FROM PRE-CERAMIC POLYMER TO HIGH-TOUGHNESS CERAMIC: AN SLA 3D PRINTING APPROACH

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Ceramic materials are known for their superior mechanical strength and environmental resilience but often face restrictions in in structural applications due to their intrinsic brittleness. An effective solution involves the utilization of polymer-derived ceramics (PDCs), which offer improved toughness and greater versatility in shaping, surpassing traditional ceramic fabrication methods. This research investigates the development of tunable ceramic cellular structures based on triply periodic minimal surface designs, produced using stereolithography (SLA) with a silicon oxycarbide precursor (SPR-684) specially formulated for vat-photopolymerization (see Figure 1). By blending the preceramic polymer with a photoinitiator, crosslinkers, and other additives, intricate 3D-printed shapes are created and subsequently pyrolyzed under nitrogen, resulting in PDCs with the desired geometries. The study evaluates the toughness, strength, and stiffness of the 3D-printed structures through quasi-static compression experiments. Comprehensive material and microstructural characterizations of the PDCs are conducted before and after pyrolysis, involving visual inspection, X-ray micro-tomography, thermogravimetric analysis, density measurements, and rheological analysis. Optimization of the 3D printing and pyrolysis parameters enables the achievement of impressive compressive strength up to 2.2 MPa and stiffness up to 330 MPa, while maintaining a minimum density of 1.4 ± 0.11 g cm^{-3}. This cost-effective SLA 3D printing technique proves ideal for crafting slender features and customized structures, offering the possibility of incorporating nanoparticles to fabricate architectured ceramics inspired by nature with tailored multifunctional properties. Moreover, the process exhibits excellent printability and is compatible with commercially available and affordable SLA and digital light processing (DLP) 3D printers, eliminating the need for humidity control during fabrication.

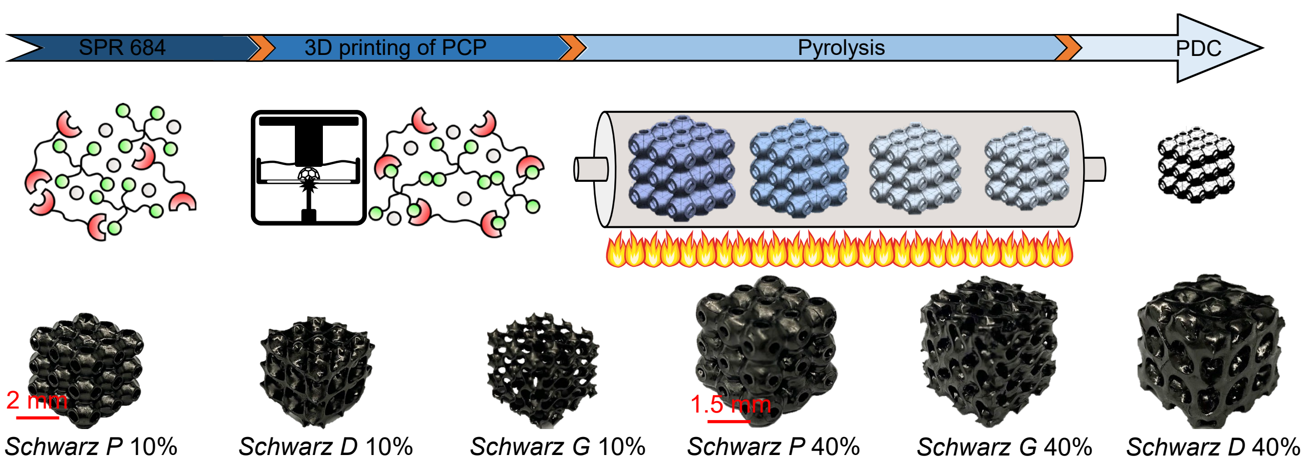

Figure 1 - Process of creating PDCs from a PCP, 3D printing, pyrolysis, and testing, and the optical images for Schwarz G, P and D structures with 10% and 40% relative densities.