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Fundamental Studies of the Role of Grain Boundaries on Uniform Corrosion of Advanced Nuclear Reactor Materials

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ABSTRACT

Corrosion is one of the major challenges and limitations of cladding and structural materials in current light water reactors and future Gen IV reactors. Controlling the corrosion behavior of these materials has become a priority, which involves understanding the relationships between microstructure and alloy composition and the corrosion rates and the development of stable oxide films.

Previous studies on Zr alloys and ferritic/martensitic steels have shown that grain boundaries can be associated with the development of unstable oxide films. Recent information has indicated that the difference between the corrosion behavior of pure Zr and some Zr alloys can be rationalized in terms of differences in grain boundary segregation of minor alloying elements. Lath boundaries in ferritic-martensitic steels have also been shown to be preferential places of attack. Grain boundary chemistry and structure are therefore suspected to play a major role in the stable or unstable growth of oxide layers.

To gain insight into the mechanisms of oxide destabilization and the role of grain boundaries, this project will investigate the early stages of corrosion by combining in-situ transmission electron microscopy observations using a novel environmental holder to perform corrosion of a sample while it is being observed in the microscope and post facto observations using state-of-the-art characterization techniques. In particular, the chemistry and structure of grain boundaries in a number of Zr alloys and ferritic-martensitic steels selected for their known oxidation behavior (stable or unstable) will be analyzed using electron backscatter diffraction, focused ion beam for site-specific specimen preparation, transmission electron microscopy and atom probe tomography, before and after corrosion treatments (360^{o}C water, 400 ^{o}C, 500 ^{o}C steam or 600^{o}C supercritical water) for various times.

The research will result in the creation and development of a new and powerful in-situ technique for the study of early stages of corrosion and will apply this technique, combined with state-of-the-art atom-probe tomography to a well-defined set of alloys and extensive set of well-characterized corrosion samples to elucidate fundamental questions on the role of grain boundaries on corrosion. This method will help address basic questions of the relationship between the microchemistry and microstructure of the alloy and its corrosion behavior. The resolution of these questions could help design better alloys for the future nuclear reactors.