Performance of Nb protective diffusion coating on U-Mo/Al dispersion fuel

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1. Introduction

Highly enriched in ^{235}U (up to 93%) were commonly used as research reactors. However, there are great international efforts like "Reduced Enrichment for Research and Test Reactors" (RERTR) project to minimize the risk of proliferation. The regulation is that ^{235}U should not exceed 20%. To achieve this aim, it is necessary to increase the volume fraction of fuel particles inside the meat. However, the technical limit is reached at approximately 55 vol.% of fuel particles in the aluminum matrix. As a solution, an uranium compound with an higher uranium density than existing U3Si2 fuel has to be selected. Also alloying the uranium must stabilize γ-phase of uranium at room temperature because adequate properties of the γ -phase of uranium showed a good irradiation behavior in the past. Hence, U-Mo alloys were selected as the best candidates. The addition of 7wt.% to 10wt.% of Mo to the U is the best compromise between a high uranium density and a good γ -stability of the U-Mo.

Up to now many test fuel plates with U-Mo powder dispersed in an Al matrix failed during in-pile irradiation because of the formation of interaction layers between U-Mo powders and Al matrix. Therefore, the formation of interaction phase is a critical problem to apply U-Mo alloys to the high-performance research reactor. Different means have been proposed to reduce the interaction between U-Mo fuel and Al matrix. There are three means. :

1. Addition of a diffusion limiting element to the matrix
2. Insertion of a diffusion barrier at the interface between the U-Mo and the Al
3. Alloying of the U-Mo with a third element

Here we present the effect of Nb coating as diffusion barrier on formation of interaction layers between U-Mo powders and Al matrix.

2. Experimental procedure

Centrifugal atomized U-7wt.%Mo powders of 45~90 ㎛ in diameter were coated with Nb by using Physical Vapor Deposition (PVD) sputtering equipment (Fig. 1.). The PVD chamber is pumped down to the 3*10-5 torr range at least and high-purity Ar gas is injected into the chamber at a rate of 34~36 cc per minute. Nb from ultra-high purity metallic targets is deposited at the power of 1 kW and chamber was rolled at nearly 4 rotations per minute continuously for homogeneous coating thickness. In this condition, sputtering continued for 3 hours and 30minutes respectively. The 3 hours coating were dividedly performed 90 minutes at a time. Second sputtering progressed 1 hour after first sputtering completion to avoid any damage from overheated chamber.

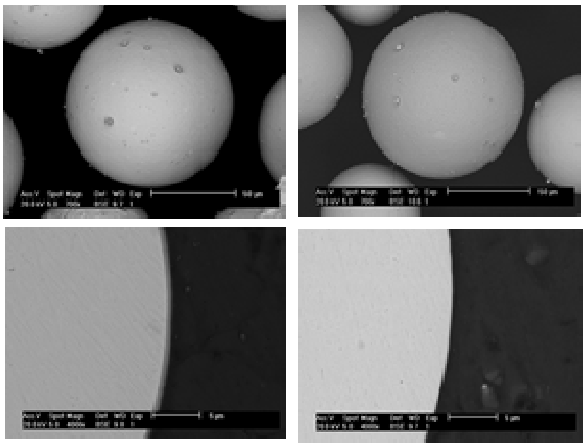
Uncoated and Nb coated U-7 wt.%Mo were mixed with pure aluminum powders at a rate of 34 rotation per minute for 1 hour. And mixed powders were pressed into a compact (10mm in diameter and about 2mm in thickness) with roughly 5 tons. The compacts annealed at 550°C for 1, 3, 5 hours respectively.

Microstructures of test specimens were examined with scanning electron microscope (SEM) and Energy dispersive spectroscopy (EDS) is used for composition measurement.

