U.S. Department of Energy

# Measuring Mechanical Properties of Select Layers and Layer Interfaces of TRISO Particles via Micromachining and In-Microscope Tensile Testing

**PI**: Mary Lou Dunzik-Gougar (Idaho State University)

**Collaborators**: Christopher McGrath and Scott McBeath (Idaho State University), and Isabella van Rooyen (INL)

**Program**: Nuclear Reactor Technologies

**ABSTRACT:**

The objectives of this project are (a) to develop a capability for sub-micrometer scale strength characterization via focused ion beam micromachining and in-situ TEM tensile testing, (b) to use this capability to determine strengths across unirradiated and irradiated TRISO-coated particle layers and layer interfaces, and (c) to make this testing capability available to other researchers.

Results of this work will fill an identified knowledge gap regarding strengths of individual layers, and of bonds between layers, of TRISO-coated particles under development in DOE's Advanced Gas Reactor (AGR) Program. Although TRISO coated particle failures are rare, recent analysis of 3 failed AGR particles revealed a cracked IPyC layer. These cracks allowed fission product Pd to corrode the SiC layer, which in turn provided a pathway for additional fission product release. It is believed that the IPyC cracked due to excessive stress resulting from a partially debonded buffer layer that shrank during irradiation. Currently the particle layers are modeled as one unit across all layers; however, these recent analyses identified the buffer-IPyC interface strength as an important parameter for fuel failure prediction modeling and prevention.

To achieve the stated objectives, the capability for in-situ TEM tensile testing (at temperature up to 400°C) will be established at Idaho State University (ISU) as part of this project. A Bruker Hysitron PI-95 nano-indenter/tensile tester TEM holder will be purchased, installed and tested in the first project phase. To prepare tensile samples, existing ISU capability for Focused Ion Beam (FIB) micromachining will be used.

Tensile testing samples from individual TRISO coating layers (buffer, IPyC and OPyC) and across the buffer-IPyC interface will be prepared. Samples from coating layers of (1) unirradiated $ZrO_2$ fuel surrogate TRISO particles, (2) unirradiated fueled TRISO particles and (3) irradiated fueled TRISO particles will be characterized. Characterization of coating layers from the three particle types will allow separation of the effects of particle production, compact production (heating and compaction of particles into compacts) and neutron irradiation (neutron fluence and high temperatures). All particles are available from the AGR Program through Idaho National Laboratory (INL), such that no particle production or irradiation is required as part of this project. The INL Co-PI, who is involved in the AGR Program, will provide the particles for the project and advise on experiment design and data analysis.

The PI will lead overall project coordination, with support from ISU Co-PIs Dr. Christopher McGrath and Mr. Scott McBeath, who will work hands-on to install and operate the TEM tensile stage, perform FIB-micromachining of the tensile samples, perform tensile testing, and data analysis. A graduate student on the project will be jointly supervised by Drs. Dunzik-Gougar and McGrath.

Outcomes from this work will be better modeling of fuel behavior and, therefore, will positively impact AGR Program efforts to qualify and license TRISO-coated particle fuel. In addition, the new testing capability at ISU will be made available to researchers for both rad and non-rad samples at reasonable cost.