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Compatibility studies of uranium nitride fuel with advanced cladding materials using multimodal diffusion experiments

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ABSTRACT:

In this work, we propose to study the compatibility of uranium nitride (UN) with two accident tolerant fuels (ATF) concept cladding materials, FeCrAl alloy and SiC/SiC composite, and compared to one representative ferritic/martensitic stainless steel, HT-9. Through multimodal diffusion experiments from low to high temperatures, we aim to mechanistically understand fuel cladding chemical interaction (FCCI) of UN with advanced cladding materials and to accelerate the development and assessment of models being pursued in the community.

To achieve the objective, we have designed a series of diffusion experiments and a multimodal characterization approach, which includes the following key investigations, as illustrated in Fig. 1. In “micro-diffusion” experiments, UN kernels featuring surfaces impregnated with micro powders of key cladding components (e.g., Fe, Cr, SiC) will undergo annealing in a differential scanning calorimeter (DSC). This approach aims to in situ reveal reactions occurring over varying time intervals and temperatures. Standard diffusion experiments using sealed quartz capsules will be performed up to 1100°C with initial bonding assisted by hot isostatic pressing (HIP) up to ~1800°C. Pressure-assisted diffusion experiments will be studied at higher temperatures up to 1800°C using HIP and spark plasma sintering (SPS). In situ diffusion in transmission electron microscope (TEM) will be used to study phase evolution during thermal heating. Multimodal characterization from the atomic scale to the mesoscale scale will be used to reveal the composition, phase, and microstructural evolution of diffusion couples under various conditions. Experimental observations on phase equilibria/stability will be used to inform thermodynamic and kinetic calculations. Then various thermo-kinetic (e.g., diffusion coefficients) and kinetic (e.g., mobility) coefficients will be determined based on concentration profiles and diffusion fluxes. The results of this work will enable future reactor designers to assess the safety of chemical interactions between fuel and clad in advanced fuel systems.

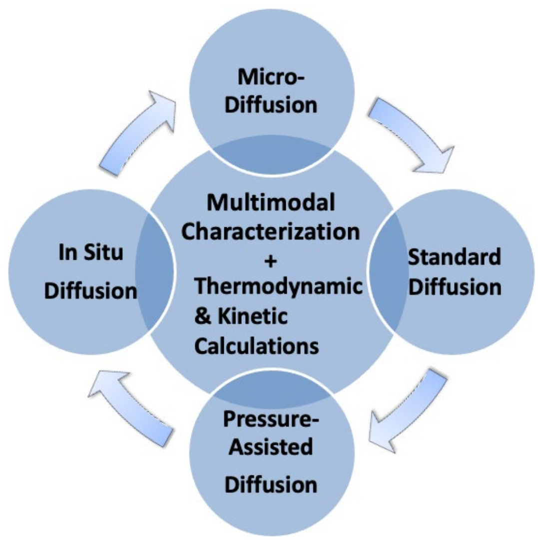

Fig. 1. Research approach of this project.