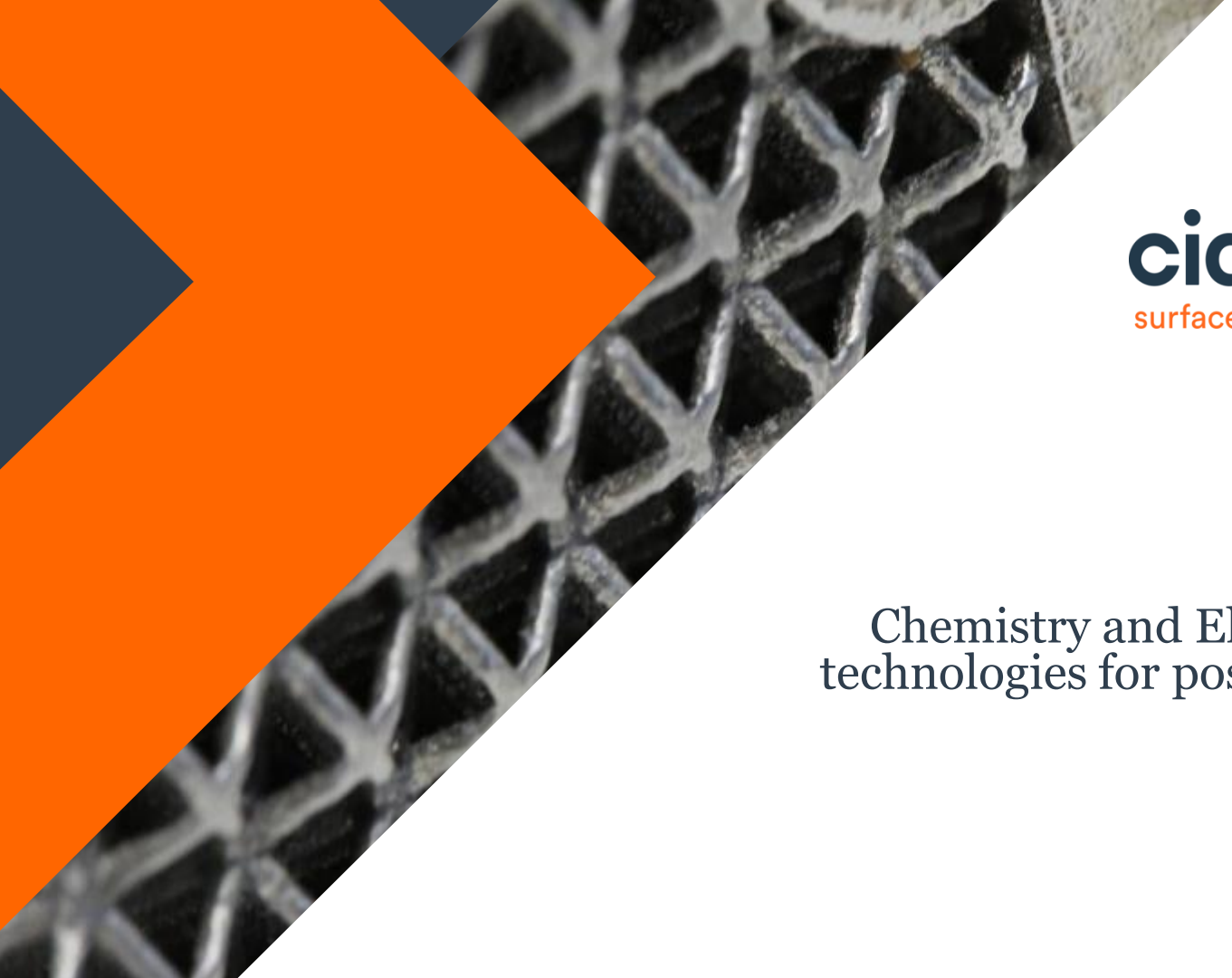


cidetec
surface engineering

Chemistry and Electrochemistry as key technologies for post-processing Additive Manufacturing parts

M. Belén García

28th of October 2021

complex

surface engineering

nanomedicine

energy storage

A big player in Surface Engineering

CIDETEC is one of the major European technological centres specialised in surface processing and finishing

H2020 projects:

23 (9 of them coordinated)

10

PATENT FAMILIES

STAFF

80

3

New technology based firms: INNOMAT, KERA-COAT, TUBA-COAT

6

PhD thesis in progress

From Lab to industry

Laboratories

From Lab to industry

Up-scaling facilities

From Lab to industry

Up-scaling facilities

LASER MODULE

MECHANICAL MODULE

ANODIZING
AND E-COATING MODULE

(ELECTRO) CHEMICAL POLISHING
MODULE

(ELECTRO)
DEPOSITION MODULE

CIDETEC's knowledge and expertise

Mechanical

- Mechanical polishing
- Milling
- Shot-peening
- Vibratory finishing
- Sand-blasting

Physical

- CVD
- PVD
- Thermal spray
- PECVD
- HVOF
- Laser coloring, marking and structuring
- Ionic implatation

WET CHEMISTRY

Chemical

- Sol-gel based and nano-enabled coatings (dip, spin and spray coating)
- Paints, ceramic, organic and polymeric coatings (dip, spin and spray)
- Chemical deposition of metals, alloys and composites
- Chemical polishing
- Conversion coatings
- Printing technologies (ink-jet, screen printing)

Electrochemical

- Electrochemical deposition of metals, alloys and composites
- Pulse-plating
- Selective deposition techniques
- Electropolishing
- Electrocoloring
- Ceramic electrophoretic deposition
- Anodization, metallization and functionalization of lightweight alloys (Al, Ti, Mg)

Technologies applied to conventional surfaces and adapted to treat additive manufacturing parts

