# Changes in the Radial Lattice Parameter of a Spent Fuel by a Radiation Shielded Micro-X-ray Diffraction System

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## 1. Introduction

Increasing the burn-up and the residence time of a fuel in a nuclear reactor is being considered because of the major advantages in the fuel cycle cost and spent fuel management. The increase in the burn-up leads to structural changes in the area of a pellet periphery (rim) within a few hundreds of micrometers in thickness. To investigate the structural changes in the rim zone, a radiation shielded micro-XRD system was built in our laboratory [1, 2]. This system satisfied the target value of a spatial resolution of less than 50 μm. However, the XRD spectrum of a spent fuel specimen was not observed due to the high background caused by a gamma radiation.

In this study, the NaI detector (scintillation counter) and the sample holder of our system were shielded. For an analysis, a spent nuclear fuel originating from the Yeonggwang-2 PWR reactor with an average burn-up of 55,000 MWd/MtU was chosen as a test specimen. The lattice contraction was observed in the rim zone which is caused by a recrystallization.

## 2. Experimental and Results

### *2.1 Sample preparation*

The spent fuel (Burn up 55000 MWd/MtU, Yeonggwang-2 PWR reactor) was cut into 3×3×0.5 mm size, molded with epoxy resin and polished with abrasive paper in a hot cell (Fig. 1). For comparison, a sintered $UO_2$ pellet was prepared as an unirradiated sample specimen.

### *2.2 Radiation shielded micro-XRD system*

The commercial X-ray diffraction system (D8 ADVANCED, BRUKER AXS) with a Cu$K_\alpha$ line filtered through a Ni foil was installed in a radiation shielded glove box to obtain XRD patterns for the $UO_2$ spent fuel. And, the XRD system was modified by replacing a normal slit diaphragm and a fixed sample stage with a microbeam concentrator and a micro-sample-positioner fabricated in our laboratory. Its detector (scintillation counter) was shielded to prevent high background by radiation from a spent fuel.

The measurement was carried out with a scanning step of 0.02° for 1s per each count and an exit slit of 0.4 mm and a detector slit of 1 mm in width. The X-ray beam current was 40 mA at a 40 kV beam generation power.

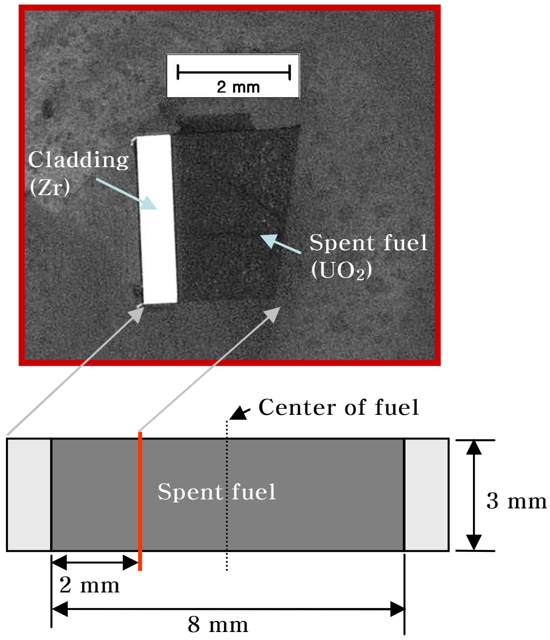


Figure 1. Spent fuel discharged from Yeonggwang-2 PWR reactor. (Burn up 55000 MWd/MtU)

### *2.3 XRD spectrum of the spent fuel*

The NaI detector (scintillation counter) and the sample holder of our system were shielded by a 5-10mm tungsten cover. Fig. 2 shows the XRD spectrum of a spent fuel specimen before and after a detector shielding. As can be seen in this figure, the XRD patterns of the spent fuel were not observed due to a very high background intensity ($10^5$ counts/s) caused by radiation from a spent fuel specimen before shielding the sample holder and the detector of our system. After a shielding, the background intensity was reduced to the range of 200 – 300 counts/s, and a XRD pattern of $UO_2$ was observed.

The XRD peaks were shifted to a low angle (2θ) and the lattice parameter (a, cubic phase) of the spent fuel from the measured spectrum was 5.476 Å. This value is much larger than that of non irradiated $UO_2$ (a = 5.467 Å), which reflects the radiation damage. The changes in the radial lattice parameter were measured and a lattice contraction in the rim zone was observed.

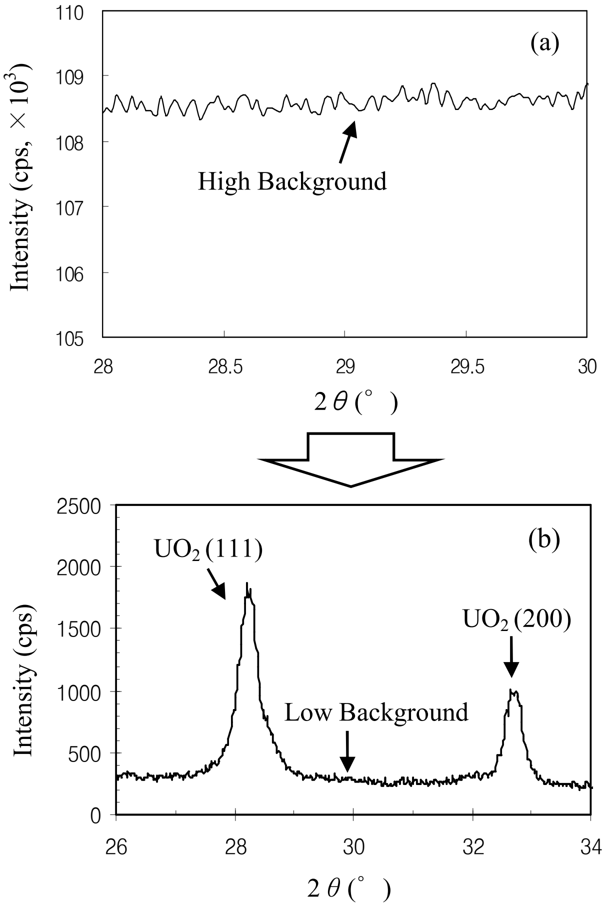


Figure 2. Comparison of background intensity for a spent fuel before (a) and after (b) detector shielding.

## 3. Conclusions

By shielding the sample holder and the NaI detector, the high background caused by radiation from a highly radioactive spent fuel specimen was reduced successfully. The XRD spectrum of a spent fuel was measured by a radiation shielded XRD system and the lattice parameter (a) of a spent fuel specimen was calculated. This value (5.476 Å) is much larger than that of non irradiated $UO_2$ (a = 5.467 Å), which reflects the radiation damage. A lattice contraction in the rim zone by a recrystallization was also observed.

## Acknowledgements

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## REFERENCES

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