Oxidation and Corrosion-resistant Uranium Silicide Fuels

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ABSTRACT:

U_3Si_2 is being considered as a promising accident tolerant fuel (ATF) currently under active development due to its high thermal conductivity and high fissile element density; however, U_3Si_2 is prone to oxidation at low temperatures of 375 ^{o}C and 430 ^{o}C under synthetic air and steam conditions, respectively. The oxidation accompanies with a strong exothermic reaction, leading to pulverization, and posts a significant challenge to maintain a coolable geometry under off normal and accident conditions.

In this project, we propose an innovative program to develop oxidation/corrosion resistant U_3Si_2 fuels by chemical doping/fillers in the ternary U-Si-B system to form a continuous borosilicate glass as a protective oxide layer with transformational fuel performance and accident tolerance. The chemical doping/fillers include B or C showing effectiveness in improving high temperature oxidation resistance in transition metal silicides, and boron/silicon-containing compounds that can form a protective borosilicate glass layer. We will also explore a truly transformational concept of using borosilicate glass as sintering additives to promote fuel sinterability through liquid phase sintering and a protective layer to enhance high temperature oxidation and corrosion resistance of silicide fuels.

The key components of the research program include: (1) design and synthesis of oxidation/corrosion resistant silicide fuels by spark plasma sintering (SPS); and (2) evaluation of high temperature oxidation and corrosion properties. Different tasks are planned to enable the design strategies for drastically improving oxidation/corrosion resistance including: (1) synthesis of monolithic U_3Si_2 fuels as control targets and boron or carbon-doped uranium silicide fuels; (2) uranium silicide composite fuels with boron or silicon-containing compounds (such as ZrB_2, SiC *etc.*) as secondary or ternary phases; (3) borosilicate glass as fillers and sintering additives to promote sinterability and oxidation/corrosion resistance of silicide fuels; and (4) high temperature oxidation and corrosion resistance evaluations and autoclave testing. The amount of doping and heterogeneous phases is limited to 5 vol%, commensurate with the current fuel forms of light water reactors without the need to increase fuel enrichment. While ^{10}B is traditionally considered as a neutron absorber to control reactivity due to its strong neutron absorption, neutron transparent ^{11}B can be enriched above 99%, enabling its unique application in nuclear fuels.

The innovative concepts proposed are based on established approaches for other engineering materials including transition metal silicides and high temperature ceramics, but yet demonstrated for nuclear fuel applications. Promising results on oxide fuels demonstrate the feasibility of creating a continuous protective scale to improve oxidation/corrosion resistance. The improvement of high temperature corrosion and oxidation resistance and thus accident tolerance is critical for the application of U_3Si_2 as a leading ATF concept. The innovative concepts of this project will also be useful for other fuel forms in enhancing oxidation/corrosion properties and thus enhanced accident tolerance for current light water reactors.