# Formation of Silicide Coating layer on U-Mo Powder

Ji Min Nam, Sunghwan Kim , Kyu Hong Lee
*Korea Atomic Energy Research Institute, 1045 Daedeok-daero, Yuseong-gu, daejeon 305-353, Republic of Korea*
**Corresponding author: shkim2@kaeri.re.kr*

## 1. Introduction

High-density U-Mo alloys are regarded as promising candidates for advanced research reactor fuel as they have shown stable irradiation performance when compared to other uranium alloys and compounds [1]. However, interaction layer formation between the U-Mo alloys and Al matrix degrades the irradiation performance of U-Mo dispersion fuel. Therefore, the addition of Ti in U-Mo alloys, the addition of Si in a Al matrix, and silicide or nitride coating on the surface of U-Mo particles have been proposed to inhibit the interaction layer growth [2-4].

In this study, U-Mo alloy powder was produced using a centrifugal atomization method. In addition, silicide coating layers were fabricated by several mixing process changes on the surface of the U-Mo particles. The coated powders were characterized by using scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDAX).

## 2. Experimental Procedures

U-7wt%Mo alloy powder was produced in this experiment. Superheated molten uranium-alloy was fed through a small nozzle onto a graphite disk spinning at about 30,000 rpm, and liquid alloy droplets were then spread from the disk by centrifugal force and cooled in an argon atmosphere. This method has advantages such as a single-step process, short processing time, a high production yield rate, high purity with less defects, and spherical formation for easy dispersion plate fabrication (Fig. 1) [5].

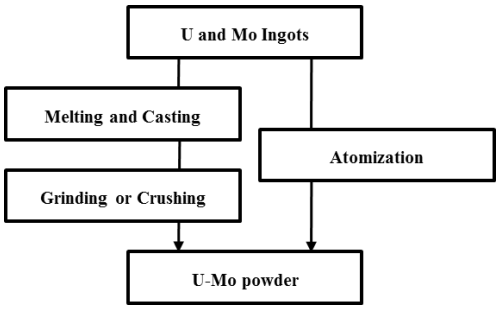


Fig. 1. Step for the fabrication of powders.

The size of atomized U-7wt%Mo particles was from 105 to 150μm, and those were mixed with Si powders in various processes. Subsequently, mixed powders were annealed in a high temperature vacuum furnace to form silicide-coating layers on the surface of U-7wt%Mo powders. Here, U-7wt%Mo powders are host materials which are coated by guest materials, i.e., Si powders in this study. A list of experiment conditions is shown as Table. 1.

| Condition | Mixing Ratio (U : Si) | Si Size (μm) |
|---|---|---|
| Sample 1 | 1:2 | ≤ 20 |
| Sample 2 | 1:2 | ≤ 10 |
| Sample 3 | 5:1 | ≤ 20 |
| Sample 4 | 10:1 | ≤ 20 |
| Sample 5 | 5:1 | ≤ 5 |

Table. 1. Mixing conditions for silicide coating

U-7wt%Mo alloys were mixed with silicon powders by using a v-mixer for 18 hours. Previously, mixed powders were annealed at 1000℃ for 1 hour under a vacuum of about $7 \cdot 10^{-5}$torr. In this study, the annealing time was reduced to 30min to decrease the thickness of the coating layer.

The microstructures of silicide-coated powders were observed by SEM, and silicide coating layers were characterized by EDAX.

## 3. Results and Discussion

The silicide-coated U-7wt%Mo particles by conventional mixing condition, referred to as sample 1 in Table .1, are shown in Fig. 2. U-7wt%Mo powders were mixed with Si powders in the ratio of 1:2 and annealed at 1000℃ for 1hr. Furthermore, the size of Si particles was about 20μm which is too big as a guest material. From the result, the thickness of silicide coating layers was 10-20μm, and various U-Si alloy phases were formed as shown in Fig. 2(b).

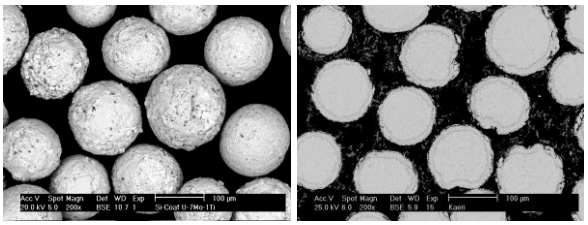

Fig. 2. (a) The surface micrograph of silicide-coated U-7wt%Mo powders, and (b) the cross-sectional image of sample 1 annealed at 1000℃ for 1hr.

For decreasing the thickness of silicide coating layers, annealing duration for sample 1 was reduced to 30min

at the same temperature. However, not only were the silicide coating layers thick (~15-20μm), but several uncoated particles were also observed as shown in Fig. 3.

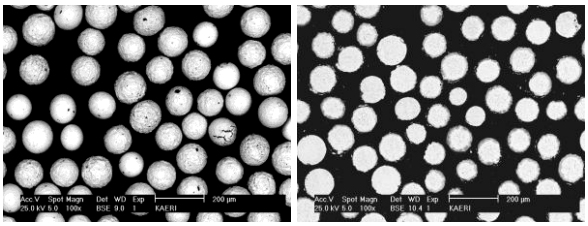

Fig. 3. (a) The surface micrograph of silicide-coated U-7wt%Mo powders, and (b) the cross-sectional image of sample 1 annealed at 1000℃ for 30min.

In the case of sample 2, Si powders were ground in a size of less than 10μm before the mixing process, and U-7wt%Mo powders were subsequently mixed with ground Si powders in the ratio of 1:2. Annealing was performed at 1000℃ for 30min, and the results are shown in Fig. 4. Contrary to expectations, most U-7wt%Mo powders were uncoated.

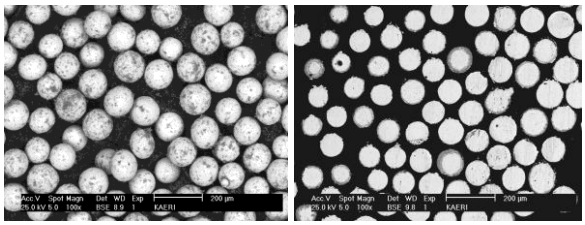

Fig. 4. . (a) The surface micrograph of silicide-coated U-7wt%Mo powders, and (b) the cross-sectional image of sample 2 annealed at 1000℃ for 30min.

In the case of sample 3, silicide coating layers were fully formed on the surface of U-7wt%Mo powders without exception. U-7wt%Mo powders were mixed with Si powders at a ratio of 5:1 and annealed at 1000℃ for 30minutes. The size of Si powders used for mixing was less than 20μm, and the thickness of formed silicide coating layers was 5-8μm. Furthermore, uncoated U-7wt%Mo particles were hardly found as shown in Fig. 5.

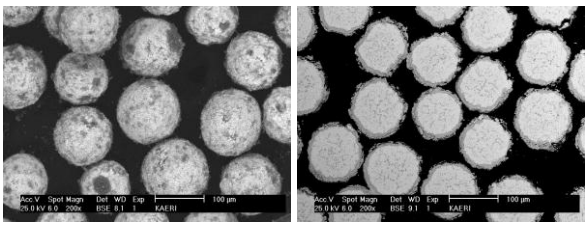

Fig. 5. (a) The surface micrograph of silicide-coated U-7wt%Mo powders, and (b) the cross-sectional image of sample 3 annealed at 1000℃ for 30min.

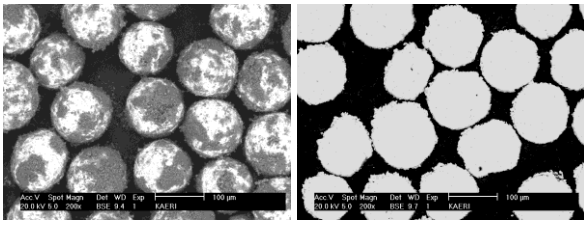

Fig. 6. (a) The surface micrograph of silicide-coated U-7wt%Mo powders, and (b) the cross-sectional image of sample 4 annealed at 1000℃ for 30min.

However, silicide coating layer was not observed for sample 4 which as mixed with a ratio of U-7wt%Mo 10 to Si powders 1. From the cross-sectional micrographs, its result was pretty much the same with that of sample 2.

For the comparison of sample 3, in the case of sample 5, a smaller size of the Si powders was used as shown in Table. 1. Here, silicide coating layers were formed on the surface of U-7wt%Mo particles with a thickness of 1 -2μm. Like the results of sample 3, most U-7wt%Mo powders showed evenly formed silicide coating layers as shown in Fig. 7.

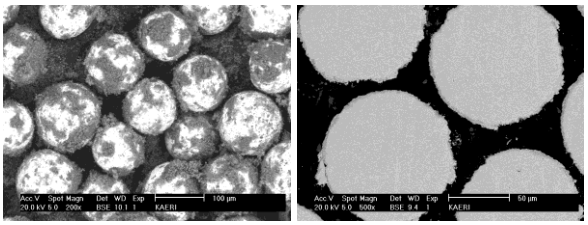

Fig. 7. (a) The surface micrograph of silicide-coated U-7wt%Mo powders, and (b) the cross-sectional image of sample 5 annealed at 1000℃ for 30min.

## 4. Conclusions

1. Decreased annealing duration did not affect the forming of silicide coating layers on the surface of U-7wt%Mo powders.
2. The variation in the mixing ratio between U-7wt%Mo and Si powders had an effect on the quality of silicide coating on the U-7wt%Mo powders.
3. The weight of Si powders should be smaller than that of U-7wt%Mo powders for better silicide coating when it comes to the mixing ratio.

## ACKNOWLEDGMENTS

This study was carried out as a National Nuclear R&D Program sponsored by Ministry of Science, ICT and Future Planning.

## REFERENCES

[1] J. L. Snelgrove, Nuclear Engineering and Design Vol.178, p. 119, 1997
[2] H. J. Ryu, Nuclear Engineering and Technology Vol.43, p. 159, 2011

[3] Y. S. Kim, Journal of Nuclear Materials Vol.430, p. 50, 2012
[4] Y. S. Kim, Journal of Nuclear Materials Vol.427, p. 233, 2012
[5] C. K. Kim, Nuclear Engineering and Technology Vol.39, p. 617, 2007