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## Improved corrosion resistance of zirconium alloys: Enlightening the mode of action of Nb doping by complementary hard x-ray chemical microscopy techniques

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Zirconium alloys are extensively used as materials in a broad range of technical applications in various types of nuclear facilities. The mechanical and physico-chemical properties of these alloys can be tuned by modifying the chemical composition, mainly by the addition of dopants. Empirical studies have revealed that one of the key properties, the corrosion resistance, can be significantly enhanced by doping the alloy with niobium. However, the processes induced by the addition of niobium being responsible for limiting the corrosion rate are not yet fully understood on a mechanistic level. Furthermore, in the case of neutron irradiation and a corrosive environment, the system gains one additional dimension of complexity and corresponding limitation in terms of detailed process understanding.

In order to elucidate fundamental aspects of such corrosion processes, complementary synchrotron-based microscopic X-ray techniques have been employed to investigate a neutron irradiated zirconium alloy with 2.5%Nb doping and a corresponding non-irradiated (autoclaved) reference sample. Extending a pilot study [Froideval et al, 2009], X-ray fluorescence (XRF), X-ray absorption spectroscopy (XAS) and X-ray diffraction (XRD) techniques has been applied simultaneously in two-dimensional, microscopic imaging mode using micro-focused X-rays. The resulting chemical images with high spatial resolution provide detailed insights into the chemical nature of the pristine metal, the metal-oxide interface, as well as the corrosion layer formed.

As the most basic chemical imaging tool, micro-XRF produces pictures of the distribution of chemical elements of interest. This allows tracing down leaching, segregation and re-distribution phenomena occurring during the build-up of corrosion layers. Using the electronic state contrast expressed at the element-specific absorption edges, oxidation state mappings reveal the variations in valencies –in the present case of zirconium and niobium –across the metal/interface/corrosion-layer composite system. Chemical images illustrating the distribution (as well as the orientation and the state) of crystalline phases formed during corrosion are elaborated by means of two-dimensional micro-XRD. Finally, spatially highly localized micro-XAS can provide information about the molecular-level coordination of a specific element, even in the case of non-crystalline ('x-ray amorphous') material domains.

The different kind of results obtained simultaneously from an identical sample voxel allows gaining new insights into the fundamental processes occurring during the corrosion of niobium-doped zirconium alloys under neutron irradiation.

References:

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