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PROCEEDINGS

Superior Mechanical Properties of a Zr-Based Bulk Metallic Glass via Laser Powder Bed Fusion Process Control

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ABSTRACT

Additive manufacturing has made the fabrication of large-dimensioned bulk metallic glasses (BMGs) achievable; however, questions remain regarding how to control the processing parameters to obtain dense and fully amorphous BMGs with desirable mechanical properties. Here, laser powder bed fusion (LPBF) was used to produce dense and fully amorphous $Zr_{59.3}Cu_{28.8}Nb_{1.5}Al_{10.4}$ BMG samples from two different starting powders within a large processing window of laser powers and scanning speeds. X-ray diffraction (XRD) revealed that fully amorphous materials with high relative densities (>99%) were obtained when the LPBF energy density ranged from ~20 J/mm^3 up to ~33 J/mm^3 for coarse powder with low oxygen and up to ~30 J/mm^3 for fine powder with higher oxygen. For the fully XRD amorphous samples, strength and hardness increased with increasing energy density while the relaxation enthalpy and ductility tended to decrease. Transmission electron microscopy revealed that the softer samples contain larger FCC-like medium range order clusters within the amorphous matrix. With higher LPBF energy density, high relative density was still achieved along with devitrification and embrittlement. While lower energy densities below ~20 J/mm^3 could retain a fully XRD amorphous structure, such samples had relative densities <99%. When comparing the two powders, the coarse powder with four times lower oxygen content gave better glass forming ability, compression ductility up to 6% plastic strain, and fracture toughness up to ~38 MPa$\sqrt{m}$. These findings demonstrate that it is possible to tailor the structure and mechanical properties of BMGs by tuning the LPBF process parameters within a wide processing window.

KEYWORDS

Laser powder bed fusion; bulk metallic glass; mechanical properties; relaxation enthalpy; medium range order

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