Radiation effects on mechanical behaviour of zirconium alloys: from dislocations to polycrystals

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Zirconium alloys are used as cladding tubes for the fuel of nuclear water reactors. In-reactor, they are subjected simultaneously to mechanical loadings and neutron irradiation. In order to gain a better understanding of radiation effects on the mechanical behavior, deformation mechanisms have been studied starting from the smallest length scale up to the macroscopic mechanical behavior. Mechanical tests have been conducted on neutron-irradiated tubes. The deformation mechanisms have been analyzed by TEM after testing but also on Zr-ion irradiated samples thanks to in situ straining inside the TEM. A process of removal of radiation defects by gliding dislocations has been observed. Interactions between dislocations and radiation defects have been studied by molecular and dislocation dynamics. This numerical study has been able to provide a good understanding of the clearing of radiation defects depending on the gliding plane of dislocations. Finally, a polycrystalline model, that takes into account these mechanisms, has been developed and compared to mechanical tests with complex loading path. A cyclic strain softening, due to the removal of radiation defects, is predicted by the model in good agreement with experiments.