Trattamenti di superficie per migliorare le finiture superficiali dei manufatti prodotti per AM

Surface treatments to improve the surface finishes of products produced by AM

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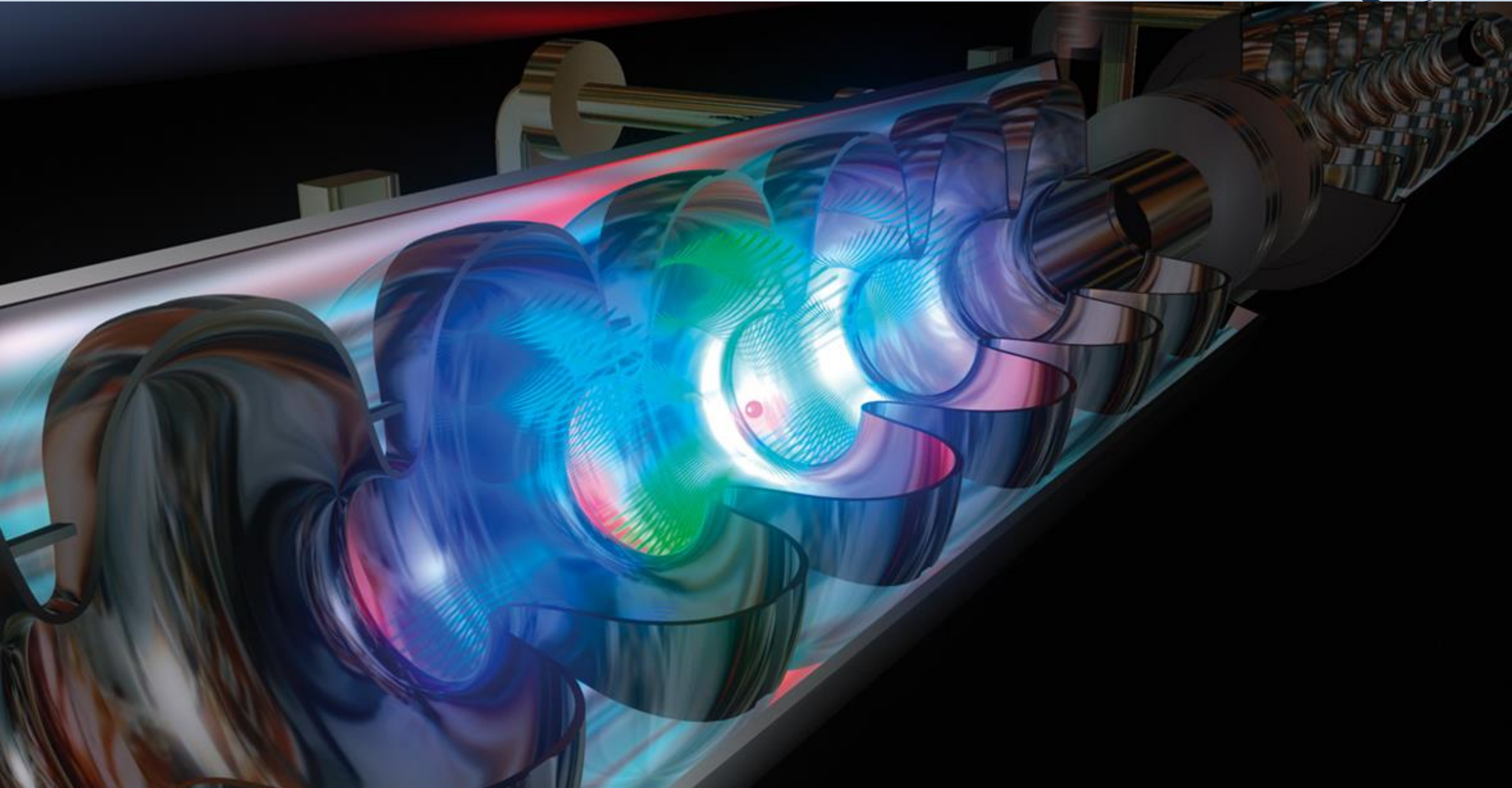
Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali di Legnaro

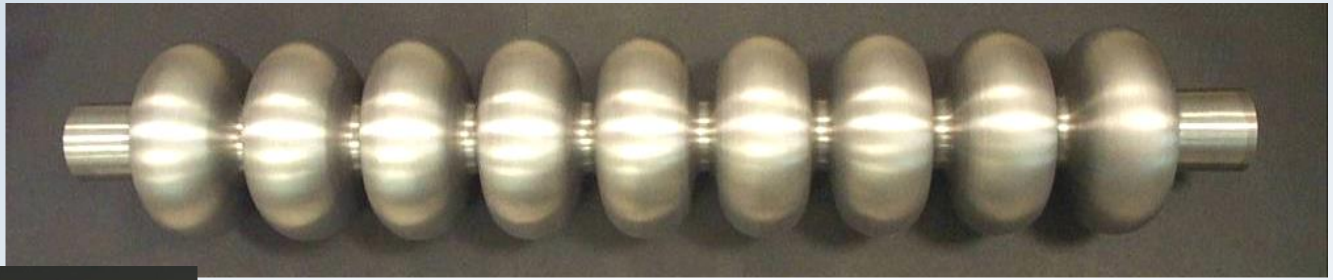
Outline

- Material Science and Technologies for Nuclear Physics Service @LNL
  - Accelerating Cavities
  - Surface treatments facility @ LNL
- Additive Manufacturing Surface Finishing
  - AM Post-processing for surface finishing improvements
  - Post-processing status of the art
- LNL tecniques
  - Tumbling
  - Vibro-tumbling
  - Electropolishing
  - Fast Electropolishing
  - Chemical Etching
- Conclusion

Material Science and Technologies for Nuclear Physics Service @LNL

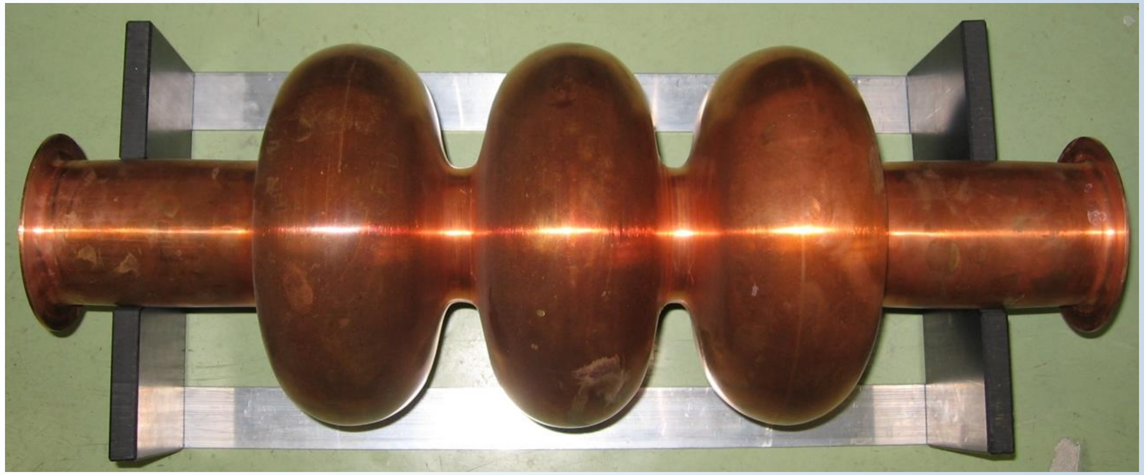


Accelerating Supercunductive RF cavities



1.5 GHz elliptical cavity

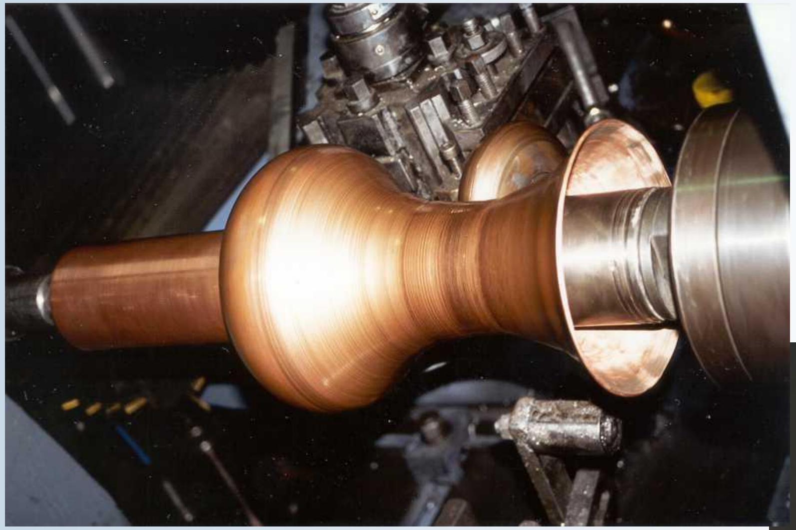
160 MHz QWR cavity



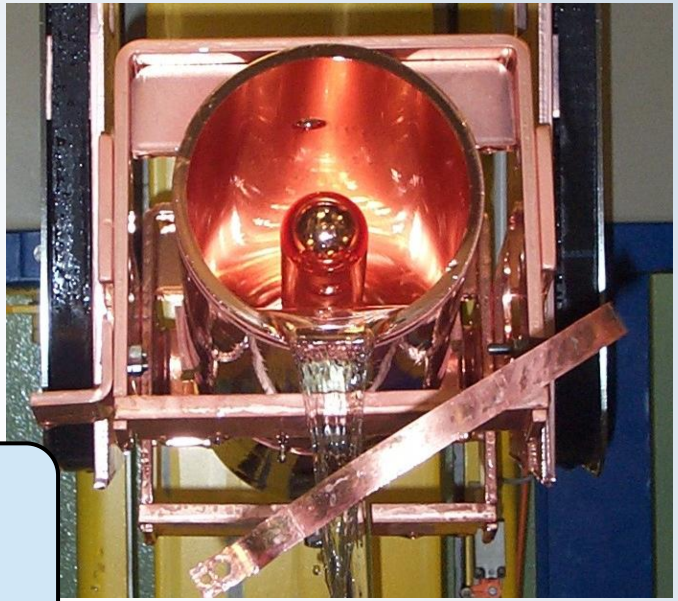
- Very Low power dissipation
- Very high accelerating field 30-40 MV/m
- **Very low surface roughness <20nm**
- High purity material

