Oxidation behavior of silicon carbide and graphitic materials

PI: Haiming Wen - Missouri University of Science and Technology

Program: RC-1.3: Oxidation Behavior in HTGR TRISO Fuel Materials

Collaborators: Joseph Graham - Missouri S&T
Haiyan Zhao - University of Idaho
John Stempien - Idaho National Laboratory

ABSTRACT:

In our proposed project, we will design and perform oxidation experiments of unirradiated and irradiated matrix-grade graphite in moisture in the kinetic oxidation regime, oxidation of unirradiated surrogate tristructural isotropic (TRISO) particles and irradiated silicon carbide (SiC) in oxygen and moisture in the passive/active transition regime, and oxidation of unirradiated surrogate TRISO fuel compact in moisture. The kinetic parameters of oxidation will be accurately measured through the oxidation studies at different temperatures with different oxidant partial pressures. The oxidation mechanisms will be ascertained in relation to the microstructures of the materials. Furthermore, the effect of irradiation on oxidation behavior will be determined via comparing the oxidation behavior of unirradiated and irradiated materials. Finally, comprehensive data and input will be provided to the safety analysis of high-temperature gas reactors (HTGR) under air and moisture ingress accident conditions. While HTGRs use pure helium as a reactor coolant, in some accident scenarios significant amounts of moisture or air can be introduced into the helium coolant and reactor core. The effects of oxidants on TRISO fuel integrity are essential considerations that are part of HTGR safety analysis, and data are needed to more accurately understand fuel oxidation and model core behavior.

HTGRs and very high temperature gas-cooled reactors (VHTRs) are a Gen IV reactor design that use helium gas as coolant, graphite as a structural material and TRISO particles as fuel. The TRISO particles are bonded using graphitic matrix materials into a cylindrical fuel compact or spherical pebble. There are certain circumstances when oxidants may be introduced into the helium coolant. Large amounts of moisture can be introduced into the helium coolant and reactor core as a result of a steam generator tube leak, and significant amounts of air can be introduced following depressurization of the helium cooling loop in some accident scenarios. The air and moisture will oxidize the TRISO fuel matrix material and the coating layers (including SiC) of the particles, and consequently the TRISO fuel integrity may be jeopardized. Data are needed to more accurately understand fuel oxidation and model core behavior for HTGR safety analysis. However, no studies have been performed on oxidation of TRISO fuel matrix material in H2O vapor. There have been limited data on the passive/active transition of SiC oxidation, and the oxidation kinetics, especially in low partial pressure in active regimes, have not been systematically studied. And there have been extremely limited studies of oxidation of irradiated graphite or SiC and the irradiation effects on oxidation are poorly understood.

In our proposed project, TRISO fuel matrix material will be subjected to oxidation by moisture with conditions relevant to the moisture ingress accident, especially in the kinetic oxidation regime to determine the kinetic parameters and oxidation mechanisms, and oxidation behavior of SiC TRISO particles will be studied under the simulated air ingress and moisture ingress accident conditions, with a focus on the poorly understood passive/active transition and oxidation kinetics under low oxygen or steam pressure. In addition, oxidation in moisture will be performed on surrogate fuel compact to study the effect of TRISO fuel matrix burnoff on the rate of oxidation and on reaction kinetics, and determine partial pressures of H_2O transported to the TRISO fuel particles. Furthermore, irradiated matrix material and SiC will be tested in moisture and/or oxygen to reveal the effects of irradiation on the oxidation behavior of the materials.