Initiation of SCC in Zirconium Alloys Examined using High-Speed Atomic Force Microscopy

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The integrity of zirconium alloys used in nuclear fuel cladding is critical to nuclear safety as the cladding provides the first barrier against release of fission products into the reactor primary circuit. The nuclear industry is currently transitioning from Zircaloy-4 to more advanced 5thgeneration materials such as Westinghouses ZIRLO. Very small changes to the alloying composition can cause substantial changes to Zircaloy corrosion performance and ZIRLO has been shown to improve its corrosion resistance principally by reducing its tin content. Iodine Stress Corrosion Cracking (ISCC) is generally accepted as the cause of Pellet-Cladding Interaction (PCI) failures, with the corrosion and cracking occurring fuel-side as the iodine is produced as a fission product from UO_2 fuel (1).

An advanced form of High-Speed Atomic Force Microscopy (HS-AFM) developed at the University of Bristol operates at speeds orders of magnitudes faster than a conventional AFM, imaging at a rate of multiple frames per second in liquid environments, therefore allowing for observation of dynamic events at the nanoscale. SCC and ISCC in Zircaloy-4 and ZIRLO has been studied using the HS-AFM to map the surface morphology by rapidly raster scanning the surface in contact mode. This technique provides a useful tool in imaging corrosion initiation events and crack formation under stress as proven by similar experiments on carbide corrosion in steels using a custom-built liquid cell to image in-situ under corrosive liquids (2).

This project will demonstrate the extension of the in-situ HS-AFM technique for Zircaloy corrosion and SCC. Zr has been imaged both in an unstressed state and under tensile stress in an iodine solution to induce cracking with in-situ HS-AFM observation of crack initiation. Real time imaging of corrosion and cracking in the HS-AFM allows a mechanistic understanding of ISCC initiation at the nanoscale to better understand the differences in corrosion behaviour between zirconium alloys which can be used to help further the development of corrosion resistant fuel cladding.

(1) P. S. Sidky, Journal of Nuclear Materials, **256** (1998) 1-17

(2) S. Moore et al, Faraday Discussions **210** (2018) 409-428