Thermal Shock Test of UO_2-12%Gd_2O_3/UO_2-2%Er_2O_3 Duplex Burnable Absorber Pellets

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1. Introduction

Duplex burnable absorber pellet has two distinct potions with different compositions. One is the annular outer portion composed of a mixed powder UO_2-2%Er_2O_3 and the other is the cylindrical inner portion composed of a mixed powder UO_2-12%Gd_2O_3. A duplex structure consisting of different materials is advantageous over a structure using either a sintered (U,Gd)O_2 or (U,Er)O_2 material as a sintered burnable absorber pellet, because the duplex structure exhibits improved nuclear performance in a nuclear reactor.[1]

However, the duplex structure may bring the two major concerns based on the fact that the inner portion and the outer portion are composed of different materials. First, during the sintering process for increasing the density of the compact, different materials cause a large difference in the densification rate between the cylindrical inner portion and the annular outer portion, and thereby generate an undesirable internal stress at the interface between both portions. Consequently, serious interstices or cracks may occur at the interface of the final sintered duplex nuclear fuel pellet. [2]

Another concern is related with the difference in thermal expansion coefficients between two portions. It is reported that the thermal expansion of lanthanide-added uranium dioxide varies with the concentration of lanthanide. [1] Thus, the large concentration difference between two portions may induce the thermomechanical stress at the interface and cause the disintegration or the fragmentation of pellet.

In this study, the crack-free UO_2-12%Gd_2O_3/UO_2-2%Er_2O_3 duplex pellets were fabricated and then thermal shock tests were conducted. The microstructure and appearance of pellets were investigated after the thermal shock test.

2. Experimental

A mixture of 2% by weight of Er_2O_3 powder, 0.1% TiO_2 and UO_2 powder was charged into a tubular mixer and was then mixed for 1 hour to prepare a mixed powder UO_2-2wt% Er_2O_3-0.1wt% TiO_2 for the annular outer portion of a duplex nuclear fuel. A mixture of titanium oxide (TiO_2) and Gd_2O_3 powder was subjected to ball milling using zirconia balls for 12 hours to prepare a TiO_2-doped Gd_2O_3 powder. Then, the powder thus prepared was mixed with UO_2 powder in a tubular mixer for 1 hour, and was then pulverized in a pestle and mortar for 10 minutes to prepare a mixed powder UO_2-12wt% Gd_2O_3-0.3wt% TiO_2 for the cylindrical inner portion.

The mixed powder UO_2-2wt% Er_2O_3-0.1wt% TiO_2 was charged into the annular outer portion and the UO_2-12wt% Gd_2O_3-0.3wt% TiO_2 was charged into the cylindrical inner portion, which was then subjected to pressing to produce a duplex compact following the same procedure in the previous study. [2]

The compact was heated to 1700°C at a rate of 5K/min., and was then maintained under a reducing gas atmosphere at 1700°C for 4 hours in a mixed gas H_2-3% CO_2 to fabricate a sintered nuclear fuel pellet.

The sintered nuclear fuel pellet thus fabricated was polished along a face parallel to an axial direction. The occurrence of cracks and defects at the interface was observed.

Thermal shock tests were conducted in tungsten mesh heating element furnace under flowing Ar gas. The samples were rapidly heated to 1200°C or cooled from 1200°C to room temperature at a rate of 50 K/min. Tested samples were polished and observed using a optical microscope.

3. Results

Figure 1 shows the cross-section of the sintered UO_2-12%Gd_2O_3/UO_2-2%Er_2O_3 duplex pellet. No cracks are found in the interface of the annular and the cylindrical portions. The large difference in the densification rate could be overcome by adding the different content of TiO_2 to the each portion. TiO_2 considerably enhances the densification of UO_2-12%Gd_2O_3 powder compact and thus reduces the internal stress at the interface.

The thermal shock tests were conducted using the crack-free duplex pellets. The results of thermal shock test are presented in Fig. 2. Figure 2(a) shows the appearance of tested pellet and the microstructures after rapid cooling from 1200°C to room temperature at a rate

Fig. 1. Interface of the duplex pellet.

of 50 K/min. No fragmentations were found but ring cracks developed in the vicinity of interface in the annular portion.

Figure 2(b) shows the appearance and microstructure of the pellet which was rapidly heated from room temperature to 1200°C at a rate of 50 K/min. The appearance was sound and no fragmentation occurred. However, some cracks were found in the polished microstructure. In rapid heating, most of cracks were concentrated in the cylindrical inner portion and propagated in a direction of perpendicular to the interface between two portions. These crack patterns were attributed to the difference in thermal expansion coefficients between two portions. Reported thermal expansion coefficients of the cylindrical inner portion and annular outer portion are ~14×10^{-6} and ~12×10^{-6} at 1200°C, respectively. [1]

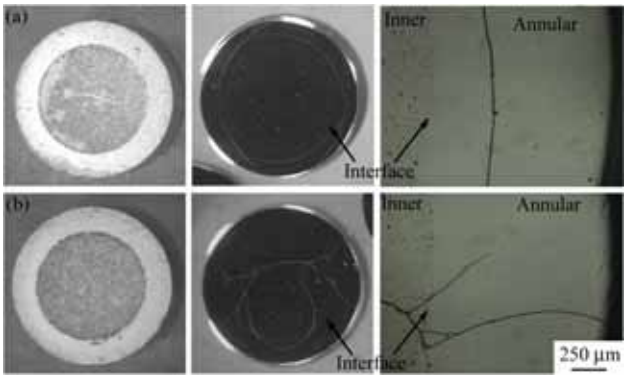

Fig. 2. Appearance and microstructure of the duplex pellet after rapid cooling (a) and rapid heating (b).

4. Conclusion

The crack-free UO_2-12%Gd_2O_3/UO_2-2%Er_2O_3 duplex pellets were fabricated and then thermal shock tests were conducted. The appearances of pellets were sound and no fragmentation occurred in rapidly cooling and heating cases. Some cracks developed differently in the interior of pellet, depending on cooling and heating. The difference in crack propagation can be interpreted in terms of the difference in thermal expansion coefficients between two portions.

Acknowledgement

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REFERENCES

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