Oxidation Study of High Temperature Gas-Cooled Reactor TRISO Fuels at Accidental Conditions

PI: Kathy Lu, Virginia Polytechnic Institute and State University

Collaborators: Isabella Van Rooyen, Giovanni Pastore, John Stempien, Idaho National Laboratory

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ABSTRACT:

The **objective** of this project is to provide a comprehensive understanding of the TRISO fuel oxidation behaviors at air and/or water ingress conditions so that HTGRs can be operated with the highest safety, efficiency, and durability. The **deliverables** are: 1) Graphite matrix and simulated TRISO fuel particles during simulated HTGR air/water vapor ingress accidental conditions have been comprehensively studied. 2) Irradiated TRISO fuel matrix graphite is comprehensively studied under high temperature oxidation conditions, new simulation capabilities are developed for the oxidation processes, 3) Comprehensive characterization and mechanical testing of the graphite matrix and the SiC layer in the TRISO particles treated over a wide range of experimental conditions are conducted. **Scope:** This project specifically focuses on the oxidation and burn-off of the graphite fuel matrix and oxidation of the TRISO fuel SiC layer at high temperature accidental states in the presence of air and/or water vapor. It will include both unirradiated and irradiated graphite fuel matrix and simulated fuel particles with the SiC layer. We will mimic varying concentrations of air and/or water vapor and temperature ranges directly corresponding to the HTGR accidental conditions, understand the graphite matrix oxidation/burn-off and SiC layer oxidation from active to passive and vice versa while simultaneously measuring the released gas/solid compositions. We will also conduct simulations to understand and predict the graphite matrix and SiC oxidation behaviors during such transient states. Comprehensive characterization of the mechanical property, composition, and microstructure of the graphite matrix and SiC layer will be carried out.

Description of the project: Phase 1 (10/1/2018-9/30/2019): Oxidation testing of unirradiated matrix graphite and simulated TRISO fuel particles. We will emulate air/water vapor levels at 800-1600°C and test the graphite matrix and simulated TRISO fuel particles at HTGR accidental conditions. Phase 2 (10/1/2019-9/30/2020): Oxidation testing of irradiated TRISO fuel matrix graphite, simulation of the graphite matrix and SiC layer oxidation. We will examine TRISO fuels to fundamentally minimize the fuel oxidation vulnerability, and develop simulation methods to predict the TRISO fuel behaviors under such accidental conditions. Phase 3 (10/1/2020-9/30/2021): Characterization and mechanical testing of the samples treated over a wide range of experimental conditions. Comprehensive evaluation of mechanical property, composition, and microstructure of the matrix graphite and SiC layer will be carried out.

The **outcomes** are as follows: 1) understanding of the TRISO fuel oxidation kinetics and mechanisms, 2) new directions for improved TRISO fuels for HTGRs, 3) screening tools to guide future nuclear fuel activities, 4) simulation capabilities that are compatible with BISON to understand and predict the graphite matrix and SiC oxidation behaviors during accidental states. **Benefits**: New TRISO fuel design and processing strategies can be conceived to overcome the current fuel limitations and meet the needs of next-generation advanced reactors. The comprehensive and integrated approach will lead to the development of a completely new paradigm of nuclear fuel design, fabrication, and development. Understanding of TRISO fuel oxidation, microstructure evolution, and degradation during accidental states will offer never-before capabilities to increase reactor efficiencies and safety. It will enable the development and deployment of safer advanced reactors and fuel cycles and help to sustain the nuclear energy generation capability.