Facile Manufacturing of Fiber-reinforced-SiC/SiC Composite using Aerodynamic Fiber Deposition (AFD) and Metal Assisted Polymer Impregnation and Pyrolysis Processes (MAPIP)

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ABSTRACT:

With further research and development of Gen IV nuclear reactors, small modular reactors (SMR) and beyond, it is quite certain that the core will contain more technologically advanced materials. One area with great need for advanced material developments is nuclear cladding**.** SiC/SiC ceramic matrix composites (CMCs) exhibit excellent damage tolerance and predictable failure behavior which are required for the cladding of accident tolerant fuels (ATFs). Superior material properties of SiC/SiC CMCs, however, come at a high manufacturing cost. Particularly, continuous SiC fibers are expensive and chemical vapor infiltration (CVI) is a time-consuming and energy-intensive process. This motivates a new economic and reliable manufacturing technique which will address two issues of current manufacturing of SiC/SiC CMCs.

The objective of the proposed research is to apply aerodynamic fiber deposition (AFD) and metal assisted polymer impregnation and pyrolysis (MAPIP) to the SiC/SiC CMC manufacturing process to address current manufacturing problems. AFD will provide SiC fiber of high mechanical strength at the low cost and MAPIP will enable SiC/SiC CMC of high crystallinity and low porosity. AFD is a new technology to manufacture fibrous preforms. Unlike existing manufacturing technologies that spin, weave, and lay fibers into the preforms in different steps, AFD spins fibers and then places them over complex geometry with controlled alignment in a single high-throughput step. Adapting AFD to CMC manufacturing will not only simplify the process of producing preforms, but also enhance the performance of CMC by changing the configuration of SiC fibers. SiC fiber preforms prepared by AFD will be transformed to SiC/SiC CMC with the dense and crystalline SiC matrix using MAPIP. In MAPIP, the polymer is mixed with metal and carbon nanoparticles before the impregnation step. A hypothesis underlying MAPIP is that the metal nanoparticles in the SiC precursor catalyze the rapid conversion of amorphous SiC to crystalline SiC below 1300°C. This will enable to increase the mechanical strength and corrosion-resistance of the composites. The combination of AFD and MAPIP will offer unique advantages such as ability to incorporate reinforcements, lower processing temperatures, and relatively easy control over the microstructure in the resulting components. This will, in turn, effectively deliver the required mechanical property (tensile strength, toughness) and radiation tolerance of SiC/SiC CMCs for the high-performance cladding of ATFs which will prevent accumulation and subsequent explosion of hydrogen by accidental heating of fuels.