Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

THE EVALUATION OF THERMAL CONDUCTIVITY IN UAl2 ROD MANUFACTURED BY POWDER METALLURGY METHOD

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1. Introduction

The structures of UAl_2 and UAl_3 are isotropic just like a $MgCu_2$ face centered cubic and $AuCu_3$ Cubic structures with relatively high melting temperatures of 1590 °C and 1350 °C, respectively. However, UAl_4 is anisotropic with an orthorhombic structure with a low decomposition temperature of 731 °C. Uranium densities of UAl_2 and UAl_3, which are 6.64 g-U/cc and 5.08 g-U/cc, are considered to be applicable for reactor fuels. In addition, UAl_2 and UAl_3 does not have a solid solution range, while UAl_4 has a small solid solution range[1]. From the above aspects, monolithic UAl_2 is considered to be the most valuable, so an effort has been made to develop the relevant fabrication technology. Monolithic UAl_2 has been reported as being fabricated by an arc-melting method, which is difficult when producing a rod type fuel. KAERI has developed a rotating disk atomization process to fabricate a uranium alloy powder. So the utilization of an atomized uranium powder has been pursued by using powder metallurgy technology. Relatively fine uranium powder was used. Blending, compaction, and extrusion were implemented in the same manner as the HANARO fuel fabrication process[2]. In this study a SEM observation of the cross section of the UAl_2 specimen was conducted to observe the fabrication voids and cracks as well as the remaining uranium phases in the monolithic UAl_2 rod. The densities of the formed UAl2 rods were measured by the immersion method. The presence of the UAl_2 phase was confirmed for the annealed specimen through an X-ray diffraction analysis. Thermal conductivities were measured and discussed from the viewpoint of nuclear fuel candidates. This study also focused on an examination of the soundness of the formed UAl_2 specimen and the feasibility of a monolithic UAl_2 fuel for nuclear reactors.

2. Experimental

The uranium powder, produced by an atomization process, was blended with Al 1060 powder by a V type mixer and compacted by a hydraulic pressure. The compact was extruded in to a rod at 400℃. And then the rod was machined into specimens of 12.5 mm in diameter and 10 mm in length. Annealing treatment was implemented for the zircaloy mould at 1200 ℃ for 10 hours under an inert atmosphere of argon gas and a tight zirconium mould as shown in Fig. 1 was filled with a finer uranium powder of about 50 μm in particle diameter. Zircaloy mould was vacuum-sealed by an electron beam welding. Specimen was cut and polished on the surface in order to examine the microstructure of the formed UAl_2, structure more accurately. SEM observation was used to examine the fabrication voids and cracks. Phase analysis was conducted by using the X-ray diffraction method. Density for the specimen was measured by an immersion method. The thermal conductivity was calculated from the thermal diffusivity α , specific heat Cp, and density p, using the following specific heat Cp, and density p, using the following relation: specific heat Cp, and density p by using the following relation:

$$K = \alpha \, Cp \, p$$

Disk sample with a 10mm diameter and 2mm thickness were taken from the pellets for the thermal diffusivity measurements.

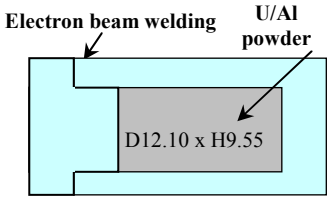

Fig.1. Zircaloy mould

Disk sample with a 10mm diameter and 2mm thickness were taken from the pellets for the thermal diffusivity measurements. The thermal diffusivity was measured by the laser flash method from room temperature to 700℃ in an argon atmosphere using a laser flash apparatus.

3. Results and Discussion

The specimens in the zircaloy moulds did not break up during an annealing for the specimens annealed at 1200℃ for 10hrs. The UAl_2 specimens were examined by using their X-ray diffraction analysis results as shown in Fig. 2. Only UAl_2 peaks appeared in the X-ray diffraction results for the fine uranium powders. In the irradiation test conducted by ANL the remaining uranium phases behaved as nucleation sites for the

fission gas bubbles thus, the process parameters should be optimized to eliminate the uranium phases as much as possible. Accordingly a fine uranium powder is preferable.

