NUCLEAR ENERGY RESEARCH INITIATIVE

# Incorporation of Integral Fuel Burnable Absorbers Boron and Gadolinium into Zirconium-Alloy Fuel Clad Material

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Long-lived fuels require the use of higher enrichments of $^{235}U$ or other fissile materials. Such high levels of fissile material lead to excessive fuel activity at the beginning of life. To counteract this excessive activity, integral fuel burnable absorbers (IFBA) are added to some rods in the fuel assembly. The three commonly used IFBA materials are gadolinium oxide and erbium oxide, which are added to the $UO_2$ powder, and zirconium-diboride that is applied as a coating on the $UO_2$ pellets using plasma spraying or chemical vapor deposition techniques. These operations are performed as part of the fuel manufacturing process in the fuel plants. Due to the potential for cross-contamination with fuel that does not contain IFBA, these operations are performed in a facility that is physically separated from the main plant. These operations tend to be very costly because of their small volume, and can add from 20 to 30 percent to the manufacturing cost of the fuel. Other manufacturing issues that impact cost are maintenance of the correct levels of dosing and reduction in the fuel melting point due to additions of gadolinium and erbium oxide.

The goal of the proposed research is to develop an alternative approach that involves incorporation of boron or gadolinium into the fuel cladding material rather than as a coating or additive to the fuel pellets. This paradigm shift will allow for the introduction of the IFBA in a non-nuclear regulated environment and will obviate the necessity of additional handling and processing of the fuel pellets. This could represent significant cost savings and potentially lead to greater reproducibility and control of the burnable fuel in the early stages of the reactor operation.

To achieve this objective, state-of-the-art, ion-based, surface engineering techniques will be applied. This will be performed using the IBEST (Ion Beam Surface Treatment) process being developed at Sandia National Laboratories, which involves the delivery of high energy ion beam pulses onto the surface of a target material. These pulses melt the top few microns of the target material's surface. The melt zone then solidifies rapidly at rates in excess of $10^9$K/sec due to rapid heat extraction by the underlying substrate heat sink. This rapid solidification allows for surface alloying well in excess of the thermodynamically dictated solubility limits. This effect can be beneficially applied to the objectives of the proposed research for incorporating boron or gadolinium into the near-surface regions of Zircaloy-4 and Zirlo material used for fuel cladding. Several variants of this approach will be investigated with the goal of optimizing the process parameters to achieve the desired structure, composition, and compositional gradient in the near-surface regions of the Zircaloy-4 and Zirlo. Detailed materials characterization of the modified surface regions will be performed at the University of Wisconsin. The durability of the modified zirconium alloys against corrosion and oxidation will be tested in steam autoclaves at Westinghouse Science & Technology Department.