Combined Synchrotron X-ray Microprobe Analysis of Corrosion Deposits in Fuel Rods of Pressurized Water Reactors

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The economics of power generation in nuclear power plants demand that pressurized water reactors (PWR) are driven to higher duty cycles and longer cycle durations. As a consequence, some reactors have experienced increased corrosion product deposits on the fuel cladding surface known as "CRUD" (Chalk River Unidentified Deposits). Among other adverse impacts, these deposits affect the thermal efficiency of the fuel rods and reduce the power output. The potential incorporation of short-lived radioactive isotopes is also of considerable concern regarding radiation exposure during maintenance works. As a more specific detriment, ferromagnetic components of the crud interfere could interfere with safety relevant measurements of the oxide layer developed on fuel rods. The nature, chemistry and identification of the crystalline phases of such crud deposits are therefore of utmost importance to understand the effective impact of crud deposits and to develop mitigation procedures preventing its formation.

In the present study, a combination of synchrotron-based microprobe techniques such as X-ray absorption spectroscopy (XAS), X-ray fluorescence (XRF) and X-ray diffraction (XRD) has been applied to CRUD particles – which were taken from fuel rods with different cycling histories in the Swiss Pressurized Water Reactor (PWR) of Gösgen Nuclear Power Plant. The microprobe measurements were done at the microXAS beamline at the Swiss Light Source (SLS) with a 1 μm^2 beam. The microXAS beamline is one of a few microprobe beamlines that allow active samples with a true 1 um^2 resolution.

With this combined analytical approach conducted at the microXAS beamline, spatially resolved micro-scale information on the oxidation state, coordination environments of Cr, Fe, Ni and Zn, as well as on the crystalline phases formed have been obtained. Such results are of importance as they can serve to gain insight into the processes which govern the formation of such corrosion products.