Physical, Mechanical, and Electrical Properties of Copper Fabricated via Sinter-Based Material Extrusion (MEX) 3D Printing

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ABSTRACT

This work uses a sintered based material extrusion additive manufacturing (MEX-AM) process to fabricate high-density copper parts via extrusion-based 3D printing technology. In the current work, copper powder-filled polymeric feedstocks and filaments with 58 vol.% and 61 vol.% solids loading were prepared and characterized for physical, thermal, and rheological properties. Subsequently, the filaments were 3D printed into tensile and tablet geometries via a benchtop MEX-AM machine. An L9 Taguchi design of experiments was performed by varying print temperature, print speed, and layer height for three levels to identify optimal process conditions to obtain the highest green density. Copper green parts were further sintered and characterized to understand the final part's physical, mechanical, and electrical properties. This study aims to provide a holistic understanding of the structure-property-processing relationship in copper parts fabricated via sintered based MEX 3D Printing.

1 Introduction

MEX is a hybrid additive manufacturing technique that combines Fused Filament Fabrication (FFF) for green part fabrication with thermal processing fundamentals of powder injection molding for debinding and sintering. A powder binder mixture is blended and extruded into a filament, which is then passed through a heated nozzle and deposited onto a heated platform, following a predetermined path to complete a three-dimensional (3D) part. **Figure 1** shows a typical MEX process overview where homogeneous blends of copper powder-binder are made using an appropriate mixer (such as torque rheometer), which are then extruded to produce filaments for 3D printing. Subsequently, parts are then printed using typical desktop fused filament fabrication (FFF) 3D printers. Finally, the green parts are processed through debinding (solvent and/or thermal) followed by sintering to achieve dense, solid parts.

Material and process parameters can affect the performance of the FFF feedstock materials. The effect of parameters such as particle size distribution, binder composition, solids loading, heating rate, hold time, and other post-processing parameters on feedstock quality and printability have been extensively studied [1–8]. However, non-ferrous alloy systems such as copper have not been extensively processed via additive manufacturing due to the challenges associated with printing and sintering these material systems. In this paper, feedstocks containing copper powders were characterized in terms of viscosity and printed part properties to test the printability using a conventional FFF machine. These green parts are further debound and sintered to obtain dense copper parts.