NUCLEAR ENERGY RESEARCH INITIATIVE

Novel Processing of Unique Ceramic-Based Nuclear Materials and Fuels

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Project Number: 05-110

Collaborators: Brookhaven National Laboratory

Related Program: Gen IV

Project Description

This project will develop high-temperature refractory ceramic fuels, in-core materials, and control elements applicable to Gas-Cooled Fast Reactors. Refractory-based ceramics such as carbides, borides, and nitrides display a number of unique properties, including extremely high melting points, hardness, high thermal and electrical conductivity, and solid state phase stability. These unique properties make them potential candidates for a variety of high-temperature nuclear reactor components.

The research effort will demonstrate the feasibility of a novel processing approach for fabricating mixed-carbide refractory composite materials. The process is based upon the pyrolysis of a mixture of preceramic polymers and submicron/nano-sized metal particles of uranium, zirconium, niobium, and hafnium, carried out in both conventional and microwave ovens under an inert atmosphere. The materials produced will include metal ceramic carbides, mixed metal carbides, and unique metal silicocarbides. The resulting materials can be graded and will have a controlled microstructure (at both micron and nano levels), fiber-reinforced configurations, and a wide range of compositional control. This processing technique involves much lower energetic requirements compared to hot isostatic sintering. It also provides the capability of fabricating net-shaped components and does not suffer from maximum component size limitations such as that of chemical vapor deposition.

Upon completion of this project, processes for fabricating a variety of unique high-temperature ceramic materials and fuels will be developed.

Work Scope

The work is broken into the following three tasks:

- One task will entail process development and material fabrication and characterization. Materials produced will be tested and characterized for physical and microstructural composition, mechanical properties, and resistance to oxidation and thermal shock
- In another task, global and local models will be developed to predict the pyrolysis and reaction process; then, the models will be integrated for comparison to experimental measurements.

- In the third task, a nuclear transport analysis will be carried out with a ceramic-based fuel form to establish nuclear characteristics and potential fuel element configurations in order to determine a reactor core design and operational conditions.