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Dispersion Target Fabrication for Fission Mo Using Atomized Uranium Powder

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1. Introduction

Among the radioisotopes for medical diagnosis, Tc-99m is most widely used. Mo-99 produced from the nuclear fission of uranium in research reactors is the key radioisotope for Tc-99m generators. Generally, major producers of Mo-99 still use targets containing highly enriched uranium (HEU). However, the international non-proliferation policy currently emphasizes the minimization of the use of HEU in medical radioisotope production [1]. Therefore, low enriched uranium (LEU) targets have been developed by casting and crushing of UAl_2 compounds. The UAl_2 particle dispersed target has a lower U-235 density when compared to HEU targets. The uranium density of the conventional UAl_2 dispersion targets is known to be lower than 2.7g-U/cm^2 [2]. To improve the low production efficiency of LEU targets, target designers try to develop high uranium density targets with LEU. KAERI has proposed that high density uranium alloys, instead of UAl_2, can be used as dispersing particles in an aluminum matrix [3]. While it is very difficult to fabricate uranium alloys powder by grinding or crushing, spherical powders of uranium alloy can be produced easily by centrifugal atomization [4].

Mini-size targets with 3, 6, and 9 g-U/cm^3 were fabricated in this study to investigate the feasibility of high density targets with atomized uranium particles. The microstructural changes after thermal treatments were observed to analyze the interaction behavior of uranium particles and an aluminum matrix.

2. Experimental procedures

Atomized spherical uranium powder and pure aluminum powder were mixed and compacted to form dispersion targets with 3, 6, and 9 g-U/cm^3. The calculated volume fractions and weight fractions of uranium dispersion targets with uranium densities ranging from 3 to 9 g·U/cm^3 are given in Table 1. The mixed powder compacts were sandwiched between 6061Al plates and hot rolled into target plates with a thickness of 1.5 mm at 500°C. Blister tests were conducted at 485°C for 1 hour to check the bonding integrity of the dispersion targets. Cross-sectional microstructures of the fabricated targets were observed by scanning electron microscopy. Additional heat treatments were applied to the targets for further reaction of the uranium particles and the aluminum matrix at 700°C for 1 to 4 hours.

Table 1. Comparison of uranium densities and U-235 content in a HEU target, an LEU target and a high density LEU target with a meat volume of 4 cm^3.

Target	Enrichment	Uranium Density	Uranium Content	U-235 Content
HEU target	93%	1.4 g·U/cm^3	5.6 g	5.2 g
LEU target	<20%	2.6 g·U/cm^3	10.4 g	2.1 g
High Density LEU target	<20%	6.5 g·U/cm^3	26.0 g	5.2 g

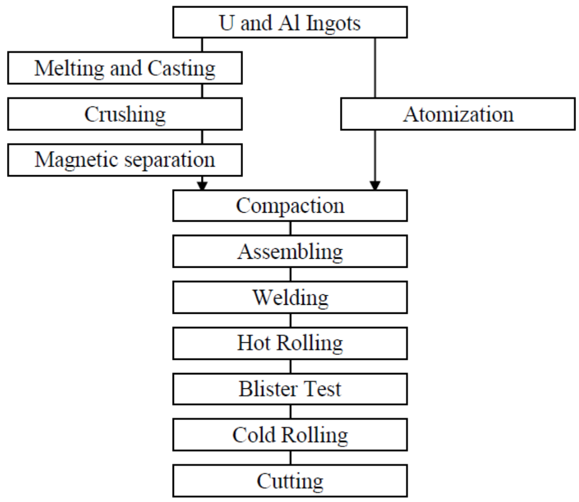


Fig. 1. A flow chart for fabrication of dispersion target plates: (left) the conventional route, (right) new route using atomized powder.

3. Results and discussion

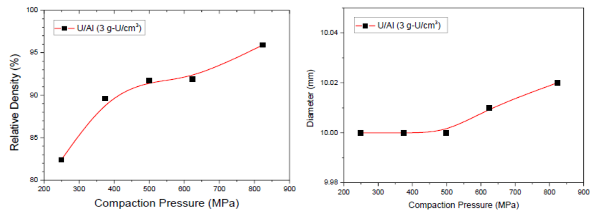
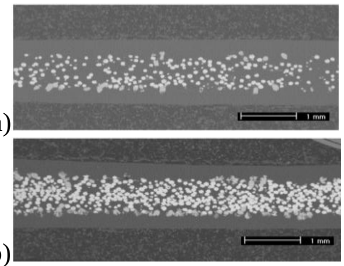


Fig. 2. Compaction behavior of U/Al mixed powder. (a) Relative density of compacts; (b) Springback property



(a)

(b)

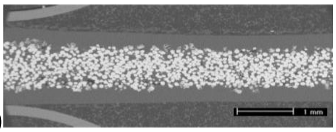
(c) 

Fig. 3. Cross section microstructures of uranium particle dispersion target plates. (a) 3 g-U/cm^3, (b) 6 g-U/cm^3, (c) 9 g-U/cm^3.