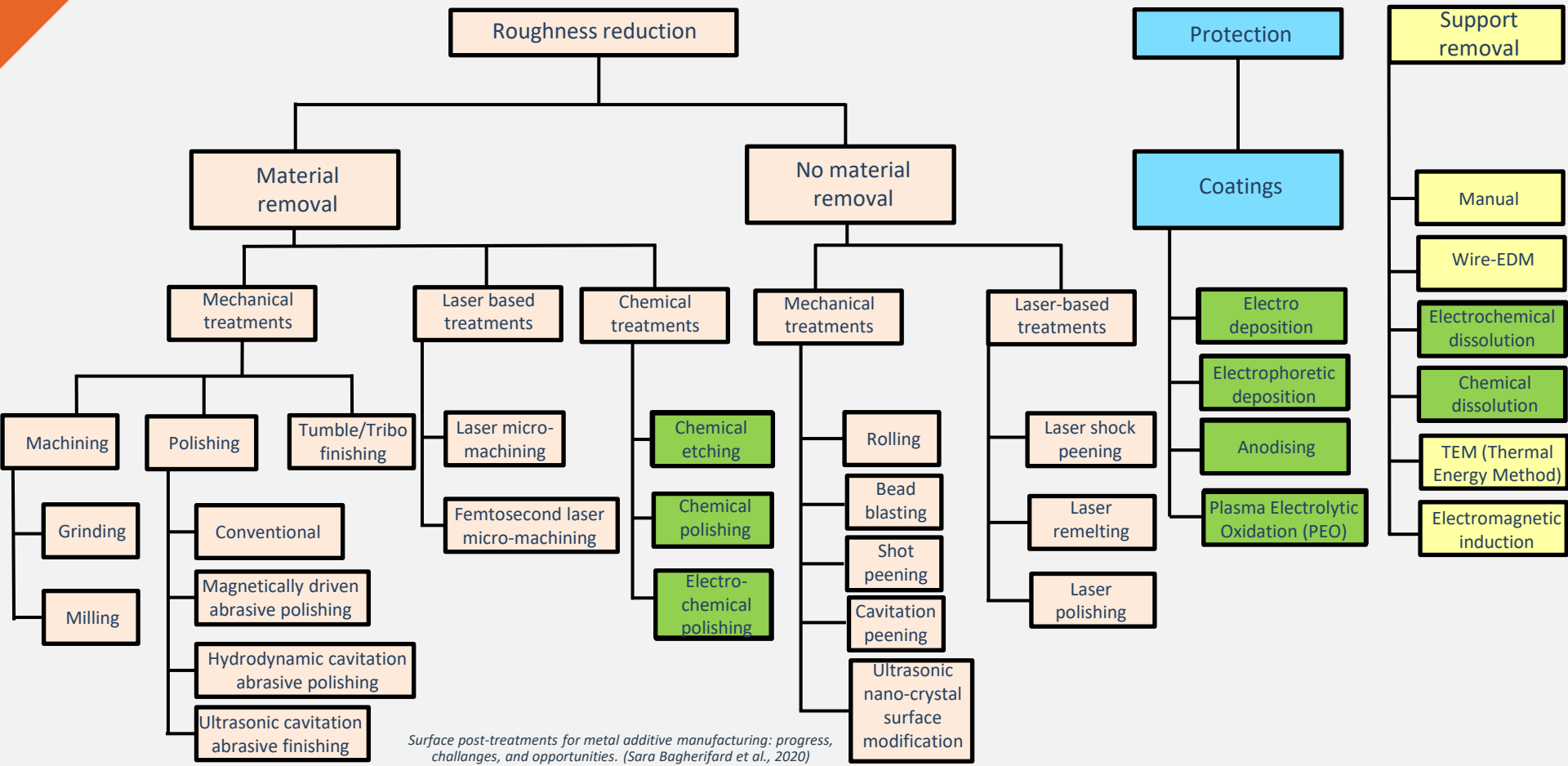
Thermoplastic

- Tailor-made thermoplastic polymers for industrial applications
- Sustainable polymers based on valorized biomass waste

Dinamyc thermosets

- Self-healing elastomers
- Novel composite manufacturing processes to obtain high production rates and increase competitiveness of thermoset composites
- Sustainable high performance thermoset composites (Bio-based, recyclable and repairable)

Surface treatments applied to AM parts



Surface post-treatments for metal additive manufacturing: progress, challanges, and opportunities. (Sara Bagherifard et al., 2020)

Chemical and electrochemical surface treatments

Chemical treatments

- Chemical polishing
- Conversion coatings
- Chemical etching
- Electroless deposition

Electrochemical treatments

- \+ Anodic processes
  - Electropolishing
  - Anodising
  - PEO
  - Anaphoretic deposition
- – Cathodic process
  - Cataphoretic deposition
  - Electrodeposition

Chemical and electrochemical surface treatments

Chemical treatments

ADVANTAGES:

- They offer the possibility to treat globally all the surface of a part
- Internal complex surfaces can be treated (mainly chemical treatments)
- Economic and easy to use processes
- Different parts could be treated at the same time
- They could be easily automated

CHALLENGES:

- Development of more environmentally friendly electrolytes
- They must be adapted to treat AM parts

Electrochemical treatments

Chemical and electrochemical treatments applied to Additive Manufactured parts

Surface roughness reduction

AM PARTS HAVE HIGH SURFACE ROUGHNESS

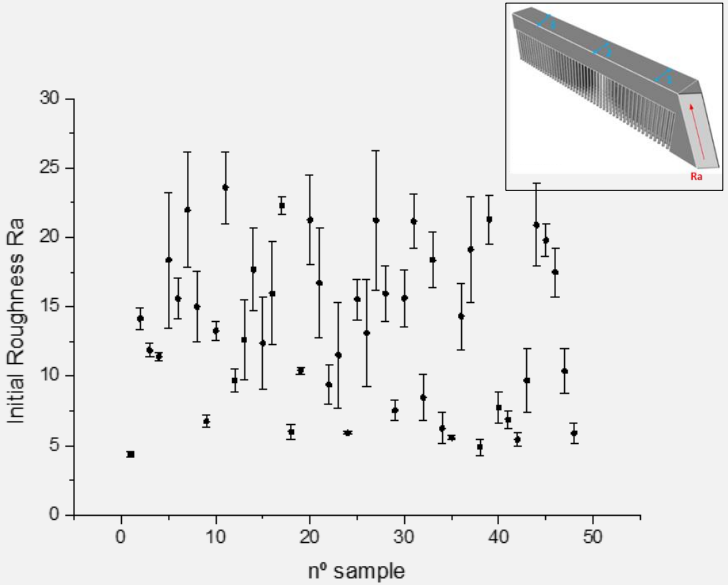
THAT DEPENDS ON DIFFERENT PARAMETERS:

