Radiation response of pure chromium for evaluation of an accident-tolerant fuel concept using chromium outer coating on Zircalloy cladding

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Chromium has been proposed as a coating layer on Zircaloy-4 fuel cladding as a possible accident-tolerant fuel design. Chromium coating is expected to increase both the oxidation resistance and the corrosion resistance under severe and off-normal conditions. However, there is a lack of understanding of the swelling resistance of this metal, primarily due to very little data published in the open literature. In the study, we used 5 MeV Fe^{+2} ion irradiation to introduce radiation damage at doses ranging from 10 to 150 peak dpa in pure chromium over irradiation temperatures ranging from 450°C to 650°C. The maximum swelling temperature was found to be ~550°C. At this temperature, Cr has a swelling incubation period of essentially zero dpa, but reaches only ~1% swelling at 10 peak dpa irradiation. Interestingly, swelling saturates at >50 peak dpa and then declines at higher damage levels.

Transmission electron microscopy shows that chromium initially develops aligned voids moving toward a void superlattice with increasing dose. This behavior of self-organization leading to void lattices and concurrent overshoot of void density and later decline in swelling has been observed in other bcc metals, always leading to relatively low swelling levels compared to non-lattice-forming metals. Such behavior is believed to arise from one-dimensionally migrating interstitial defects that annihilate portions of voids lying outside the shadow of their neighbors in the alignment direction, thereby suppressing additional void nucleation and slowing or reducing void growth. The study is important to evaluate the safety margin of Cr-coating, indicating that excessive void swelling and associated strains with the underlying Zircaloy will not be a problem.