Title: Additive Manufacturing of Zirconium Carbide for Space Nuclear Propulsion

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Abstract:
The idea of a human space mission to Mars has only been a thought of science fiction until recent years; however, NASA and a few others are attempting to make this dream a reality. It is believed that nuclear thermal propulsion (NTP) spacecraft could be realized for Mars missions using uranium carbide (UC) fuel to heat a liquid propellant for propulsion. This is due to UC's inherent efficiency, long lasting performance, and lower cost. However, UC can be difficult to process into complex geometries due to its high melting temperature. Accordingly, there has been an increase in additive manufacturing (AM) research for refractory ceramics due to its wide variety of uses, precision, and low cost in comparison to other alternatives. One of the greatest advantages of AM is the ability to make unique and complex geometries. Over the last decade, researchers have been investigating the ability to AM technical ceramics, but limited studies are available researching zirconium carbide (ZrC), which has been identified as a surrogate for UC due to their similar materials characteristics, including melting temperature, crystal structure, and similar behaviors during thermal processing. The goal of this project is to create dense, 3-dimensional ZrC structures using a direct write AM process. Accordingly, we formulated a printable ZrC ink using a polyethlyenemine polymer and two solvents, hydrochloric acid (HCl), and DI water. This mixture was then extruded using an nScrypt direct write AM printer. We have demonstrated the feasibility of this process to repeatably print 3-dimensional structures of ZrC for complex geometries necessary for NTP applications.