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Analysis of interaction layer inhibition of nitride or silicide coated U-Mo powder

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1. Introduction

U-Mo/Al dispersion fuel is being developed as a high-uranium-density fuel for high-performance research reactors owing to its excellent stability during irradiation [1]. The interaction layer formation between the U-Mo particle and Al matrix has been considered one of the most challenging issues in the development of U-Mo/Al dispersion fuel [2]. The use of larger-than-usual size U-Mo powder (200~50 ㎛) can be an acceptable option to mitigate the interaction problem [3]. One of the remedies to the interaction problem is the small amount of Si addition to the Al matrix. Recent irradiation tests have shown that the use of Al-(2~5wt%)Si matrices retard the growth of interaction layers effectively during irradiation. Because the interaction formation also degrades the thermal properties of dispersion fuel, it is necessary to minimize the interaction layer growth. Recently, KAERI has proposed silicide or nitride-coated U-Mo fuel for minimization of the interaction layer growth [4]. The silicide or nitride coatings are expected to act as diffusion barriers on the U-Mo particle and their out-of-pile diffusion tests showed improved diffusion barrier performances of the silicide and nitride layers.

To analyze the effects of the nitride or silicide coating layers, coated U-Mo particle fuels were annealed by varying the heat treatment time (1h and 5h) at 580℃ / 10^{-6} torr.

2. Experimental procedures

Centrifugally atomized U-7wt%Mo and U-7wt%Mo-1wt%Ti particles with 90~150㎛ in diameter were used for nitride or silicide coating. A vacuum rotator heat treatment furnace was developed by nitride coating on the surface of U-Mo particles. The operation conditions are listed in Table 1.

Table 1. The operation conditions of nitride coating.

Parameters		Conditions
Back ground pressure		1×10^{-6} torr
Working pressure		3×10^{-5} torr
N2-gas flow		80 sccm
Number of Revolution		30 rpm
Temperature		1000 ℃
Holding Time	U-7Mo	6 hours
	U-7Mo-1Ti	1~4 hours

Pure Si powder (99%, -325 mesh) was used for silicide coating on U-Mo particles by vacuum annealing. U-Mo particles and pure Si powder were mixed in a ball mill with a rotation speed of 30 rpm for 8 hours. The mixed powder was annealed at 1000℃ for 1 hour under a vacuum of about 7×10^{-5} torr.

U-Mo/Al dispersion rods were extruded after mixing Al powder and coated U-Mo particles. To form the interaction layers, annealing was performed with 580℃ for 1hour and 5hours in a vacuum furnace.

Cross-sectional microstructures of the specimens were observed using SEM and characterized by EDX.

3. Results and discussion

Nitride coating layers were formed on the surface of U-7wt%Mo particles to a thickness of about 1~2 ㎛, and the layers were formed on the surface of U-7wt%Mo-1wt%Ti particles with a thickness of 10~15 ㎛, as shown in Fig. 1(a) and (b).

Silicide coating layers were formed on the surface of U-7wt%Mo particles with a thickness of about 7~8 ㎛, as shown in Fig. 1(c). Fig. 1(d) shows the silicide coating layers formed on the surface of U-7wt%Mo-1Ti particles. The coating layer has a thickness of about 10~15 ㎛.

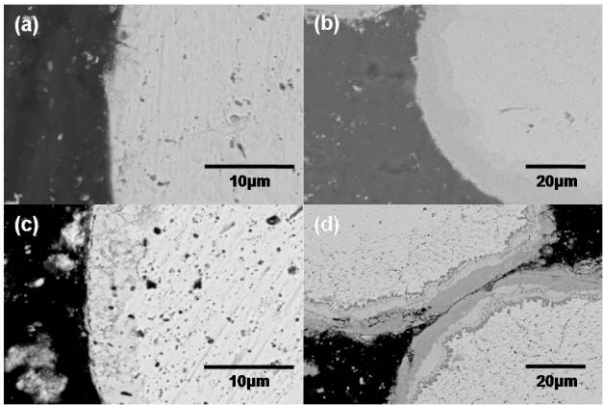

Fig. 1. SEM images of as extruded U-Mo dispersion fuels (a) nitride coated U-7wt%Mo particle (b) nitride coated U-7wt%Mo-1wt%Ti particle (c) silicide coated U-7wt%Mo particle (d) silicide coated U-7wt%Mo-1wt%Ti particles

Fig. 2 shows the cross-sectional SEM images of the coated dispersion sample annealed at 580℃ for 1 hour. After annealing, the dark gray-colored reaction regions

were formed on the surface of the particles. Some coating layers were destroyed during extrusion at 400℃, and the interaction layers formed on the uncoated surfaces of the particles.

