Post Irradiation Examination of the Irradiated U-Mo Dispersion Fuels: KOMO-5

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1. Introduction

KOMO irradiation test program has been conducted for the high U-density U-Mo dispersion fuels using centrifugal atomized U-Mo powder at KAERI [1]. The purposes of the KOMO irradiation tests are the followings; 1) upgrading the HANARO reactor core, 2) diversifying the back-end options spent fuel, and 3) scientific contribution to understanding the U-Mo fuel performance. Details of the KOMO irradiation tests are summarized in Table 1.

From the KOMO irradiation tests, the effects of U-Mo particle size, U-Mo volume fraction, irradiation temperature, Si contents in the Al matrix, and surface treatment on U-Mo powder are identified [2,3].

In this study, the KOMO-5 irradiation test, which is consists of 12 kinds of U-Mo fuel rods including full-length fuels, and the post-irradiation examination (PIE) results are described.

Table 1: KOMO Irradiation Test at HANARO

Test ID	Fuel	Matrix	U-loading (gU/cc)	Max. BU (at%U235)
KOMO -1	U-7Mo U-9Mo	Pure Al	3.4 6.0	13
KOMO -2	U-7Mo U-9Mo	Pure Al	4.0 4.5	68
KOMO -3	U-7Mo U-7Mo-1Zr U-7Mo-0.2Si	Pure Al Al-0.4Si Al-2Si	4.5	66
KOMO -4	U-7Mo U-7Mo-1Zr U-7Mo-1Ti	Al-2Si Al-5Si Al-8Si	4.5 ~ 5.0	54
KOMO -5	U-7Mo U-7Mo-1Zr U-7Mo-1Ti Coated fuel	Al-5Si + B.A	5.0	85

2. Methods and Results

2.1 KOMO-5 Irradiation test

For the KOMO-5 irradiation test, 12 kinds of U-Mo dispersion fuel rods were designed and fabricated by reflecting the results of the previous KOMO irradiation tests. The key concerns of the KOMO-5 were the performance of full-size U-Mo-1X(X=Ti, Zr)/Al-5Si fuels and the effect of silicide and nitride coating on the interaction layer growth. Table 2 listed the main parameters of the KOMO-5 irradiation test fuel rods. The U-density is 5 g-U/cm^3 for all fuel rods.

Table 2: KOMO-5 irradiation test fuel rods

Fuel Material	Matrix	U-Mo Particle Size (μm)	Fuel Meat Diameter (mm)	Fuel Length (mm)
U-7Mo	Al-5Si ($CdO+B_4C$)	< 150	5.49	700
U-7Mo-1Zr	Al-5Si ($CdO+B_4C$)	< 210	5.49	700
U-7Mo	Al-5Si ($CdO+B_4C+Er_2O_3$)	< 150	5.49	700
U-7Mo-1Ti	Al-5Si ($CdO+B_4C$)	< 210	5.49	700
Silicide Coated U-7Mo	Al	140~210	6.35	200
Silicide Coated U-7Mo	Al-2Si	140~210	6.35	200
Silicide Coated U-7Mo-1Ti	Al	140~210	6.35	200
Silicide Coated U-7Mo-1Ti	Al-2Si	140~210	6.35	200
Nitride Coated U-7Mo	Al	140~210	6.35	200
U-7Mo	Al-2Si (pre IL)	210-300	6.35	200
U-7Mo	Al-5Si (pre IL)	210-300	6.35	200
U-7Mo-1Zr	Al-5Si (pre IL)	210-300	6.35	200

Fig. 1 shows a cross-section of the full-size U-7Mo/Al-5Si fuel with burnable absorbers and the EDS elemental mapping results. The U-Mo fuel particles and B.As were well distributed in the Al matrix.

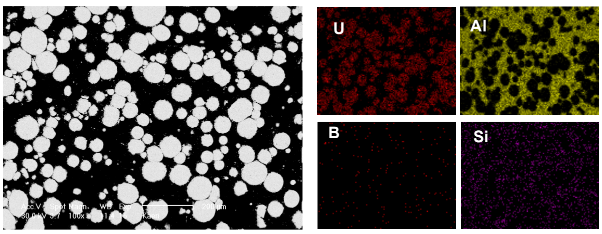

Fig. 1. An SEM image of U-7Mo/Al-5Si fuel rod and its EDS elemental mapping

KOMO-5 irradiation test had been conducted from May 25, 2011 to July 28, 2012 at HANARO OR3 irradiation hole, 227.8 EFPDs. Average and maximum burnups for the full-size fuel rods were calculated to be 71 at%U-235 and 85 at%U-235, respectively.

2.2 Post Irradiation Examination

After irradiation at HANARO, the U-Mo fuel assembly was cooled for 3 months at the HANARO pool. PIEs such as gamma scan, microstructure, density and EPMA have been carried out for the irradiated U-Mo fuel rods.

