Assessing molten salt corrosion resistance of stainless steel 316H in nuclear reactor environments

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ABSTRACT:

Stainless steel 316H (SS 316H) has garnered significant attention from the nuclear industry as a promising structural material for deployment in advanced reactors, particularly the Molten Chloride Fast Reactor (MCFR) and fluoride salt-cooled high-temperature reactor (FHR). One of the key advancements that has facilitated the exploration of this material is additive manufacturing (AM), which allows complex designs that were previously unattainable using traditional manufacturing methods. Recent advancements have been made in the development of in-pile molten salt corrosion capability for the PULSTAR reactor at NCSU, while creep/fatigue testing capability in molten salt environments has been achieved at UCI. These two distinctive capabilities offer valuable opportunities into the behavior of materials, such as SS 316H, under molten salt corrosion conditions within reactor environments.

Our goal is to leverage a blend of innovative molten salt corrosion experiments and cutting-edge characterization techniques to advance our understanding of molten salt corrosion behavior in both commercial and AM SS 316H, particularly in radiation or stress environments. The corrosion behavior of SS 316H in reactor environments can be significantly influenced by microstructure variations resulting from different manufacturing processes. To explore this idea comprehensively, we have designed a multifaceted research approach consisting of the following key investigations: 1) To assess the impact of manufacturing on corrosion resistance, we will conduct electrochemical studies comparing two distinct types of SS 316H in $MgCl_2$-NaCl eutectic salt. 2) We will subject both types of SS 316H to in-pile corrosion testing within the PULSTAR reactor at NCSU, allowing us to analyze the specific corrosion response under neutron irradiation. 3) To understand the effects of stress on corrosion behavior, we will conduct creep-fatigue experiments in controlled molten salt environments at UCI. The in-pile corrosion and creep-fatigue experiments present unique test conditions, enabling us to explore the corrosion resistance of SS 316H under neutron irradiation and stress, respectively. 4) To comprehensively investigate microstructural evolution during corrosion in various environments, we will employ a multimodal characterization approach spanning from atomic to mesoscale levels. This thorough analysis will encompass dislocations, voids, cracks, precipitates, and their interactions with cellular boundaries and grain boundaries of SS 316H.