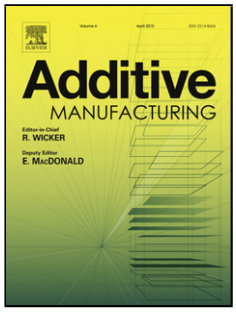


Title: A novel freeform extrusion fabrication process for producing solid ceramic components with uniform layered radiation drying

Authors: Amir Ghazanfari, Wenbin Li, Ming C. Leu, Gregory E. Hilmas

PII: S2214-8604(16)30163-4
DOI: http://dx.doi.org/doi:10.1016/j.addma.2017.04.001
Reference: ADDMA 166

To appear in:

Received date: 7-7-2016
Revised date: 3-3-2017
Accepted date: 11-4-2017

Please cite this article as: Amir Ghazanfari, Wenbin Li, Ming C.Leu, Gregory E.Hilmas, A novel freeform extrusion fabrication process for producing solid ceramic components with uniform layered radiation drying (2010), http://dx.doi.org/10.1016/j.addma.2017.04.001

# A novel freeform extrusion fabrication process for producing solid ceramic components with uniform layered radiation drying

Amir Ghazanfari [a,*], Wenbin Li [a], Ming C. Leu [a], Gregory E. Hilmas [b]

[a] Department of Mechanical and Aerospace Engineering, Missouri University of Science and Technology, Rolla, MO, USA
[b] Department of Materials Science and Engineering, Missouri University of Science and Technology, Rolla, MO, USA

## Abstract

An extrusion-based additive manufacturing process, called the Ceramic On-Demand Extrusion (CODE) process, for producing three-dimensional ceramic components with near theoretical density is introduced in this paper. In this process, an aqueous paste of ceramic particles with a very low binder content (<1 vol%) is extruded through a moving nozzle at room temperature. After a layer is deposited, it is surrounded by oil (to a level just below the top surface of most recent layer) to preclude non-uniform evaporation from the sides. Infrared radiation is then used to partially, and uniformly, dry the just-deposited layer so that the yield stress of the paste increases and the part maintains its shape. The same procedure is repeated for every layer until part fabrication is completed. Several sample parts for various applications were produced using this process and their properties were obtained. The results indicate that the proposed method enables fabrication of large, dense ceramic parts with complex geometries.

**Keywords:** 3D printing; extrusion freeforming; fused deposition; robocasting; radiation drying.

## 1. Introduction

Several additive manufacturing techniques have been developed or modified to fabricate three-dimensional ceramic components, including 3D Printing [1], Ink-jet Printing [2], Selective Laser Sintering (SLS) [3], Stereolithography (SLA) [4], Laminated Object Manufacturing (LOM) [5], and extrusion-based techniques. All of these techniques involve adding ceramic materials layer by layer. A comprehensive review on additive manufacturing of ceramic-based materials was recently published by Travitzky et al. [6].

Extrusion-based methods are among the most popular approaches for freeform fabrication of ceramic components due to the simplicity and low cost of their fabrication system, high density of their fabricated parts, their capability of producing parts with multiple materials [7] and/or as functionally graded materials [8,9], and the low amount of material wasted during processing. Major extrusion-based processes include Extrusion Freeform Fabrication (EFF), Fused Deposition of Ceramics (FDC), Robocasting (RC), and Freeze-form Extrusion Fabrication (FEF).

EFF [10] was the first technique to utilize extrusion of ceramic slurries (organic-based) to produce three-dimensional components. Slurries of alumina in liquid acrylic monomers were

* Corresponding author (amir.ghazanfari@mst.edu).