NUCLEAR ENERGY UNVERSITY PROGRAMS

ALD Produced B_2O_3, Al_2O_3 and TiO_2 Coatings on Gd_2O_3 Burnable Poison Nanoparticles

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Abstract

This project will demonstrate the feasibility of using atomic layer deposition (ALD) to apply ultrathin neutron-absorbing, corrosion-resistant layers consisting of ceramics, metals, or combinations thereof, on particles for enhanced nuclear fuel pellets. Current pellet coating technology utilizes chemical vapor deposition (CVD) in a fluidized bed reactor to deposit thick, porous layers of C (or PyC) and SiC. These graphitic/carbide materials degrade over time owing to fission product bombardment, active oxidation, thermal management issues, and long-term irradiation effects. ALD can be used to deposit potential ceramic barrier materials of interest, including ZrO_2, Y_2O_3:ZrO_2 (YSZ), Al_2O_3, and TiO_2, or neutron-absorbing materials, namely B (in BN or B_2O_3) and Gd (in Gd_2O_3). This project consists of a two-pronged approach to integrate ALD into the next-generation nuclear plant (NGNP) fuel pellet manufacturing process:

- Researchers will apply Al_2O_3 and TiO_2 coating on Gd_2O_3 particles to fabricate homogeneous gadolinium aluminate and titanate ceramic powders and study their thermo-mechanical properties. Of significant interest are the thermo-physical properties of Gd_2O_3-containing composite materials, such as aluminates ($GdAlO_3$) and titanates (Gd_2TiO_3), so that the thermal conductivity, coefficient of thermal expansion, specific heat, etc., are known for NGNP modeling and simulations. $GdAl_2O_5$ and Gd_2TiO_3 can either be integrated into the fuel pellet core using traditional solid-state techniques, or can be applied to the surfaces of UO_2 particles using standard ALD techniques.
- The second aim is to coat nanometer-scale ZrO_2, YSZ, and BN/B_2O_3 films on carbonaceous powders to test the high-temperature corrosion resistance and thermo-mechanical properties of these chemically inert ceramic materials. The CVD-derived, porous carbonaceous layers—namely C, PyC, and SiC—are extremely sensitive to oxidation at high temperatures, especially in low-oxygen partial-pressure environments found in nuclear reactors. Researchers will test coated powders in this environment using a high-temperature thermogravimetric analyzer, and will measure corrosion resistance and thermal shock properties of C and SiC particles for varying ALD film thicknesses.