Surface tretments on Nb onto Cu cavity

Machining



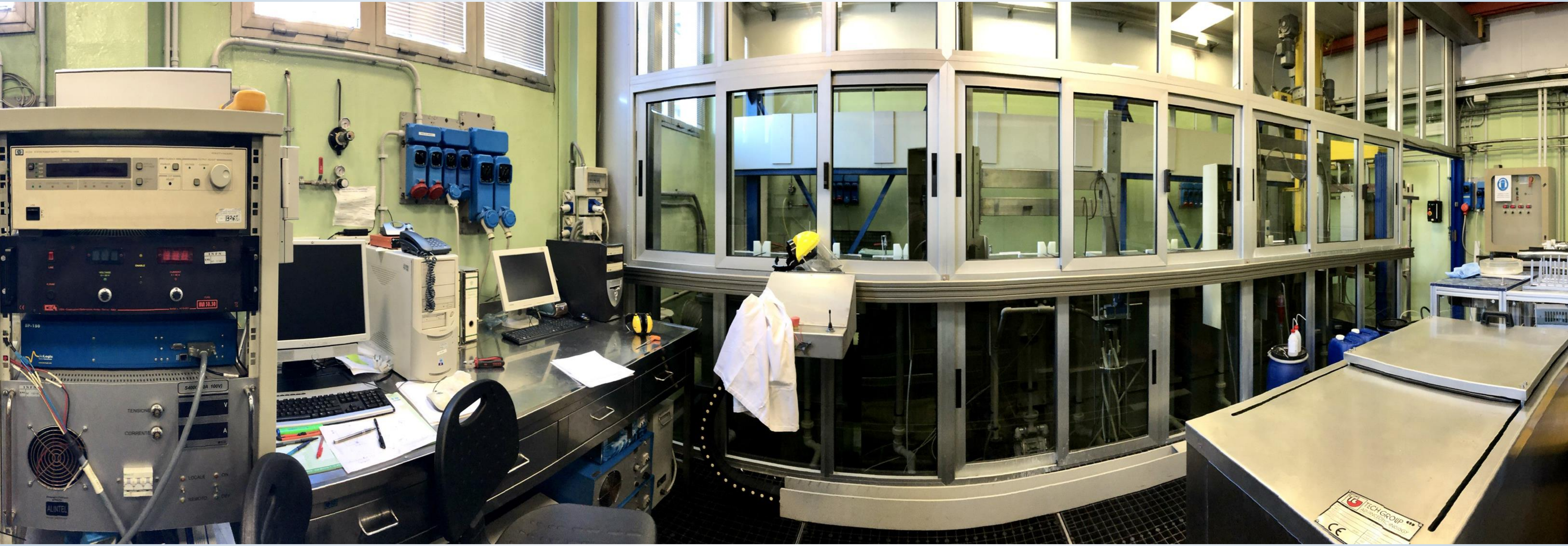
Surface chemical cleaning



Roughness less than
20 nm for Cu substrate

Nb thin film coating using PVD tecniques

Chemical Facility



Coating Plant

Cryogenic Plant

Material characterizations

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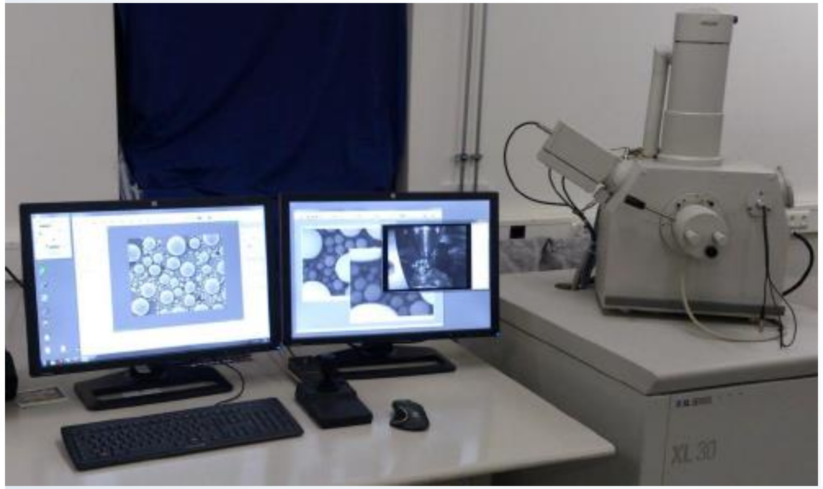
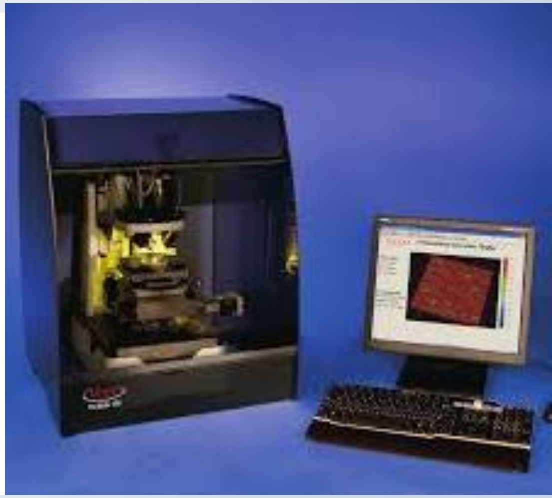
XRD

