Improving Reliability of Novel TRISO Fuel Forms for Advanced Reactors via Multiscale, High-Throughput Characterization and Modeling

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ABSTRACT:

The anisotropic nature of graphite flakes and the unique fabrication routes for TRISO containing fuel forms leads to possible local and long-range texture. This texture could produce anisotropic bulk properties, as the graphite flake alignment surrounding particles or in a pebble's fuel free-region could be direction dependent. The inability to model local and long-range anisotropic thermal properties based on our current understanding of properties may result in either an over- or underprediction of fuel (and particle) temperatures. This has implications regarding prediction of fuel performance, as many relevant phenomena are related to temperature including, but not limited to, fission product release. Ultimately, accurate models of integral fuel form thermal properties supports a more accurate determination of fuel temperatures. ***We propose the use of a parallelized thermal conductivity (k) measurement device coupled with multiscale models to accurately predict the thermal conductivity of TRISO fuel composites.***

This proposal overcomes the issue plaguing many "localized" microscale measurements, namely the inability to scale local measurements up to engineering scale properties. We will do this by using Bayesian inference techniques on the 10^5 k measurements we can collect in 1 week to predict an effective thermal conductivity of each sample and validate this value compared to a bulk k measurement computed from thermal diffusivity, specific heat, and density measurements. ***Quality assurance*** of the measured microscopic properties will be ensured by calibration of the P-SDTR device compared to standard reference materials and validation of local k measurements at several key locations with the IR microscope, albeit with a lower throughput.

The ***specific objectives*** of this project are to:

1. Measure the microscopic and bulk thermal conductivity of TRISO/graphite composites that are representative of material/fuel systems and perform uncertainty quantification (UQ)
2. Integrate property data with uncertainty into thermal models for use in the BISON fuel performance code.

The key innovations that make this possible are: **(1)** Our P-SDTR can provide a statistically significant number of measurements over a large enough area in a short enough time to ensure that the homogenization of local to bulk properties is a valid representation of the entire fuel form. **(2)** The IR microscope can provide local temperature rise to validate models. **(3)** Bayesian inference paired with Monte-Carlo techniques can predict the effective thermal conductivity (k_{eff}) based on constituent properties and composite microstructure. **(4)** Close collaboration with TRISO fuel form industry partner ensures research is applicable to furthering the DOE mission.

The ***key outcome*** will be more accurate understanding of graphite structure and properties for the novel TRISO fuel form used in the FHR pebble-bed reactor and other graphite matrix based fuel concepts (HTGRs and microreactors), which will inform reactor modeling for optimized performance and licensing.

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