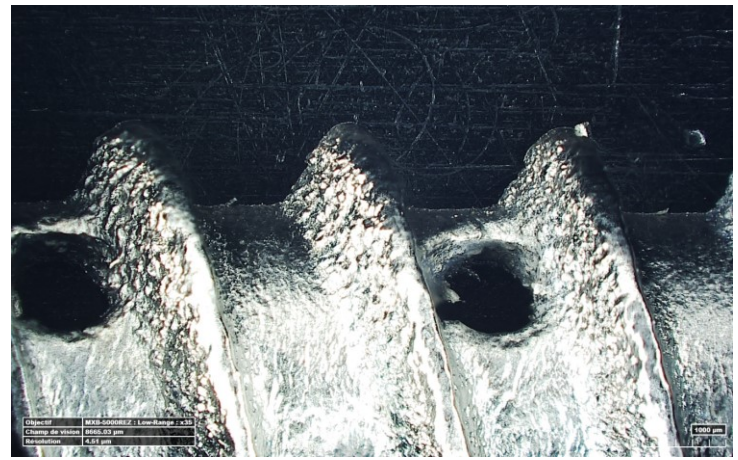
Conclusions and perspectives

CONCLUSIONS

The first **scale-up attempt of TA6V** electropolishing is promising and offers a possibility to **reduce significantly the roughness** (around 70 - 80 %) **without deforming sensitive areas**.







PERSPECTIVES

Further works on **TA6V electropolishing scale-up** will concerned :

- **improvement** of **cathode designs** and/or **masking of sensitives area** (possibly supported by simulations)
- treatments of **other complex geometric parts** (ideally with bigger surfaces)
- monitoring the **electrolyte ageing**

This will be extended to other alloys, including super nickel alloys, aluminum alloys and stainless steels.

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9 EXPERTISES MATÉRIAUX & PROCÉDÉS

POUDRES MÉTALLIQUES

FONDERIE AVANCÉE

ANALYSE DU CYCLE DE VIE & RECYCLAGE

TRAITEMENTS DE SURFACE MÉCANIQUES

TRAITEMENTS & REVÊTEMENTS DE SURFACE

TRAITEMENTS THERMIQUES & THERMOCHIMIQUES

MATÉRIAUX COMPOSITES

ASSEMBLAGES MULTI-MATÉRIAUX

ANALYSES & CARACTÉRISATION