SEM-EDS

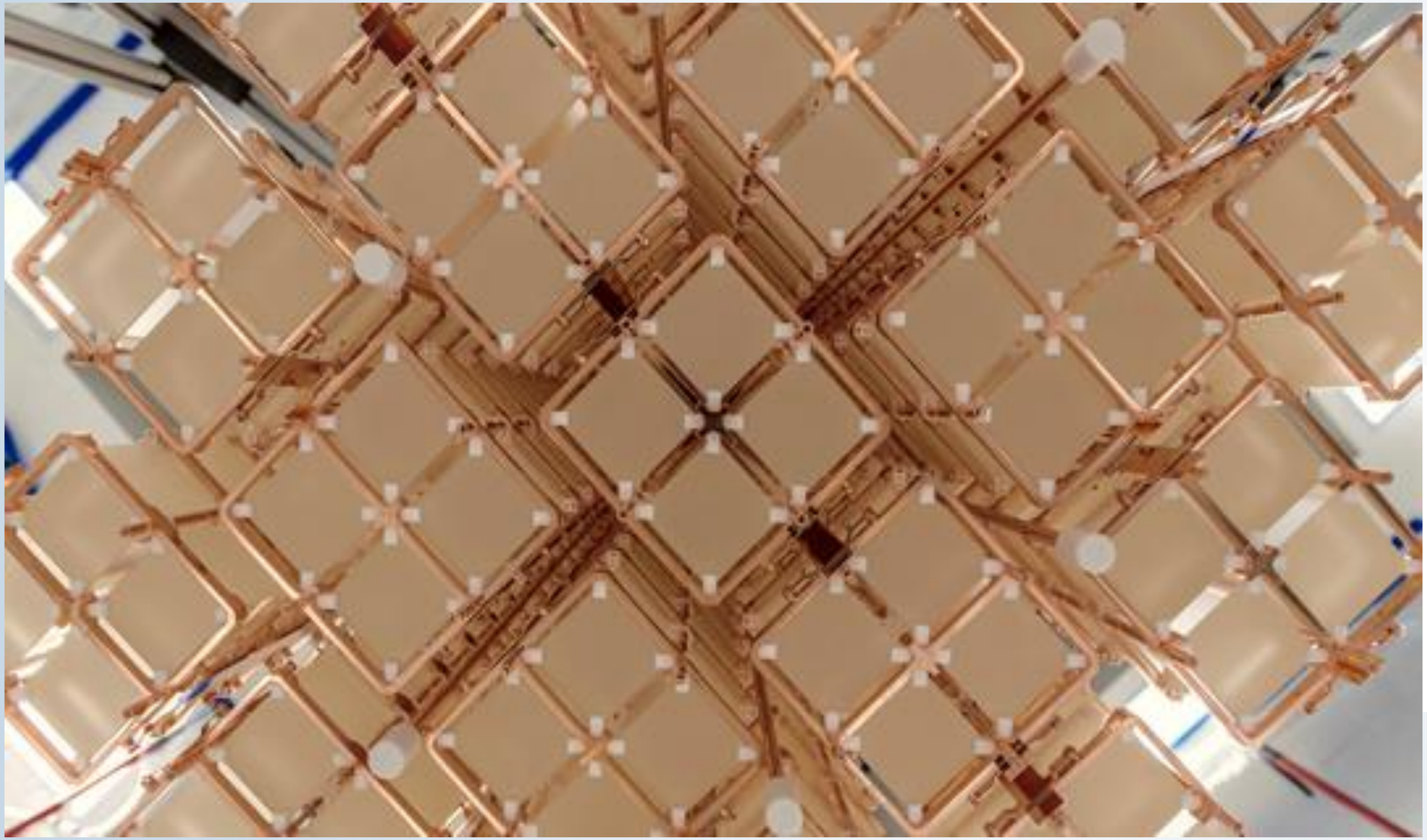


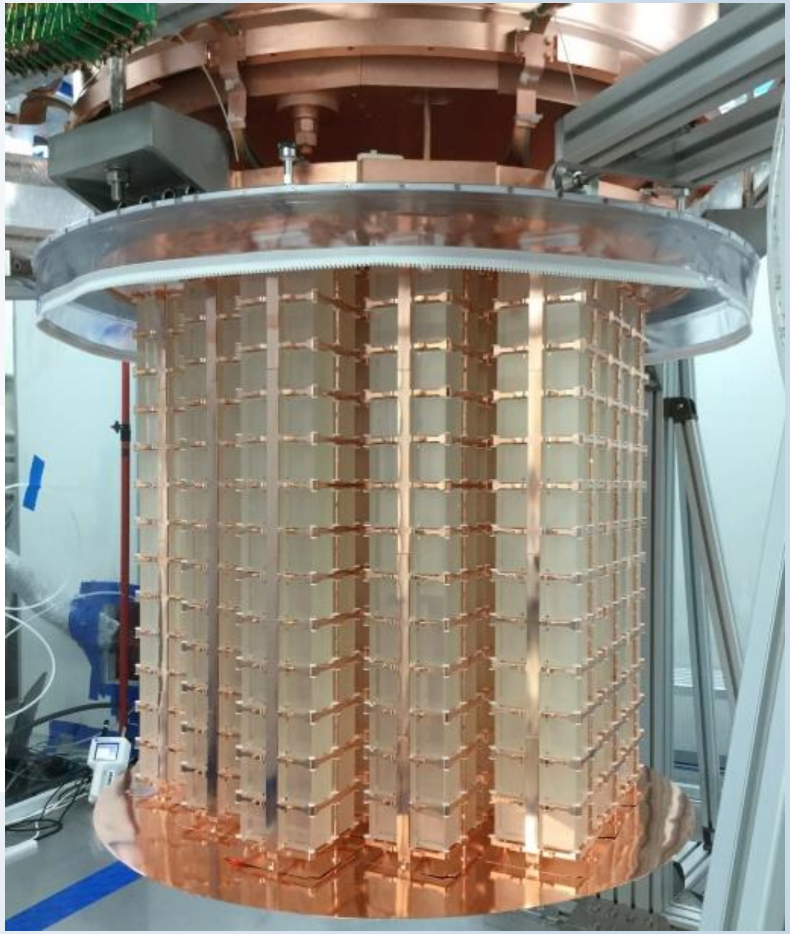
Optical Microscope

Profilometer



CUORE: Cryogenic Underground Observatory for Rare Events





CUORE: Cleaning Level

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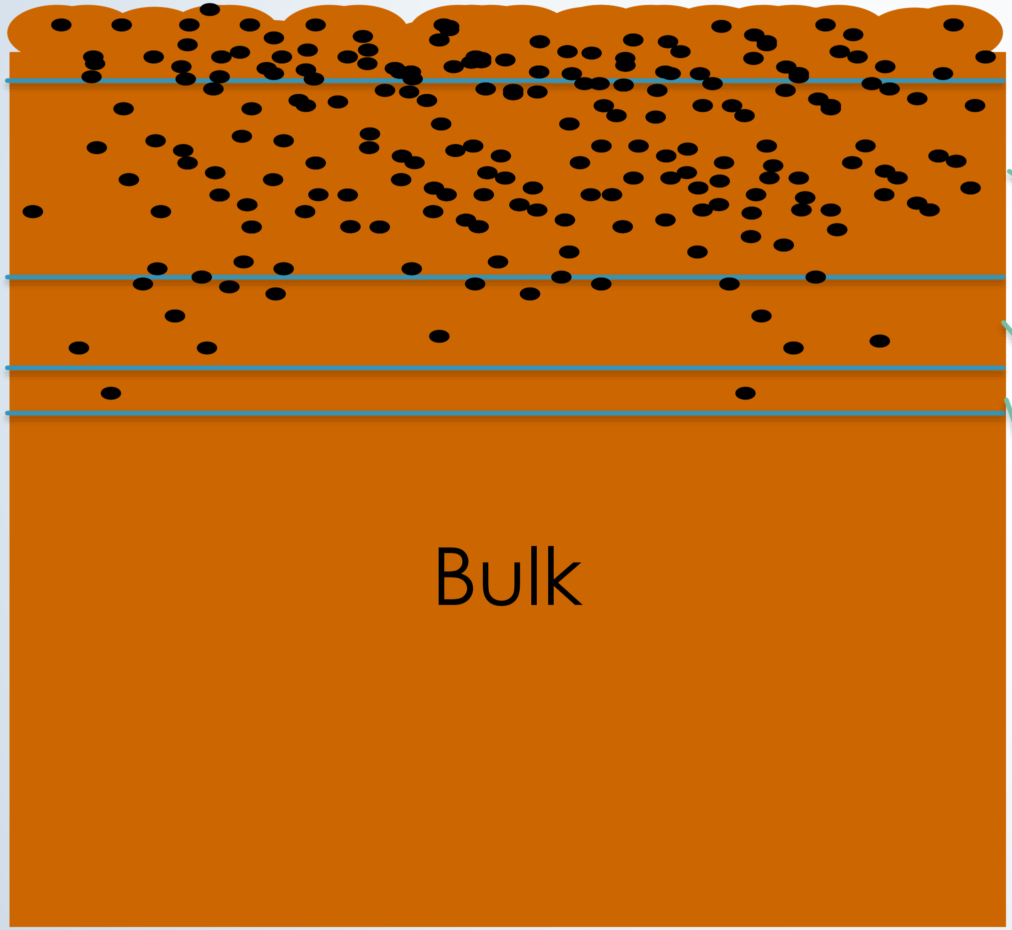
Copper Surface



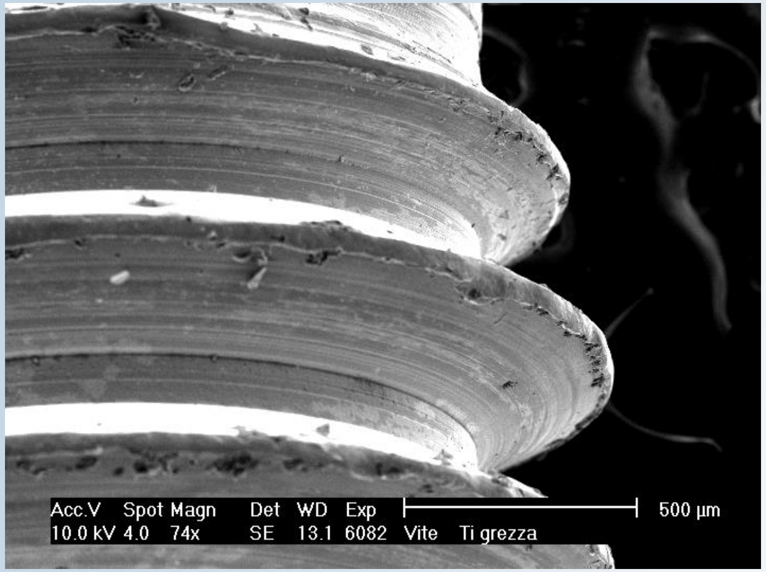
Tumbling ~ 1.2 μm
Rate ~ 0.06 μm/h

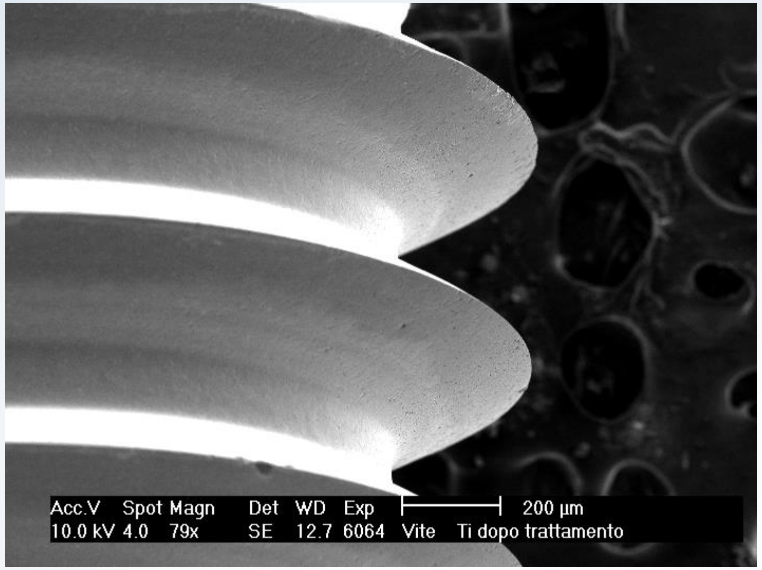
Electropolishing: 100 μm
Rate ~ 12 μm/h

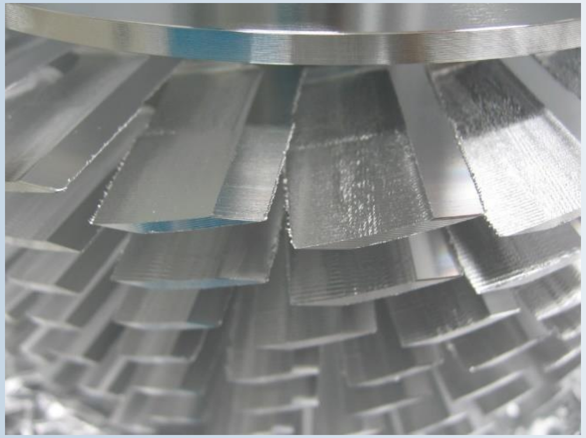
SUBU5 (Sulfamic+Butanol) ~ 10 μm
Rate ~ 120 μm/h

