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Microstructure Changes in a high burn up Spent Fuel (57,900 MWd/tU)

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1. Introduction

In the nuclear industry, an increase in the burn up and the residence time of fuels is being considered because of the advantages in the fuel cycle cost and the spent fuel management. But, it leads to structural changes in an outer zone (rim) of a UO_2 pellet within a few hundreds of micrometers in thickness. Despite its thin layer, this rim would determine the thermal behavior of a fuel. Therefore, to identify a rim zone effect, the microstructures such as the pores, the grains and the UO_2 lattice size have been investigated by many researchers [1-2].

In this study, the microstructure changes in the rim of a UO_2 spent fuel, the corrosion layer of a Zry-4 cladding and the interface between a fuel and a cladding were investigated by a micro-XRD and a SEM.

2. Experimental methods

A fuel sample examined in this study was a spent fuel of average burn up 57,900 MWd/tU discharged from Yeonggwang-2 PWR reactor. This spent fuel was cut into 3 × 3 × 0.5 mm dimension including a rim and a cladding, molded with epoxy resin and polished with an abrasive paper in a hot cell as shown in Fig.1.

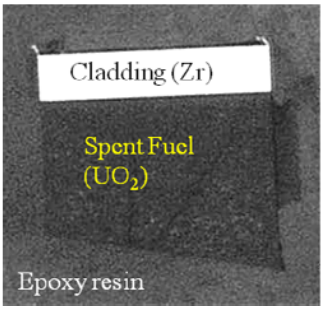

Figure 1. A spent fuel discharged from Yeonggwang-2 PWR reactor (average burn up 57,900 MWd/tU).

The diffraction and image analysis of a spent fuel was done by a micro x-ray diffractometer (micro-XRD) modified in our laboratory [3] and a scanning electron microscope (SEM) installed in the radiation shielded glove boxes individually.

3. Results

The lattice parameters of UO_2 (cubic phase) were obtained in a radial direction from the rim to the core of a spent fuel by micro-XRD (Fig. 2). All those had the larger values than 5.467 Å (a, the original value of UO_2) because of the radiation damage. In a rim region, the lattice contraction was observed due to the recrystallization. And in the core region, the reduced lattice parameters were obtained due to the lattice recovery by the thermal healing at high temperature.

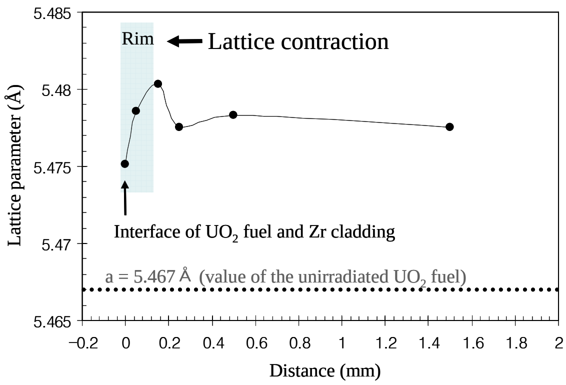

Figure 2. The lattice parameter change in a radial direction from a rim to the core of a spent fuel (average burn up 57,900 MWd/tU).

The SEM images for the rim and the core regions of a spent fuel are shown in Fig. 3. In the rim region, the small grains of ~ 1 ㎛ and the pores of ~ 2 ㎛ in diameter were observed. Before the irradiation, the original UO_2 pellet has the grains of ~ 10 ㎛ in diameter and no pores, but after the irradiation, the grains of UO_2 pellet became small and their boundaries were observed and the pores were generated. In the core region, the grain boundaries and the pores were not observed.

The gap between a UO_2 pellet and a zircaloy-4 cladding disappeared because they interacted with each other at high temperature [4].

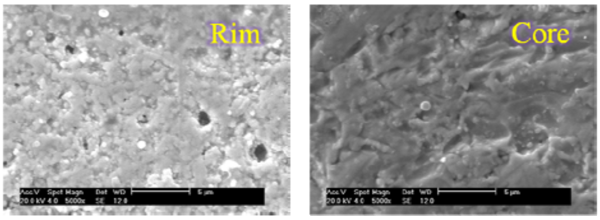

Figure 3. Scanning electron microscopy (SEM) images of a rim and the core of a spent fuel (average burn up 57,900 MWd/tU).

The dark layer in the outer region of a zircaloy-4 cladding was observed and its thickness was about 40 ㎛ (Fig. 4). It was the zirconium oxide layer produced by the oxygen diffusion from the cooling water into a cladding during the operation of a nuclear reactor. Its chemical structure was identified as ZrO_2 by micro-XRD (Fig. 5).

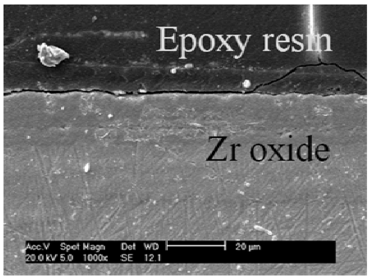

Figure 4. SEM image in the outer layer of a zircaloy-4 cladding of a spent fuel (burn up 57,900 MWd/tU).

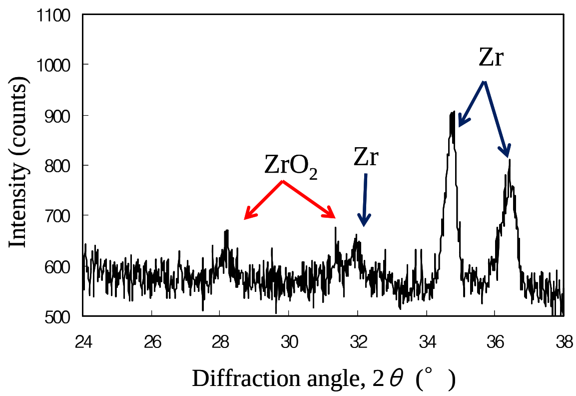

Figure 5. XRD spectrum in the outer layer of a zircaloy-4 cladding of a spent fuel (burn up 57,900 MWd/tU).

3. Conclusions

The microstructure changes of a UO_2 spent fuel of an average burn up of 57,900 MWd/tU were examined by a micro-XRD and a SEM. A lattice contraction, grains of 1 ㎛ and pores of 2 ㎛ in diameter were observed in the rim region of a UO_2 pellet. A zirconium dioxide layer of 40 ㎛ in thickness was identified in the outer region of a zircaloy-4 cladding. A pellet / cladding chemical interaction (PCCI) was also observed. A quality and quantity analysis of some elements in the interaction layer is scheduled.

Acknowledgements

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