Interface between U-55wt%Zr Fuel and Pb

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1. Introduction

The blanket fuel assembly for HYPER(Hybrid Powder Extraction Reactor) contains a bundle of pins arrayed in a triangular pitch which has a hexagonal bundle structure. The reference blanket fuel pin consists of the fuel slug of the TRU-xZr(x=50-60wt%) alloy and it is immersed in lead for a thermal bonding with the cladding. The blanket fuel cladding material is ferritic-martensitic steel HT9.

During irradiation, fuel swells and comes into contact with the cladding, then metallurgical reaction at the fuel-cladding interface occurs and affects the integrity of the cladding. Beside, the interfacial reaction between the fuel and lead should be well understood in order to evacuate the fuel performance before contact between fuel and cladding.

Therefore, the U-55wt%Zr metallic fuel was fabricated by mixing, pressing, sintering and extrusion. This work has been done to investigate the microstructures of fuel and the interfacial reaction between the U-55wt%Zr fuel and Pb according to the annealing time at 650°C.

2. Methods and Results

2.1 Experimental Methods

Uranium powder was manufactured by a centrifugal atomizer, and the zirconium powder(Sejong materials Co. Ltd, Korea) was prepared by the hydride-dehydride process. The U-Zr metallic fuel was performed by mixing, pressing and sintering at the optimum compaction and sintering conditions. The sintered U-55wt%Zr was extruded by an indirect extrusion machine at 760℃ and a 13:1 extrusion ratio. In order to clarify the interfacial reaction between the fuel and lead, a series of experiments has been executed with fuel in a Pb melt at 650°C for 100, 200, 1000hrs. The composition of the diffusion layers and the diffusion depth were analyzed by using SEM/EDS.

2.2 Microstructure of U-55wt%Zr and Interfacial Reaction between U-55wt%Zr Fuel and HT9

The uranium and zirconium particles are shown in Fig. 1. Most of the uranium particles have a smooth surface and a generally near-perfect spherical shape with a few attached satellites. On the other hand, the zirconium particles fabricated by the hydride-dehydride process have an irregular morphology.

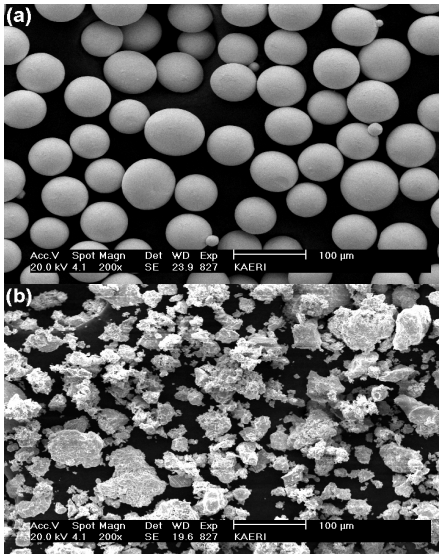
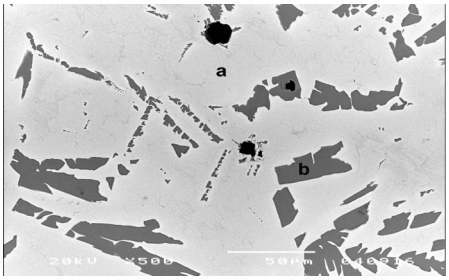


Figure 1. Photographs of the atomized U powder(a) and Zr powder(b).

Fig. 2 shows the Back-scattered electron (BSE) image of the sintered sample. In the case of the equilibrium condition, U-55wt%Zr is composed of δ-UZr_2 and α -Zr phases as depicted in the phase diagram[1]. As can be seen in this picture, the α -Zr phases are distributed in the δ phase which is observed. As a white matrix. Also, small amounts of pores are found through out the sample. It is certain that the compaction pressure is a very important factor in deciding the porosity of the metallic fuel, because the interlinkage of the pores are rare compared to the ceramic materials. uranium decreased and δ-UZr_2 increased as zirconium content in (U-10wt%Zr)-Zr fuels increased.



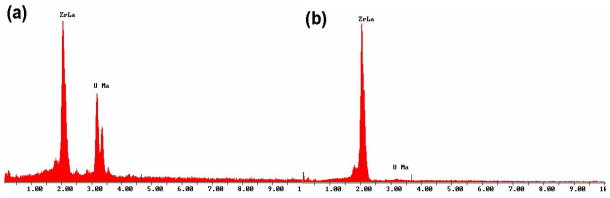


Figure 2. SEM micrograph and EDS analysis results for U-55wt%Zr sintered sample. (a) δ -UZr_2 matrix, (b) α -Zr phase.

