

3D comprehensive effective heat conductivity model of UO₂

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The thermal conducting properties of UO₂ pellet degrade over lifetime of a nuclear power plant and it can be a critical limiting factor of the safety and efficiency of the reactor. A commercial UO₂ pellet contains microstructural inhomogeneities, such as grain boundaries, voids and Helium bubbles. Since those microstructural defects seriously affect thermal properties of the nuclear fuel, understanding correlation between effective thermal conductivity and temporal distribution of the imperfections is a quite important task. Especially, Helium bubbles nucleate due to the He generation by the fission product and their nucleation and growth behavior are heavily affected by the grain boundary network. So far, there have been valuable attempts to quantify the correlation between microstructural characteristics, such as average grain size, porosity with effective heat conductivity in 2D. The phase-field method is a powerful methodology to predict the microstructural evolution, such as He bubble evolution, grain growth. We generated polycrystalline 3D microstructures with He bubbles. First of all, we investigated the interaction between grain boundaries and He bubbles. Next, we established comprehensive 3D effective heat conductivity model of UO₂ with consideration of bubble size distribution and relative size ratio between average helium bubble volume and average grain volume.