Versatility of dislocation motions in polycrystalline UO_2 investigated by TEM

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Uranium dioxide (UO_2, fluorite structure) is the most common nuclear fuel material for pressurized water reactors (PWRs). To this aim, UO_2 is sintered into cylindrical pellets which are stacked in a zirconium alloy cladding tube. The nuclear fuel undergoes significant microstructural changes during in-pile irradiation, affecting its physical and mechanical properties and limiting its lifetime in the reactor. These microstructural changes are due to the combined action of various factors throughout the irradiation process.

To understand the impact of microstructure evolution during irradiation on fuel creep deformation, particularly at high temperatures during off-normal power transients, polycrystalline UO_2 fuels submitted to uniaxial compression tests at 1550°C were studied using TEM.

In this talk, I will discuss the recent efforts made to characterize dislocation motion mechanisms in deformed UO_2, as well as their impact on the formation of dislocation microstructures and networks.

In UO_2, dislocation motion can be a complex process since three slip modes are commonly observed including *i.e.*, {001}, {110} and {111}, all characterized by the same Burgers vector ½<110>. Critical resolved shear stress (CRSS) have been measured in both ½<110>{001} and ½<110>{110} slip modes and show significant variations with temperature attributed to lattice friction, dislocation core structure and mobility processes. Unlike what is classically observed in metals with a face-centered cubic structure, the ½<110>{001} slip system is the most favorable slip mode as having the lower CRSS below an athermal transition temperature $T_a^{\{001\}}$ ~1600 K, when compared to ½<110>{110} that is activated at larger stress. No CRSS can be found for ½<110>{111} since it has never been tested independently from the two other slip modes in stoichiometric UO_2. For this latter, dislocation observations were attributed to cross slip from {100} or {110}.

The results presented emphasize the complexity of dislocation motion in UO_2 since it involves glide in these three different systems, sometimes multiple cross slip and a mixed mechanism involving climb, called mixed climb, which was not evidenced in this material up to now. During mixed climb, the dislocation moves by a combination of glide and climb events in the so-called mixed climb plane close, but clearly distinct, from pure slip and climb planes. This process provides additional degrees of freedom to dislocation motion and spread the deformation in the UO_2 crystal without the classical crystallographic slip plane constrain.