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An Investigation to Establish Multiphysical Property Dataset of Nuclear Materials Based on *In-Situ* Observations and Measurements

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ABSTRACT:

In-core nuclear materials including fuel pins and cladding materials fail due to issues including corrosion, mechanical wear, and pellet cladding interaction. One of the fundamental issues that determine nuclear fuel performance is microstructure evolution dependence of thermal and mechanical properties of fuel pellet and cladding materials and how it is affected by overall oxygen diffusion, hydride formation, fuel thermal expansion, and overall failure of fuel pellet-cladding system, in an irradiation-driven environment. Improved multiscale, multiphysics, and multidimensional simulation capability can significantly help nuclear fuel models especially with respect to pellet-cladding mechanical interaction, fuel fracture, oxide formation etc. However, multiscale microstructure related effects required in such approach require *in-situ* experimental examination, the subject of the proposed work. The proposed work focuses on presenting an *in-situ* measurement based experimental approach to facilitate such an understanding with focus on Zircaloy claddings. Emphasis of the proposed research is on supplying the proposed validating dataset for NEAMS simulations as a function of temperature, irradiation, and environment using complementary *in-situ* experiments. With success, future efforts will be expanded to UO_2 and pellet-cladding interactions.

This project aims are to: **(1)** Investigate irradiation driven microstructure change influence on mechanical, as well as thermal properties and **(2)** Predict the microstructural-thermal-mechanical property relationship, as a function of irradiation damage, temperature, and environment. The literature puts more focus on the thermal properties of the oxides and hydrides, which show compounded deleterious effect after 1200 ^{o}C. At this point the oxidation reaction at surface may surpass the decay heat production in the fuel to become the dominant source of fuel temperature rise. Because the oxidizing species is water (steam), the reaction produces a significant amount of hydrogen gas, which precipitates as hydrides. The hydrides increase susceptibility to corrosion, and their low thermal conductivity and high coefficient of thermal expansion adversely impact thermal loading as well as mechanical stability. The role of irradiation, corrosion, and hydride formation are all deleterious and are the critical areas in the research community. The latest need in the area is innovative concepts on small scale testing, considering the specialty of irradiation chambers. Issue at hand is the ability to understand small scale (nanoscale to mm scale) microstructure evolution dependent material behavior. At the nanoscale and microscale, the predominant mechanism becomes surface and interface (i.e., diffusion) mediated deformation. Because of the change in defect dimensionality (1D or 2D), the influence of microstructure on thermal and mechanical properties can be expected to be significant. It is expected, therefore, that experiments performed in the proposed work here can be directly used to validate microstructure evolution dependent multiphysics multiscale modeling predictions made by combination of BISON and MARMOT (e.g. thermal expansion induced cracking and lower length scale microstructure effects, pellet-clad mechanical interaction, effect of oxides, hydrides on pellet-cladding system failure etc.) as well as to improve current multiphysics models. With success of the proposed work more material systems will be tried in collaboration with National Lab Partners.