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Enhanced Shielding Performance of HLW: Storage Packages via Multi-Component Coatings

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ABSTRACT:

Of critical importance in the transport of used nuclear fuel and high-level waste after prolonged storage, is the integrity and survivability of the waste package. Also a key feature of nuclear waste management is the long-term isolation of the waste from the biosphere. Engineered barriers that achieve both of these goals can be fabricated via novel multi-layer multi-component coatings. The objective of this research is to develop an outer shield material for use in packaging that is not only resistant to the corrosion, radiation, diffusion, and thermal cycling processes that affect fuel packages during long term storage, but that is also wear tolerant and mechanically robust so that it can survive repeated handling and transportation. To accomplish this goal, we propose a new multi-layer composite coating that will provide the robust material needed to enhance long-term HLW storage and facilitate safe transport of storage packages.

The proposed waste package shield provides a barrier to prevent water, dirt, and chemical contaminants from the atmosphere or soil from making contact with waste packages that would damage and weaken them during long-term storage. Further, it incorporates components that protect the structural materials used in the packages and enhance their mechanical properties so that the waste package may be moved or transported as necessary over the storage lifetime. Through this research effort, the team will develop multi-component, multi-layered coatings using techniques other than thermal spraying, and will evaluate and optimize a three-component coating for the outside of waste packages that will provide a multi-purpose barrier. In this approach, we will determine the thickness of each layer and the most efficient and effective techniques with which the coating will be achieved. This novel coating approach will provide a diffusive barrier, thermal cycling and corrosion and impact resistances. Complete characterization of coatings composition, microstructure, morphology, and interfacial character of the layers or nanocomposite components will be conducted.

To accomplish the project objective of providing a multi-purpose barrier coating to protect HLW storage packages over time and facilitate safe transport, we will fabricate a variety of multilayer and composite coatings using the constituent materials we have selected for evaluation and optimization. Analysis will include, scanning electron microscopy (SEM), energy dispersive x-ray spectroscopy (EDX), high resolution transmission electron microscopy (HRTEM), x-ray photoelectron spectroscopy (XPS), x-ray diffraction, and secondary ion mass spectrometry (SIMS). Following initial characterization of the as deposited coatings, the mechanical, adhesion, oxidation, diffusion, corrosion, radiation, and wear properties of the shield materials will be tested. Stress, strain, and hardness will be quantified using nano-indentation, adhesion and wear with reciprocating sliding tribometry, oxidation via measurement of oxide layer growth, and corrosion using polarization methods for sulfate, bicarbonate, and calcium chemistries. Hydrogen diffusion will be measured by exposing coated and non-coated samples to hydrogen at an elevated temperature followed by SIMS analysis to quantify changes in hydrogen content. Cyclic polarization testing will be performed to determine the corrosion susceptibility.