C-SiOC-SiC Coated Particle Fuels for Advanced Nuclear Reactors

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Program: MS-FC-1: Fuel Cycle R&D

ABSTRACT:

The **deliverables** for this program are: 1) New nuclear fuel systems based on coating of C-SiOC-SiC composites on CeO_2 substitute fuel particles; 2) Comprehensive evaluation of the new fuel design microstructures and compositions as well as ion irradiation testing and quantification of the new fuel responses; and 3) Understanding of the evolution of the C-SiOC-SiC-CeO_2 composites under simulated reactor conditions and during ion irradiation testing. The **scope** of the work includes nuclear fuel design using SiOC plus graphitic carbon and nanocrystalline SiC plus graphitic carbon fuel encapsulating systems; nuclear fuel system processing and performance studies to creatively use carbon with tailoring level of SiOC and SiC nanocrystallite contents for improved irradiation resistance, easy processibility, stress tolerance, and thermal management; lab testing and ion irradiation to understand the fuel particle and bulk pellet evolution behaviors under the simulated harsh nuclear environments; and comprehensive characterization of atomic to macroscopic structures. The **objectives** are to provide novel C-SiOC-SiC nuclear fuel encapsulants, improve fuel damage tolerance, understand fuel self-stabilizing behavior under irradiation, and predict this new material system behaviors for nuclear fuel advancement. The ultimate objective is to provide next generation nuclear fuel materials with increased fuel efficiency and durability.

Description of the project: Phase 1 (10/1/2018-9/30/2019): C-SiOC-SiC composite synthesis. We will be the first to synthesize the novel yet versatile C-SiOC-SiC nanocomposites with different carbon/SiOC/SiC phases and Si:O:C ratios for nuclear fuel applications. Phase 2 (10/1/2019-9/30/2020): C-SiOC-SiC-CeO_2 nuclear fuel synthesis and ion irradiation testing. We will use CeO_2 as a substitute for nuclear fuel cores. The CeO_2 kernels encapsulated in the C-SiOC-SiC matrix as particle and bulk fuel formats will be irradiated at University of Michigan using the Tandetron accelerator. The simulated fuel stability, damage tolerance, and structural evolution will be evaluated. Phase 3 (10/1/2020-9/30/2021): C-SiOC-SiC-CeO_2 nuclear fuel characterization. A complete array of micro- to nano-scale imaging and composition analysis will be carried out to assess the interaction and stability of the fuel composites.

The **outcomes** of this program are as follows: 1) new directions and possible replacement guidance for current nuclear fuel materials in operation, 2) new fuel materials for future nuclear reactor material design and development, (3) nuclear composite microstructure evolution and performance degradation understanding, (4) screening tools to guide future nuclear fuel material activities, (5) mechanisms of nuclear fuel material evolution and degradation and effective strategies to mitigate/reduce undesirable fuel behaviors. **Benefits**: Understanding of material interaction, microstructure evolution, and degradation of the nuclear fuel materials will offer never-before capabilities to design new fuels and increase reactor efficiencies. It will enable the development and deployment of next-generation advanced reactors and fuel cycles. It will also help to sustain the nuclear energy generation capability by facilitating the deployment of new fuels for light water reactors. The comprehensive and integrated approach will lead to the development of a completely new paradigm of nuclear material design, fabrication, and development. In addition, the research will train and provide a future supply of nuclear scientists and engineers through research exposure to nuclear technologies.