Fig. 2 to 4 show the cross-section micrograph of U-7Mo/Al-5Si(full-size), U-7Mo-1Zr/Al-5Si(full-size) and silicide coated U-7Mo/Al at the max. burnup. In case of U-7Mo/Al-5Si, the center of the fuel meat fully reacted to Al matrix, while U-7Mo-1Zr/Al-5Si didn't show that phenomenon in spite of higher burnup. It reveals that the third element addition to U-Mo fuel is very effective to suppress the interaction layer growth [4].

The silicide coated U-7Mo/Al fuel showed both thin and thick interaction layer. The former is at the well-coated powder, while the latter is at the uncoated or unstable coated powder.

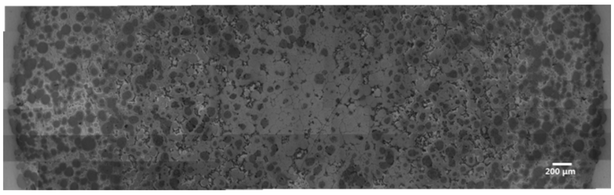

Fig. 2. Cross-section of U-7Mo/Al-5Si (BU 83 at%U-235)

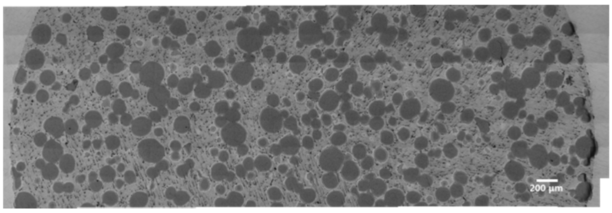

Fig. 3. Cross-section of U-7Mo-1Zr/Al-5Si (BU 85 at%U-235)

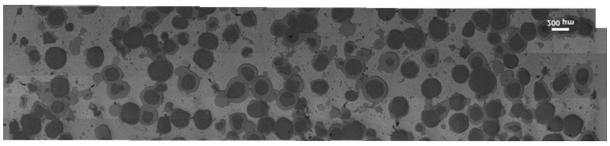

Fig. 4. Cross-section of silicide coated U-7Mo/Al (BU 68 at%U-235)

EPMA elemental mapping result of U-7Mo/Al-5Si fuel showed that Si in the Al-Si matrix piled up at the outer rim of interaction layers. The Si elemental mapping data of silicide coated fuel (fig. 6) showed that well-coated powder didn't react to Al matrix. The sound Si-rich layer blocked the Al diffusion to the U-Mo powder.

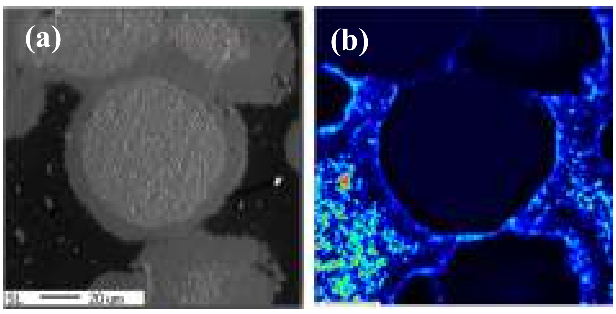

Fig. 5. (a) IL and (b) EPMA elemental mapping of Si for U-7Mo/Al-5Si

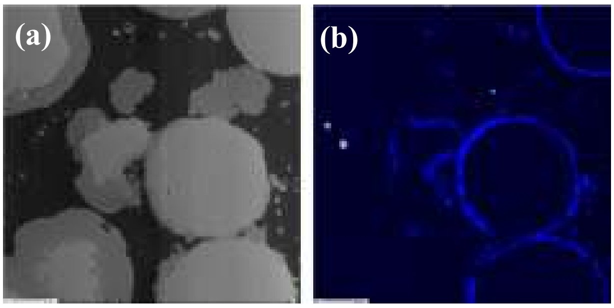

Fig. 6. (a) IL and (b) EPMA elemental mapping of Si for silicide coated U-7Mo/Al

On the other hand, the nitride coating was not effective to block the Al diffusion. Even though the nitride coating was remained at the out of the U-Mo fuel, Al diffused to U-Mo powder through the nitride coating.

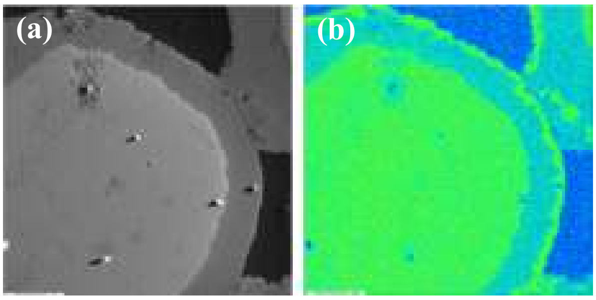

Fig. 7. (a) IL and (b) EPMA elemental mapping of N for nitride coated U-7Mo/Al

3. Conclusions

The post irradiation examination of the KOMO-5 irradiated U-Mo dispersion fuel rods (227.8 EFPD) exhibited a sound fuel performance up to 85 at%U-235. In addition to Al-Si matrix, the third elements such as Ti and Zr are effective to suppress the interaction layer growth. EPMA analyses of the silicide or nitride coated U-Mo/Al fuels showed that the silicide coating is more effective to reduce the interaction layer than the nitride coating.

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