- AM process
- Manufacturing parameters
- Material
- Fabrication angle
- Geometry
- Supports

THAT AFFECTS SURFACE PROPERTIES:

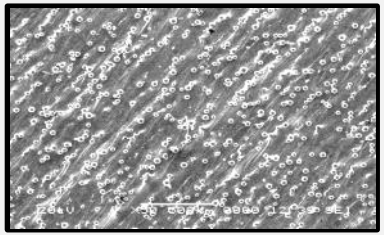
- Fatigue behaviour
- Friction properties
- Heat exchange
- Aesthetics

Moreover, parts produced with the same process parameters in the same platform could also have different surface roughness



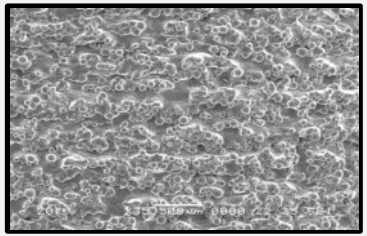
As-built roughness of the plane built at 45º of cantilever parts produced in the same platform and with the same parameters (Inconel 718 produced by SLM)

Ti6Al4V **SLM**



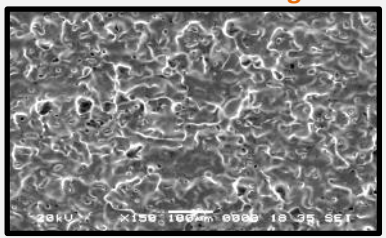
Ra 10 µm

Ti6Al4V **EBM**



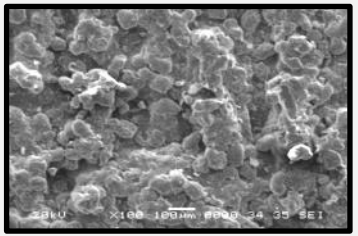
Ra 24 µm

Invar **Binder Jetting**



Ra 31 µm

PA12 **Multi Jet Fusion**

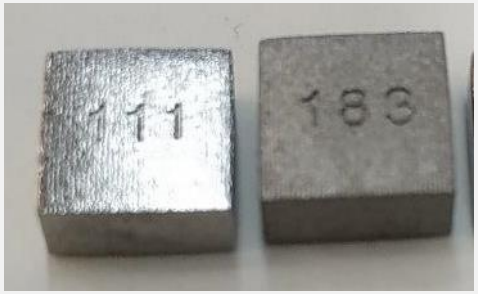


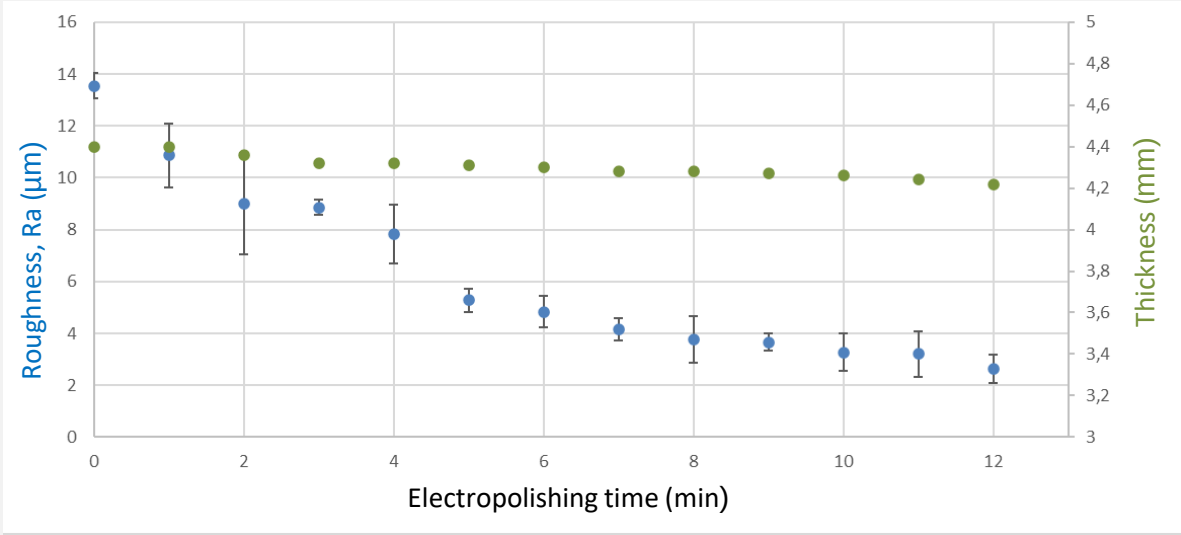
Ra 25 µm

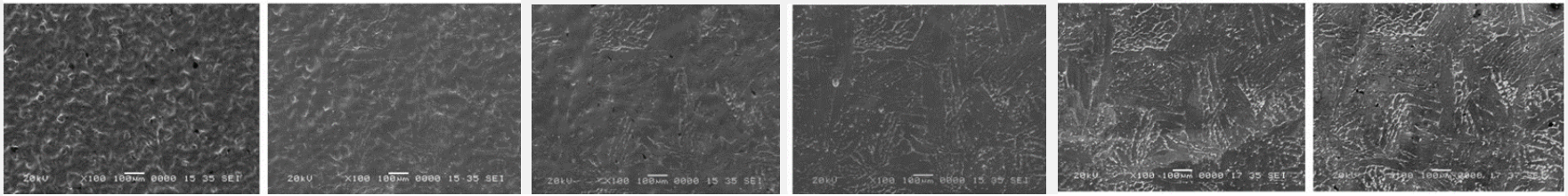
Electropolishing applied to reduce roughness of AM Parts

