ADDITIVELY MANUFACTURED TANTALUM CATHODE FOR FEBIAD TYPE ION SOURCES: PRODUCTION, GEOMETRIC MEASUREMENTS, AND HIGH TEMPERATURE TEST

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Abstract

The Laser Powder Bed Fusion (LPBF) is an Additive Manufacturing (AM) technology suitable to produce almost free-form metallic components. At Legnaro National Laboratories (LNL) of the Italian National Institute for Nuclear Physics (INFN), the LPBF process was recently used to produce parts of the Forced Electron Beam Induced Arc Discharge (FEBIAD) ion source for the SPES Isotope Separation On-Line (ISOL) facility. In this work are presented the feasibility assessment and production steps of tantalum cathodes produced via AM; in addition, the results concerning both the dimensional–geometrical measurements and the preliminary high-temperature test are reported.

INTRODUCTION

In this work the AM production of prototype tantalum cathodes is presented, together with their preliminary characterization activities. In particular, relevant dimensional/geometrical features were measured and a preliminary high temperature test was performed to assess the compatibility of the AM components to the operative working conditions. The SPES (Selective Production of Exotic Species) facility at LNL-INFN operates according to the ISOL technique to produce Radioactive Ion Beams (RIBs) necessary for the performance of research activities in interdisciplinary scientific fields [1, 2].

MATERIALS AND METHODS

The cathode design was slightly modified in order to be entirely produced using the EOS M100 DMLS system from Electro-Optical Systems GmbH (EOS GmbH, ...
without additional subtractive manufacturing post-processing, as shown in Figure 3.

Figure 2: AM cathode design (left) compared to the standard one (right).

The M100 machine is equipped with a 200 W Yb:YAG laser with a wavelength of 1064 nm and a 40 µm Gaussian spot diameter. A spherical Ta powder manufactured by Taniobis (Taniobis GmbH, JX Nippon Mining and Metals group, Goslar, Germany) with a Particle Size Distribution (PSD) of D10=10 µm, and D90=63 µm was used to produce the samples. The process was performed under a controlled atmosphere (Argon gas) in order to keep the oxygen content in the building chamber below 0.1%, and the building plate was pure copper as it is particularly suitable for additive manufacturing of refractory metals compared to the commonly used steel platforms [6, 8]. The layer thickness used was 0.03 mm.

A feasibility analysis concerning the critical parts of the AM cathode was performed (Figure 4): to define the proper inclination of the tilted surfaces, several samples having different slopes were prepared.

Furthermore, aiming to determine the process parameters that allow to enhance the surface quality, three concentric cylinders were produced by considering different production settings. Afterwards, the dimensional features of such samples were measured the by the Coordinate Measuring Machine (CMM) Zeiss Accura.

The experimental apparatus that allows to reproduce the operating conditions of the cathode is shown in Figure 4, while its working principle is detailed in [4]: the cathode is heated up by joule effect thanks to a dedicated power supply, while the high vacuum level (10-6 mbar) is maintained inside the aluminum chamber by a turbomolecular pump. The sample was maintained at ≈2200°C by applying a constant electric current of 440A for about 120 hours.

Furthermore, the observing windows in Kodial® glass allow to measure the samples temperature through infrared pyrometers from both their frontal and lateral surfaces.

RESULTS AND DISCUSSION

Three AM tantalum cathodes prototypes as the ones reproduced in Figure 6 were successfully produced by LPBF.

Two cathodes were measured by the CMM to get information regarding their geometric and dimensional features, indeed these measurements provided the displacements with respect to the nominal dimensions of the component. The results concerning the main features are reported in Table 1.
Table 1: The CMM Results Reported Below Allowed to Quantify the Displacement From the Nominal Dimensions of the Component (Δ)

<table>
<thead>
<tr>
<th>Dimensional/Geometric Feature</th>
<th>Avg Value</th>
<th>Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter Cylinder Ø3</td>
<td>2.936 mm</td>
<td>0.064 mm</td>
</tr>
<tr>
<td>Diameter Cylinder Ø12</td>
<td>12.018 mm</td>
<td>-0.018 mm</td>
</tr>
<tr>
<td>Cylindricity Ø12</td>
<td>0.025 mm</td>
<td>-</td>
</tr>
<tr>
<td>Flatness Flange</td>
<td>0.035 mm</td>
<td>-</td>
</tr>
<tr>
<td>Distance 16mm</td>
<td>16.056 mm</td>
<td>-0.056 mm</td>
</tr>
<tr>
<td>Flatness Front surface</td>
<td>0.003 mm</td>
<td>-</td>
</tr>
<tr>
<td>Cone angle 80°</td>
<td>79.549°</td>
<td>0.452°</td>
</tr>
</tbody>
</table>

Regarding the dimensions of the parts, the displacements Δ were always below 0.1 mm, moreover the accuracy of the geometric features (i.e., flatness and cylindricity) of the main cathode surfaces was limited at the order of ≈ 0.03 mm.

Figure 8: The cathode front (left) and lateral (right) surfaces can be observed during the HT test through the viewports.

The remaining produced cathode was subjected to a preliminary high temperature (HT) test detailed in the previous section through the dedicated experimental setup. The component was observed during the HT test through the Kodial® viewports which allow to qualitatively assess the deformations of the front surface due to the thermal expansion that occurs at such a temperature level. Neither defects nor distortions were observed during the permanence at high temperature, as can be seen from the images reported in Figure 8. Once concluded the HT test, the cathode was subjected to a visual examination, which confirmed the absence of either relevant distortions or fractures as can be seen in Figure 7.

CONCLUSION

The LPBF technology allowed to successfully produce prototypical tantalum cathodes that were subjected to geometrical characterization and preliminary high temperature test.

The accuracy of the dimensional and geometric features was quantified by CMM measures, in particular the displacement with respect to the nominal dimensions were always below 0.1 mm.

Figure 8: The cathode after the HT test does not present relevant distortions. Furthermore, the recrystallization due to the high temperature long time exposure can be appreciated.

The preliminary high temperature test at about 2200°C for a period of 120 hours suggested the suitability of the LPBF production process for the manufacturing of tantalum cathodes, indeed the tested sample did not present significant deformations due to thermal stresses after visual inspection. However, further CMM measurements will be performed to quantify the distortions after the HT test.

Such preliminary results lay the foundations for the development of innovative ion source components exploiting the unparallel design degrees of freedom provided by the AM technologies.

REFERENCES