MATERIALS ENGINEERING
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"Microstructure and Mechanical Properties of Textured Silicon Carbide Formed Via Direct Ink Writing and Templated Grain Growth"

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ABSTRACT

Silicon carbide (SiC) is a ceramic material of interest for many applications due to its mechanical properties, oxidation resistance, and high thermal conductivity. However, one limitation of SiC is its low fracture toughness. There is evidence that SiC with crystallographic texture and an anisotropic microstructure of aligned plate-shaped grains has improved fracture toughness without sacrificing strength. Previous techniques to create these materials have used either pressure during densification or a strong magnetic field, but these processes limit possible geometries that can be created. In this dissertation, the additive manufacturing technique direct ink writing (DIW) and pressureless templated grain growth (TGG) are proposed as a route to complex-shaped textured SiC.

DIW is a colloidal processing technique where ceramic suspensions are extruded through a nozzle along a path, building up a part layer-by-layer. High aspect ratio particles can be aligned via the forces in the print nozzle. In this work, single crystal SiC platelet seed particles were added to a SiC suspension and aligned with DIW. After densification, samples were annealed above the sintering temperature. During annealing, TGG occurs where the platelet seed particles grow at the expense of the finer matrix particles, and this results in crystallographic texture.

First, work on the development of the DIW process for the creation of textured SiC is presented. Aqueous SiC suspensions were developed with a high solids loading (53 vol%) and low polymer content (< 5 vol%) to maximize the density achieved during sintering which is ideal for TGG. Next, textured SiC ceramics over 95% theoretical density were created via pressureless sintering and annealing. SEM, x-ray diffraction, and electron backscatter diffraction were used to determine the effects of DIW, seed particles, and annealing temperature on the crystallographic texture. Finally, the mechanical behavior of these materials was explored via 4-point flexural strength testing and Weibull analysis. Textured SiC created with aligned platelet seed particles was found to have comparable mechanical strength to those fabricated without seed particles despite having a coarser microstructure, suggesting texture may influence the mechanical properties. The effect of texture and printing defects on the mechanical and fracture behavior of these materials is discussed.

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