# Thermal Conductivity of Metallic Micro-Cell Fuel Pellet with Different Unit Cell Geometry

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## 1. Introduction

Increasing the thermal conductivities of nuclear fuel pellets can relieve the severe temperature gradients across the pellets, which can improves the reliability and safety of nuclear fuel [1, 2]. Recently, the metallic micro-cell pellets have been successfully fabricated to increase the thermal conductivities of nuclear fuel pellets with the minimal inclusion of thermal conductive materials (e.g., Mo, W, Cr, etc.) to $UO_2$ [3, 4, 5]. Here we numerically characterize the effects of the geometry, such as the size and the aspect ratio, of the $UO_2$-Mo micro-cells on their thermal conductivities.

## 2. Simulation model

The unit $UO_2$-Mo micro-cell of the fuel pellet was simplified to the two-dimensional rectangular shape as shown in Figure 1. The $UO_2$ was enclosed by the Mo with the uniform thickness. To quantify the micro-cell shape, the aspect ratio (AR) was defined as the ratio of the length ($L$) in the heat flux direction to the length ($H$) normal to the heat flux direction. The contents of Mo in the $UO_2$-Mo micro-cells were fixed as 5 vol% in this study. The properties of thermal conductivities of $UO_2$ and Mo were adopted from MATPRO and CRC Handbook [6, 7].

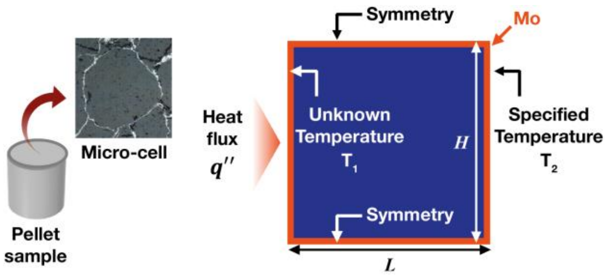


Figure 1. Schematic of a simulation model for the $UO_2$-Mo micro-cells.

Boundary conditions were applied to the model as follows: constant heat flux ($q''$) to the left side, constant temperature ($T_2$) to the right side, and symmetric boundary conditions to the top and bottom sides. The steady-state heat conduction equation was solved. The numerical simulation was carried out by using the commercial software (Comsol Multiphysics®) to determine the temperature ($T_1$).

The effective thermal conductivities ($k_{eff}$) of the micro-cells were computed by using Fourier heat equation (*eq 1*) as follows:

$$k_{eff} = q'' \frac{L}{(T_1 - T_2)} \qquad (1).$$

## 3. Result and discuss

### *3.1 Effects of the micro-cell sizes on their thermal conductivities*

The effects of the micro-cell size on the thermal conductivity of the $UO_2$–Mo pellet fuel were investigated. The micro-cell size increased from 100 to 500 μm, while their aspect ratio was held constant as 0.5. The thermal conductivity had no change with varying the micro-cell sizes (Figure 2). The numerical results agreed well with the experimental results within an error of 8.0%. As the micro-cell size increases under the same aspect ratio, the increase of the thermal resistance by increasing the length ($L$) of the micro-cell was exactly compensated by the decrease of the thermal resistance by increasing the height ($H$).

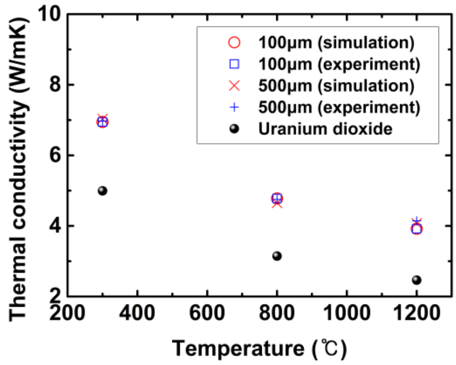


Figure 2. Size effects of the micro-cells on thermal conductivities at 300℃, 800℃, and 1200℃.

### *3.2 Effects of the micro-cell aspect ratios on their thermal conductivities*

Increasing the aspect ratios of the micro-cells under the same contents of the Mo in $UO_2$ significantly increased their thermal conductivities (Figure 3). This also matched well with the experimental data within an error of 7.9%. The increase in the aspect ratio of the micro-cells resulted in the fast reaching of the thermal equilibrium across the height of the micro-cell (*i.e.*, the decrease of the thermal resistance of the micro-cell), which outweighs the increase in the thermal resistance of the micro-cell by increasing the length of the cell.

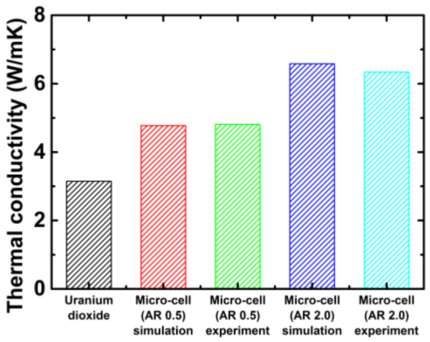


Figure 3. Thermal conductivity of the micro-cells in terms of aspect ratio at temperature of 800℃.

## 4. Conclusion

The geometric effects of the metallic ($UO_2$-Mo) micro-cells on their thermal conductivities were numerically investigated in terms of the size and the aspect ratio of the micro-cells. Our simulation results agreed well with the experimental measurements. Under the same contents of the Mo in the $UO_2$, changing the sizes of the micro-cells did not vary their thermal conductivities as long as their aspect ratio was fixed. However, increasing the aspect ratio of the micro-cells greatly increased their thermal conductivities. The $UO_2$-Mo micro-cells with the Mo of 5 vol% and the aspect ratio of 2.0 can increase the thermal conductivities of the $UO_2$ pellets by 2.1 times at 800℃, which has the potential of the significant improvement in the reliability and the safety of the nuclear fuel by decreasing the maximum temperature of the pellet.

## ACKNOWLEDGEMENT

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