Fig. 1. Physical Vapor Deposition (PVD) system

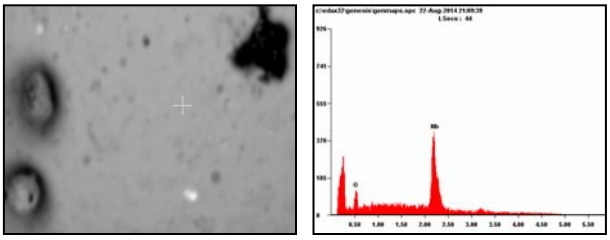
3. Result

The backscattered electron images of scanning electron microscopy (SEM) show coated powders in 3 dimension and cross sections of powders embedded in an Al matrix (Fig. 2.). NU-7 wt.% Mo powders were coated with Nb homogeneously and no uncovered particles have been observed. The 3 hours sputtering Nb coating thicknesses is 475±125 nm. 30 minutes sputtering Nb coating thickness couldn't be confirmed because of low resolution of SEM. However, EDS data of the 30 minutes sputtering coating indicates the existence and the oxidation of Nb coating layer (Fig. 3). Uncoated, 3 hours Nb coated, and 30 minutes Nb coated U-7Mo/Al compacts were annealed at 550°C for 3, 5 hours (Fig. 4). The degree of interaction phase formation fraction of powder was different in same



(a) 3hours Nb coated U-7Mo (b) 30minutes Nb coated U-7Mo

Fig. 2. 3D images (top) and cross section images (bottom) of Nb coated U-7Mo powders show coating homogeneity.



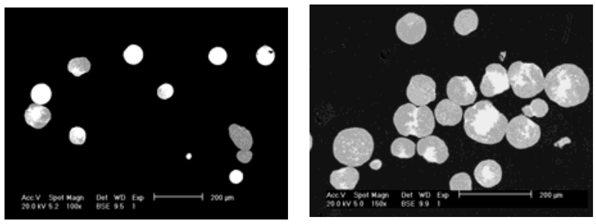
Matrix Correction: ZAFElement	**At%**
O	18.19
Nb	81.81

Fig. 3. EDS data of 30 minutes coated U-7Mo indicates existence of Nb coating on U-7Mo indicates the existence of Nb coating layer on U-Mo powder.

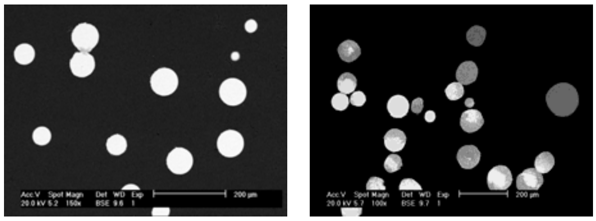
specimen, at the range of 0 ~ 100%. The interaction phase is composed of U, Mo and Al; 16.04 at.% U 2.69 at.% Mo, and 81.27 at.% Al (Fig. 6). However, when comparing the specimens annealed under same condition, the ratio of total interaction phase area to total area decreases clearly as the thickness of Nb coating layer increase. The results show Nb coating layer effectively suppressed the interdiffusion between U-7Mo and Al.

4. Conclusions

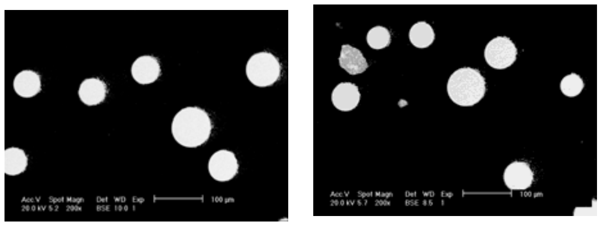
We present the effect of Nb coating on formation of interaction layers between U-Mo powders and Al matrix. Centrifugally atomized U-7 wt.% Mo powders were used, and Nb was coated on the surface of U-7 wt.% Mo
by sputtering. Subsequently, the Nb-coated U-7 wt.% Mo powders were mixed with pure Al powders, and were made into compacts. The compacts were annealed at 550°C for 1, 3, 5 hours, respectively, and the result showed that the Nb coating on U-7 wt.% Mo effectively suppressed the growth of interaction layers between U-7 wt.% Mo and Al matrix.



(a) uncoated U-7Mo/Al



(b) 30 minutes Nb-coated U-7Mo/Al



(c) 3hours Nb-coated U-7Mo/Al

Fig. 4. Cross section images of U-7Mo/Al compacts annealed at 550°C for 3 h (left) and 5h (right) show the ratio of total interaction phase area to total area decreases clearly as the thickness of Nb coating layer increase.

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