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International Collaboration to Advance the Technical Readiness of High Uranium Density Fuels and Composites for Small Modular Reactors

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Program: FC-2.1: Next Generation LWR Fuels for SMR Applications

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ABSTRACT:

An international team of high uranium density fuels (HDFs) experts advised by industry leaders in nuclear reactor innovation propose a US-UK collaboration to advance the technical readiness of UN, UB_2, and their composites for fuel forms specific to small modular reactors (SMRs). The team brings nearly a decade of collaborative history in fuel fabrication, accident testing, and uranium compound chemistry with overlapping interest in not only understanding the fundamental thermochemistry of uranium compounds but also bringing these promising fuel forms to market. To this effect the team proposes a dual thrust approach to bridge the critical data gaps in HDF performance with a specific focus on the impact of common impurities and microstructural variations that originate at fabrication and can impact fuel swelling rates, chemical stability, thermal transport properties, and a number of other fuel performance metrics:

1) ***Uncertainties in scalable fabrication and associated contaminant concentration:*** Unlike traditional UO_2 and even doped-UO_2 fabrication, HDFs display sensitivity to air and other oxidants during fabrication, operation, and spent fuel storage. The impact of insoluable and even soluable amounts of oxygen and carbon impurities on the operational and accident performance of HDF's is not understood. The investigators will fabricate uranium bearing samples from varied depleted uranium (dU) feedstocks and employing diverse synthesis techniques to produce sample sets with different microstructures as well as varied oxygen and carbon impurity levels. The impurity concentrations, of the feedstocks and samples will be quantified under the proposed scope of work to link to the impact to performance.
2) ***Thermal and oxidative performance:*** Among the proposed benefits of employing HDF's in conventional and advanced reactors are the associated enhanced thermal transport properties; however the impact of impurity concentrations and microstructural variations to these critical performance properties has not been studied. Therefore, the team will measure thermal diffusivity and thermal expansion as functions of temperature for each fuel form fabricated under the first task of this proposal. Furthermore, a well-established challenge to deploying HDF's in water-cooled reactors, including water cooled SMR's or gas cooled SMRs with water-based secondary cycles, is hydrothermal corrosion and/or steam oxidation of the fuel. Therefore, steam and pressurized water exposures will be performed to observe and quantify oxidation behavior as a function of impurity concentration and composite percentage.

In addition to the materials science instigations which are the focus of the proposed NEUP, the team will address HDF applicability to an SMR fuel cycle. Specifically the team will investigate the neutronic benefits and challenges to deployment of UB_2 and/or UN by performing reactor physics modeling which builds upon previous work performed under the DOE Advanced Fuels Campaign. Lastly, the team will assess the degree to which isotopic separation would be neutronically required, as it is a concern for a UN and/or UB_2 fuel form to mitigate the deleterious neutronic impact of ^{14}N and/or ^{10}B.