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ADDITIVE MANUFACTURING OF BULK REFRACTORY FIBER WITHIN THE TA-HF-C SYSTEM FOR ULTRA HIGH-TEMPERATURE REINFORCED COMPOSITE MATERIALS

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This work discusses the production of ultra-high temperature material (UHTM) fibers that can be used to reinforce composite materials in extreme environments. Carbon-fiber-based, carbon-matrix composites are commonly used for many UHTM applications; however within an oxygen containing atmosphere, C-C composites are limited by oxidation well-below their ultimate sublimation temperatures. Hence, research is being carried out to create alternative materials, with very high melting points, but that have greater oxidation resistance. SiC-fiber reinforced composites offer one alternative, but are limited to temperatures below 1870K. Of the 12 binary compounds that have melting points above 3270K, Hafnium Carbide (4170K) and tantalum carbide (4150K) have the highest melting points. The ternary tantalum-hafnium-carbide system, which is derived from hot-isostatically-pressed HfC and TaC powders, has been shown to have a melting point in excess of 4260K. Obviously, these refractory materials are extremely hard to draw/extrude into wires or fibers.

In this paper, we demonstrate the first-ever synthesis of Ta-Hf-C compounds in fiber form, where we have used hyperbaric laser chemical vapor deposition (HP-LCVD) to decompose gas-phase precursors. TaC, HfC, and $Ta_xHf_yC_z$ fibers were grown from tantalum (V) chloride, hafnium (IV) bromide, and octadecane precursors within a heated glass chamber. Fine-grained and amorphous fibers were grown, depending on the precursor pressures and laser-induced temperatures. Several growth modes were observed, including kinetically-limited and mass-transport limited growth. This additive manufacturing approach holds promise for the bulk fabrication of fine-grained and glassy Ta-Hf-C chopped fiber for UHTM composites, and can be applied to many different material systems. An overview of the HP-LCVD process will be provided, as well as various implementations for producing bulk fiber and microstructures for metal-matrix and ceramic-matrix composites fabrication.

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Example of a fine-grained micron-scale Ta_4HfC_5 Fiber grown by HP-LCVD: