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Fabrication of Duplex Coated U-Mo-Ti Atomized Powder

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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-Ti alloy powder was produced using a centrifugal atomization method. In addition, nitride and silicide duplex coating layers were fabricated on the surface of the U-Mo-Ti particles. The coated powders were characterized by using X-ray diffraction, SEM, and EDX.

2. Experimental procedures

U-7wt%Mo-1wt%Ti alloy powder was used 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.

Atomized particles were coated in a high temperature vacuum furnace to form coating layers by silicon powder pack cementation and gas nitriding. A list of experiment conditions is shown as Table. 1.

Table. 1. The conditions of silicide and nitride coating

Nitride coating		Silicide coating	
Working pressure	$6{\cdot}10^{-3}$torr	Working pressure	$7{\cdot}10^{-5}$ torr
Nitrogen gas flow	80sccm	Ball mill	8h
Temperature	1000℃	Temperature	1000℃
Holding time	1h	Holding time	1h

Nitirde coating has been performed through gas flowing in a rotating heat treatment furnace (30rpm). Silicide coated powder was fabricated in a high temperature vacuum furnace, and U-7wt%Mo-1wt%Ti alloys were mixed with silicon powders by using a ball mill for 8 hours.

The U-7wt%Mo-1wt%Ti alloy powder was extruded into rods after mixing with Al. The dispersion rod samples were annealed at 580℃ for 1 hour in a high temperature vacuum furnace to form interaction layers.

The produced silicide or nitride coating particles were duplex coated under the same conditions by silicon powder or nitrogen gas.

The microstructures of single- or duplex- coated powders were observed by scanning electron microscopy (SEM). X-ray diffraction and Energy dispersive x-ray spectroscopy (EDX) experiments were performed to characterize the duplex coating layers.

3. Results and discussion

The differences in the silicide or nitride coating and duplex coating were compared, as shown in Fig. 1. In the single-coated U-7wt%Mo-1wt%Ti particles, a silicide-coated particle has rough surfaces and several silicon particles were shown on the surface (a). However, the nitride coated particle surface was smooth and showed several cracks (b). Figs. 1(c) and 1(d) show the duplex coated U-7wt%Mo-1wt%Ti particles. The silicide-coated particles on the nitride-coated surface were very smooth. However, nitride coated particles on the silicide-coated surface have very rough surfaces and active cohesion occurs between particles.

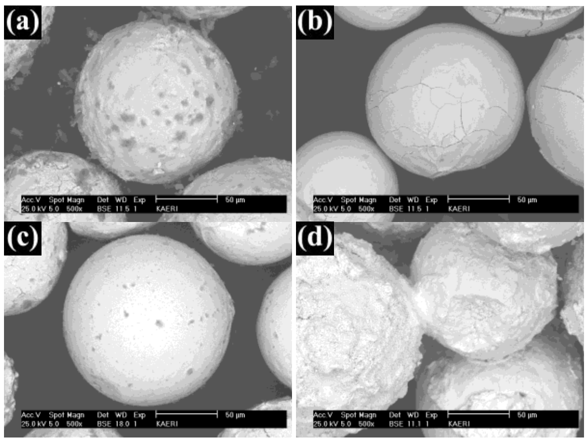

Fig. 1. Spherical morphologies in SEM images of atomized particles : (a) silicide-coated U-7wt%Mo-1wt%Ti, (b) nitride-coated U-7wt%Mo-1wt%Ti, (c) silicide-coated U-7wt%Mo-1wt%Ti on the nitride-coated particles, and (d) nitride-coated U-7wt%Mo-1wt%Ti on the silicide-coated particles.

Fig. 2 shows the differences in the interaction layers between silicide and nitride coating. Silicide and nitride coating layers were fabricated on the surface of U-7wt%Mo-1wt%Ti particles with a thickness of about 10−20 micrometers. The coating layers fabricated on U-7wt%Mo-1wt%Ti particles inhibit the formation of interaction layers, while interaction layers were formed on uncoated surfaces, as shown in Fig. 3.

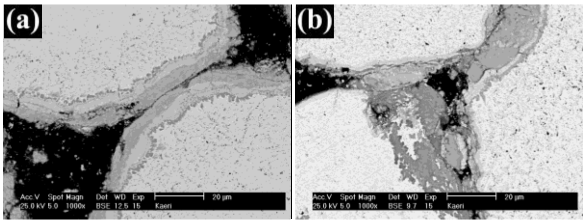

Fig. 2. Cross-section SEM images of annealed U-7wt%Mo-1wt%Ti extruded rods using single coated particles: (a) silicide-coated U-7wt%Mo-1wt%Ti, and (b) annealed silicide-coated U-7wt%Mo-1wt%Ti.

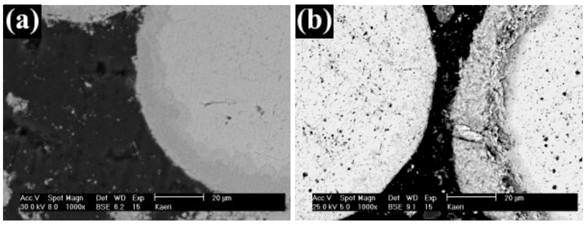

Fig. 3. Cross-section SEM images of annealed U-7wt%Mo-1wt%Ti extruded rods using single-coated particles: (a) nitride-coated U-7wt%Mo-1wt%Ti, and (b) annealed nitride-coated U-7wt%Mo-1wt%Ti.

The microstructures of duplex coated particles are shown in Fig. 4. Silicide coating after nitride coating results show that duplex coating layers were not formed. The nitride coating layer inhibits the formation of additional coating layers. However, silicide coating layers on some uncoated particle surfaces were observed.

The results of nitride coating after silicide coating show that silicide coating layers form second phases during nitride coating inside of the particles.

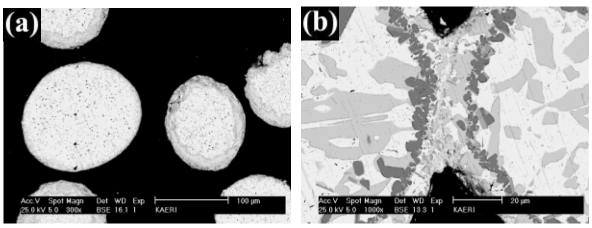

Fig. 4. Cross-section SEM images of duplex coated U-7wt%Mo-1wt%Ti particles: (a) silicide-coated U-7wt%Mo-1wt%Ti on the nitride coated particles, and (b) nitride-coated U-7wt%Mo-1wt%Ti on the silicide-coated particles.

4. Conclusions

1. Silicide and nitride single coating layers were fabricated on the surface of U-7wt%Mo-1wt%Ti alloys with a thickness of about 10−20 micrometers.
2. The results of an annealing test showed that the coating layers inhibit the formation of interaction layers.
3. The results of duplex coating showed that nitride coating layers inhibit the formation of other coating layers.

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