The Effect of a Ceramic Coating on Zr Alloys in Terms of Corrosion

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1. Introduction

Nuclear plants safety is currently major issue around the world. Nuclear safety, problems could result in fuel cladding breaks. Therefore, it is very important to analyze fuel cladding mechanical properties.

Polycarbosilane(PCS) is a special ceramic whose protection films inhibit oxidation chemical resistance and strength at high temperatures. The PCS coating was carried out under various reaction conditions. The results showed that the supercritical process tries to moderate oxidation conditions such as temperature, time, and solution amount.

In this study, we used specimens of the types currently used in nuclear reactors(zry-4, zirlo), as well as their corresponding coating specimens (PCS, CrN and CrN + Tungsten), to conduct an oxidation analysis four type of conditions(water, LiOH, LiOH+Boron, and steam) over the course of a month

2. Experimental Setup

2.1. Specimen Preparation

The specimens used in this study were Zry-4 and Zirlo, which are used in commercial nuclear power plants. These foil specimens were cut to lengths and widths of approximately 10mm-20mm, respectively, and had a single hole drilled into the top of each side, these holes were about 3.2mm in diameter. They were cleaned, and etched before the test. After performing the previous process, coated specimens were produced, and an oxidation experiment conducted. The specimens coated were (PCS, CrN, and CrN + Tungsten)

Hydrido polycarbosilane (HPCS) was supplied by Starfire Systems. The coating solution was prepared in toluene as 20wt% HPCS. Chrome nitride(CrN) was supplied by Oerikon

2.2 Experimental Procedures

The low-temperature oxidation values of Zr-alloys in water, high LiOH, LiOH+Boron and Steam used in this study are shown in Figures. 2 and 3. Table 1. shows the chemical compositions of the solution elements.

Table 1. Chemical compositions of solution elements

360℃			400℃
Water	LiOH-Boron	High-LiOH	Steam
-	Li(ppm)	Boron(ppm)	Li(ppm)	-
	3	1000	70	

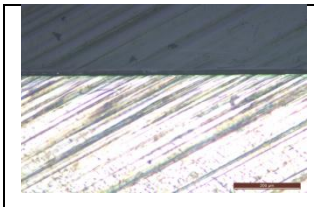
In the case of steam oxidation, amount of water is about in the mini-autoclave saturated moisture. The weight gain was continuously measured and recorded by a computer connected to the microbalance.

Figure 1. Mini autoclave system(SUS 304)

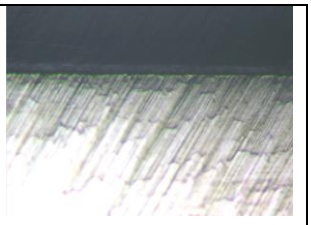
3. Results and Discussion

In this study, we measured for one monththe oxidation kinetics of Zry-4 and Zirlo coatings and original claddings. Figure.2 shows the microstructures of specimens oxidized at 360-400℃ at various conditions. The specimen oxidized in same with primary reactor system at 150atm. Weight gain by oxidation in four different sets of conditions was measured by an electronic microbalance (Fig.3).

Figure. 2 shows that the original specimens had a uniform oxide layer on the surface compared unlike CrN and CrN+tungsten, whereas coated specimens saw oxidation form through cracks in the coating surface. In the case of CrN+tungsten, oxidation still provided a protective layer. However PCS coated specimens formed thicker oxidation layers than did the original specimens at 360℃ water condition. As a result, the PCS material might support the acceleration of oxidation. Oxidation thickness depends on oxidation conditions, but is limited to approximately 2μm to 10 μm.