- Bright surfaces with low surface roughness can be achieved

Evolution of surface roughness and morphology as a function of electropolishing time for **17-4 PH Steel** obtained by **Binder Jetting**



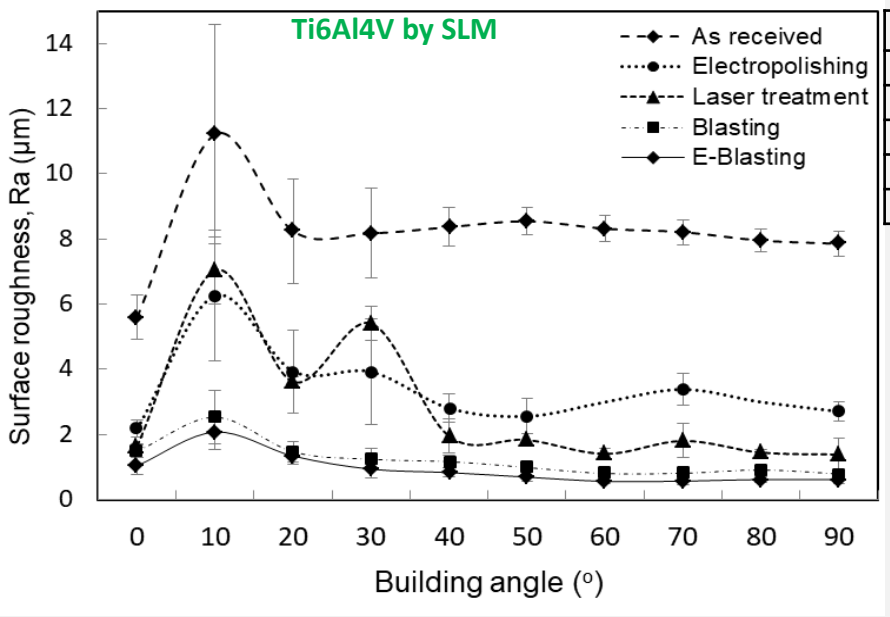




As-built | 1 min EP | 3 min EP | 6 min EP | 8 min EP | 12 min EP

Electropolishing applied to reduce roughness of AM Parts

- Combined with blasting, electropolishing could produce very low homogeneous surface roughness regardless the samples building angle. The resulting surfaces are clean.



EDX analysis, in weight %, of elements in the as-received and treated surfaces built at 0º				
	As-received	EP	Blasting	E-Blasting
Al	6.9 ± 0.4	6.2 ± 0.6	7.2 ± 0.4	6.6 ± 0.6
Ti	89.4 ± 0.5	90.1 ± 0.6	81.9 ± 1.0	90.2 ± 1.5
V	3.6 ± 0.3	3.7 ± 0.1	3.6 ± 0.4	3.5 ± 0.2
Si	-	-	7.4 ± 0.6	-

After blasting the surface is contaminated with blasting material (glass microspheres).

After electropolishing this contamination is removed.

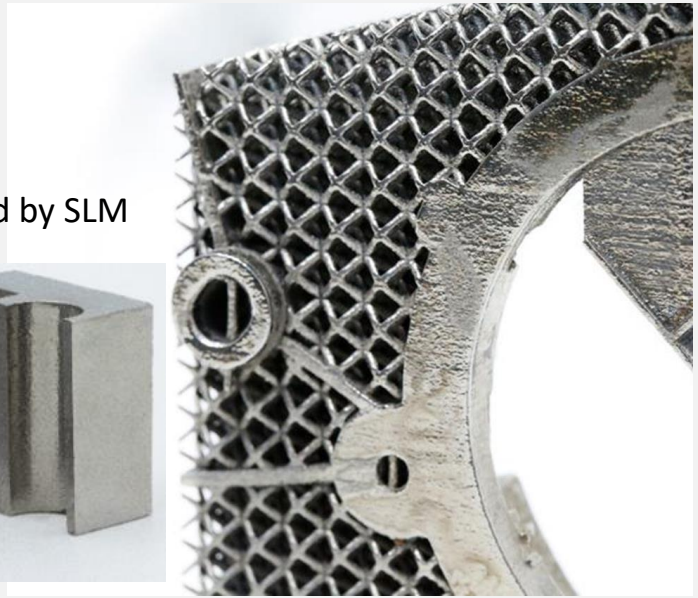
FRONTIERS project
Regional Funding
(Basque Government)

Electropolishing applied to reduce roughness of AM Parts

- Relative complex geometries can be homogeneously treated

Inconel 718 produced by SLM

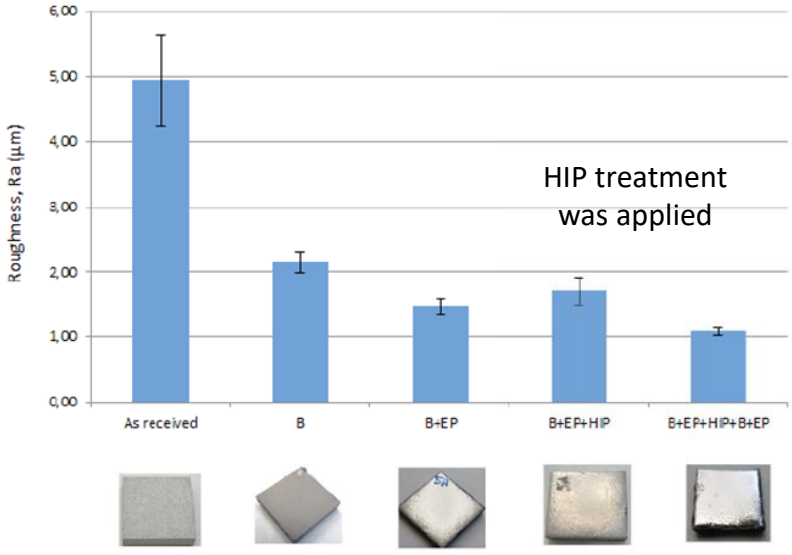
Ti6Al4V produced by SLM

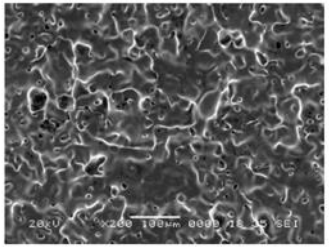


Electropolishing applied to reduce roughness of AM Parts

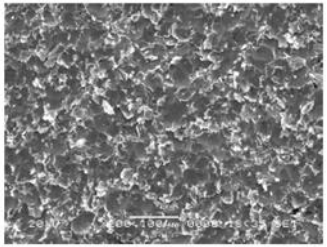
- However, as material is removed homogenously from the surface, if the part has internal porosity it is revealed after electropolishing and the achieved surface roughness is not as low as expected.
- This behavior could be avoided by applying HIP to the part

