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Fabrication of Cr-doped UO_2 Fuel Pellet using Liquid Phase Sintering

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1. Introduction

To enhance the in-reactor performance and safety of LWR (Light Water Reactor) nuclear fuel, many researches have been conducted in various aspects. From the view point of a nuclear fuel pellet, it can be said that the representative issues are a reduction of the FGR (Fission Gas Release), the increment of resistance to the PCI (Pellet Cladding Interaction), and an enhancement of the thermal conductivity of the fuel pellet.

Typically, the FGR can be reduced by the application of a large-grain fuel pellet because the moving path of the fission gas to the grain boundary is much longer. An enhancement of the thermal conductivity of a pellet can be obtained by the addition of a higher thermal conductive material in the pellet. In addition, the resistance to the PCI can be increased through a plasticity increase of the pellet.

Thermal conductivity of ceramic materials is generally lower than that of metallic materials. The thermal conductivity of uranium oxide which is a typical ceramic material is low as well. The steep temperature gradient in the fuel pellet results from the low thermal conductivity. Therefore, the thermal conductivity improvement of a nuclear fuel pellet can enhance the fuel performance in various aspects. The lower centerline temperature of a fuel pellet affects the enhancement of fuel safety as well as fuel pellet integrity during nuclear reactor operation. Besides, the nuclear reactor power can be uprated due to the higher safety margin. So, many researches to enhance the thermal conductivity of nuclear fuel pellet have been performed in various ways [1-3].

To improve the thermal conductivity of UO_2 pellet, an appropriate arrangement of the high thermal conductive material in UO_2 matrix is one of the various methods. We intended to control a placement of chromium as the high thermal conductive material. The metallic chromium and chromium oxide were arranged in a grain boundary of UO_2 using a liquid phase sintering method. The liquid phase sintering of Cr-doped UO_2 pellet could be adjusted using a control of an oxygen potential in sintering atmosphere.

2. Experimental and Results

Chromium oxide powder at 3 wt% (SIGMA-ALDRICH, 99.9%) was mixed and milled with ADU-UO_2 (Ammonium Diuranate) using a ball mill for 24 h.

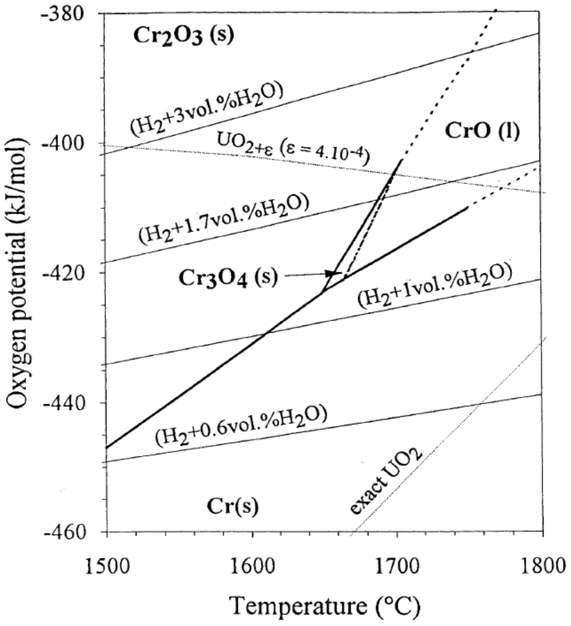

Fig. 1. Thermodynamic equilibrium between metallic Cr and Cr oxides [4].

The prepared powder mixtures were compacted by using a single acting press at about 300 MPa, and sintered at 1750 ℃ for 4h in a H_2+1.8%CO_2 atmosphere. The liquid phase sintering can be conducted by an application of these sintering conditions (Figure 1). That is to say, for the sintering of Cr_2O_3-doped UO_2 in the CrO liquid phase region, a temperature and oxygen potential in the sintering atmosphere were adjusted.

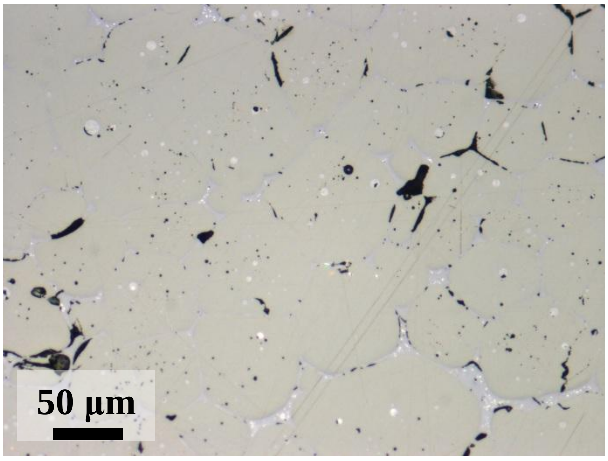

Fig. 2. The microstructure image of the liquid phase sintered Cr-doped UO_2 pellet.

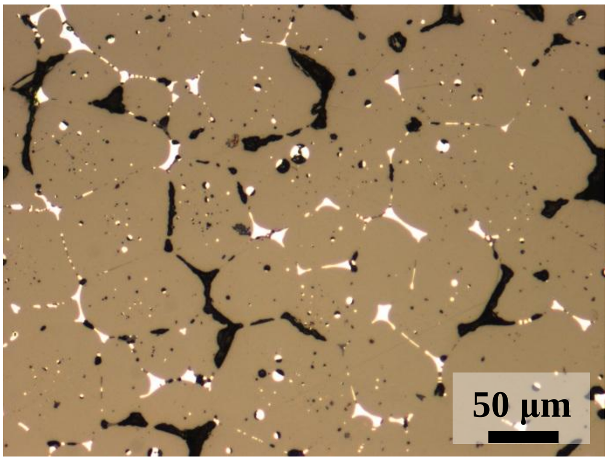

Fig. 3. The microstructure image of the heat-treated Cr-doped UO_2 pellet for the reduction of chromium oxide

Figure 2 shows a microstructure image of liquid phase sintered Cr-doped UO_2 pellet. It can be shown that the chromium oxide is arranged in the grain boundary.

And then, the sintered pellet was heat-treated at 1590 ℃ for 10h in a H_2 atmosphere for a reduction of the chromium oxide in the grain boundary. Figure 3 shows that most of chromium oxide is reduced to the chromium. However, large pores were formed by the chromium volatilization during the reduction process. It is predicted that the large pores will play a role to decrease the thermal conductivity of pellet. Therefore, the formed large pores must be eliminated.

3. Summary

To improve the thermal conductivity of UO_2 pellet, it was intended to control the arrangement of chromium in the UO_2 using the liquid phase sintering method. In the results, the Cr-doped UO_2 pellet that the metallic chromium is arranged in the grain boundary is fabricated. The further study for elimination of the formed large pores is in progress.

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