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Corrosion of nickel-based structural materials for nuclear reactors by molten fluoride salt: From bulk content of corrosion products to elemental imaging of corrosion changes

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Abstract

This work is focused on the study of corrosion treatment of molten fluoride salt (MFS) on three candidate structural materials (Ni, ferritic steel with protective Ni coating, and Ni-based alloy). The samples were exposed to an MFS mixture (60 mol% LiF + 40 mol% NaF) at a temperature of 680 °C for 112, 350 and 1000 hours. Their corrosion resistance was tested by the determination of the content of corrosion products in MFS by ICP-OES (Inductively Coupled Plasma with Optical Emission Spectrometry) analysis and comparison of elemental ratios. Distinctive differences in the ratios were found for ferritic steel with protective Ni coating. Morphological changes induced by MFS treatment were revealed and studied by EPMA (Electron Probe Micro Analysis) and LA-ICP-MS (Laser Ablation Inductively Coupled Plasma of Mass Spectrometry). Elemental maps of the corroded area were acquired by both methods. The analyses of corrosion products show that the best candidate material is nickel.

Key words: molten fluoride salt, LA-ICP-MS, EPMA, corrosion, elemental imaging, Ni-based structural material

1. Introduction

The Molten Salt Reactor (MSR) is a promising nuclear reactor type, which belongs to the group of Generation IV reactor systems [1]. The great benefits of this reactor design are its efficient fuel utilization, minimum radioactive waste and economical use with a safe and environmentally friendly operation [2-4]. Molten salts, exhibit the most appealing properties; they can be used as reactor coolant or a transfer medium in high temperature process heat loops from nuclear reactors to hydrogen production. This explains why they were taken into consideration in the development of nuclear energy technology.

These salts are characterized by a high thermal conductivity, low viscosity, high boiling points, the largest heat capacity per unit volume without any need of pressurization, and insensitivity to radiation [4]. Compared to chloride salts, fluoride salts are more frequently used because fluorine does not require an expensive isotope separation process. Potential