Invar produced by Binder Jetting

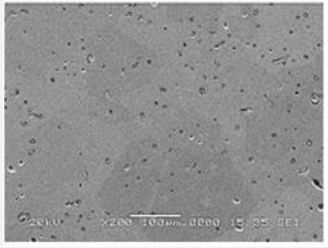




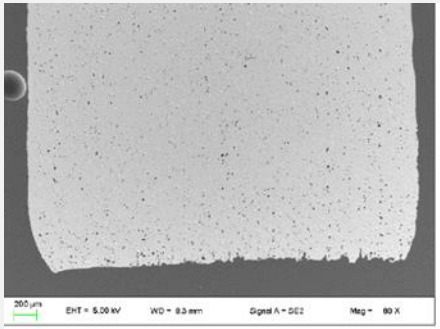
As built



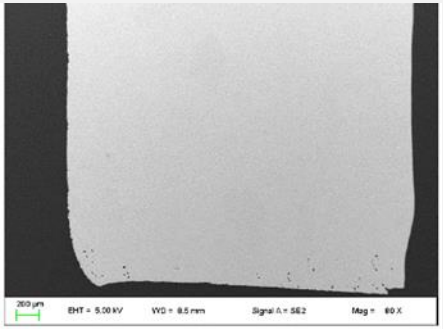
blasted



blasted + electropolishing



As built



After HIP

Chemical polishing applied to reduce roughness of AM Parts

- Chemical polishing could be used to reduce the surface roughness of a metallic part.
- Usually the achieved roughness reductions is less than the one achieved by electropolishing
- However, very narrow internal channels can be polished.

Clean Sky 2 | AMAN ECO

Assesment of Additive Manufacturing limits for eco-design optimization in Heat Exchangers (Oct. 2019 – Sep 2022)

LORTEK | EPSILON | Mondragon Unibertsitatea | FIT | cidetec surface engineering | TUHH | CTME | SAFRAN

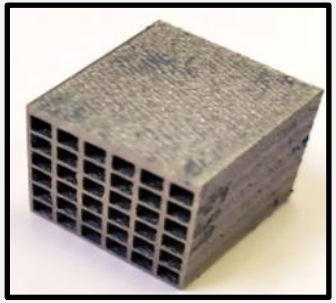
- Two different materials: **AlSi7Mg0.6** and **INCO718** manufactured by **SLM**
- **Design** of different geometries
- **Pressure resistance, Gas tightness** and **Aerothermal properties** evaluation
- **FEM** and **CFD** simulations
- **Surface finishing of internal channels (2x2x200 mm^3)**
- **Eco-design**

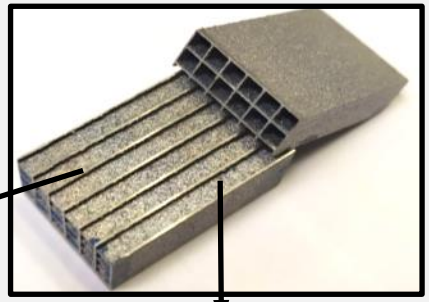
→

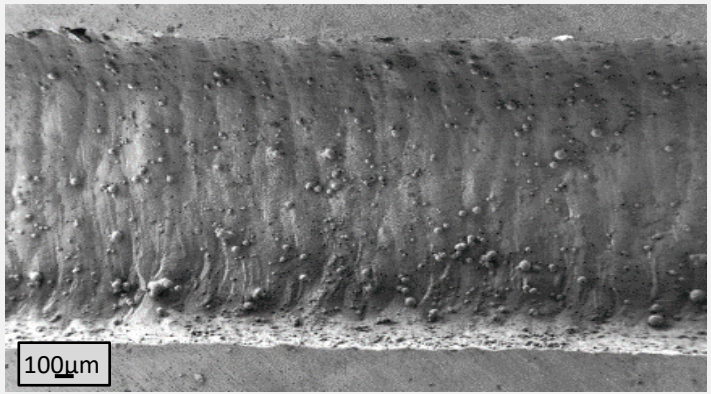
- **Increase efficiency up to 10 %**
- **Reduction of costs by 30 %**
- **Reduction of material waste by 15 %**
- **Reduce time-to market up to 1 month**

Chemical polishing applied to reduce roughness of AM Parts

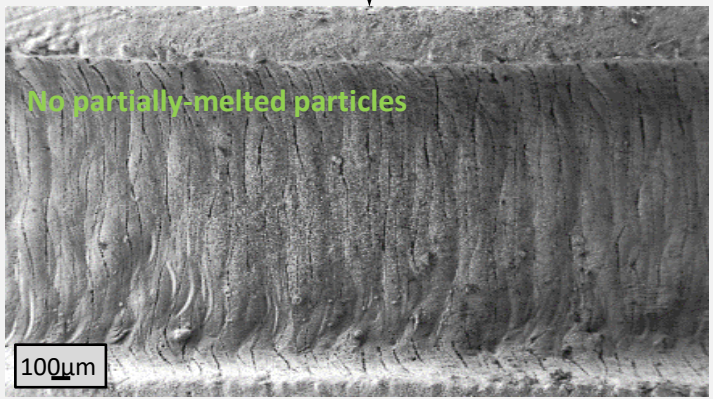
- Very narrow internal channels can be polished







