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Effects of Silicide Coating on the Interdiffusion between U-7Mo and Al

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

1. Introduction

Gamma phase U-Mo alloys are regarded as one of the promising candidates for advanced research reactor fuel when it comes to the irradiation performance [1]. However, it has been reported that interaction layer formation between the U-Mo alloys and Al matrix degrades the irradiation performance of U-Mo dispersion fuel. The excessive interaction between the U-Mo alloys and their surrounding Al matrix lead to and excessive local swelling called 'pillowing'. For this reason, KAERI suggested several remedies such as alloying U-Mo with Ti, or Al matrix with Si. In addition, silicide, or nitride coatings on the surface of U-Mo particles have also been proposed to hinder the growth of interaction layer [2-5].

In this study, centrifugally atomized U-7Mo alloy powders were coated with silicide layers at varying T (T = 900 and 1000 ℃) for 30 min, respectively. U-Mo alloy powder was blended with Si powders and subsequently heat-treated to form uranium-silicide coating layers on the surface of U-Mo alloy particles. For an annealing test, silicide-coated U-Mo alloy powders were made into a compact, and Al powders were used as a matrix. The compacts were annealed at 550 ℃ for 2 hr and 4 hr, respectively, and scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) were used for analyzing microstructures of the compacts.

2. Experimental Procedures

U-7Mo alloy powders were produced by the centrifugal atomization and particles with 105~150 μm in diameter were used in this study. [6] Otherwise, the sizes of Si powders to blend were around 5 μm in diameter, and the blending between the Si powders and the U-7Mo powders was conducted by a mixer with zirconia balls. After 1 day of the mixing process, mixed powders were subsequently heat-treated at varying temperature (T = 900 and 1000 ℃) for 30 min, respectively.

Sample	Heat-treated conditions	
	Temperature	Duration
A	900 ℃	30 min
B	1000 ℃	30 min

Table. 1. Experimental conditions for the silicide coating

After the heat-treatment, sample A and B were mixed with Al powders, and then made into compacts for annealing process. The annealing process was conducted under 10^{-5} torr vacuum, and samples were cooled in the furnace. Annealing temperature was fixed with 550℃, and an annealing duration was varied from 2 to 4 hr.

Effects of silicide coating layers on U-7Mo / Al interdiffusion was analyzed using cross-sectional micrographs of the samples, and EDS was also used for the phase confirmation.

3. Results and Discussion

After the heat-treatment, unreacted Si and U_3Si_5 mixed-layer formed on the surface of U-7Mo particles, and thickness of the layer was less than 5 μm in the case of sample A. On the other hand, in the case of sample B, Si totally reacted with U-7Mo, and formed multi coating layers. Those coating layers were composed of U_3Si_2, U_3MoSi_2, and Ti rich layer from the outside to the inside of U-7Mo particles, respectively. Surface coated U-7Mo powders were mixed with Al powders, and then were made into compacts as shown in Fig. 1.

(a)

(b)

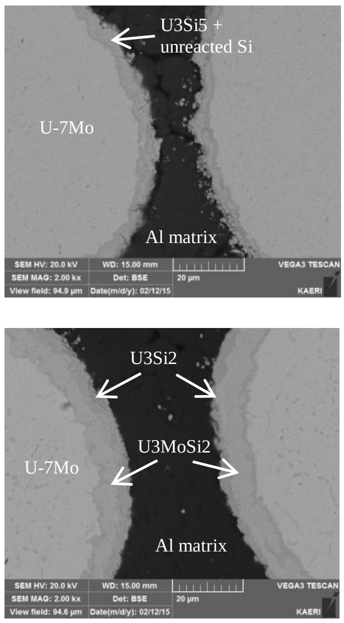
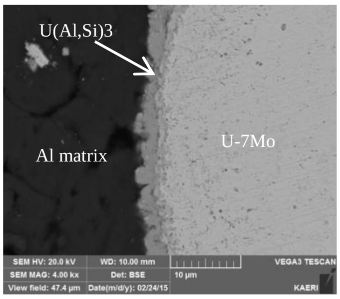
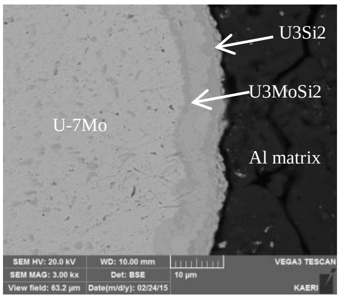


Fig. 1. Cross-sectional micrographs of compacts of (a) the sample A, and (b) the sample B.

