Analysis of Matrix Burnoff in Off-Normal HTGR Conditions and the Impact on TRISO Particle Oxidation

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Very high temperature gas reactors are in development to meet both civilian and military need for a safe, economical, and "portable" power source but require a fuel form resilient to off-normal conditions including high temperatures and mixed atmospheric conditions. Tristructural isotropic (TRISO) particles may meet this need, as the fuel is encapsulated in part by silicon carbide (SiC). SiC has high oxidation resistance in a combination of high temperature, oxygen, and steam environments due to the formation of a passive oxidation layer (silicon dioxide). In certain off-normal conditions, the helium coolant of high temperature gas reactors could be contaminated with low concentrations of oxidants, particularly oxygen (O_2) and steam (H_2O). At these concentrations (<0.1 atm steam) and temperatures (800–1600°C), the thermodynamics of SiC conversion to SiO_2 and carbon support active oxidation increasing the potential recession rate of SiC. Further complicating the reaction chemistry, the simultaneous "burnoff" of matrix graphite both "getters" O_2 and H_2O and produces additional oxidation products (carbon dioxide [CO_2] and carbon monoxide [CO]). In this study we monitor the ratio (e.g. CO_2:CO) of volatile reaction products from experimentally simulated matrix burnoff utilizing a quadrupole mass spectrometer to establish the mixed gas atmospheres and oxidation conditions TRISO particles will be exposed to in off-normal conditions. With this knowledge, we investigate the impact these atmospheres have on the integrity of the TRISO particles and matrix material. Varied testing conditions include partial pressure of H_2O (pH_2O; 0–10%), partial pressure of O_2 (pO_2; 0–20%), temperature (800–1600 °C), ramp rate (5–20 °C/min), and exposure time. Mass change from both surrogate TRISO particle oxidation and unirradiated matrix material has been quantified with a thermogravimetric analyzer. Data produced from these conditions will facilitate oxidation behavior analysis of both the matrix material and TRISO particles as a function of pH_2O, pO_2 and temperature. The presented study will ultimately yield information to better model the outcome of the TRISO nuclear fuel form exposure to mixed gas conditions.