

## **Effects of Reactor Exposure on Nuclear Fuel Cladding**

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**Abstract.** In face of increasing worldwide demand for electricity generation and the increasing concerns with the contribution of fossil fuel emissions to climate change, nuclear power is again being considered for further development in the US and abroad. New reactor construction is being proposed, using both, evolutionary concepts based on the current fleet of Light Water reactors (LWRs) and advanced reactor concepts. The materials used in these reactors have to maintain outstanding performance for years, or even decades, in an extreme environment, in which they are exposed to a combination of high temperature and pressures, aggressive chemistry and a constant fast neutron flux.

Among the many materials used in reactor core are metallic alloys which are used for nuclear fuel cladding, structural materials and for the pressure vessel. Under neutron irradiation atomic displacements are generated in these materials, causing the steady state defect concentration to be highly supersaturated relative to thermal equilibrium conditions. As a result, while under irradiation these materials are very far from equilibrium, allowing configurations to be observed that are not seen outside irradiation. Phenomena such dimensional instability (irradiation creep and growth and void swelling), microchemical evolution (irradiation-induced segregation), irradiation dissolution of stable phases and precipitation from undersaturated solid solution can be observed, depending on the relative balance between damage and annealing. In addition, chemical degradation caused by exposure to high temperature water can cause phenomena such as general corrosion, hydriding, stress corrosion cracking, crud deposition and localized forms of corrosion such as nodular corrosion and shadow corrosion and fuel-clad interactions. These microstructural changes can severely impact fuel cladding properties such as strength, ductility, corrosion resistance and fracture toughness.

As utilities and fuel vendors attempt to push materials to higher temperatures and doses many challenges become apparent in all these areas. We will review these concepts and challenges to implement them as well as the opportunities to use current advances in computational techniques and in experimental tools and techniques to understand these processes in a fundamental manner. We will also review the opportunities for Graduate Study in nuclear Engineering at Penn State.

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**Biography.** Arthur Motta is the Chair of the Nuclear Engineering Program and a Professor of Nuclear Engineering and Materials Science and Engineering at Penn State University. He holds degrees in Mechanical Engineering and Nuclear Engineering from the Federal University of Rio de Janeiro, Brazil, and a Ph.D. in Nuclear Engineering from the University of California, Berkeley. Before joining the Penn State faculty in 1992, he worked as a research associate for the CEA at the Centre for Nuclear Studies in Grenoble, France, for two years and as a post-doctoral fellow for AECL at Chalk River Laboratories in Canada.



Prof. Motta works in the area of radiation damage and environmental degradation to materials with specific emphasis in Zr alloys, with current projects in the areas of mechanical testing, corrosion and radiation damage. He has special interests in using advanced characterization techniques such as x-ray scattering from synchrotron radiation sources, transmission electron microscopy, and in situ irradiation to discern fundamental mechanisms of corrosion and radiation damage.

Prof. Motta is a Fellow of the American Nuclear Society (ANS) and in 2015 he received the Mishima Award from the ANS for outstanding contributions in research and development work on nuclear fuel and materials. In 2016 he was awarded the ASTM William J. Kroll Medal for sustained impactful contributions to zirconium metallurgy including corrosion, hydriding, mechanical properties and irradiation effects.