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Crystallographic study on irradiated metallic fuels by micro X-ray diffraction

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1. Introduction

Researches on irradiated metallic fuel have been performed to understand the irradiation behavior because it showed different properties from oxide fuel under irradiation [1-3]. In particular, the results obtained from scanning electron microscopy (SEM) and electron probe micro analyzer (EPMA) provided the information on the microstructure of irradiated metallic fuel, which was used to inspect the phenomena of swelling and fuel-cladding chemical interaction (FCCI). However, these analytical tools did not give crystallographic data of irradiated metallic fuel.

Herein, we will demonstrate the crystallographic characteristic of two irradiated metallic fuels at approximately 2.9 at.% burnup using micro-XRD system.

2. Experimental Details

Metallic fuels of U-10Zr (U-based alloy with 10 wt% Zr) and U-10Zr-5Ce (U-based alloy with 10 wt% Zr and 5 wt% Ce) with initial ^{235}U enrichment of 19.75 wt% were fabricated using a gravity casting method under Ar atmosphere [4-5]. The fuel rods composed of the metallic fuel, sodium, and ferritic-martensitic steel T92 cladding were irradiated at up to approximately 2.9 at.% burnup under simulated fast reactor conditions in the High-flux Advanced Neutron Application Reactor (HANARO) with around 182 effective full power days (EFPD).

For the sample preparation for micro-XRD experiments, the slices of irradiated metallic fuels were embedded in the resin, which was used to make the irradiated sample fit the holder of micro-XRD equipment.

A radiation-shielded micro-XRD system (Figure 1) installed with micro-beam collimator was used to measure diffraction patterns of irradiated metallic fuels where beam size is approximately 50 μm in width. Beam position of micro-XRD was checked using a microscope equipped with micro-XRD. Micro-XRD spectra were acquired in the range of 20–70° with a scanning step of 0.04° for 60 s. As a X-ray source, Cu K_α X-ray radiation filtered through Ni foil was used. Lattice constant was estimated by the refinement of obtained diffraction patterns using the Pawley method.

Fig. 1. A radiation-shielded micro-XRD system.

3. Results

Figure 2 displayed optical images of irradiated U-10Zr and U-10Zr-5Ce metallic fuels on the holder of micro-XRD system. As shown in Figure 2, two distinct golden and black colored areas on irradiated U-10Zr and U-10Zr-5Ce metallic fuels were observed with bright cladding on both sides. To verify the crystal structures on two distinct colored fuel regions, we conducted micro-XRD experiments from one outer edge of cladding to the fuel center along the radius. Through the analysis of micro-XRD data, we were able to identify that the crystal structures of golden and black colored areas in two irradiated metallic fuels were α-U and UO_2, respectively.

On the basis of the profile change in lattice parameter along irradiated metallic fuel radius, we demonstrated that the change in UO_2 lattice parameter depended on the concentration of Zr and fission products. In addition, through analysis of α-U lattice constant we confirmed that the irradiation growth occurred on *b*-axis.

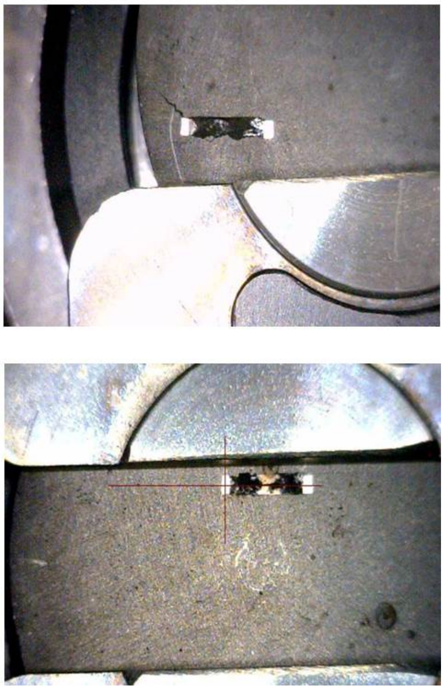
(a)
(b)


Fig. 2. Optical images of irradiated (a) U-10Zr and (b) U-10Zr-5Ce metallic fuels.

4. Conclusions

We described the crystallographic results for irradiated U-10Zr and U-10Zr-5Ce metallic fuels using micro-XRD system. Based on the measured diffraction patterns, UO_2 and α-U phases were identified in both irradiated metallic fuels. In UO_2 region, we suggested that the variation in lattice constant is related to the concentration of Zr and fission products. Additionally, we found that the irradiation growth proceeded in the *b*-axis direction of α-U phase.

We expected that this work will contribute to understanding for irradiation behavior of metallic fuels.

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