Zr-rich Precipitates in the Sintered Zr-U Alloys

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1. Introduction

Zr-U binary alloys have been considered as one of candidate nuclear fuels for fast reactors, due to especially their excellent thermal conductivity [1-3]. They are usually fabricated by the high-vacuum and high-temperature sintering process. When the Zr-U pellets are exposed to the high temperature during sintering, the constituent redistribution can occur in the pellets in the presence of a temperature gradient. As a result, the formation of Zr-rich phase may be possible. This phenomenon can result in changes in physical and mechanical properties of the Zr-U alloys. In this study, the formation of Zr-rich particles during sintering of Zr-U pellets was examined, and the effects of cooling rate after sintering at high temperature on the distribution of Zr-rich particles were discussed.

2. Methods and Results

2.1 Powders

The Zr-powders were prepared by a hydriding-dehydriding process, and their average size was analyzed as about 88 μm (Figure 1). The chemical composition was analyzed to be about (in ppm) 4000 O, 700 N and 50 H.

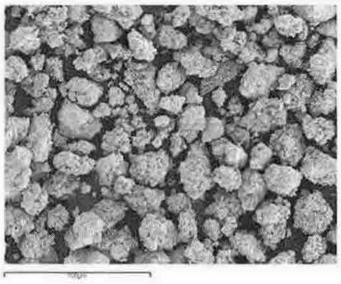

Figure 1. SEM image of Zr-powders prepared by a hydriding-dehydriding process.

The U-powders were prepared by an atomizing process, and their shape showed spherical-type particles (Figure 2). The average size of spherical-type particles was observed as about 48 μm, and the chemical compositions were analyzed to be about (in ppm) 2500 O and 100 H.

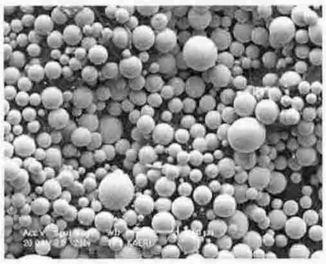

Figure 2. SEM image of U-powders prepared by an atomizing process.

2.2 Sintering and examination

The Zr-U powders were mixed and then pressed to form cylindrical-type pellets. The sintering of Zr-U pellets was performed at 1500°C under a high vacuum for 2 hours. After sintering, two-kind cooling rates (2 and 10°C/min) were adopted. The sintered Zr-U alloys were subject to cut to their longitudinal directions, and the longitudinal sections were then polished. The microstructure was examined using a scanning electron microscope (SEM)/an energy dispersive spectroscope (EDS). The crystal structures of precipitates were analyzed by a transmission electron microscope (TEM).

2.3 Zr-rich precipitates

Figure 3 shows the microstructure of Zr-U alloy cooled in a cooling rate of 2°C/min after sintering. The microstructure of the alloy consisted of hcp δ-UZr_2 (white) and hcp α-Zr (dark) phases, indicating that the bcc β phase could not retained upon cooling. The crystal structures were confirmed by the X-ray diffraction patterns. The α phase forms first at the original β grain boundaries, followed by a decomposition of the β phase into δ and α phases during cooling [4]. The globular precipitates revealed to be hcp Zr-rich particles with O and U. It was reported that the Zr-rich phase in U-Pu-Zr alloys were considered to form due to the interstitial impurities, because the composition of this phase was analyzed to be about 80 wt% Zr with O, N and C [5]. It is thus considered that the formation of Zr-rich particles observed in the sintered Zr-U alloy is attributed to the impurities, especially O and N, present in the Zr- and U-powders as raw materials.

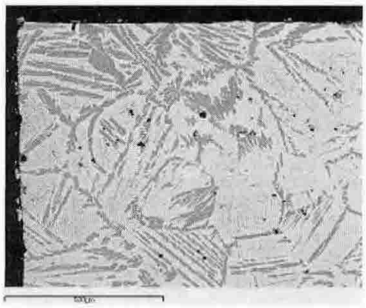

Figure 3. Microstructure of Zr-U alloy cooled in a cooling rate of 2°C/min after sintering.

Figure 4 shows the microstructure of Zr-U alloy cooled in a cooling rate of 10°C/min after sintering. The microstructure consisted of δ (white) and α (dark) phases. It was apparent in the micrograph that the globular Zr-rich particles were much reduced. This means that the fast cooling rate acts to restrain the formation of globular Zr-rich particles during cooling, resulting in the distribution of lath-type α phase. It is thus concluded that the fast cooling rate promote to the changes in the microstructure of especially α-Zr phase from globular-type to lath-type distributions, resulting in the increase in the hardness.

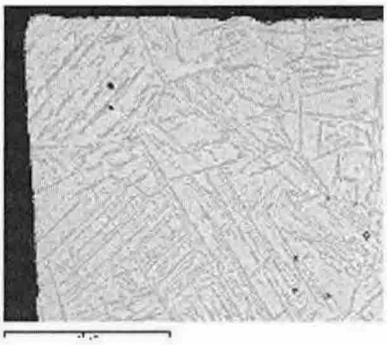

Figure 4. Microstructure of Zr-U alloy cooled in a cooling rate of 10°C/min after sintering.

3. Conclusion

Zr-rich particles in the Zr-U alloys are formed possibly due to the impurities such as O, N and C. They also contain about 5 wt% U. Their size and shape are mainly decided by the cooling rate after sintering. It is thus concluded that the reduction in the concentration of impurities in the Zr- and U-powders would be necessary to reduce the content of undesirable Zr-rich particle in the Zr-U alloys. In addition, it is believed that the size, shape and distribution of Zr-rich particles in the alloys would be controlled by the cooling rate after sintering.

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