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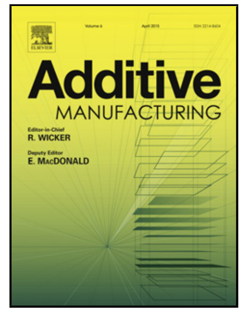

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Dielectric Strength Heterogeneity Associated with Printing Orientation in Additively Manufactured Polymer Materials

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Abstract

Anisotropy in dielectric properties can have deleterious effects in structures intended for use in high-field environments. We show that dielectric anisotropy is introduced into parts fabricated using additive manufacturing techniques based on the orientation in which the part is printed. Dielectric strength testing data, based on the ASTM D149 standard, are presented for samples fabricated using the polymer jetting (PolyJet), stereolithography (SLA), fused deposition modeling (FDM), and selective laser sintering (SLS) additive manufacturing techniques. Each unique printing direction available based on the printing method was examined in turn. Each printing technique was found to introduce anisotropic dielectric properties within the sample coupons that were a function of the original orientation in which the part was printed, and the direction of structural susceptibility was found to be print-method dependent. Differences in dielectric strength for coupons printed in different orientations were found to exceed 70% for some combinations of printing technique and polymer. Overall, test coupons printed with stereolithography (SLA) were found to exhibit the lowest degree of dielectric strength anisotropy between print orientations. Dielectric failure mechanisms are discussed.

Keywords — **Dielectric materials breakdown, Polymer plastics, Additive manufacturing.**

1. Introduction

The field of additive manufacturing (AM) has advanced greatly in the last decade. In additive manufacturing, also called 3D printing or rapid prototyping, layer by layer deposition is used to build up three dimensional objects. This allows for near net-shape fabrication of parts with complex geometries (to within the resolution of the chosen additive manufacturing process).

One of the limiting factors in high voltage electrical generation and distribution systems is the electric field stress on the dielectric insulating components, such as bushings [1–3]. Excessive electric field stress may result in dielectric breakdown events [4] that can cause damage to components and reductions in system lifetime. By carefully choosing the geometry of a high voltage insulator to minimize electric field stresses, the size and durability of the insulator can be better optimized, thus reducing component cost and enhancing the overall reliability of the high voltage system.

Additive manufacturing (3D printing) techniques allow for the fabrication of dielectric insulators with highly complex geometries [5–8]; however, the relative lack of bulk dielectric strength data [9–11] for many of the materials employed in additive manufacturing potentially limits the utility of these materials for the fabrication of structures destined for use in high electric field environments. Further, the data gathered in the present study suggest that the choice of printing orientation of the structure with respect to