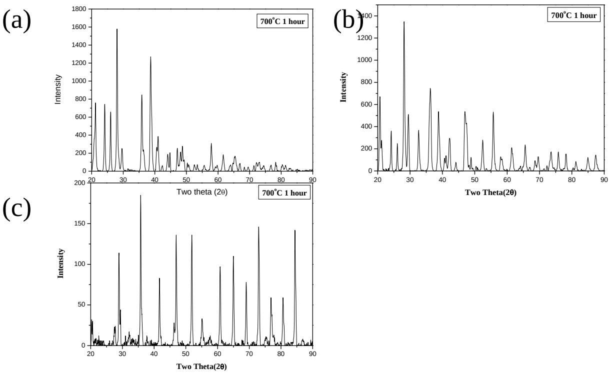


Fig. 4. XRD patterns of UAl_x formed by annealing
(a) 3g-U/cm^3 (b) 6g-U/cm^3 (c) 9g-U/cm^3, heat treated at 700℃ for 1 hours

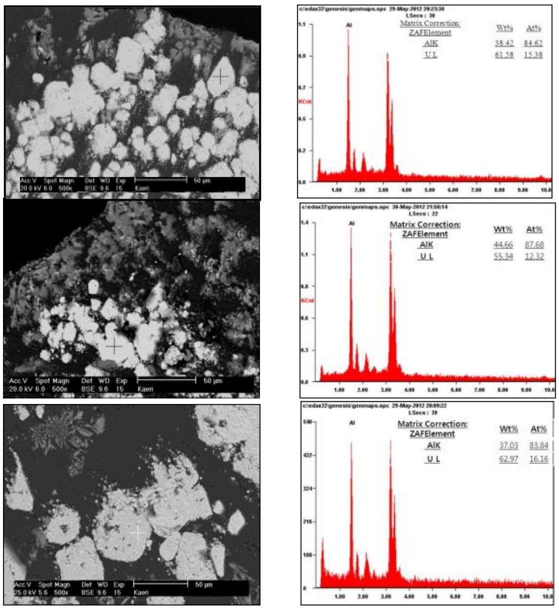


Fig. 5. SEM micrographs and their EDS spectrum showing the variation of U-Al composition of 6g-U/cm^3 with increasing annealing time(1,2,4 hours, 700℃)

Compaction behavior was evaluated by measuring the green densities and radial springback of the U/Al compacts. Compaction pressure is the main parameters controlling the green properties of U/Al compacts. The relative density of U/Al mixed powder compacts increases up to 95% with a compaction pressure from 250 MPa to 800 MPa, and the radial springback also increases up to 0.2% with the compaction pressure, as shown in Fig. 2. The springback should be measured to design the compaction die cavity and Al sandwich frames because the final width of dispersion meat is determined by the initial compact width

The transverse cross-section image of a 3, 6, 9g-U/cm^3 mini -size target is shown in Fig. 3. The mini-size target was fabricated successfully using a hot rolling method, and had 1.5mm thickness of the included UAl_x powders. Also, annealing was performed after hot rolling at 500℃. The agglomeration of UAl_x could not be found.

Fig. 4 shows XRD patterns obtained after the heat treatment at 700℃ for 1hour. The growth of UAl_3 and UAl_4 was observed at 3, 6, 9g-U/cm^3 heat treated samples.

The microstructure of 6g-U/cm^3 mini-size target after heat treatment at 700℃ for 1, 2, 4 hours was observed by scanning electron microscopy and performed EDS analyses as shown Fig. 5.

It was confirmed that uranium particles reacted with the aluminum matrix. The variation of UAl_x composition is not much among the heat treated samples, because uranium particles and aluminum were reacted thoroughly in 1hour.

4. Conclusions

- An mini-size dispersion target with atomized uranium particles up to 9 g-U/cm^3 were fabricated by hot rolling at 500°C.
- Atomized uranium particles react with the aluminum matrix to form UAl_x phases during the fabrication processes.
- Most of the uranium particles in the dispersion targets were converted into UAl_x after annealing at 700°C.

ACKNOWLEDGMENTS

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