The Microstructure of Multi-wire U-Mo Monolithic Fuel

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1. Introduction

In order to use low-enriched uranium (LEU) instead of highly enriched uranium (HEU) for high performance research reactors, the reduced enrichment for research and test reactors (RERTR) program is developing high uranium density fuel such as U-Mo/Al dispersion fuel. U-Mo alloys have an excellent irradiation performance when compared to other uranium alloys or compounds [1]. But the results from the post-irradiation examination of the U-Mo/Al dispersion fuels indicate that an interaction between the U-Mo alloy fuel and the Al matrix phases occurs readily during an irradiation and it is sensitively dependent on the temperature [2, 3].

In order to lessen these severe interactions, a concept of a multi-wire type fuel was proposed. The fuel configuration is that three to six U-Mo fuel wires (1.5 mm ~ 2 mm in diameter) are symmetrically arranged at the periphery side in the Al matrix as shown in Fig. 1.

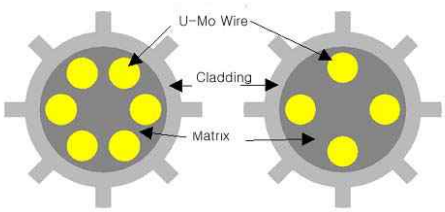

Fig. 1 The configuration of the multi-wire fuels with sixfold wires(left) and fourfold wires(right).

This multi-wire fuels showed very good fuel performance during the KOMO-3 irradiation test.[4,5] At the KOMO-3 test, the specimen of the multi-wire fuels were U-7Mo/Al and U-7Mo-1Si/Al. In this study we investigate the microstructure change of the U-7Mo and U-7Mo-1Ti with some variation of annealing conditions. In addition to this, we want to check the effect of adding Ti element to U-7Mo on the gamma phase stability.

2. Experimental Methods

In order to produce the U-7Mo and U-7Mo-1Ti monolithic wires, an injection casting technology using quartz tube was applied as shown in Fig.2. U, Mo, Ti metal pieces were melted in a crucible under a vacuum atmosphere ($4x10^{-2}$ torr). As soon as the quartz tubes are lowered and dipped into the melt, Ar gas was fed into the melting chamber until an atmospheric pressure was achieved. Then the melt was filled up along the quartz tube. In this way, U-Mo rods of 2 mm in diameter, were successfully produced by this method. For the gamma phase stability test, the specimen were homogenized by heat treatment of 1 h at 950 ^{o}C, thereafter quenched to get the gamma phase. These specimens were annealed at 500 ^{o}C 1 h, 3h. For an analysis of microstructure and gamma phase stability, a micro X-ray diffraction system and SEM/EDX were used.

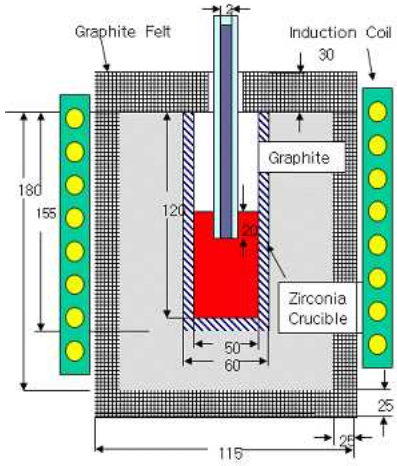

Fig. 2. Schematic diagram of an injection casting method.

3. Results

The chemical analysis results of the produced U-7Mo and U-7Mo-1Ti are shown in table 1.

Table 1. Chemical analysis results of speicmens

	Mo	Ti	U
U-7Mo	6.6±0.2	-	Bal
U-7Mo-1Ti	7.6±0.2	0.52±0.01	Bal

SEM image and EDX analysis results of gamma heat treated U-7Mo-1Ti are shown in Fig. 3 and Fig. 4.