Before chemical treatment **Ra (µm)= 8,6**



After chemical treatment **Ra (µm)= 4,8**

Chemical polishing applied to reduce roughness of AM Parts

- Chemical polishing could be used to reduce the surface roughness of polymeric parts.
- Different aesthetics can be obtained with the same electrolyte

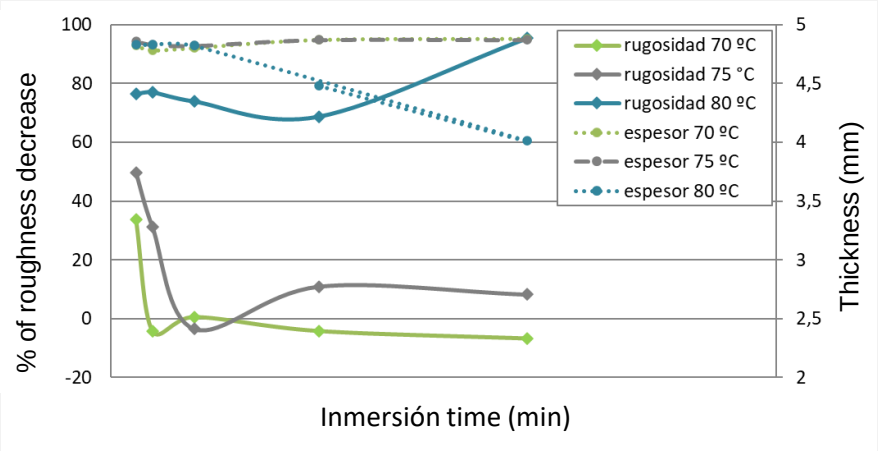
As built
Ra: 25 µm

Chemical treatment → 1-1.5 min
+
Rinsing with water
+
Curing time → 100ºC, 3h

After chemical polishing
Ra 3,1 µm
White finishing

Chemical treatment → 1-1.5 min
+
Curing time → 100ºC, 3h

After chemical polishing
Ra 3,4 µm
Black finishing

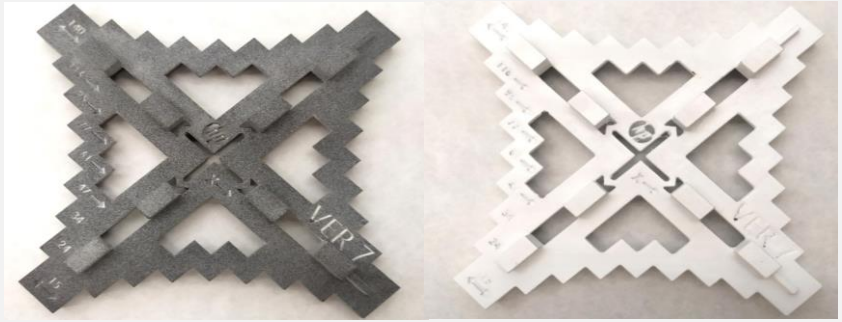


Compromise between roughness reduction and thickness decrease
80 ºC and 1-1.5 min

Chemical polishing applied to reduce roughness of AM Parts

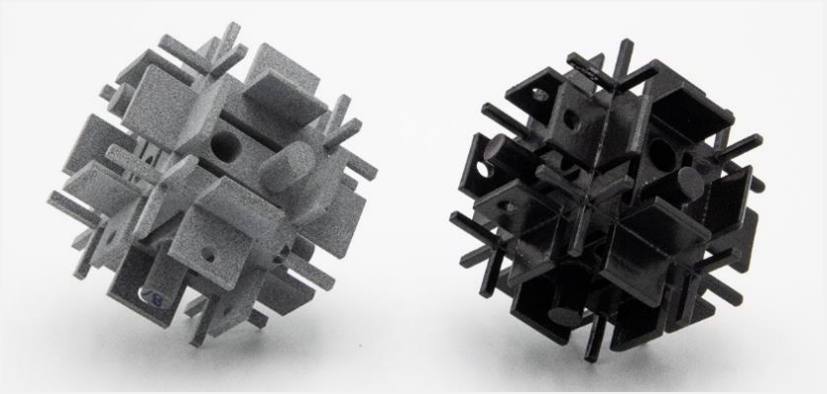
- Chemical polishing could be used to reduce the surface roughness of a polymeric parts.
- Different aesthetics can be obtained with the same electrolyte
- Complex parts can be treated

PA12 obtained by MJF



Before CP **After CP**

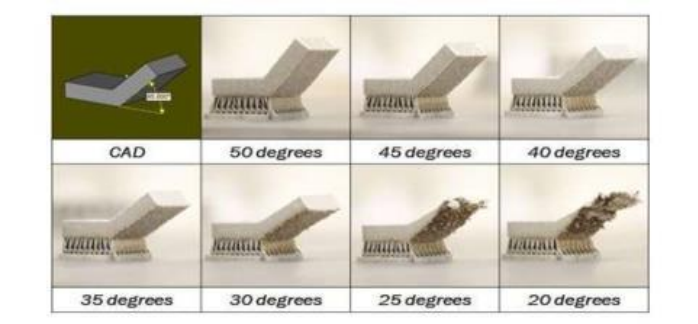
PA12 obtained by MJF



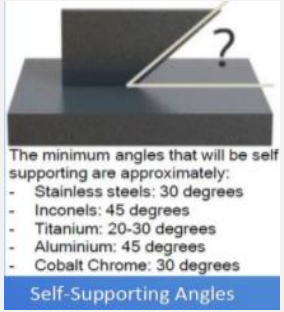
Before CP **After CP**

CONFORT project
Regional Funding
(Basque Government)

Support Removal



Effect of the absence of supports on the structural integrity of parts processed by PB technologies. Additive Manufacturing Magazine "7 Helpful Numbers Quantify Design Rules for Additive Manufacturing"



Additive Manufacture Development, Applications and lessons learned, Omar Mireles, Nuclear and Emerging Technologies for Space, 2019