Subsequently, annealing process was conducted at 550℃ for 2 hr, it was shown that the coating layer of U-7Mo particle reacted with the Al matrix. Unreacted Si and U_3Si_5 mixed coating layer was disappeared, and the whole coating layer changed to $U(Al,Si)_3$ phase which is typical uranium-aluminum intermetallic compound, as shown in Fig. 2(a). In the case of sample B, it was noted that Al diffusion into U-7Mo particle was effectively interrupted by the silicide coating layers. From Fig. 2(b), cross-sectional micrograph showed that the thickness and phases of the coating layers were pretty much the same as those of as-prepared compacts of the sample B.



(a) Sample A.



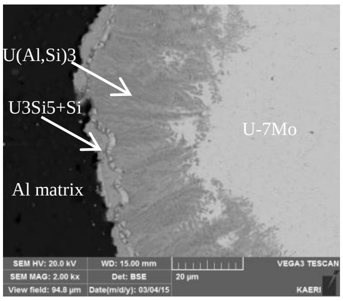
(b) Sample B.

Fig. 2. The cross-sectional micrographs of compacts of (a) the sample A, and (b) the sample B which were annealed at 550℃ for 2 hr, respectively.

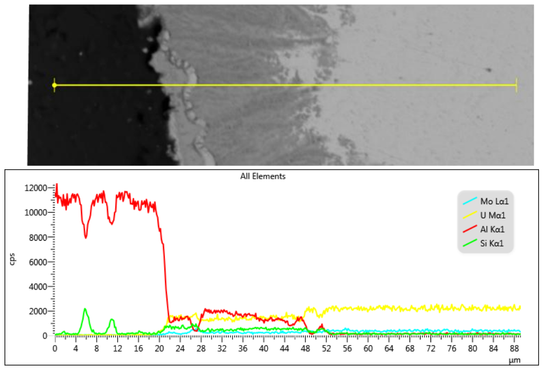
Further annealing up to 4 hr at 550℃, in the case of sample A, Al penetrated into the silicide coating layer, and reacted with U-7Mo particle. From EDS results, transformed uranium aluminide intermetallic compunds were mainly $U(Al,Si)_3$. $U(Al,Si)_3$ phase left the silicide coating layer behind, and formed inside of U-7Mo particles, as shown in Fig. 3(a) and (b). In the case of sample B, Al could not penetrate the silicide coating layer and the coating layers were remained constant, as shown in Fig. 3(c) and (d). From the results, we made a comparison between the compacts of sample A and B, and it was shown that Al can easily diffuse into unreacted Si and U_3Si_5 mixed layer while U_3Si_2 acted as a good diffusion barrier at 550℃ though those layers had the same thickness. It also showed good agreement with report of A.E. Dwight [6]. The author showed that Si-rich uranium silicide like U_3Si_5 has higher solubility for Al than U-rich uranium silicide U_3Si_2.

In this sense, the type of uranium silicide is the one of the keys to protect U-Mo alloy powders from the diffusion of Al matrix.). However, in depth study should be followed to characterize the mechanism of suppression of interdiffusion between U-Mo alloys and Al matrix by uranium silicide coating layers.

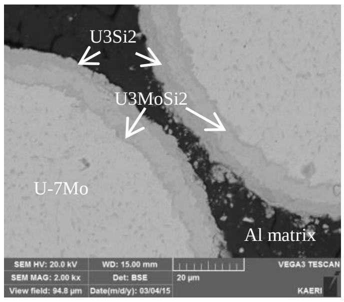
(a)



(b)



(c)



(d)

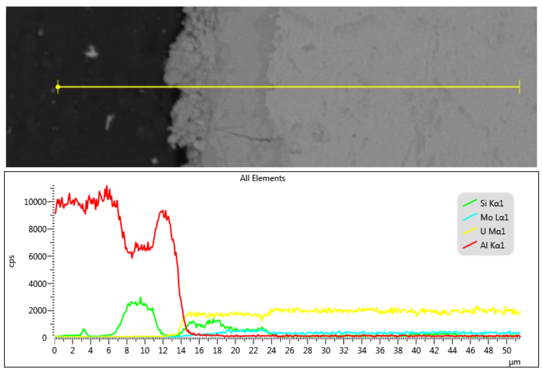


Fig. 3. The cross-sectional micrographs of 550℃ for 2 hr annealed compacts of (a) the sample A, (b) the sample B, and corresponded EDS results (b) and (d), respectively.

ACKNOWLEDGMENTS

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