Understanding of degradation of SiC/SiC materials in nuclear systems and development of mitigation strategies

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Program: FC 2.3: Damage and Failure Mechanisms for SiC/SiC Composite Fuel Cladding and Mitigation Technologies

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ABSTRACT:

SiC_f/SiC_m composite materials are considered for accident tolerant fuel claddings for light water applications (LWR's). The excellent neutronic properties, high strength and high temperature stability make them outstanding candidates. However, it was found that SiC_f/SiC_m composites do corrode in LWR conditions, which needs to be addressed before these promising cladding materials can be deployed.

This program addresses this challenge utilizing a coating approach. We feature a high throughput screening approach to evaluate the best possible coating to protect the underlying SiC_f/SiC_m materials from LWR corrosion. The team aims to understand the interaction between the coating and the environment via corrosion testing and modeling but also investigates the interaction between substrate and coating with similar tools. Autoclave exposure of rapid screening coupons in prototypical environments in combination with thermodynamic modeling (CALPHAD) and Finite Element Methods (FEM) will be utilized. Special attention will be given to the coating/substrate mechanical bond since a debonding of the coating from the substrate is unacceptable. Small scale mechanical testing together with thermal cycling and FEM modeling will provide guidance on the ideal coating system design.

Further, the team will incorporate the obtained knowledge into possible scalable technologies. The SiC_f/SiC_m manufacturer is engaged and we will investigate if the already well established Chemical Vapor Infiltration (CVI) technology can be adapted to allow coating in the same autoclave as the SiC_f/SiC_m manufacturing. The team recognizes the importance to provide a cost effective way in applying a protective coating on the SiC_f/SiC_m cladding tubes. The team aims to build upon already existing CVI infiltration capabilities to make a coating process scalable with little cost increase for the final component. Again, a fundamental understanding of the industrial coated SiC_f/SiC_m materials will be obtained allowing to make a through long term prediction of the coating in a reactor environment.

Ultimately, one has to understand the materials performance under the combined corrosion and irradiation conditions. The team will utilize and adapt the already existing Irradiation and Corrosion tool at Los Alamos national Laboratory for LWR corrosion studies and aim to understand the effect of direct radiolysis on SiC_f/SiC_m as well as the coated SiC_f/SiC_m material.