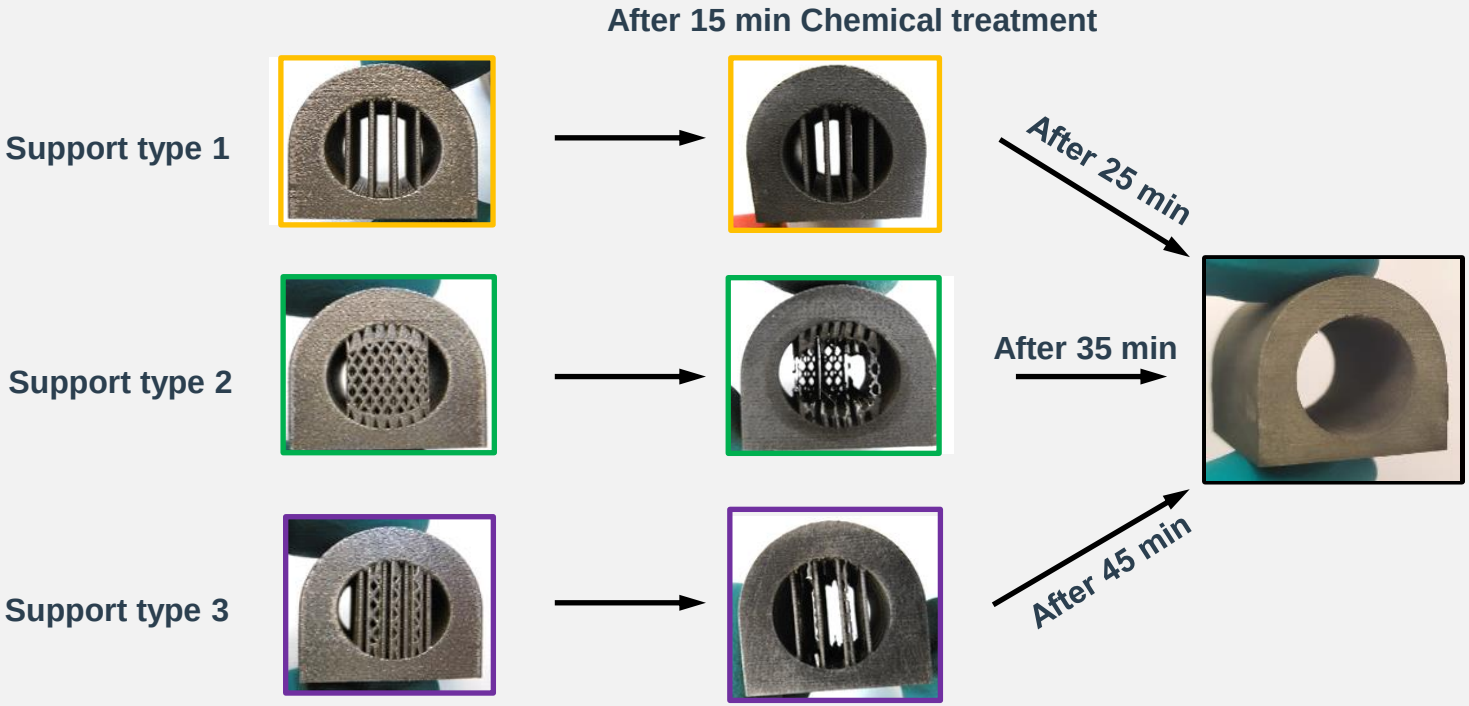
- Supports are necessary for the correct manufacture of pieces, they allow the piece to be correctly fixed to the platform. In addition, they hold closed angles and cantilever geometries as well as dissipate the heat generated during manufacturing.
- Usually, supports are removed manually and a treatment of blasting/polishing process is necessary to remove the main remains and surface defects left on the part.

Chemical treatments for support removal

Chemical to remove supports of AM Parts

- Chemical treatments could be optimized to remove supports and polish surfaces at the same time

INCO718 produced by SLM



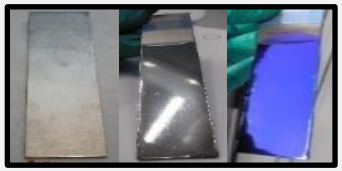
This is usually done manually and, after that, a blasting process is needed to remove all the support structure
With (electro)chemical processes → we achieve a more stable process removing both human factor and blasting treatment

Electrochemical treatments for Surface protection

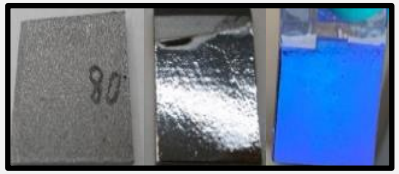
Ti6Al4V anodising

- Same anodising parameters were applied to previously electropolished Ti6Al4V parts produced by different technologies.
- All surfaces were homogeneously treated.