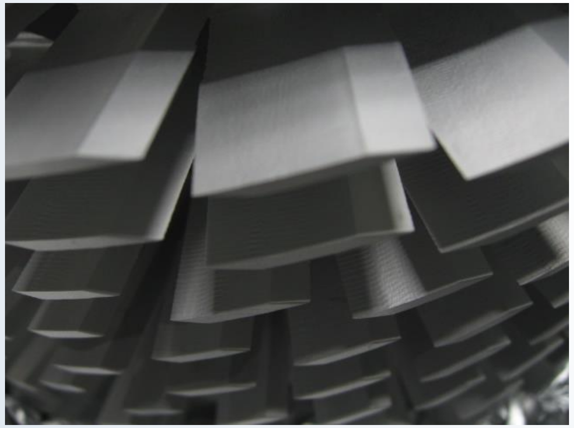
Plasma~ 0.2 μm
Rate ~ (1μm/h)

Technology Transfer

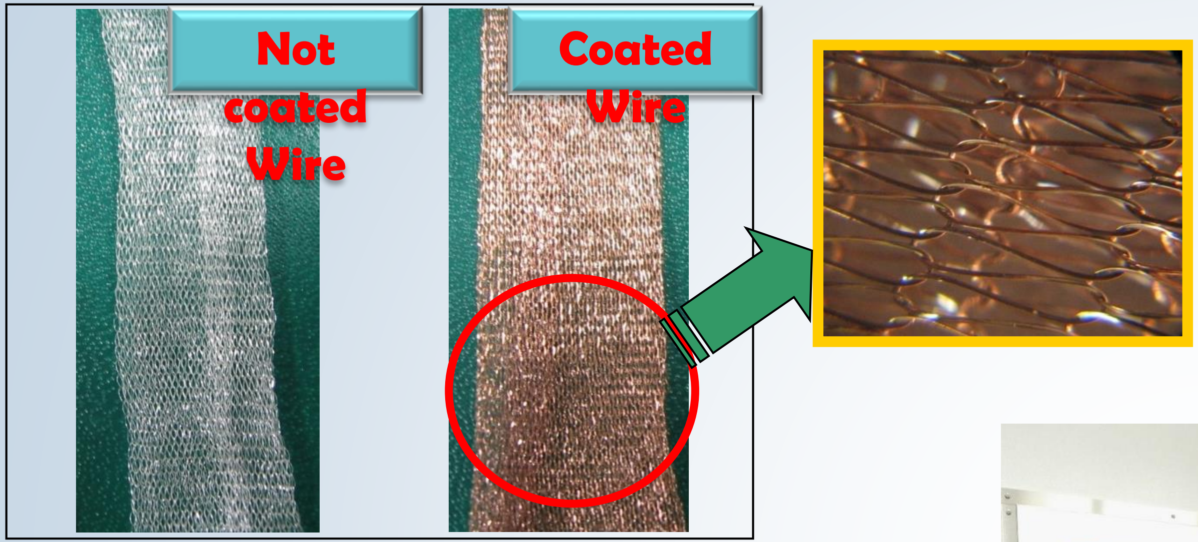








Technology Transfer



Additive Manufacturing

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AM Advantages:

- Unbounded geometric freedom.
- To control the local geometric (micro-structure).
- Avoid the use of tooling.
- Lowered inventory requirements.
- Waste-less fabrication.
- Unattended operation (allowed fully automated operation).
- Customer-driven design.

AM disadvantages:

- Demand for better materials.
- Existing CAD systems.
- Data management (Size of STL file).
- Low-volume production.
- Financial overheads.
- **Surface Quality of Products.**

J. Inst. Eng. India Ser. C (August 2018) 99(4):481–487

AM Surface Finishing

- The Additive Manufacturing (AM) Industry **requires improved surface finishes** to enhance component performance.
- Surface finishing of AM parts is **a leading challenge** as the industry pushes for broader application
- Metal AM, has very rough surface finish: typically **5-40 μm Ra**

Name of process	Minimum Layer thickness (mm)	Surface roughness (Ra) (μm)
Selective Laser Sistering (SLS)	0.125	5-35
Fused Deposition Modelling (FDM)	0.254	9-40
3D printing (3DP)	0.175	12-27

J. Inst. Eng. India Ser. C (August 2018) 99(4):481–487

Post-processing techniques: an overview

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There are a number of common **post-processing techniques** that can bring a 3D printed part to the necessary **smoothness**.

- Ultrasound cleaning (removes the debris deposited on the component)

- Centrifugal Disc polishing
- High-energy centrifuge (Centrifugal deburring)
- Ultrasonic abrasion finishing
- Vibratory grinding
- Stream Finishing
- Abrasive Flow Machinig
- Fluidized bed machining
- Magnetic Abrasive Finishing
- Laser polishing
- Electrochemical polishing
- Chemical polishing

Post-processing techniques: an overview

Polishing **small internal passages is a very challenging task**, in particular for AM parts where the initial average roughness is high.

At the extreme, **post-processing costs** can erode the advantages 3D printing brings in the first place by **adding steps (and time)** to the manufacturing process.

Post-processing techniques: an overview

Vibratory grinding

Centrifugal Disc polishing

Post-processing techniques: an overview

Stream Finishing

Vibratory Grinding

Post-processing techniques: Abrasive Flow Machining (AFM)

- **One Way**
- **Two Way**
- **Orbital**

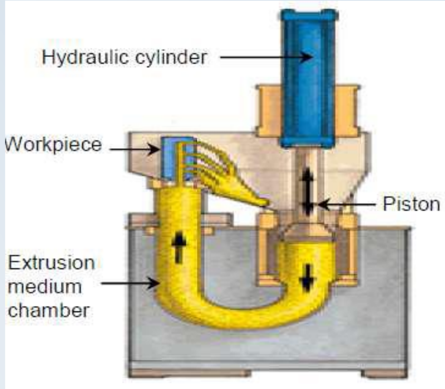
$\left.\right\}$ **Abrasive Flow Machining (AFM)**

AFM:

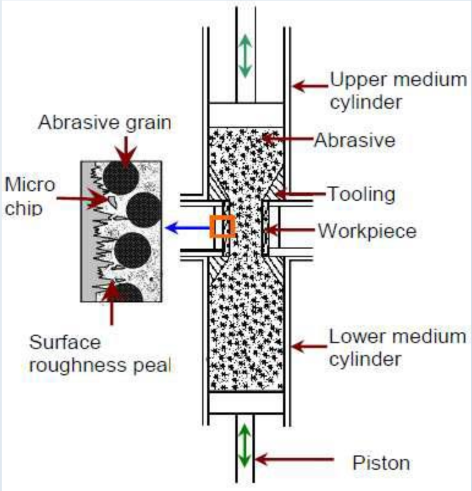
- Easy flowability
- Better self deformability
- Fine abrading capability
- Layer thickness of material removed is, order of about 1µm to 10 µm
- Best surface finish that has been achieved as 50nm and tolerances +/- 0,5 µm

Post-processing techniques: Abrasive Flow Machining (AFM)

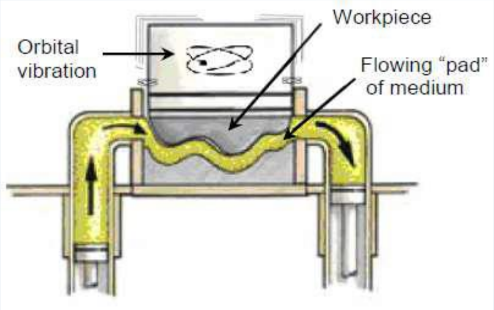
- **One-way flow** AFM processing pushes abrasive media through the work piece in only one direction.



- **two-way flow** AFM process uses two vertically opposed cylinders to extrude an abrasive media back and forth through or around passages formed by the workpiece and tooling.

