Flexible Hard Ceramic Coatings by Ultrasonic Spray Mist-CVD for Dry Storage Canisters of Spent Nuclear Fuel and Waste

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ABSTRACT:

Stress corrosion cracking (SCC) has been identified as a potential safety concern in welded stainless steel dry storage canisters (DSC) used for storage and transportation of spent nuclear fuel. Flexible hard multi-component ceramic coatings offer a promising solution to address the challenge of SCC in DSC. The objective of the project is to develop and evaluate the use of emerging ultrasonic spray mist chemical vapor deposition (Mist-CVD) manufacturing process to deposit flexible hard multi-component ceramic coatings on dry storage canisters (DSC) of spent nuclear fuel for mitigating the impact of SCC. Such new ceramic coatings are enabled by alternating the single ceramic coating layer with Zr-Al-O flexible buffer layers to prevent cracking while offering excellent resistance to corrosion, heat, wear and hydrogen permeation. The success of the project will generate crucial insights into the potential deployment of flexible hard ceramic coatings to enhance the reliability of long-term storage and maintenance of DSC.

The proposed research will focus on optimized deposition of flexible hard multi-component ceramic coatings using enabling ultrasonic spray Mist-CVD technique to mitigate the concern of SCC in DSC. Our efforts will include systematic deposition experiments of ceramic coatings and complete microstructural characterization and material property evaluation. Special emphasis will be put on the evaluation of protection effects of flexible hard ceramic coatings on the heat-affected zone of the fabrication welds in the DSC, where the initiation of pitting and transition to SCC growth may be promoted when exposed to an aggressive chemical environment. We will conduct well-defined corrosion experiments in aggressive chemical environment (with different pH's) at different temperatures to test the performance of as-deposited and annealed ceramic coatings in simulated working environments of DSC. The feedback will be used to timely optimize the deposition processes to further improve the quality of ceramic coatings. A fundamental understanding of the composition-structure-property-performance relationship of these emerging flexible ceramic coatings materials will be established to identify key factors that lead to their wide applications in DSC. This innovative research will provide essential technical basis for promoting the deployment of advanced flexible ceramic coatings towards improved DSC for storage and transportation of spent nuclear fuel and waste. The scientific output of this project will advance the state of scientific knowledge to design and deposit the promising flexible hard ceramic coatings to mitigate the concern of stress corrosion cracking. Thus the current technical gaps can be effectively addressed to reduce the risks during storage and maintenance of DSC.