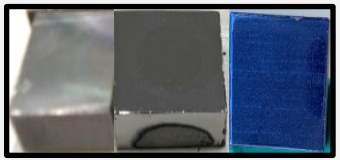
Conventional



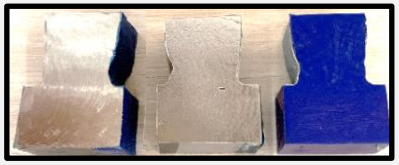
SLM

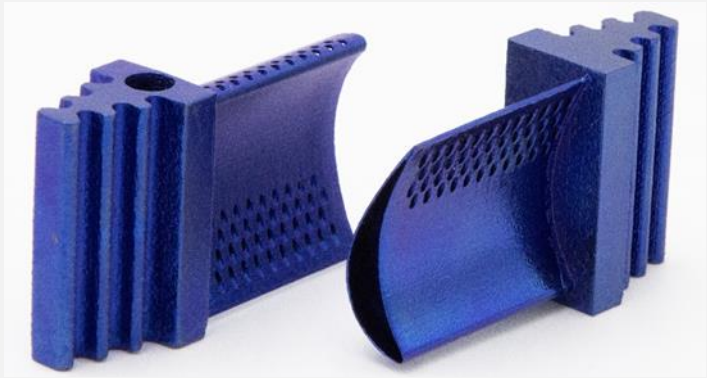


LMD



WAAM

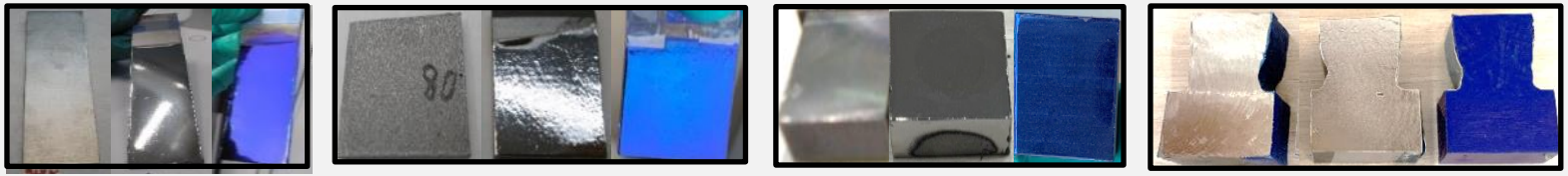


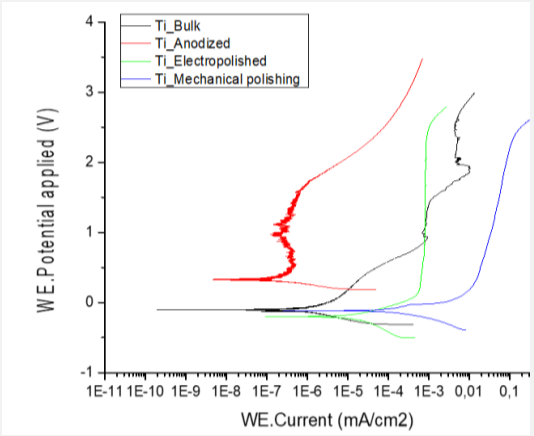


Anodized Ti6Al4V parts produced by SLM

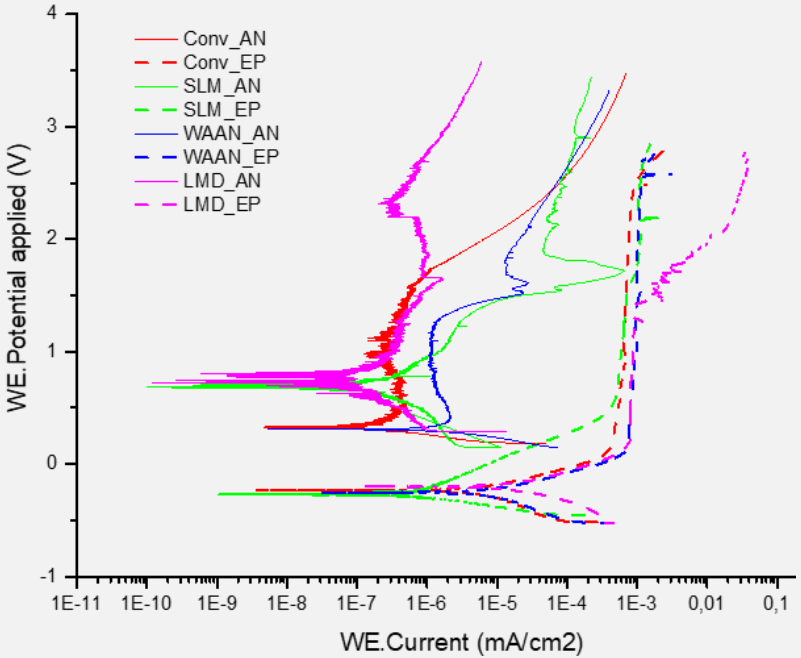
Ti6Al4V anodising Analysis of corrosion behavior (polarization curves)

Conventional **SLM** **LMD** **WAAM**





Anodizing improves the corrosion behavior of the electropolished surfaces, *higher* E_{corr} and *smaller pasivation current density*



Electropolished surfaces have similar corrosion behaviour.

Anodising improves the corrosion resistance of all these surfaces but their behaviour is different depending on the production process.

Electrodeposition on polymers

- Metallic coating on polymers provide them with electrical or thermal conductivity, corrosion resistance, wear resistance or aesthetics.
- Different steps need to be applied (pre-treatment, chemical deposition and electrodeposition)
- Pretreatment is the most critical step and depends on polymer composition and its fabrication process
- Usually, pretreatment is carried out with Cr(VI) electrolytes that needs to be avoided due to environmental and healthy issues.

CHALLENGE: to develop a pretreatment without Cr(VI), that activates AM polymer substrates for further metallization

Thermoplastic electrocoated with Cu using a Cr(VI) free pre-treatment step developed at Cidetec

CONCLUSIONS

There are multiple post-processing methods, from manual to automated, to eliminate support structures, reduce roughness and protect or funcionalise AM surfaces.

Selection of the most appropriate method must be done based on sample characteristics (AM process, material, geometry, initial surface roughness) and part requirements (surface quality, dimensional tolerances, aesthetics, necessity of protection)

(Electro)chemical surface treatments are well known industrial processes, which can be adapted to improve AM parts, from support removal to surface finishing, protection and functionalization

The advantages of (electro)chemical surface treatments include:

- The possibility of reducing surface roughness in complex geometries, including internal channels (chemical polishing)
- The capacity to provide very low surface roughness without contamination and aesthetically attractive (electropolishing)
- The ability to protect metal and polymer surfaces, among others, by anodising, PEO or (electro)plating
- Cost-effective

CONCLUSIONS

Some challenges of (electro)chemical technologies applied to AM surfaces are related to:

- The electrolyte formulation (for some processes and materials there is a necessity to develop environmentally friendly electrolytes)
- The electrolyte management
- The metalisation by electrodeposition of polymers such as PA12, PA6, PEEK, ULTEM...

(Electro)chemical surface treatments could be automated and digitalized to be connected with all the AM value chain.

THANK YOU
GRACIAS
ESKERRIK ASKO

cidetec
surface engineering

a greater future today

M.Belén García
bgarcia@cidetec.es