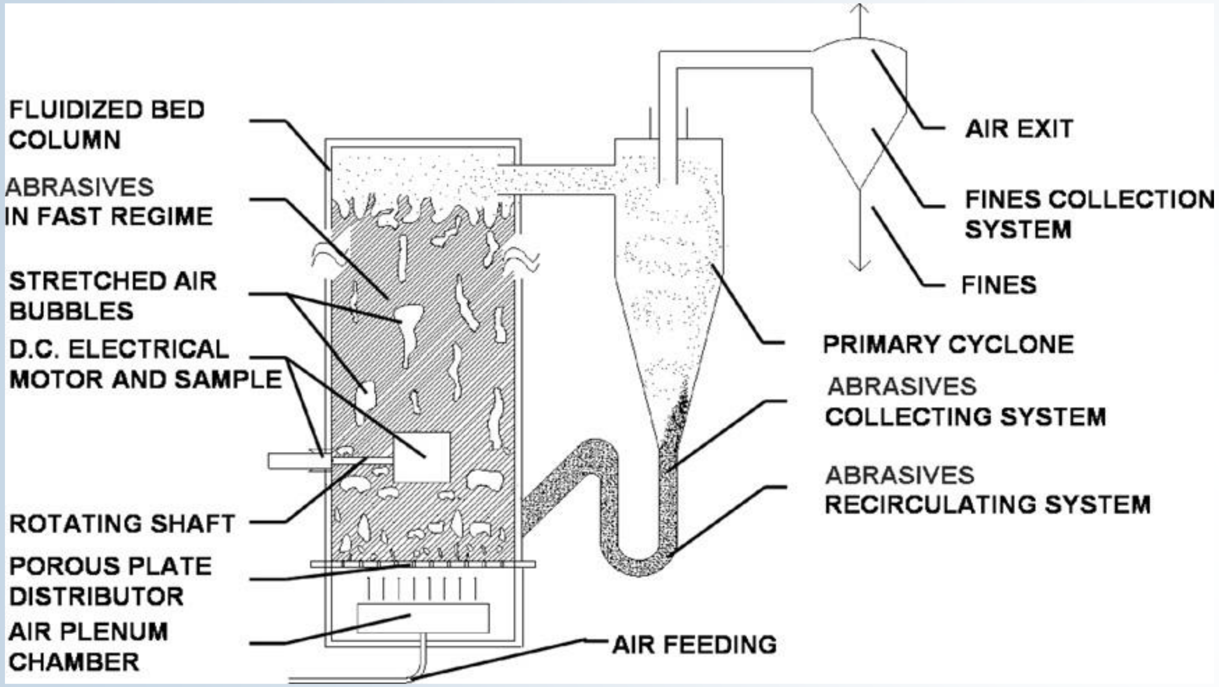


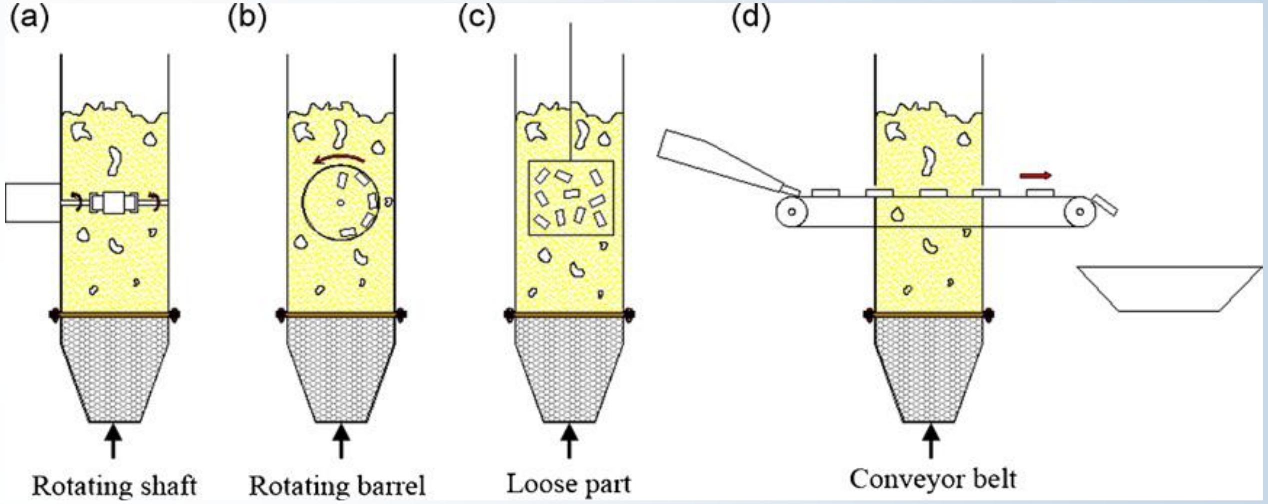
- **Orbital AFM**: surface and edge finishing are achieved by rapid, low-amplitude, oscillations of the work piece relative to a self-forming elastic plastic abrasive polishing tool.



Post-processing techniques: Fluidized bed machining

Fluidized bed machining





Journal of Materials Processing Technology 209 (2009) 6087–6102

Post-processing techniques: an overview

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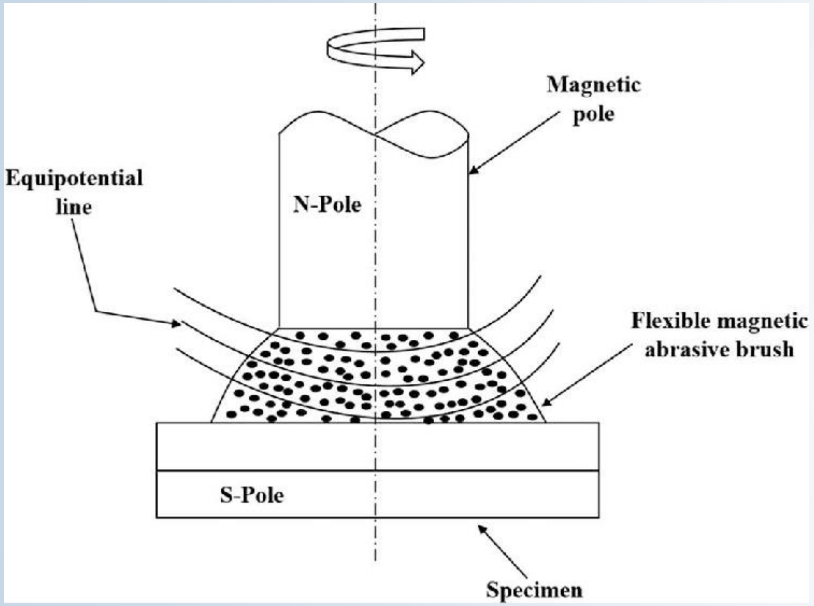
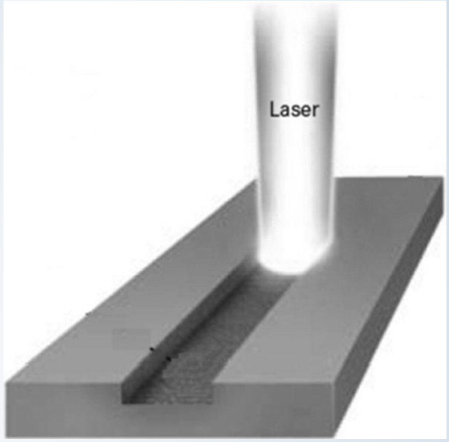
Magnetic Abrasive Finishing



Laser Finishing



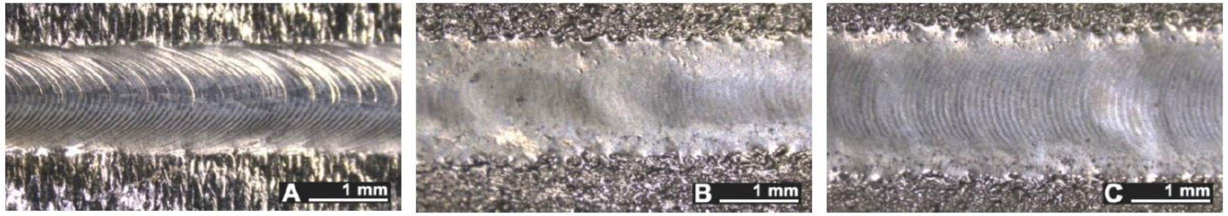
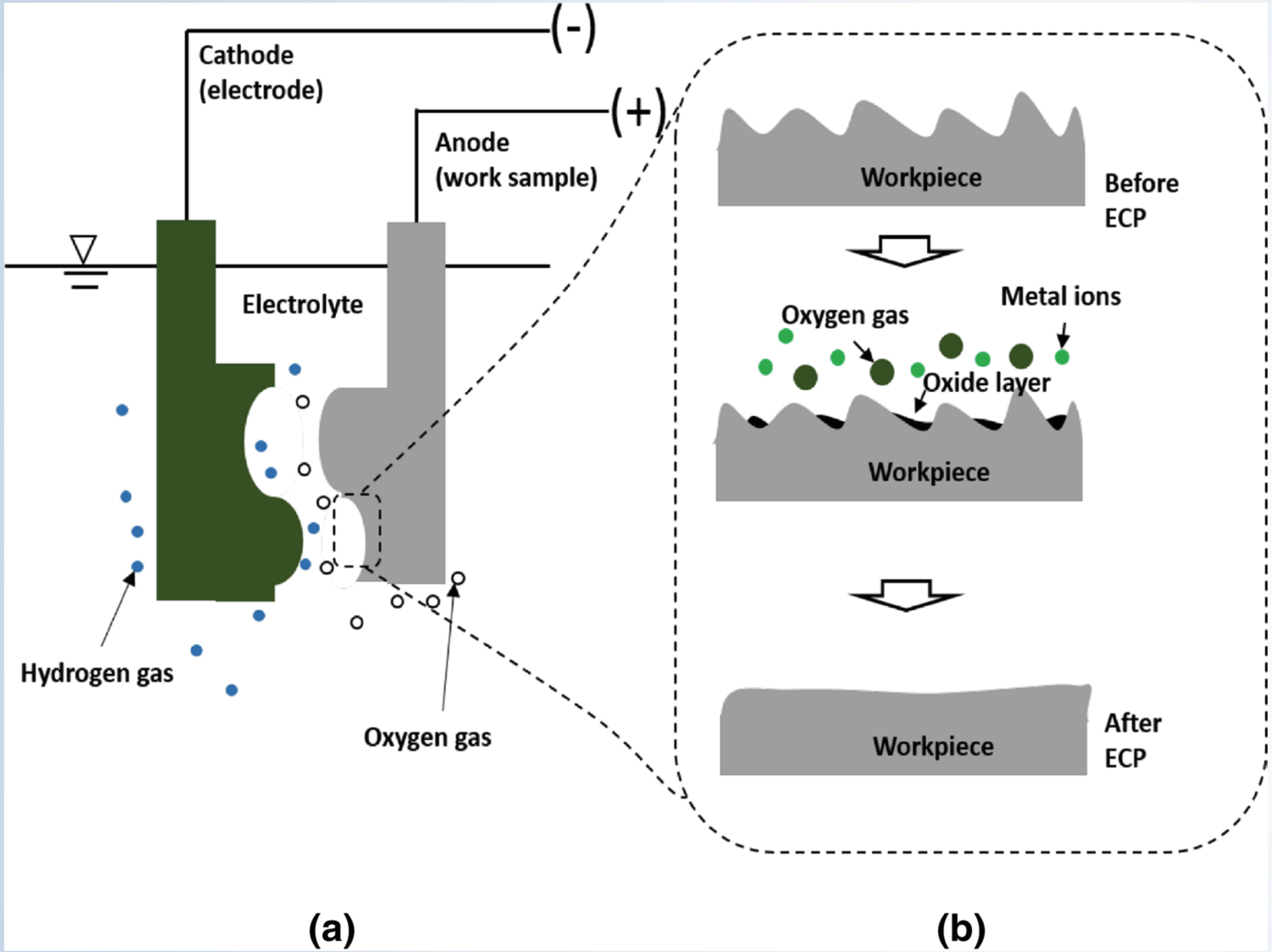


Figure 6. Examples of visual inspections upon laser surface modification (LSM) with laser beam wobbling, 2 mm amplitude at 400 Hz frequency: (**A**) flat-built; (**B**) 45°-built; and (**C**) upright-built samples.