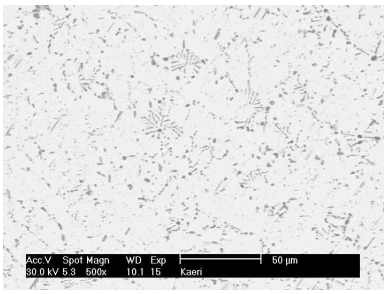

Fig. 3. SEM image of gamma heat treated U-7Mo-1Ti

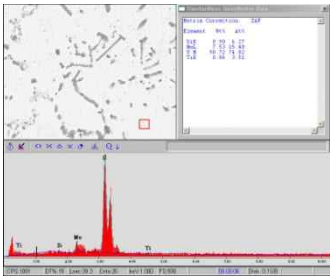

Fig. 4. Composition of U-7Mo-1Ti by EDX analysis

The gamma heat treated the U-7Mo and the U-7Mo-1 Ti specimen showed the gamma phase, but the 1 hour, annealed specimen started to dissolve the gamma phase into the alpha phase as shown in Fig. 5 and Fig. 6.

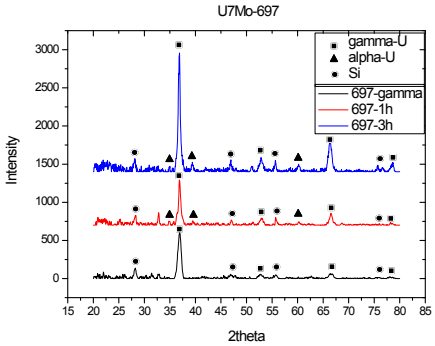

Fig. 5. XRD patterns of U-7Mo with annealing conditions.

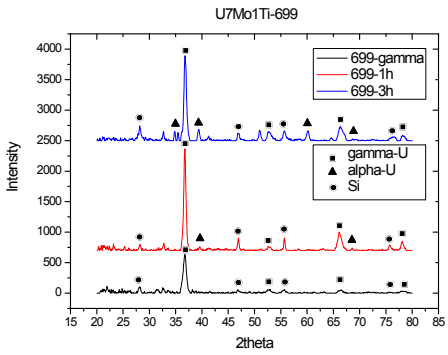

Fig. 6. XRD patterns of U-7Mo-1 Ti with annealing conditions.

The as-casted wires of U-7Mo and U-7Mo-1Ti have about 1% Si element by XRD pattern. It is considered to be introduced from a quartz mold with a main composition of SiO2.

From the XRD analysis results, there was not much difference in the gamma stability of adding Ti element to U-7Mo.

The SEM image of the U-7Mo-1Ti specimen with 3h annealing at 500 oC shows grain growth compared with Fig. 7. EDX analysis shows movement of the Mo and Si element to the grain boundary.

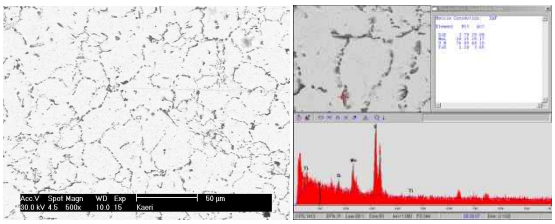

Fig. 7. SEM image and EDX analysis results of U-7Mo-1Ti with 3 h annealing.

4. Conclusion

This study wanted to check the adding efficacy of Ti to the U-Mo monolithic fuel on the gamma phase stability, but there was no much difference of XRD patterns. It was also found that there are Si elements on U-7Mo and U-7Mo-1Ti introduced from quartz mold during casting by XRD analysis. In accordance with the increased annealing time, the specimens showed grain growth.

Acknowledgements

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REFERENCES

[1] D.D. Jr. Keiser, S.L. Hayes, M.K. Meyer, C.R. Clark, JOM, Vol. 55 No. 9 (2003), pp55-58

[2] G.L. Hofman, , J.L. Snelgrove, S.L. Hayes, M.K. Meyer, in: Proceeding of the 24th International Meeting on Reduced Enrichment for Research and Test Reactors(RERTR), Bariloche, Argentina, 2002

[3] G.L. Hofman, Y.S. Kim, M.R. Finlay, J.L. Snelgrove, in: Proceeding of the 25th International Meeting on Reduced Enrichment for Research and Test Reactors(RERTR), Chicago, USA, 2003.

[4] Y.S. Lee, et al, Transactions of KNS Autumn Meeting, PyeongChang, Korea, 2008.

[5] Y.S. Lee, et al, Proceeding of RRFM, 2009