Zry-4_Original



Zirlo_ Original

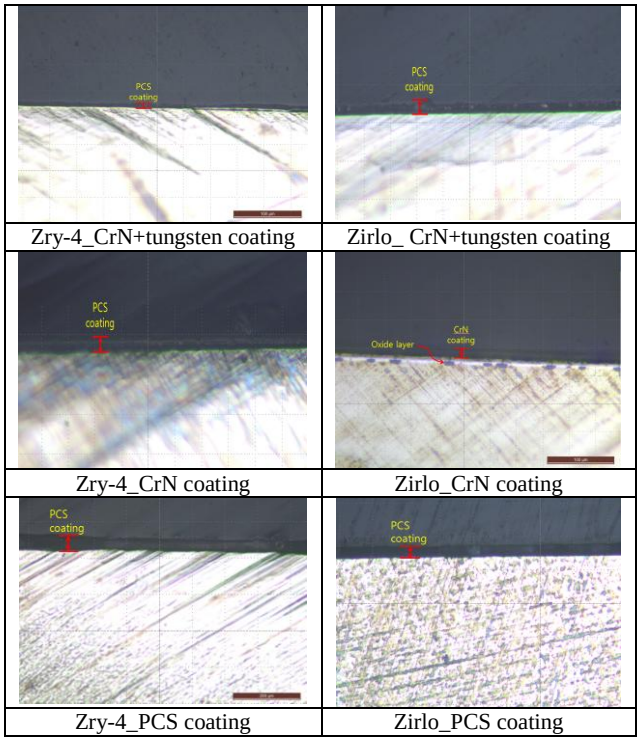
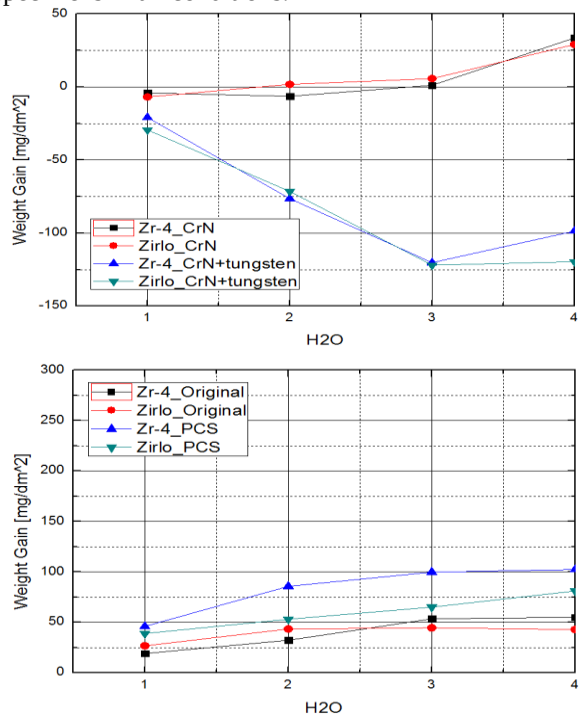


Figure 2. Optical microscopy images of Zry-4 and Zirlo - coated specimens oxidized in several condition at 360℃ for 1 month.

Figure.3 shows that the CrN oxidation rates were reduced or the same in water until the three-week mark, after which the CrN curve shows a suddenly increased oxidation rate at 4weeks. The reason for this might be enhanced oxidation after the coating layer evaporated due to crack formations across the surface.

For PCS specimens, oxidation rate resulted in sudden changes in weight gain (Fig.3). The PCS specimens' oxidation rates were higher than those of the original specimens in all conditions.



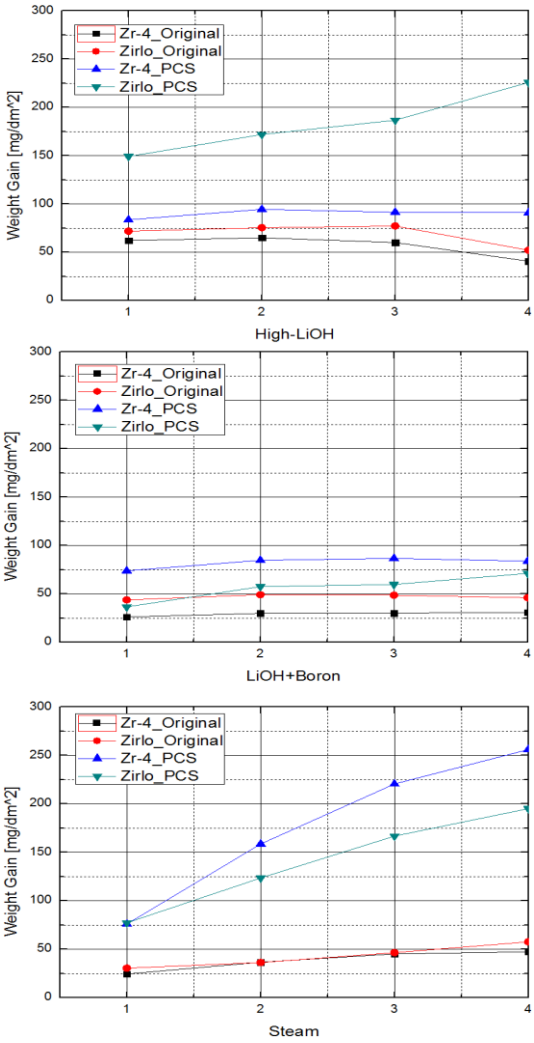


Figure 3. Oxidation behaviors of Zry-4 and Zirlo including water, LiOH, LiOH+Boron, and steam conditions, at 360°C and 400°C for 4 weeks

4. Conclusions

CrN coating layers were successfully formed with good protection on metal surface and without any defect. Figure. 2 shows that the original specimens were formed with a uniform oxide layer on the surface, unlike CrN and CrN+tungsten. However, CrN coated specimen formed protective coating layers, inhibiting oxidized layers (Fig. 2.3)

However, both Zry-4 and Zirlo PCS coated specimens experience suddenly high oxidation rates in all kinds of conditions. As a result, the specimens supported the acceleration of oxidation by PCS.

References

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[2] Ly, H. Q., Taylor, R. J. and Heatley, F. Conversion of Polycarbosilane(PCS) to SiC-based ceramic part I, Characterization of PCS and Curing Product. *J. Mater. Sic.*, 36 (2001) 4037-4043.