Degradation Mechanisms of Light Water Reactor Fuel Materials Following a Cladding Breach

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The joint drivers of improvements to accident tolerance and a desire for increased reactor performance have motivated exploration of nuclear fuels that improve upon the deficiencies of reference uranium dioxide. The primary shortcomings of uranium dioxide are its low thermal conductivity and poor fracture strength. These properties along with increased uranium density and high melt point constitute the chief performance objectives of nuclear fuel design. A wide rage of monolithic and composite fuel concepts are being assessed not only to establish their ability to offer improved performance, but also to demonstrate a capacity to perform acceptibly in the far broader service conditions and enivoments that a nuclear fuel form must endure.

One specific anticipated off normal condition is breach of cladding. As designed, the cladding material retains a fully hermetic seal that segregates the coolant (e.g. pressurized water or steam) from the operating nuclear fuel. Clad breach can occur due to a number of mechanisms. These are genearlly understood for zirconium alloys, but the proposed adaptation of iron-chromium-aluminum and silicon carbide composite cladding materials suggests previously unknown breach mechanisms may become relevant. Cladding failure will allow for ingress of the water coolant into the fuel-cladding gap. The outcome of this event will dictate the viability of a proposed fuel-clading system for light water reactor service.

This talk will summarize ongoing research into the various mechanisms that govern the respose of the fuel material to a cladding breach. First, the metrics that would define unacceptable performance will be proposed. Second, the thermodynamic conditions relevant to simulation and experimental study of this problem will be outlined. This critical topic will be shown to be subject to significant uncertainty, providing important opportunity for further work in the community. Finally, examples of recent experimental efforts to catalog the performance of a number of nontraditional light water reactor fuels such as uranium nitrides, uranium silicides, and other composites will be disucssed. These findings will highlight known mechanisms of degredation under both oxidizing and reducing conditions under relevant temperatures and pressures.