# Heavy ion irradiation study of coated U-7Mo/Al dispersion fuels

Sunghwan Kim [a*], Yong Jin Jeong [a], Kyu Hong Lee [a], Ki Nam Kim [a], Jong Man Park [a], K. Mo [b], Y. Miao [b], Y.S. Kim [b], A.M. Yacout [b]
[a] *Korea Atomic Energy Research Institute, Daedeokdaero 989beon gil 111, Yuseong-gu, Daejeon, Republic of Korea*
[b] *Argonne National Laboratory, 9700 S. Cass Ave., Lemont, IL 60439, USA*
[*] *Corresponding author: shkim2@kaeri.re.kr*

## 1. Introduction

High density low enriched uranium (LEU) U-7Mo dispersion fuels have been a promising candidate to convert highly enriched uranium (HEU) of high performance research reactors. [1-4] However, in-pile behaviors from various qualifying tests showed detrimental local swelling at the high burn up and high fission rate regions. [5-7] Recently, coating the surface of U-7Mo particles to inhibit the interaction between the particles and Al matrix was proposed by SCK·CEN, and the post irradiation experiment (PIE) clearly showed that the protective layer is effective to eliminate the interaction. [8] In this study, Mo, W, Zr coated and uncoated U-7Mo/Al dispersion fuel samples were irradiated by Xe at the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL) to emulate in-pile irradiation behaviors.

## 2. Experiments and Results

8 $gU/cm^3$ mini-plates were fabricated at KAERI for the ATLAS irradiation test. In mini-plates, Mo, W, Zr coated and uncoated U-7Mo powders were dispersed in the Al matrix, respectively. Metal coating of U-7Mo particles were performed in physical vapor deposition (PVD) at KAERI, and the thickness of each coating layer was 200 nm. 1 cm diameter disks were punched from the mini-plates for the heavy ion irradiation tests, and the one side of the Al cladding was removed from the disks by mechanical polishing. The exposed surface was irradiated by the ion beam during the irradiation test. The irradiation was performed with 84 MeV $Xe^{26+}$ ions, beam current of 200 particle nano Ampere (pnA) and final doses were $2.7 \times 10^{17}$ $ions/cm^2$. The microstructures of irradiated samples were analyzed by focused ion beam (FIB), scanning electron microscopy (SEM) and Energy dispersive spectroscopy (EDS) at ANL.

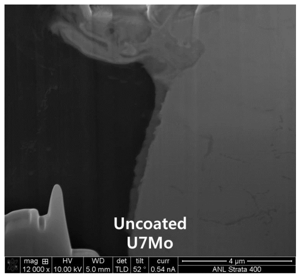


Fig. 1. The FIB cross-sectional micrograph of the irradiated uncoated U-7Mo/Al sample

### *2.1 Uncoated U-7Mo/Al*

During swift heavy ion irradiation, interaction layers formed between U-7Mo and Al matrix as shown in Fig. 1. The interaction layers were mainly composed of U-Al compounds as shown in Fig. 1. Generally, the composition of the interaction layer correlated to the uranium density, irradiation temperature, and burn up is the key to estimate the irradiation damage. However, it is difficult to quantitatively calculate the interaction layer formation with ion irradiation damage level because the thickness of the layer is too thin to analyze which is less than 0.5 $\mu m$. Besides it, the uncoated U-7Mo/Al sample showed that the ion damage induced inter-diffusion occurred at the edge of the U-7Mo particle surface.

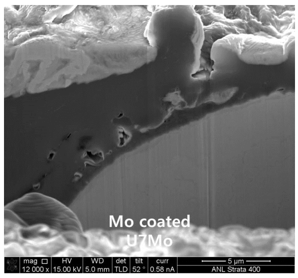


Fig. 2. The FIB cross-sectional micrograph of irradiated Mo-coated U-7Mo/Al sample

### *2.2 Mo-coated U-7Mo/Al*

It was shown that about 200 nm thick Mo layer was homogeneously and smoothly coated on the surface of all U-7Mo particles. However, prior to the ion irradiation, the Mo layer could be damaged and broken near the surface of the particles during the sample fabrication process. In that part, very thin U-7Mo/Al interaction layer was grown as shown in Fig. 2.

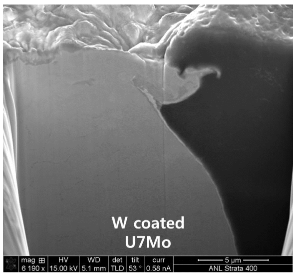


Fig. 3. The FIB cross-sectional micrograph of irradiated W-coated U-7Mo/Al sample

*2.3 W-coated U-7Mo/Al*

As indicated in Fig. 3, the diffusion of Al into U-7Mo particles was effectively prevented by the W coating layers. In the W-coated U-7Mo/Al sample, damaged and fractured W layers were also observed. However, no interaction layer was found not only in the damaged areas but also in the undamaged areas.

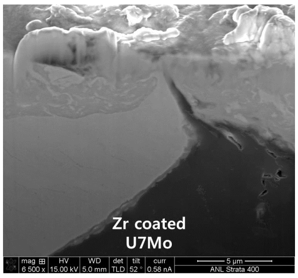


Fig. 4. The FIB cross-sectional micrograph of irradiated Zr-coated U-7Mo/Al sample

*2.4 Zr-coated U-7Mo/Al*

The Zr coated U-7Mo/Al samples showed discrete parts in the Zr coating layer, and through those parts, Al diffused into the U-7Mo particle and formed U-Al interaction layers. It is noted that those interaction layers seemed to have minor Zr and Mo contents, but it is hard to claim because the interaction area is very narrow and thin to analyze. However, the surface of the samples showed different contrasts compared two other samples, and the EDS results also showed that U, Zr, and Al were mixed in the interaction areas which is the same result with H.Y. Chiang. [9].

## 3. Conclusions

During the heavy ion irradiation tests, Al diffusion into the U-7Mo particle was effectively interrupted by Mo or W coating layers. However, the Zr coating layer showed U, Zr and Al mixed areas at the interface which indicate that Zr is not a valid candidate to the protection of U-7Mo from Al matrix.

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