Materials 2017, 10(1), 30; https://doi.org/10.3390/ma10010030

J. Inst. Eng. India Ser. C (August 2018) 99(4):481–487

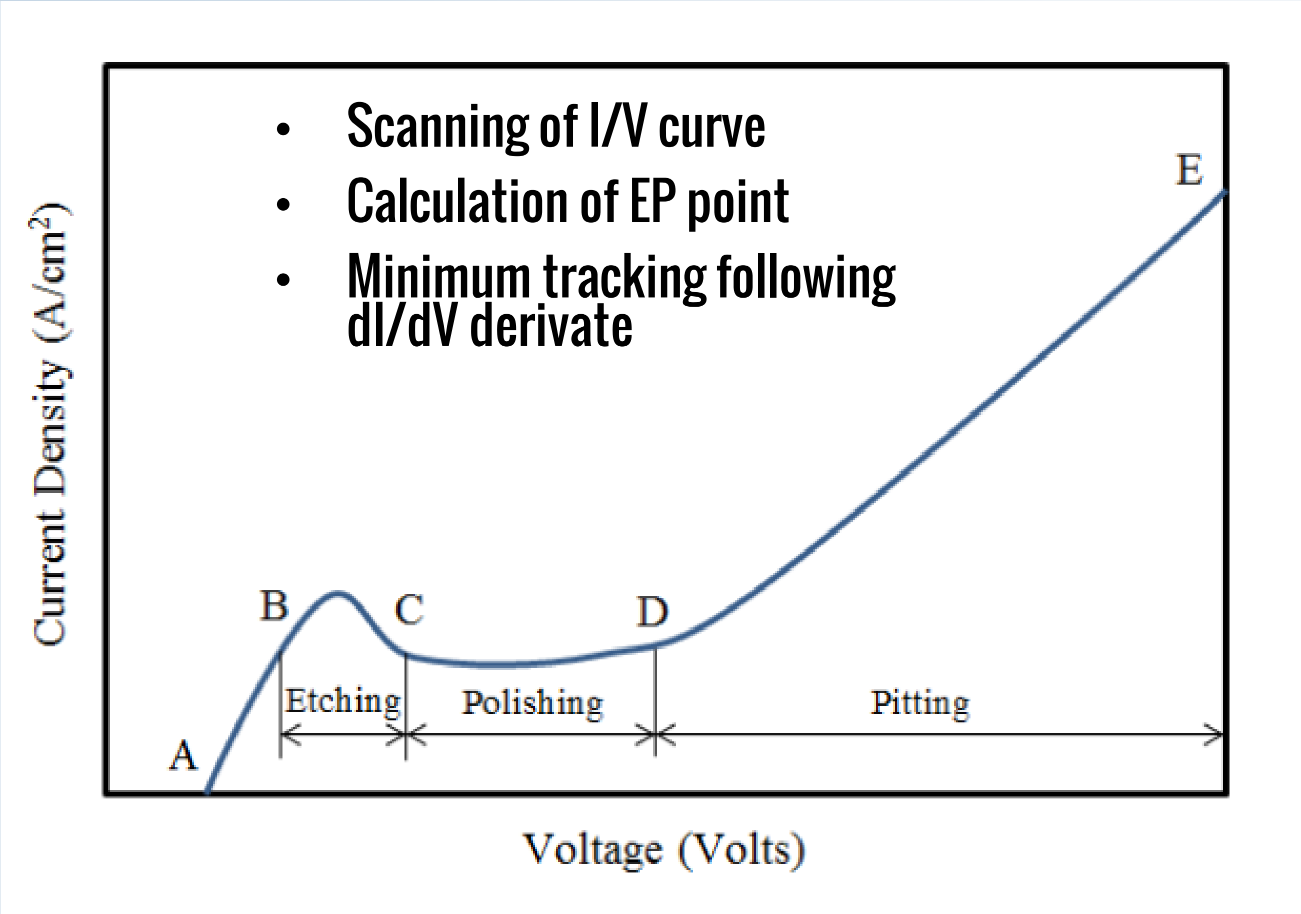
Post-processing techniques: Electropolishing

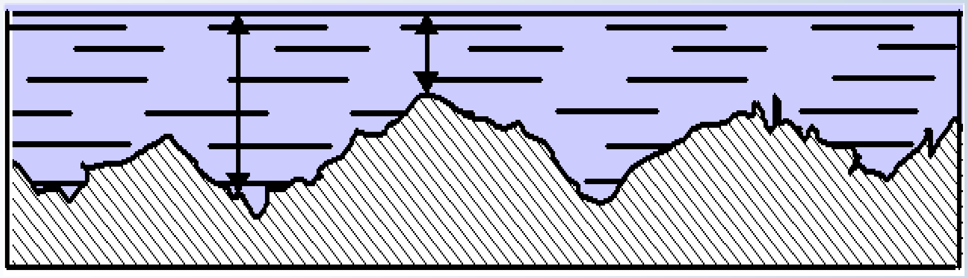


Electropolishing can improve metal surface quality through **electrochemical dissolution and levelling process**

International Journal of Precision Engineering and Manufacturing-Green Technology
https://doi.org/10.1007/s40684-019-00019-2

Post-processing techniques: Electropolishing





The peaks dissolve faster than the valleys, which produces a leveling effect on the surface

Electropolishing and chemical polishing techniques have been developed to produce copper surfaces of Ra<20 nm.

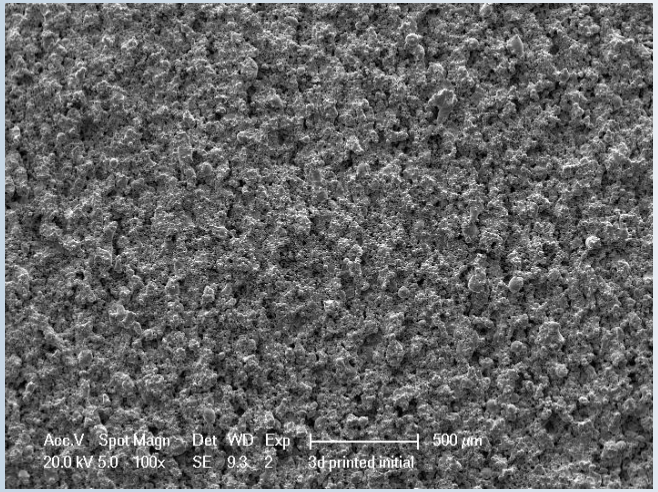
Post Processing on 3DP Copper

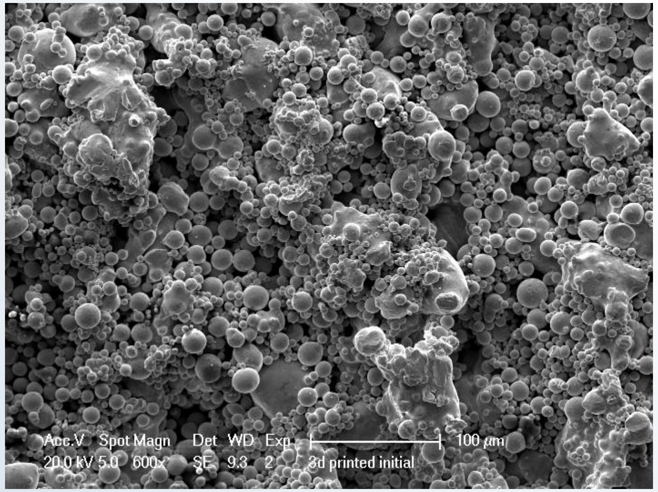
3D-PRINTED SAMPLES

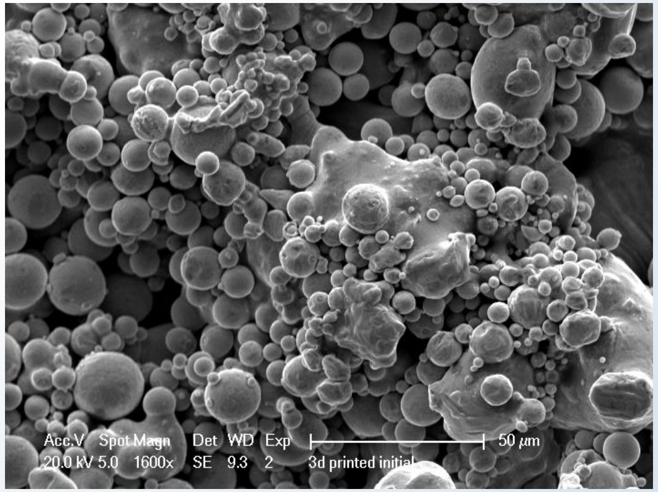
INITIAL PARAMETERS

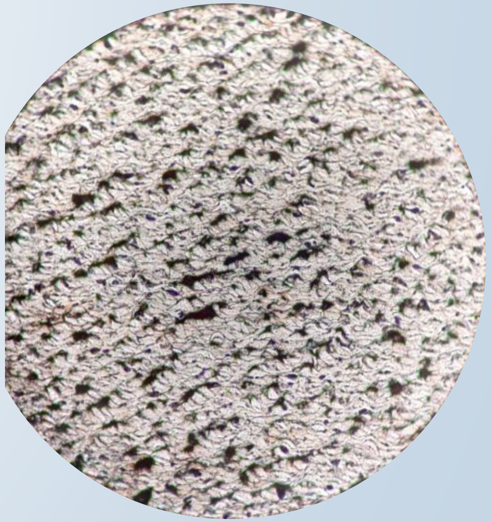
Ra ~11 µm

Base			
Long, 6mm		Short, 1 mm	
Ra, nm	Rq, nm	Ra	Rq
10757	13832	8655	10457
12063	14733	11403	14499
11943	15151	12635	15690
~11588	**~14572**	**~10898**	**~13548**









