Ceramic Coatings for Clad (The C3 Project): Advanced Accident-Tolerant Ceramic Coatings for Zr-Alloy Cladding

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ABSTRACT

The goal of this NEUP-IRP project is to develop a fuel concept based on an advanced ceramic coating for Zr-alloy cladding. The coated cladding must exhibit demonstrably improved performance compared to conventional Zr-alloy clad in the following respects:

1. During normal service, the ceramic coating should decrease cladding oxidation and hydrogen pickup (the latter leads to hydriding and embrittlement).
2. During a reactor transient (e.g., a loss of coolant accident), the ceramic coating must minimize or at least significantly delay oxidation of the Zr-alloy cladding, thus reducing the amount of hydrogen generated and the oxygen ingress into the cladding.

The specific objectives of this project are as follows:

1. To produce durable ceramic coatings on Zr-alloy clad using two possible routes: (i) MAX phase ceramic coatings (MAX phases are transition and Group III metal carbides or nitrides); and (ii) graded interface architecture (multilayer) ceramic coatings, using yttria-stabilized zirconia (YSZ) as the outer protective layer.
2. To characterize the structural and physical properties of the coated clad samples produced in 1. above, especially the corrosion properties under simulated normal and transient reactor operating conditions.
3. To perform computational analyses to assess the effects of such coatings on fuel performance and reactor neutronics, and to perform fuel cycle analyses to assess the economic viability of modifying conventional Zr-alloy cladding with ceramic coatings.

This project meets a number of the goals outlined in the NEUP-IRP call for proposals, including:

1. improve the fuel/cladding system through innovative designs (e.g. coatings/liners for zirconium-based cladding)
2. reduce or eliminate hydrogen generation
3. increase resistance to bulk steam oxidation reactor (LWR) nuclear fuel assemblies, due to improved cladding properties and built-in accident resistance, as well as the possibilities for enhanced fuel/clad system performance and longevity.