Additive Manufacturing Results of Multi-Principal Element Alloy (MPEA) Design Work

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ABSTRACT

In an intense effort to expand alloy choices for AM, new multiple principal element alloy (MPEA) designs are being explored that should be suited to the processing parameters of fusion-based AM. The MPEAs discussed in this work were designed based on density functional theory, addressing chemical disorder, where electron charge density and formation enthalpies are used to tune composition. In a preliminary trial of this MPEA design strategy, single-phase body-centered cubic (BCC) structures were targeted and design validation involved chill casting and gas atomized powder and directed energy deposition (DED) builds of 19Al-19Fe-19Ni-19Co-19Cr-5Cu (at.%). While confirmed to be single-phase BCC, the alloy was found to be brittle in the DED builds and after laser surface re-melting of the chill castings, even after stress relief annealing. Further MPEA designs using the same components emphasized the addition of ductility by incorporating a secondary face-centered cubic (FCC) phase. Four alloys were produced by chill castings, annealed, and subjected to laser re-melting track tests before powder synthesis. Microstructural analysis of cast and annealed substrates and re-melted zones enabled selection of an improved AM candidate composition, 43Ni-25Al-9.0Fe-9.0Cr-9.0Co-5.0Cu, which was predicted to have equal thermodynamic favorability for BCC and FCC phases and appeared to mitigate solidification and residual stress cracking. This alloy was gas atomized experimentally and by an industrial partner to provide feedstocks for DED build parameter development and full density prismatic builds. These samples were sectioned for tensile testing and the promising results are reported herein.

INTRODUCTION

Additive manufacturing (AM) is rapidly being deployed and further developed as a manufacturing method to produce net-shape parts with complex internal and external geometries and for functional systems with reduced part counts. Other AM benefits can include compositional gradation, topology optimization, rapid prototyping, and cost advantages from reducing material waste of expensive alloys. Multi-principal element alloys (MPEAs), a more inclusive category than high entropy alloys (HEAs), are an exceptionally broad and unexplored alloy class [1] that seems to be a perfect fit for AM since they can exhibit exceptional