Analysis of the CRUD in spent PWR fuel Cladding

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1. Introduction

A spent fuel rod with a high burn-up from a commercial nuclear power plant has been studied in the cladding region. When the cladding of a fresh fuel rod is loaded in to a reactor, the properties are degraded by an oxidation, hydride and micro-structural chemical changes after a mechanical contact. After high burn-up, some of the cladding outside materials changed the hull and CRUD (Chalk River Unidentified Deposits) of pellets. The CRUD has been studied to obtain the data by chemical structure and x-ray mapping.

2. Experimental

Two kinds of EPMA specimen were prepared.
-. The spent fuel rod with 53,000 MWd/tU made by UO_2 cladding tube was cut and mounted in a Hot-cell.
-. The scratched cladding tube outside of the spent fuel rod with 53,000 MWd/tU and its attached particles on a carbon tape.

3. Results and Discussion

The spinel is the most important chemical form in a CRUD and oxides. The spinel chemical forms consist of AB_2O_4. A representative CRUD has an oxide compound $NiFe_2O_4$, trevorite and $ZnFe_2O_4$, franklinite[1]. $NiFe_2O_4$. $NiFe_2O_4$, trevorite is an obviously the most stable compound with a small solubility. Figure 1 shows the spent fuel rod with 53,000 MWd/tU made by UO_2 cladding which was cut and mounted in Hot-cell. It shows the Fe, O distributions well. Figure 2 is the result of the 15 point quantitative analysis on the 5 ㎛ CRUD thickness. Table 1 represents the concentration of the 7th to 15 points of figure 2. Puts out this crud Layer spinel as CRUD compositions are $NiFe_2O_4 + Fe_2O_3$, which is a stable compound as shown Table 1.

