NUCLEAR ENERGY UNIVERSITY PROGRAMS

Developing a High Thermal Conductivity Fuel with Silicon Carbide Additives

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Abstract

The objective of this research is to increase the thermal conductivity of uranium oxide (UO_2) without significantly impacting its neutronic properties. The concept is to incorporate another high thermal conductivity material, silicon carbide (SiC), in the form of whiskers or from nanoparticles of SiC and a SiC polymeric precursor into UO_2. This is expected to form a percolation pathway lattice for conductive heat transfer out of the fuel pellet. The thermal conductivity of SiC would control the overall fuel pellet thermal conductivity. The challenge is to show the effectiveness of a low temperature sintering process, because of a UO_2-SiC reaction at 1,377°C, a temperature far below the normal sintering temperature. Researchers will study three strategies to overcome the processing difficulties associated with pore clogging and the chemical reaction of SiC and UO_2 at temperatures above 1,300°C:

- Prepare composites of UO_2 particles and SiC preformed whiskers oriented to form a percolation pathway processed by a two step UO_2 low-temperature sintering process.
- Coat UO_2 particles with a mixture of a SiC polymeric precursor and nanosize SiC particles and sinter as pseudo SiC particles at moderate temperatures of ~1,200°C to form a SiC matrix/UO_2 particle composite.
- Prepare open porous UO_2 infiltrated with a SiC polymeric precursor by a PIP process with the aid of supercritical (SC) CO_2 to overcome the capillary wetting problems.

As the most common fuel material in commercial nuclear power reactors, UO_2 has the advantages of a high melting point, good high-temperature stability, good chemical compatibility with cladding and coolant, and resistance to radiation. Low thermal conductivity is a primary disadvantage, leading to a large temperature gradient in the fuel pellet that results in a very high centerline temperature. High fuel temperatures cause high thermal stresses and high fission gas release. Additionally, the high stored heat due to the poor thermal conductivity makes the loss of coolant accident (LOCA) so serious.