Understanding the corrosion mechanism of stainless steels in supercritical water through advanced characterization

Zhao Shen*, Xiaoqin Zeng

School of Materials Science and Engineering, Shanghai Jiao Tong University, Shanghai

shenzhao081@sjtu.edu.cn

Abstract Supercritical water-cooled reactors boast high thermal efficiency, simple structures, and compact designs. However, they experience severe uniform corrosion of internal components like fuel claddings because they operate above water's thermodynamic critical point. This paper investigates the corrosion behavior of T91 ferritic-martensitic steel, 304 austenitic stainless steel, HR3C super austenitic stainless steel, and 800H nickel-based alloy after undergoing 1500 hours of exposure to supercritical water at 600 degrees Celsius. Utilizing multi-scale microcharacterization techniques, the study identifies that while T91 and 304 steels show a continuous structure of inner oxide layers under scanning electron microscopy, high-resolution transmission electron microscopy reveals a discontinuous structure featuring a dual-phase of metal and oxide phases. This internal oxidation is severe in supercritical water due to the low chromium content in the matrix, preventing the formation of a protective Cr_2O_3 layer throughout the test period, thereby diminishing their corrosion resistance. In contrast, 800H alloy exhibits good corrosion resistance as it transitions from internal to external oxidation over time, eventually forming a dense Cr_2O_3 layer that protects the base material. HR3C steel, with a very high chromium content, quickly forms a dense external Cr_2O_3 layer, providing exceptional corrosion resistance. The paper also meticulously characterizes the surface oxide films of these materials using high-resolution transmission electron microscopy, coaxial TKD, and three-dimensional atom probe, revealing the chemical and microstructural evolution of these oxide layers during corrosion.