Copper 3DP in LNGS – INFN laboratory

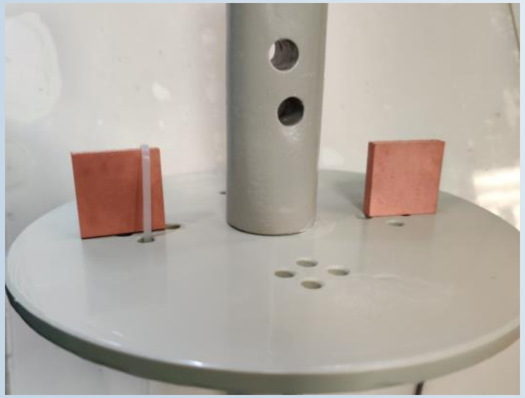
Post Processing on 3DP Copper: TUMBLING

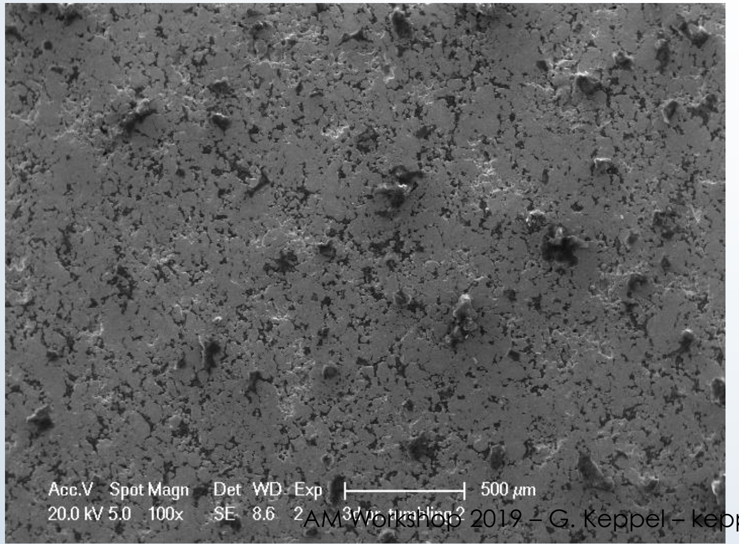
MECHANICAL POLISHING

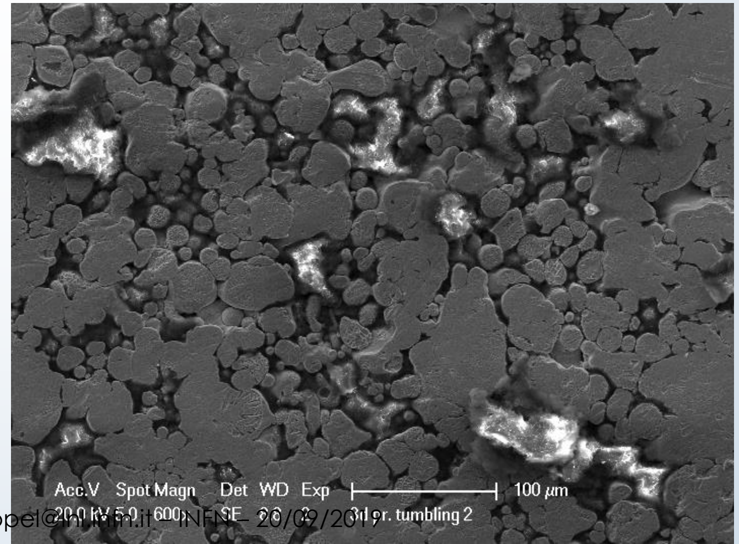
Parameters	Values
Time	24 h
Speed	~40 rev/min
Media quantity	~3500 ml
Water quantity	~1250 ml
Rodaclean soap quantity	5 ml

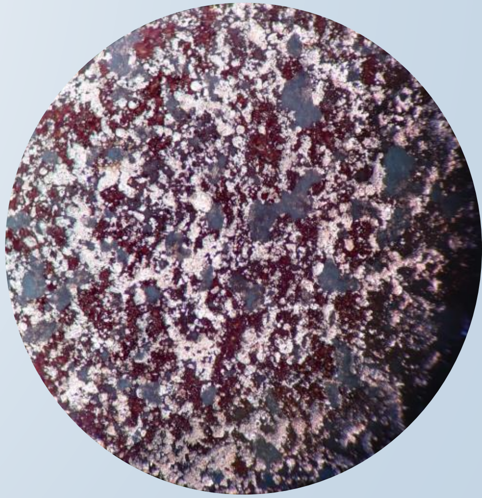
Sample	Ra, nm (6 mm)	Ra, nm (1mm)
Tumbling 1	5600	6312
Tumbling 2	4294	5561
Tumbling non fixed	2691	3037
Avarage	**4970**	**4195**