BSE images of the hot extruded rod are shown in Figs. 3. In the sintered samples mentioned above, the α -Zr phases are also distributed in the white δ phase matrix and the porosity was drastically decreased because of the densification by the extrusion process.

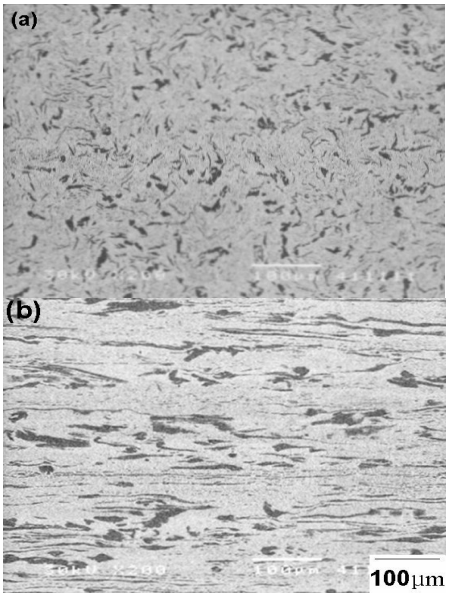


Figure 3. SEM micrographs of the extruded rod. (a) transverse direction, (b) longitudinal direction.

Figure 4 shows the EDS line profile result on the interface between the U-55Zr and Pb according to the annealing time at 650°C. The microstructures of each sample consisted of two distinctive regions; the reaction zone in the vicinity of the surface and the initial zone in the inner area. It should be noted that the thickness of the reaction zone is 26μm, 36μm and 46μm at 100hr, 200hr and 1000hr respectively as the annealing time increased. The reaction zone also consisted of two regions; the α-Zr layer and Zr depleted area. The α-Zr layer may be formed by a diffusivity difference between the U and Zr atom, that is, the Zr atom diffuses into the Pb melt during an annealing while the U is relatively intact due to a lower diffusivity. The TRU in the metallic fuel is reported to react with stainless, as a cladding material then forms eutectic at a low temperature. So, it is anticipated that the α-Zr layer should effectively act as a reaction barrier with the cladding material.

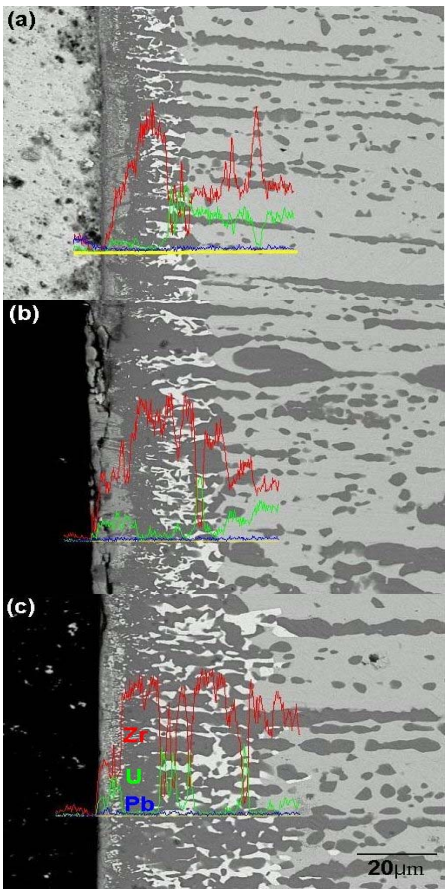


Figure 4. Line profiles of the interface of the U-55Zr fuel with a Pb bonding according to the annealing time at 650°C. (a) 100hr, (b) 200hr, (c) 1000hr.

3. Conclusion

The α -Zr phases are distributed in the white δ-UZr_2 phase matrix also and the porosity has been drastically decreased because of the densification by the extrusion process. The interface between the U-55Zr fuel and Pb according to the annealing time at 650°C consisted of a reaction zone and an initial zone in the inner area. The reaction zone consisted of a α-Zr layer and a Zr depleted area and the thickness of that is 26μm, 36μm and 46μm at 100hr, 200hr and 1000hr respectively.

REFERENCES

[1] Phase Transformation in Materials, 2nd Ed. D.A. Porter and K.E. Easterling., 1992