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I.FAST task 10.3: Refurbishment of accelerator components by Additive Manufacturing (AM) technologies

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Identification of possible component for repair

Tantalum cathode of Internal Cold cathode Penning Ionization Gauge (PIG) ion source of the Advanced Molecular Image Technologies (AMIT) superconducting cyclotron in CIEMAT
Plasma is formed by the gas and by axial magnetic field accelerated electrons that move in the helical orbit.

Opposite side cathode is bombarding with positive ions that heat up cathode and that start to supply electrons by thermionic emission.
Ta Cathode damage

The cathodes sputtering by ions form the discharge which produces a crater-shaped erosion profile.

Unused and used electrodes
Ta cathode AM repair as a prototype

- To show AM capability in accelerators
- To establish pros and cons
- To signify sustainability
- To improve AM technologies
Characterization before repairs

Sample labels: Ta-0 (unused), Ta-1, Ta-2

Activities:

• Optical 3D measurement (Alicona Infinite focus)
• Surface morphology by SEM
• Surface chemical analysis by EDS
• Microstructure by Optical microscopy and SEM
3D laser scanning

Ta-0  Ta-1  Ta-2
Grain structure

Cut directions
Grain structure Base

Ta-0

Uniform grain. Size approx 10-20micron

Ta-1

Ta-2
Grain structure Head

**Ta-1**
Few grains. Sizes approx. 50-300μm

**Ta-2**
One grain structure at tip.
Strategies for repair I

Mass production process

1. Cut off head at distance L;
2. Produce new electrode tip on top
Strategies for repair II

Individual repair process

1. 3d laser scan (+graphite coating)
2. Individual CAD
3. Individual CAM
4. Remove material from surface at depth H
5. Add material to damage crater
6. Machine to remove excess material
Technologies for repair

Directed Energy Deposition with wire

Process head COAXwire mini

- Miniaturized version for high-precision processing of complex components with fine wire
- Wire diameter 100 – 600 μm
- Complete material utilization
Technologies for repair

Directed Energy Deposition with powder

Principle of DED with powder
Preliminary tests - wire

Results DED wire

Dots

Single tracks
Electrode repair - wire

Single dot strategy
Distinct oxidation layer. Uniform porosity with few large inclusions. Large grain size.
Preliminary tests - powder

Tracks

Domes

Dots
Electrode repair - powder

Concentric circles strategy for domes
Preliminary tests - powder

Lack of fusion, inclusions and pores, coarse grain structure.
Preliminary tests - powder

Multi layer build-up

Overheating and layer flowing after 10 layers (3mm)
Electrode repair - wire

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Electrode repair - powder

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Survey

- To find out accelerator community experience with AM (repairs and production)

- Searching for potential components for repair and production applications

Inputs for MS45 (M24)
Next steps

• Metallographic analysis of repaired parts at PoliMi
• In-situ testing at CIEMAT

• Study of Survey results in details
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