Study of Epsilon Particle Behavior in Nuclear Fuel Oxide

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1. Introduction

Uranium oxide is usually used as fuel material in nuclear reactors. Stability of nuclear fuel is one of the important issues. Because, nuclear fuel is designed to operate under critical driving conditions in a nuclear reactor, including high dose and high temperature. However, a lot of fission products is generated during burnup which change the chemical and physical properties of the fuel.[1] Among the fission products, called epsilon particles, such as metallic phases exist by their high content of noble metals with low oxygen affinity.[2] The metallic phases are observed as composition and crystal structure of fission product precipitates such as face-centered cubic (fcc) α-Pd(Ru, Rh) phase, body-centered cubic (bcc) β-Mo(Tc, Ru) phase, and hexagonal close-packed (hcp) ε-Ru(Mo, Tc, Rh, Pd) phase. [3]

In this work, we report the study of uranium oxide with Mo of epsilon particles using powder X-ray diffraction and SEM/EDAX. Since we can`t measure to the experiments of real fuels, we prepare simulated nuclear fuels and observe the behavior of epsilon particle formation.

2. Experimental

Uranium oxide with molybdenum oxide pellets (UMo-1 (0.5wt% of MoO_2) and UMo-2 (1wt% of MoO_2)) were ground thoroughly with agate mortar and pestle and pressed into pellets. The pellets of on the alumina tube were heated to 1700 °C for 18h and cooled to room temperature at a rate of 6 °C h^{-1} in H_2 atmosphere for inducing a generation condition of the epsilon particle.

The X-ray powder diffraction patterns were collected on a Bruker D8 - Advance diffractometer using Cu Kα radiation with 40 kV and 40 mA. The scan ranges were 20 - 120° with a step size of 0.02°, and a step time of 0.1s. Scanning electron microscopy/Energy-dispersive analysis by X-ray (SEM/EDAX) was performed using a JEOL JSM-6610LV to observed metallic phase in nuclear fuel.

3. Results and discussion

The powder X-ray diffraction patterns for UMo-1 and UMo-2 are shown in Fig. 1. The diffraction peaks of Mo metal (40.5° and 58.6°) are consistently increased to the as MoO_2 is replaced Mo metal (PDF #: 01-071-3771) by reduction condition.

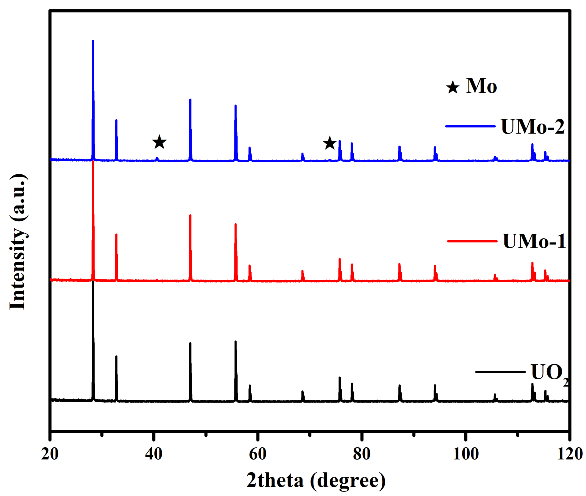

Fig. 1. Powder X-ray diffraction patterns of the UO_2 phases with epsilon particle.

The SEM/EDAX images of products are shown in Fig. 2. Spherical type of epsilon particles is existed in UO_2 matrix. The Mo particle sizes are observed in the range from 0.2 ㎛ to 1 ㎛. Interestingly, it is observed that the size of Mo particles increased according to increase the MoO_2 content. If the Mo amounts are increasing, the distance between the particles is closed and agglomerated with each other, which is expected to increase the particle size. In addition, it is expected to affect the properties of nuclear fuel.

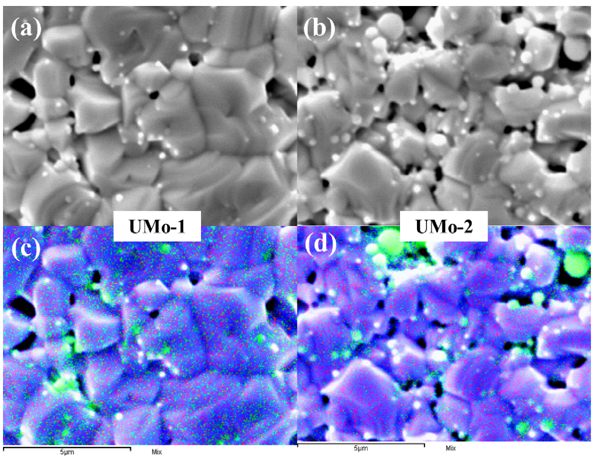

Fig. 2. The images of SEM (a and c) and EDAX (b and d) the UO_2 phases with epsilon particle (green: Mo, blue: U, red: O).

4. Conclusions

The epsilon particle in nuclear fuel has been studied using powder X-ray diffraction and SEM/EDAX. We observed the effect of the increasing Mo amounts on UO_2 surface. In further work, we will study the effect of changes in the size of epsilon particles on nuclear fuels such as UO_2.

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REFERENCES

[1] J. Bruno, R. C. Ewing, Spent Nuclear Fuel. *Elements*, *2*, 343-349, 2006.

[2] W. Jiang, M. A. Conroy, K. Kruska, N. R. Overman, T. C. Droubay, J. Gigax, L. Shao, R. Devanathan, Nanoparticle Precipitation in Irradiated and Annealed Ceria Doped with Metals for Emulation of Spent Fuels. *The Journal of Physical Chemistry C*, *121* (40), 22465-22477, 2017.

[3] Kleykamp, H.; Paschoal, J. O.; Pejsa, R.; Thommler, F. Composition and structure of fission product precipitates in irradiated oxide fuels. *Journal of Nuclear Materials*, *130*, 426-433, 1985.