A multi-scale microstructure simulation framework for fission gas bubble growth: phase-field and cluster dynamics modeling

Dong-Uk Kim[1], Sophie Blondel[2], Brian Wirth[2], and Michael Tonks[1]

[1]University of Florida
[2]University of Tennessee

The fission gas behavior within nuclear fuel has huge impact on nuclear fuel performance due to creation of gas bubbles inducing coevolution of gas diffusion field and the microstructure. However, significant uncertainties exist in the mechanisms on the gas diffusion, bubble nucleation and growth, and re-solution of bubbles, which are key factors to understand what is happening in the fuel during the reaction. Despite the intensive experimental efforts, the complex nature of the underlying physics and harsh condition hinder both observation and understandings on the fission gas behavior. To overcome the difficulties, an alternative way can be suggested via computational approach. In this study, a multi-scale-multi-physics simulation tool is presented to reproduce and clarify the mechanisms on microstructure evolution driven by fission gas diffusion and bubble growth using phase-field method which is one of the most powerful interfacial tracking methods in meso-scale. The fission gas production due to the nuclear reaction, the lower length scale phenomena which phase-field method cannot solely cover was rendered by using weak-coupling with cluster dynamics modeling code separately. The simulation application was built upon MOOSE (Multiphysics Object Oriented Simulation Environment) framework coupled with Xolotl, high performance plasma-surface interaction simulator. The capability of the framework to reproduce the microstructure evolution will be demonstrated by simulating the bubble growth in a realistic polycrystalline nuclear fuel system.