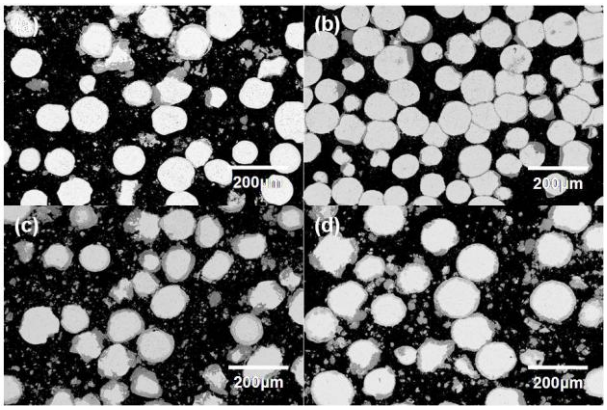

Fig. 2. SEM images of as annealed (580℃/1h) U-Mo dispersion fuels (a) nitride coated U-7wt%Mo particles (b) nitride coated U-7wt%Mo-1wt%Ti particles (c) silicide coated U-7wt%Mo particles (d) silicide coated U-7wt%Mo-1wt%Ti particles

After annealing for 5 hours, the thickness of the interaction layers was thicker than those annealed for 1 hour, as shown in Fig. 3. In the case of some particles, interaction layers were infiltrated into the internal core of U-Mo particles. As the results of annealing tests for 5 hours, silicide coating was more effective than nitride coating in suppressing the formation of interaction layers. An additional reduction of the interaction layer thickness was not shown in the Ti added U-Mo samples.

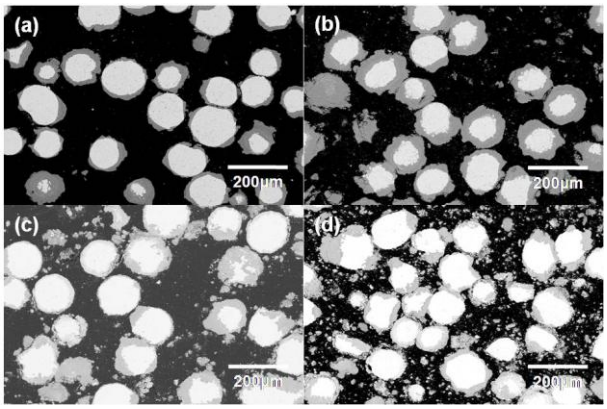

Fig. 3. SEM images of as annealed (580℃/5h) U-Mo dispersion fuels (a) nitride coated U-7wt%Mo particles (b) nitride coated U-7wt%Mo-1wt%Ti particles (c) silicide coated U-7wt%Mo particles (d) silicide coated U-7wt%Mo-1wt%Ti particles

The EDX analysis results showed that the nitride coating layers consisted of uranium-nitride compounds such as UN and UN_2, as shown in Fig. 4.

Fig. 5 shows the EDX analysis results of a silicide coating layer. Silicide coating layers were composed of Si, Mo, and U. It represents compounds such as U3Si, U_3Si_5 and U_3MoSi_2.

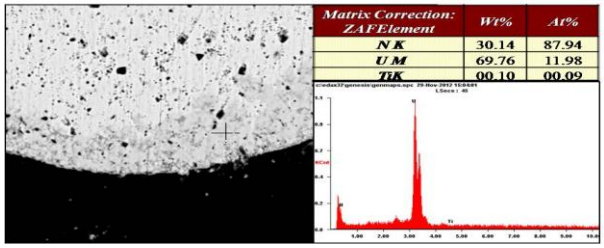

Fig. 4. EDX analysis of a nitride coating layer in a U-7wt%Mo-1wt%Ti particle

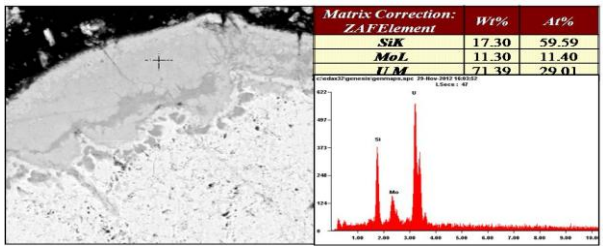

Fig. 5. EDX analysis of a silicide coating layer in a U-7wt%Mo-1wt%Ti particle

4. Conclusions

1. The thickness of the coating layers increased with Ti addition to U-Mo fuel particles.
2. The results of the annealing tests showed that silicide coating was more effective than nitride coating in suppressing the formation of interaction layers.
3. The EDX analysis of the coating layers showed that, they consisted of compounds such as UN, UN_2, U_3Si, U_3Si_5, and U_3MoSi_2.

ACKNOWLEDGMENTS

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REFERENCES

[1] J.L.Snelgrove et al., Nuclear. Engneering. Des. 178 (1997) 119.
[2] G.L.Hofman et al Proceedings of International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR), Chicago, USA, October 5-10, 2003.
[3] C.K.Kim et al., Nuclear Engineering Technology, 39 (2007) 617.
[4] H.J.Ryu et al., Nuclear Engineering Technology, 43 (2011) 59.