Microstructure design insights for UO_2 composite fuels from a microstructure dependent thermal resistor model and fission gas study

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UO_2 fuels with high thermal conductivity additives are prospective accident tolerant fuels. The microstructure of a composite fuel plays an important role in its thermal performance. A microstructure dependent thermal resistor model was developed to investigate this structure-property relationship. This model utilizes the continuousness of a composite measured from a 2D micrograph using a genetic algorithm to predict the thermal conductivity of the 3D fuel. By simulating many 3D microstructures and evaluating 2D slices of its structure it is possible to investigate how microstructural changes impact a composite's effective thermal conductivity. Using this tool, insight can be gained into which features of a microstructure, such as particle shape, orientation, and volume fraction, have the largest impact on a composite's thermal properties. From this, guidelines are created to identify where the greatest potential gains in thermal conductivity can be had from engineering a better microstructure. By optimizing a composite's microstructure either the fuel's performance can be maximized or less additive can be used to achieve an equivalent performance. The presence of fission gas could partially or completely eliminate the benefits of the additive, regardless of how well designed the microstructure is. Therefore, a study was performed to identify when fission gas coverage of the additive phase makes the composite fuel's performance equal to or less than that of a pure UO_2 fuel.