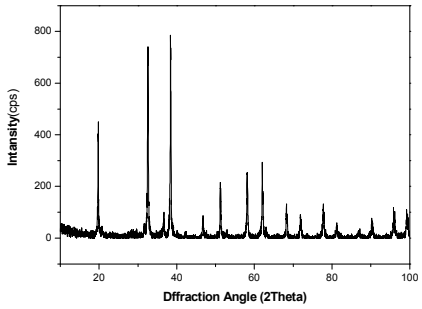

Fig.2.A typical X-ray diffraction result for the UAl_2 specimen formed by an annealing.

The measured relative densities of the annealed specimens are shown in Table.1.

	Zircaloy Mould
Density	7.68 g/cc
U density	6.26 g-U/cc
Relative density	94.4%

Table.1. Density of the annealed UAl2 specimens for zircaloy mould.

The micrograph of the UAl_2 specimen formed by an annealing with a fine uranium powder using a zircaloy mould is shown in Fig. 6. According to the figure some different microstructures were observed. In the center region, the UAl_2 grains were separated and voids occurred at the interface. On the other hand, in the periphery region the UAl_2 grains were tightly in contact with each other even though some large voids existed at the interface. It is construed that a tensile stress in the center region and a compressive stress in the periphery region prevailed. The reason for this would be that the zircaloy mould would impact more so on the periphery region thus blocking an expansion of the specimen. When this material is used for a nuclear fuel, the fabrication voids would reveal a compensation role during an irradiation. Accordingly the excess space in the zircaloy mould, which affects the fabrication voids, needs to be controlled from the viewpoint of a swelling compensation.

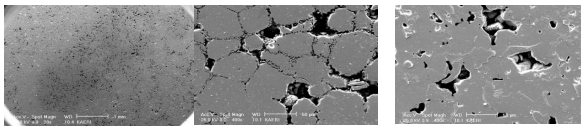

Fig.6. Micrographs of the UAl_2 specimen annealed in the zircaloy mould; (A) whole cross-section, (B) center region, (C) periphery region

Thermal diffusivity, specific heat and thermal conductivities measured for the UAl_2 specimen formed by an annealing with a Zircaloy mould are represented in Fig.3. UAl_2's thermal conductivity was varied from 8 to 15 W/m/K. These thermal conductivities are not bad for a nuclear fuel. The UAl_2 is thus considered to be a valuable candidate for a future nuclear fuel by taking into consideration a fuel meat's geometry.

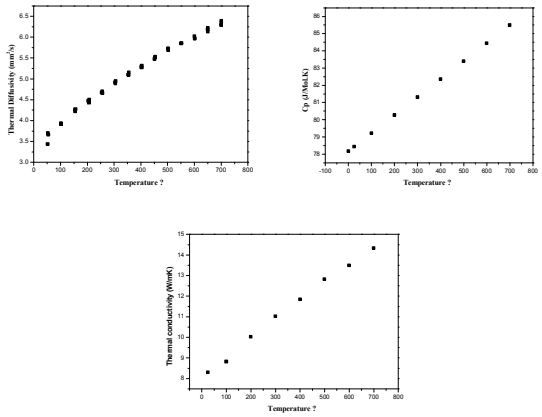

Fig.3. Thermal conductivities, specific heat measured and Thermal diffusivity measured for the UAl_2 specimen formed by an annealing at 1200 °C for 10 hours with zircaloy mould.

3. Conclusion

Monolithic UAl_2 rod could be fabricated by the powder metallurgy method, which consisted of blending U powder and Al powder, with a compacting, extruding, moulding, and an annealing at 1200 °C for 10 hours. The maximum density of the UAl_2 specimen was 7.68 g/cc in density with 94.4% of a relative density. A fine uranium powder of an average of 50 μm in diameter could achieve an almost pure UAl_2 phase without a uranium phase. These fabrication voids could be used from the viewpoint of a compensational effect for fission gas bubbles by controlling the excess space of a zircaloy mould. The x-ray diffraction results confirmed that all the annealed specimens fabricated by using the fine uranium powder were properly incorporated in the UAl_2 phase. The annealing-formed UAl_2 revealed a little lower thermal conductivity range from 8 to 15 W/m/K. These thermal conductivities are not bad for a nuclear fuel. This kind of annealing-formed UAl_2 is thus considered to be a valuable candidate for a future nuclear fuel by taking into consideration a fuel meat's geometry.

5. Reference

[1] G.L. Hofman, J.L. Snelgrove, "Material Science and Technology," Vo. 10A, Nuclear Materials, Part I, New York 1994

[2] C.K.Kim, et al., "Activities for the HANARO Fuel Fabrication at KAERI," RRFM 2004, Munchen, Germany