Contribution ID: **28**

Type: **not specified**

LPBF of pure copper for particle accelerator applications

Pure copper is largely used to manufacture particle accelerator components, such as vacuum devices and accelerating cavities, because it combines excellent electrical and thermal conductivity with good workability and solderability. These components often feature complex geometries, like connectors and internal cooling channels, that can only be manufactured following sophisticated routes that involve several brazing, machining, and heat treatment operations. These result in high production costs and long lead times.

In this work, laser powder bed fusion (LPBF) of pure copper is investigated for the manufacture of particle accelerator components, because it has the potential to create complex geometries that cannot be easily fabricated with conventional techniques. Also, it is particularly suited to manufacture prototypes and one-off parts with lower costs and lead times.

Commercial LPBF machines equipped with both infrared and green laser sources are used to fabricate pure copper samples and prototypes, like electrodes for high-voltage (HV) testing and thin membranes for helium leak testing. As-printed specimens are characterized in terms of chemical purity, surface roughness, microstructure, mechanical properties, and electrical and thermal conductivity.

LECO measurements reveal a similar oxygen content of about 0.04 wt.% for all specimens. As-printed parts exhibit rough external surfaces with a large amount of partially sintered particles. An anisotropic microstructure consisting of elongated grains oriented along the build direction was observed in all specimens. Occasional defects like unmelted particles and sub-surface porosity result in a relative density of about 99.3%. All printed parts show a similar microhardness of about 75 HV0.05. As regard the physical properties, specimens exhibit electrical conductivity and thermal diffusivity above 95% of the pure copper standards. Slightly lower electrical and thermal properties are measured in the transversal direction compared to the build direction due to the microstructural anisotropy.

Future developments include microscopy investigation of the electrodes after being subjected to vacuum arc breakdown testing to determine the surface features produced during breakdown. Also, thin membranes that failed tightness testing will be characterized to identify structural defects causing helium leakage.

Type of contribution

Talk

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