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Modeling of Lanthanide Transport in Metallic Fuels: Recent Progresses

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fission products as well as lanthanide impurities in recycled feedstock are known to migrate to the periphery of metal fuels and initiate FCCI that weakens the cladding material. We will present here the most recent developments regarding efforts to implement reliable lanthanide transport models into the 3D fuel performance analysis code, BISON, and experimental and analytical efforts to determine the solubility of certain lanthanides in liquid metals that may be the mechanism for liquid-like transport.

Using ab-initio MD, we found that the solubility of cerium in liquid sodium at 1000K was less than 0.78 at. %, and the diffusion coefficient of cerium in liquid sodium was calculated to be 5.57 10-5 cm2/s. We extended the MD work to two temperatures 723 K and 1000 K for Cerium (Ce), Praseodymium (Pr), and Neodymium (Nd) diffusion in Sodium (Na) and Cesium (Cs) three abundant Ln fission products diffusion coefficients in liquid Na at multiple temperatures. The Ln diffusivities are found to be in the magnitude order of liquid diffusion (10-5cm2/s) and the temperature dependence of diffusivity is developed according to Arrhenius equation.

Experiments have been performed to measure the solubility of lanthanides in liquid sodium.. Using ICP-MS to measure the concentration of lanthanide in the sodium sample, the solubility at that testing temperature is calculated. The experimental results indicated that the solubility of cerium, praseodymium, and neodymium varied from 1x10-6 to 3x10-5 at. % between 723 to 823 K with considerable scatter. The time dependence of solubility is also obtained from experiments conducted at different equilibration times.

To better describe the Ln transport behavior, a model of Ln transport through porous media is being developed from pore-scale to a continuum description through three main steps: 1) Ln dissolution at an isothermal fuel-pore interface, 2) Ln migration within a single 1D tubular pore along a temperature gradient, 3) Ln transport through porous media with specific porosity. Temperature effects are considered with inclusion of Soret term. Finally, an integrated model with regarding to an effective diffusivity, porosity and Soret effect is obtained. Initial results of modeling are discussed.

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