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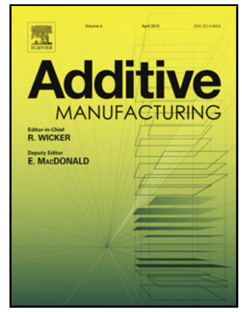

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Additive Manufacturing of Multifunctional Reactive Materials

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Abstract

This paper demonstrates the ability to 3D print a fluoropolymer based energetic material which could be used as part of a multifunctional reactive structure. The work presented lays the technical foundation for the 3D printing of reactive materials using fusion based material extrusion. A reactive filament comprising of a polyvinylidene fluoride (PVDF) binder with 20% mass loading of aluminum (Al) was prepared using a commercial filament extruder and printed using a Makerbot Replicator 2X. Printing performance of the energetic samples was compared with standard 3D printing materials, with metrics including the bead-to-bead adhesion and surface quality of the printed samples. The reactivity and burning rates of the filaments and the printed samples were comparable. Differential scanning calorimetry and thermal gravimetric analysis showed that the onset temperature for the reactions was above 350°C, which is well above the operation temperature of both the filament extruder and the fused deposition printer.

Keywords: PVDF, Energetic Materials, 3D Printing

1. Introduction

In the past 25 years, additive manufacturing (AM) technologies have evolved from rapid prototyping into a legitimate manufacturing process for functional parts and products. Several 3D printing methods, such as fusion based material extrusion, vat photopolymerization, and laser sintering, have been well developed, and the knowledge base behind the printing of standard materials is comprehensive [1, 2, 3]. However, while the printing techniques have become commonplace, there is still significant work to be done in characterizing and implementing the printed materials. Standard materials, such as acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA), have been well studied for material extrusion, but until very recently, material selection outside of these standard materials has been limited.

Ongoing AM research seeks to surpass rapid prototyping and its geometrical advantages for structural applications by encompassing the printing of multifunctional materials. For example, AM has been shown to be a viable way to print functional electronic devices [4, 5, 6]. Inkjet printing has been used to print electronic circuits by selectively depositing an ink consisting of either a conductive polymer or metal nanoparticles suspended in a solvent [7, 8]. These 2D efforts have even been coupled with 3D printing to additively manufacture structures with integrated electronic components [9]. AM has also been used to make functional devices such as batteries [10]. Recent efforts have attempted to infuse additives into the traditionally used AM polymers to improve their functionality [11, 12]. Within material extrusion, significant efforts have focused on using these additives to improve the strength of the material [13, 14]. While there has been significant advances in the printing of functional materials over the past decade, other classes of materials still need to be studied to assess their compatibility with AM. Due to the current limitations caused by traditional manufacturing techniques, one class of functional materials that would greatly benefit from AM is structural energetic materials.

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