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Nitride Coating Effect on Oxidation Behavior of Centrifugally Atomized U-Mo Fuel

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1. Introduction

Uranium metal and uranium compounds are being used as nuclear fuel materials and generally known as pyrophoric materials [1-3]. Nowadays the importance of nuclear fuel about safety is being emphasized due to the vigorous exchanges and co-operations among the international community. According to the reduced enrichment for research and test reactors (RERTR) program, the international research reactor community has decided to use low-enriched uranium instead of high-enriched uranium. As a part of the RERTR program, KAERI has developed centrifugally atomized U-Mo alloys as a promising candidate of research reactor fuel. Kang et al. studied the oxidation behavior of centrifugally atomized U-10wt% Mo alloy and it showed better oxidation resistance than uranium [4]. In this study, the oxidation behavior of nitride coated U-7wt% Mo alloy is investigated to enhance the safety against pyrophoricity.

2. Experimental Procedures

The U-7wt% Mo alloy powder used in this study was produced by KAERI-designed centrifugal atomizer and fabrication method and procedure has been provided by Kim et al. [5]. In order to coat nitride layer on the surface of U-7wt% Mo alloy powder, the vacuum rotator heat treating furnace was designed by KAERI. About 20 g of U-7wt% Mo alloy powder was loaded in the crucible and heat-treated at 920^oC for 3hrs flowing nitrogen gas of 30 sccm. The N_2 partial pressure was controlled to be 7.8×10^{-2} torr ~ 7.2×10^{-2} torr by vacuuming. The sample tube was rotated during the annealing and the rotation speed was 3.2 rpm. The oxidation test was performed using a thermogravimetric analyzer. The U-7wt% Mo alloy powder was contained in an alumina crucible and heated up to 100^oC in a flow of Ar gas and maintained for 1hr to evaporate the water. While the oxidation test was performed, air was continuously injected from 100^oC to 500^oC. After maintaining for 20m at 500^oC, the sample was cooled down to room temperature in an Ar atmosphere. The flow rate of air and Ar was 100 cc/min at atmospheric pressure. Cross-sectional microstructures of nitride coated U-7wt% Mo alloy powder were observed by using scanning electron microscopy (SEM) and the phase of nitride coated U-7wt% Mo alloy powder was investigated by using X-ray diffractometer.

3. Results and Conclusions

U-7wt% Mo alloy powder was fabricated by using centrifugal atomizer as seen in Figure 1a. The shape of U-7wt% Mo alloy powder is spherical and the size of it is about 50~80um. In order to compare the oxidation behavior, nitride coated U-7wt% Mo alloy powder was successfully fabricated by annealing the centrifugally atomized U-7wt% Mo alloy powder at 920^oC for 3hrs. Cross-sectional image showed that sound and dense layers having the thickness of around 1.5um were formed on the surface of U-7wt% Mo alloy powder (Figure 1b). The phase of layer formed on the surface of U-7wt% Mo alloy powder was proved to be uranium mononitride (UN) by analyzing the XRD patterns (Figure 1c).

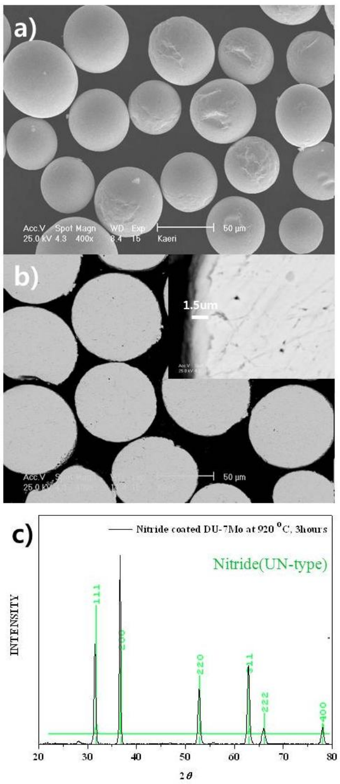

Figure 1. a) SEM image of centrifugally atomized DU-7Mo powder, b) SEM image of nitride coated DU-7Mo powder (Inset shows the enlarged one), c) XRD data of nitride coated DU-7Mo agree with UN

Figure 2 shows the TGA data of U-7wt% Mo alloy powder and nitride coated U-7wt% Mo alloy powder. Weight increase of U-7wt% Mo alloy powder is initiated at the lower temperature compared with nitride coated U-7wt% Mo alloy powder (Figure 2a). It means that oxidation of U-7wt% Mo alloy powder starts faster than nitride coated U-7wt% Mo alloy powder. As you can see in Figure 2b, the time when the weight gain is reached at 20wt% is 57.3min of U-7wt% Mo alloy powder and 63.4min of nitride coated U-7wt% Mo alloy powder. From these TGA results, we can notice that nitride coating on the surface of U-7wt% Mo alloy powder plays a role as oxygen barrier and retards the oxidation rate.

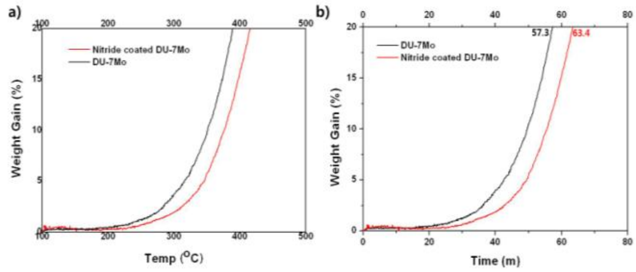

Figure 2. TGA data showing the time when the weight gain of DU-7Mo and Nitride coated DU-7Mo is reached at 20%

In addition, while most of nitride coated U-7wt% Mo alloy powder maintained its spherical shape after TGA test, the spherical shape of U-7wt% Mo alloy powder was collapsed at the same treatment as seen in Figure 3. This shows that the phase of U-7wt% Mo alloy powder changes into brittle one such as oxide phase faster than nitride coated U-7wt% Mo alloy powder and it has fragile property. From this result, we can conclude that nitride coating on the surface of U-7wt% Mo alloy powder enhances the oxidation resistance.

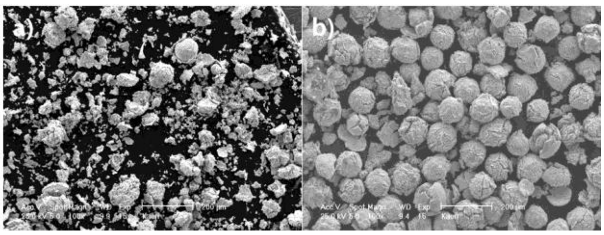

Figure 3. SEM images after the TGA test of a) DU-7Mo and b) Nitride coated DU-7Mo

4. Summary

Nitride coating technique was introduced on the surface of U-7wt% Mo alloy powder to enhance the oxidation resistance. As a result of TGA test, nitride coated U-7wt% Mo alloy powder shows better oxidation resistance than U-7wt% Mo alloy powder.

Therefore, we can conclude that nitride coating on the surface of U-7wt% Mo alloy powder plays an important role as an oxygen barrier and retards the oxidation rate of U-7wt% Mo alloy powder. In addition, this study can apply to every nuclear fuel for enhancing the safety against pyrophoricity.

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