Cluster dynamics and phase field model of gas bubble evolution and volumetric swelling in polycrystalline UMo fuels

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U-10 wt% Mo alloys (UMo), with less than 20 wt% ^{235}U enrichment, are considered a candidate for replacing highly enriched ^{235}U fuels currently used in high power research and test reactors in the USA. Irradiation examination of UMo monolithic fuel designs showed that irradiation-induced recrystallization dramatically speeds up the swelling kinetics. Recrystallization refines grain sizes from about ten micrometers coarse grains to about 200nm fine grains. Our hypothesis for the higher swelling kinetics in the recrystallization zone is that the small grain size and low gas bubble density release the constraint of interstitial loop growth. In this work, a gas bubble evolution model integrating phase field and cluster dynamics methods is developed to study the effect of interstitial loop growth on gas bubble evolution and volumetric swelling kinetics in polycrystalline UMo fuel. The cluster dynamics is used to describe the evolution of interstitial loops, and vacancy clusters, and dislocation density. The phase field model is used to describe the gas bubble nucleation and growth. With the model, the effect of defect mobility, clustering rate, fission rate, interstitial emission from interface on gas bubble evolution were systematically simulated. The comparison of gas bubble size, density and volumetric swelling from simulations and experimental data confirm that the interstitial loop growth in recrystallization zone is the physics behind the fast swelling kinetics in recrystallization zone. The application of the developed model in optimizing the initial microstructure for desired fuel performance will be discussed in the talk.