The study on the PCI region in spent PWR fuel Cladding

Yanghong Jung, Heemoon Kim, Byoung-ok Yoo, Yongsun Choo, Kwonpyo Hong
Korea Atomic Energy Research Institute 150 Ducjin-dong, Yuseong-gu, Daejeon 305-353, Korea
nyhjung@kaeri.re.kr

1. Introduction

The spent fuel rod with high burn-up in commercial nuclear power plant has been studied in PCI region. When the cladding of fresh fuel rod is loaded in reactor, the properties are degraded by oxidation, hydride and micro-structural chemical changes after mechanical contact. After high burn-up, the cladding becomes the hull of pellets. The hull has been studied to obtain data of chemical structure. In the oxidation layer of it, some of fission products have been found.

2. Experimental

The spent fuel rod with 53,000 MWd/tU made by UO_2 was cut and mounted in Hot-cell for EPMA sample. For the quantitative analysis, 50 radial beam spots on the hull were set up and activated.

3. Results and Discussion

Oxygen distribution in hull was checked as shown in figure 1,2 and was found high density in 13 μm from pellet. It was assumed to be oxidation region.

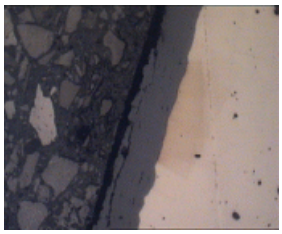

Figure 1 Camera image of PCI region

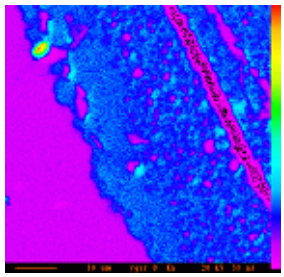

Figure 2 Image mapping of oxygen in the hull

Fe, Cr, Ni and Sn in cladding with low solubility are formed as metallic precipitates in high burn-up, which degrade cladding properties[1]. Figure 2,3 and 4 show small amount of precipitates of Sn and Fe in local region in the hull. But Nitrogen which make corrosion has homogeneous distribution with small content as shown in figure 5.

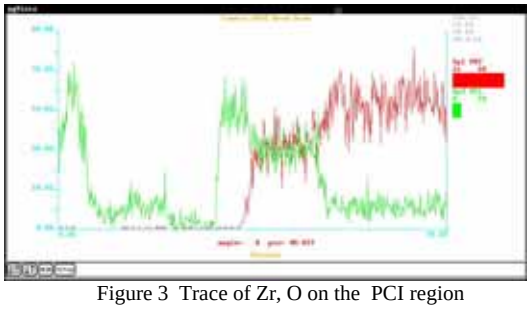

Figure 3 Trace of Zr, O on the PCI region

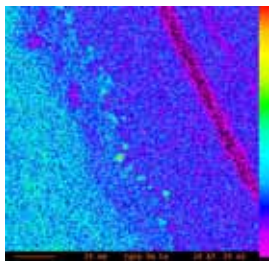

Figure 4 Image map of Sn

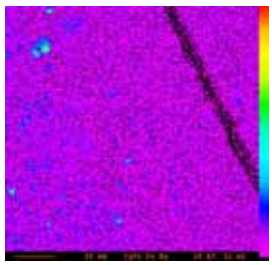

Figure 5 Image map of Fe

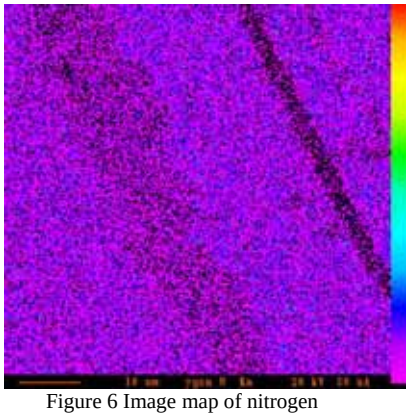

Figure 6 Image map of nitrogen

In this EPMA test, 50 beam points from outside to inside of PCI region show the distribution of Zr,O,U and Sn as figure 6.

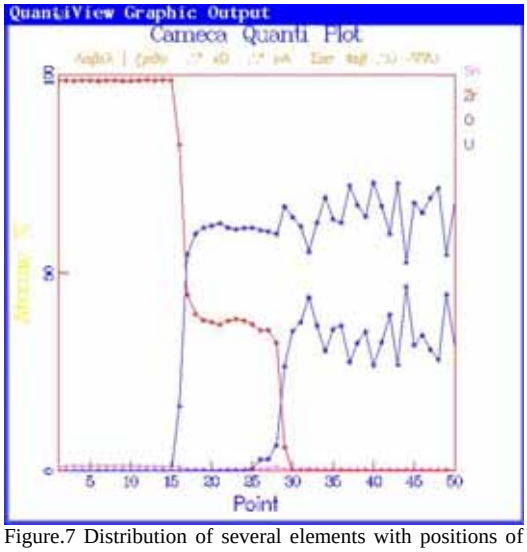

Figure.7 Distribution of several elements with positions of beam points

The oxidation region would be between 17 and 30 of point number and the thickness was 13 μm as same as figure.1. point number of 30 to 50 in UO_2 region, the contents were 34 at.% for uranium and 66.7 at.% for oxygen, respectively. It showed exact stoichiometric UO_2.

Figure 7 shows distributions of fission products in PCI region. 25 beam points were set up on that region. Point number 1 was placed on cladding side. High concentration of fission products were observed in range of 5 μm but Cs and Sr were observed over 10 μm. It is almost same results of Restani[2]. He used SIMS and found that Sr and Cs were observed 12μm and 10μm far from UO_2 pellet by fission recoil.

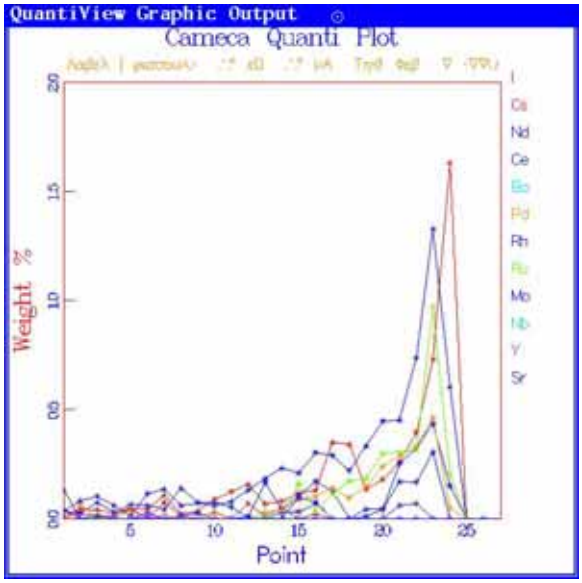

Figure 8 Distributions of fission products in PCI region

3. Conclusions

EPMA test for UO_2 spent fuel rod with 53,000 MWd/t-U was performed to observe chemical behaviors in PCI region. The thickness of oxidation region was 13 μm and metallic precipitates of Fe and Sn were found but the amounts were too very low to be considered. Distribution of Nitrogen, corrosion factor, was homogeneous without local high density. In this oxidation region on hull, some of fission products were found in 5 μm from pellet but Sr and Cs found about 10 μm by fission recoil.

References

[1] I. L. Jenkins and R. F. Taylor, “Treatment of stainless steel and zircaloy cladding hulls”, Pacific Northwest laboratory, Richland, Washington, PNL-2985(1979).

[2] R. Restani et. al., “Characterization of PWR cladding hulls from commercial reprocessing ” NAGRA Technical report 92-13(1992).