Ra using tumbling :
from ~ 11 µm to ~ 4,5 µm

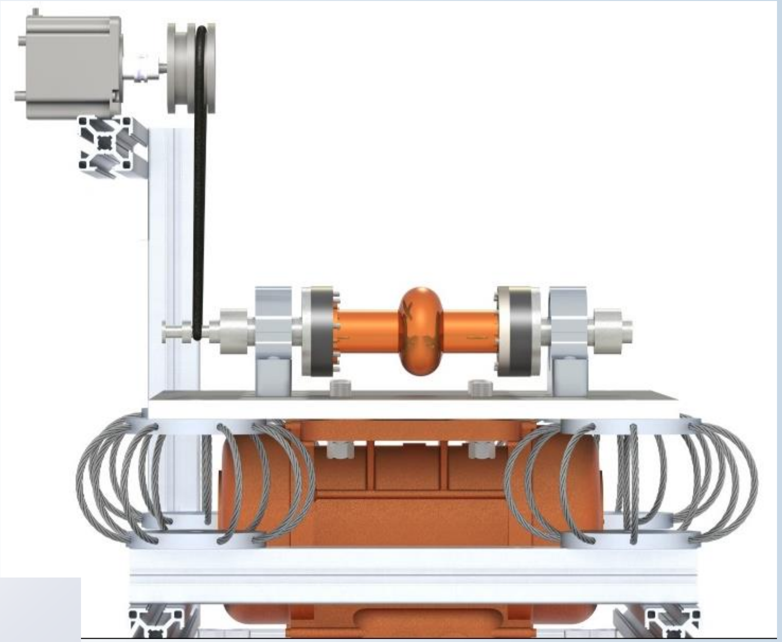




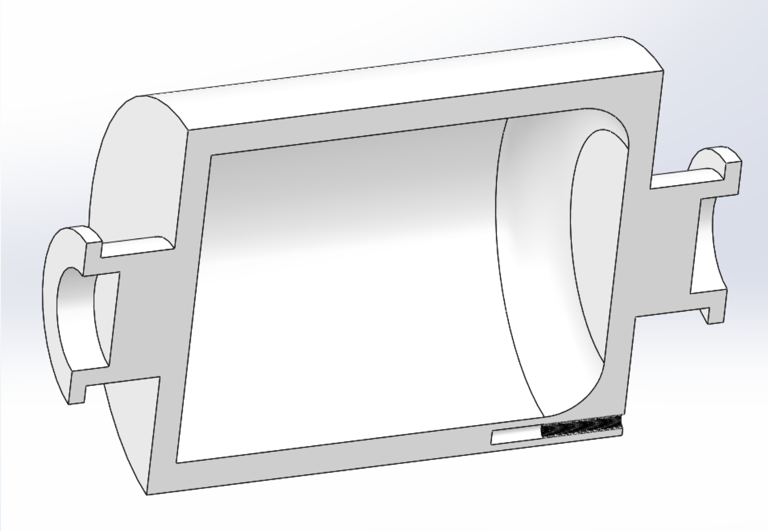




Post Processing on 3DP Copper: Vibro-Tumbling



UNDER DEVELOPEMENT



Post Processing on 3DP Copper: Chemical Polishing

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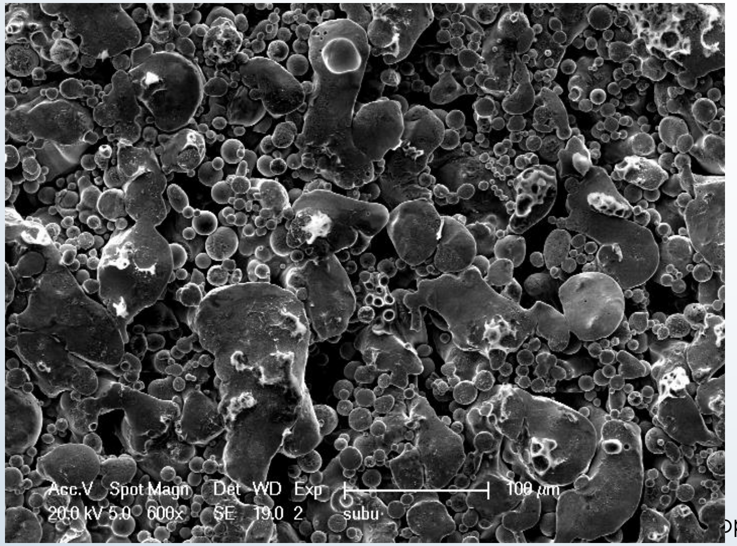
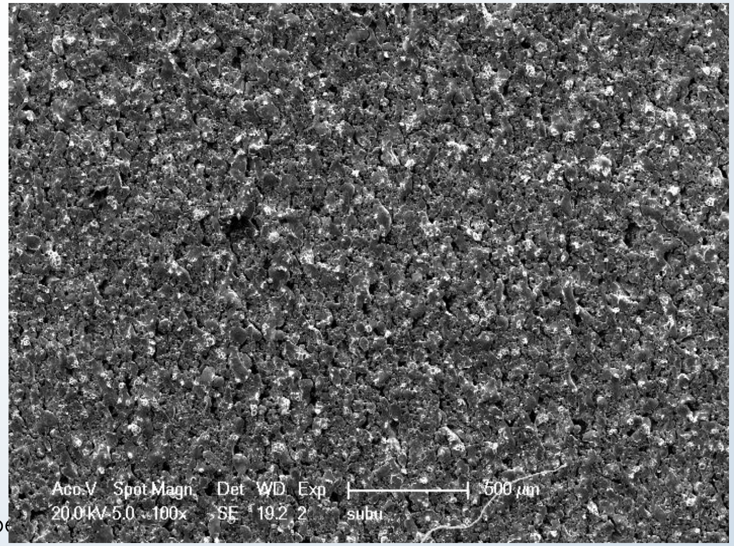
SUBU TREATMENT

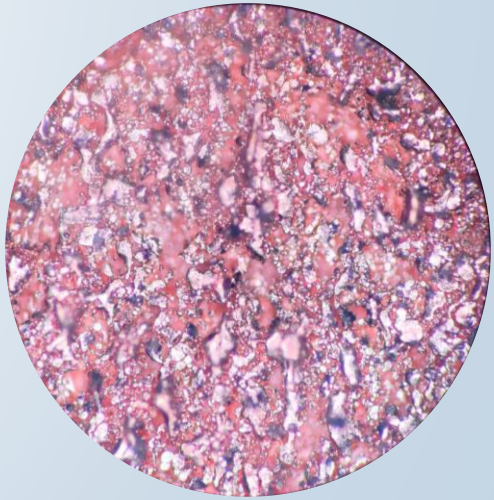
Parameters	Value
Volume	4 l
Time	5 min
Sulfamic acid	5 g /l
Ammonium citrate	1 g/l
Hydrogen peroxide	50 ml/l
Butanol	50 ml/l

Sample	Ra, nm (6 mm)	Ra, nm (1mm)
SUBU avarage	9706	7843

Ra using Chemical Etching :
from ~ 11 µm to ~ 8 µm







Post Processing on 3DP Copper: Electropolishing

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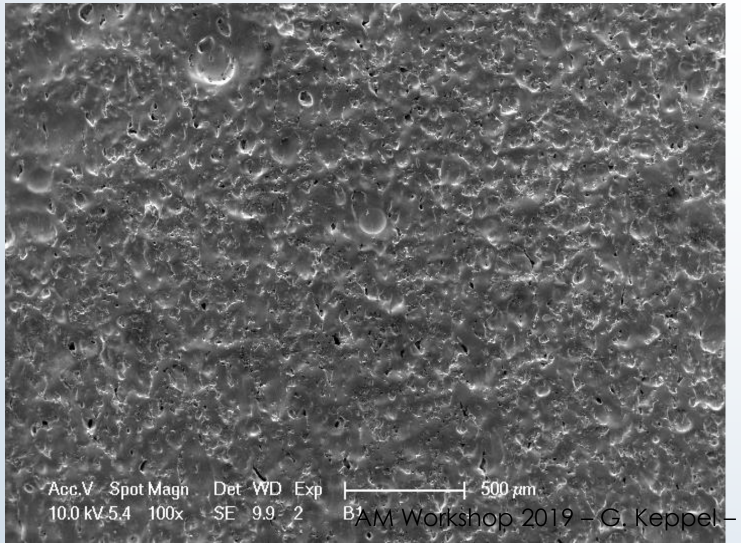
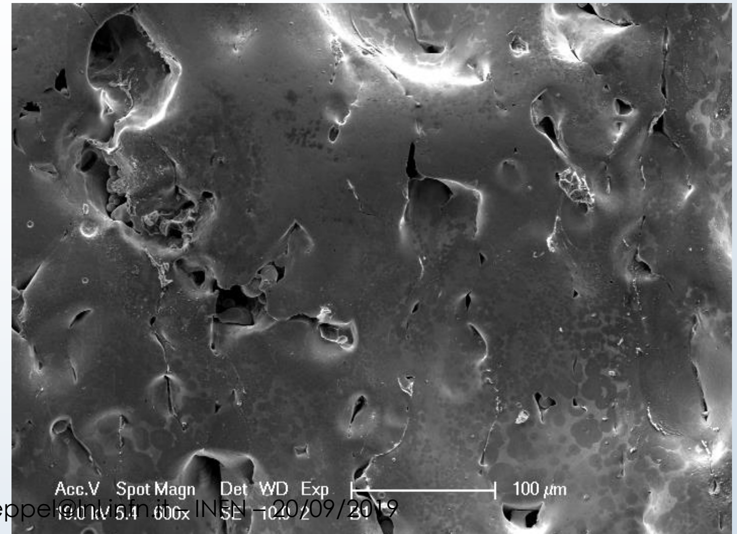
EP, TO IMPROVE MICRO-ROUGHNESS

Parameters	Value
Volume	variable
Time	10-45 min
Phosphoric acid	60%
Butanol	40%
Working voltage /current density	Smart choose, based on conductivity value

Sample	Ra, nm (6 mm)	Ra, nm (1mm)
UNDER MEASURMENT		





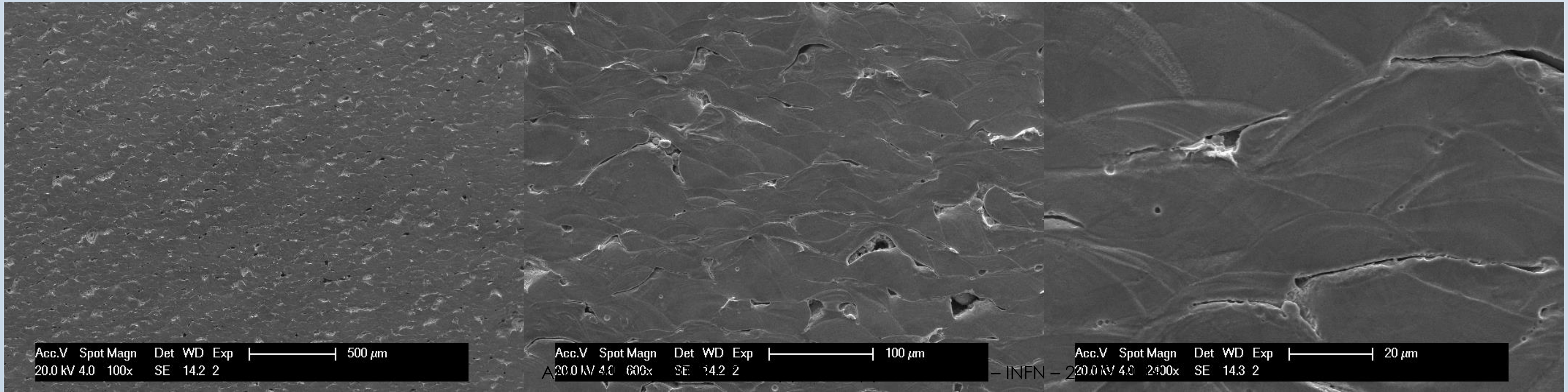
Post Processing on 3DP Copper: Fast Electrolpolishing

- Similar to electrochemistry (electrodes, solution and etc.)
- Absence of hazardous compounds
- Hight productivity & low time
- Higher metals spectre of treatment
- Perfect for planar and elliptical shapes
- Quick surface decontamination (from 30 seconds)
- Continuous polishing process
- removal of various contaminations (paints, oils, scales, rust/oxides, abrasive impurities)

Process time	Long, 6mm		Short, 1mm	
	Ra	Rq	Ra	Rq
12	1666	2087	639,5	784,28
8:30	1323	1855	975	1834

Ra using Chemical Etching :
from ~ 11 µm to ~ 1 µm

Quality could be increased, by using pre-treatment mechanical polishing.
The more we got better and smooth on both micro and macro – levels, the more polishing effect is possible to achieve.



Conclusion and comments

- **Chemical process** seems to be **very promising** for reducing 3DP surface roughness.

- Fast EP reduce in short time 3DP roughness

- The surface treatments technologies can be converted to **industrial application**.

- A combination of different process need to be further investigated for improving 3DP surface quality.

Master in Surface Treatments for Industrial Applications

- Organized by INFN and UNIPD
- Registration Deadline: 03/10/2019
- More than 300 h of lectures plus more than 400 h of practical activities in laboratory and/or industrial stage

For more info:
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martin@lnl.infn.it

https://www.unipd.it/corsi-master/surface-treatments-industrial-applications

www.surfacetreatments.org