New Coatings for Nuclear Fuel Waste Canister Storage and Transport

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ABSTRACT:

Background: Due to the lack of a solution for permanent disposal of spent nuclear fuel (SNF) in the United States, most of the SNFs are enclosed in 304/304L/304H stainless steel canisters and placed in dry storage casts at nuclear power plant sites for interim storage. This requires that the structural integrity of dry storage canisters is maintained for decades. During dry storage and transport, chloride-bearing atmospheric salts, dusts, and aerosols can deposit on canister surfaces due to passive air flow through the overpacks. The relative humidity (RH) in air can exceed the critical RH for salt deliquescence as canister surface cools. As a result, brines can form on the canister surface and lead to localized corrosion. This process can start at some locations of a canister surface very early due to the non-uniform temperature distribution. Such a corrosive environment, along with the high tensile residual stresses, can result in stress corrosion cracking (SCC) and eventually lead to through-wall failures.

Objectives: This program is to develop novel SiOCN(H) coatings for nuclear fuel waste canisters in order to address nuclear waste container corrosion and failure problems, identify new and effective mitigation strategies, and safeguard nuclear waste storage, transport, and disposal, in both terrestrial and marine environments. We will advance the prevention of nuclear waste canister pitting corrosion and stress corrosion cracking (SCC) by developing a new SiOCN(H) coating strategy. Specifically, we will:

i) develop effective corrosion-resistant SiOCN(H) coatings on 304/304L/304H canisters for improved resistance to pitting in chemically aggressive, chronically stressed, and highly corrosive nuclear environments;

ii) evaluate coating structural changes under different SNF storage conditions and test their corrosion responses under aggressive and long-term brine conditions;

iii) advance fundamental understanding of the coating failure mechanisms under combined stress and corrosion conditions as well as identify coating failure repair strategies, especially when exposed to pitting and SCC environments for SNF canisters.

The novelties of our approaches are: 1) through covalent bonding with iron-based substrates, inorganic SiOCN(H) coatings can be formed with controlled thickness, composition, and structure to provide corrosion resistance for the steel surfaces under different corrosive environments, and 2) water availability as well as electron and charge transfer kinetics to the metal substrates can be inhibited via the SiOCN(H) coatings to minimize corrosion under stress in brine environments. The efforts come from a strong and collaborative team and have great potential to create a truly scalable and game-changing paradigm for SNF storage and transport safety.

Significance: This project directly addresses the FC-4.2 topic of the DE-FOA-0002128 solicitation, “Spent Fuel and Waste Disposition: Storage & Transportation”. The research will help to sustain nuclear energy generation by enabling safe and long term SNF transport and storage. The comprehensive and integrated SiOCN(H) coating approach will lead to the development of a completely new paradigm of SNF canister corrosion prevention.