EFFECTS OF RADIATION DAMAGE ON THE CRITICAL RESOLVED SHEAR STRESSES IN ZIRCONIUM ALLOYS FOR NUCLEAR APPLICATIONS

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Nuclear power provides 10% of the world's electricity and is likely to expand as countries seek to provide low-carbon energy in the future. Of the current operating 442 commercial nuclear reactors, 96% are water cooled and thus have their uranium oxide fuel contained within a zirconium alloy cladding. This cladding limits fission product release into the primary water loop, as well as acting as the main transport medium for neutrons and heat.

Under irradiation, like most metals, these zirconium alloys exhibit strong hardening effects. Typically, the yield stress of Zr-alloys doubles during the early stage of irradiation while a dramatic loss of strain-to-failure is observed. Irradiation hardening is currently qualitatively described by <a> loops being barriers for dislocations during mechanical loading. This hardening is also supplemented by irradiation-induced precipitates, but their effect on irradiation hardening in Zr-alloys is currently unknown.

Like most of other hexagonal close packed (HCP) materials, zirconium deforms anisotropically via plastic slip on the basal, prismatic and pyramidal planes. As loop formation is also crystallographically influenced, a full picture of the radiation damage effects in zirconium must be gathered on a piece-by-piece basis, with the influence of damage levels, strain rate and temperature being determined on each slip system.

We present here the first steps towards painting this picture of radiation damage effects in zirconium. Nano-indentation testing using spherical and Berkovich tips correlated with indented grain orientations from EBSD has been used for initial rapid screening of irradiation hardening and strain softening effects, as required by complementary CP-FEM models. Subsequently identified "interesting" samples have been selected for more quantitative micro-mechanical investigation to determine critical resolved shear stresses on specific slip systems.