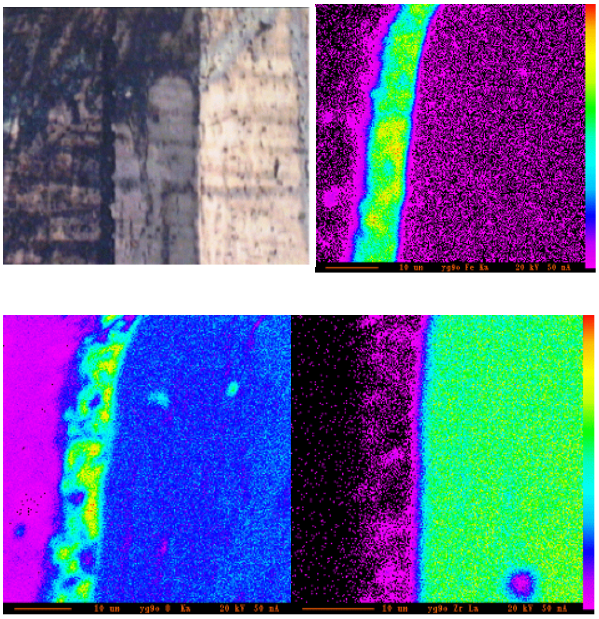

Figure 1 Image Map of Fe, O, Zr and Camera Image of the mounted specimen

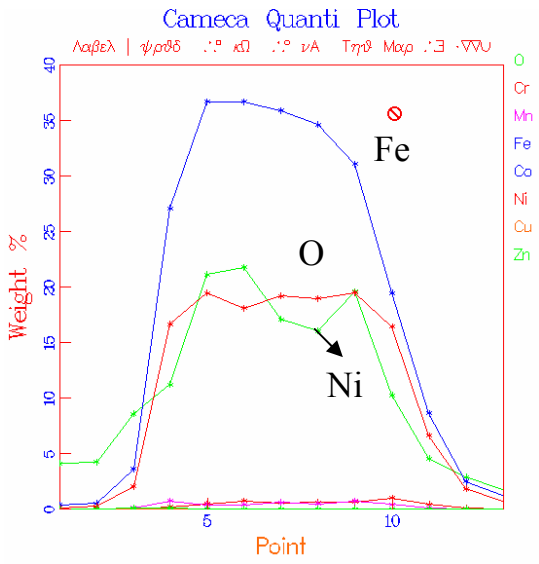

Figure 2 Quantitative analysis on CRUD layer

Table 1 Crud composition on point #7 at the figure 2

	Weight %		Atomic %	
	average	dev	average	dev
O	17.68	4.25	**54.021**	3.708
Cr	0.693	0.189	0.718	0.406
Mn	0.547	0.141	0.507	0.154
Fe	32.454	6.676	**28.614**	2.258
Co	0.006	0.01	0.004	0.008
Ni	18.651	1.177	**16.127**	2.917
Zn	0.013	0.018	0.01	0.013
Total	70.044		100	

Figure 3 is the results from the scratched cladding tube outside the spent fuel rod with 53,000 MWd/tU and its attached particles on a carbon tape. As shown from the figure, Zn is the most important concentration on the scratched CRUD. In order to prevent radioactivity increases there are put it on cooling water in Zn[2]. It is confirmed that Zn makes the deposit in CRUD from the figure Table 2 which represents the concentration of the average from the 20 points on the figure 3. Compare to Table 1, it is well known the most stable spinel compounds is $NiFe_2O_4$ + Fe_2O_3 on the CRUD. But it was composed of only a Zn oxide compound which shown in Table 2.

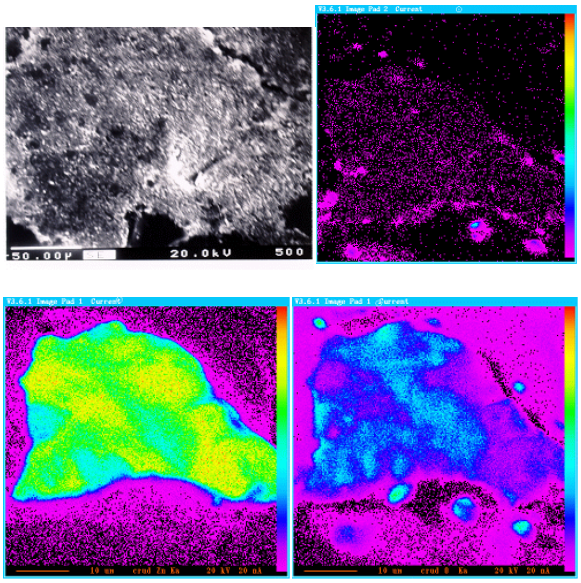

Figure 3 Image Mapping of Fe, Zn, O and Camera Image of the mounted specimen

Table 2 Crud composition at the figure 3

	Weight %		Atomic %	
	aver	dev	aver	dev
O	13.0	2.5	43.5	8.2
Cr	0.1	0.1	0.1	0.1
Fe	0.1	0.1	0.1	0.1
Ni	0.0	0.0	0.0	0.0
Zn	68.8	10.4	56.4	8.2
Total	82.0		100.0	

3. Conclusions

EPMA analysis for a UO_2 spent fuel rod with 53,000 MWd/t-U was performed to observe the chemical behaviors in the CRUD region. The thickness of the CRUD region was 5 μm. The most important chemical form in the CRUD and the most stable compound of CRUD compositions $NiFe_2O_4$ + Fe_2O_3 were confirmed. The spent fuel rod with 53,000 MWd/tU made by UO2 cladding was cut and mounted in a Hot-cell. It shows the Fe, O distributions well. Also the spinel layer as the CRUD compositions of $NiFe_2O_4$ + Fe_2O_3 is the most stable compound indolently. But the specimen with a scratched cladding tube outside and its attached particles on a carbon tape, was composed of only Zn oxide compound.

References

[1] I. L. Jenkins and R. F. Taylor, “Treatment of stainless steel and zircalloy cladding hulls”, Pacific Northwest laboratory, Richland, Washington, PNL-2985(1979).
[2] R. Restani et. al., “Characterization of PWR cladding ls commercial reprocessing ” NAGRA Technical report 92-13(1992).