DEVELOPMENT of TECHNOLOGY for MANUFACTURING of PLATE TYPE TARGETS for FISSION Mo-99 PRODUCTION

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1. INTRODUCTION

Mo-99 at CCHEN: Current Production

Currently CCHEN produces ^{99m}Tc by Neutron Activation of purified molybdenum trioxide (Merck ® MoO_3) in RECH-1 research reactor.

Production capacity (weekly): 20 capsules with 40 g of MoO_3 each one, irradiated by 18-24 hours.

Coverage limited to capital city (Santiago) and surroundings.
Current week production: 3 – 7 Ci (average)

The improvement of production of Mo-99 at CCHEN have the objective to satisfy the national demand, which reaches 55 Ci per week.

R&D in Mo-99 at CCHEN

Between 2005 and 2011, CCHEN participated in an IAEA CRP "Developing Techniques for Small Scale Indigenous ^{99}Mo Production using LEU Fission or Neutron Activation"

Achievements: Production of thin uranium foils, assembly and disassembly of tube targets, cold dissolution tests, separation and purification of solutions, calculations, design and manufacture of irradiation devices.

Pending activities: (not completed in the CRP)
Safety Analyses, Target irradiation in reactor, Cintichem process with irradiated LEU, recovery of Mo-99, purification of the solution through ion exchange columns, irradiated waste management, quality controls of purified Mo-99 solution, validation for radiopharmaceutical use

R&D Project: Development of Technology for Manufacturing of Plate type targets for Fission Mo-99 Production

Period: 2021 – 2026
Main goal: Development of manufacturing technology of dispersion type targets
Stages:
1. Phase transformations observed in dispersions of uranium compounds in aluminium matrix, considering manufacturing parameters and heat treatment conditions for phase transformations of the U-Al system.

2. Develop the technology for manufacturing plate-type targets based on UAlx compounds dispersed in aluminum matrix.

3. Develop the radiochemical-metallurgy processes of dissolution, separation, extraction and purification of the ^{99}Mo.

4. Study the irradiation conditions and the radioactive activity that would be generated in the target once irradiated, in positions of known fluxes, inside the core of the RECH-1 reactor.

5. Develop treatment and management technologies for radioactive waste generated from fission ^{99}Mo production processes

2. MATERIALS AND METHODS

Manufacturing of tube type targets

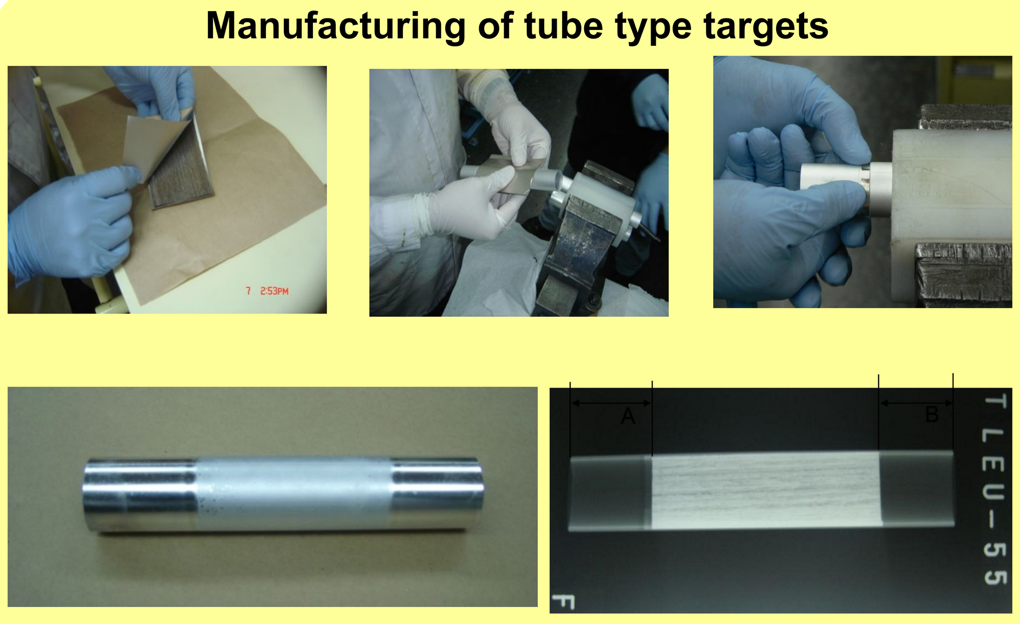


Figure 1. Annular (tube) type target manufacturing. Final product and industrial radiography examination

Phase transformation study

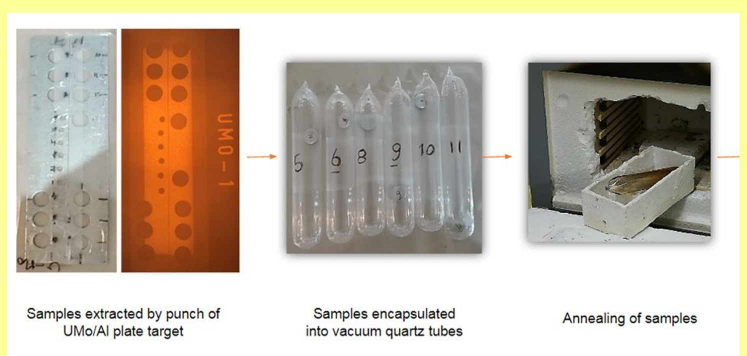


Plate of U-Mo alloy
2 – 48 Hrs
550°C
Vacuum

U-10 wt% Al alloy
5 Hrs
950°C
Vacuum

Figure 2. Phase transformation test: Thermal treatment of samples of UMo plate type target Below, vacuum thermal treatment of U-10 wt% Al alloy lumps, wrapped into copper envelope

Manufacturing of dispersion type targets

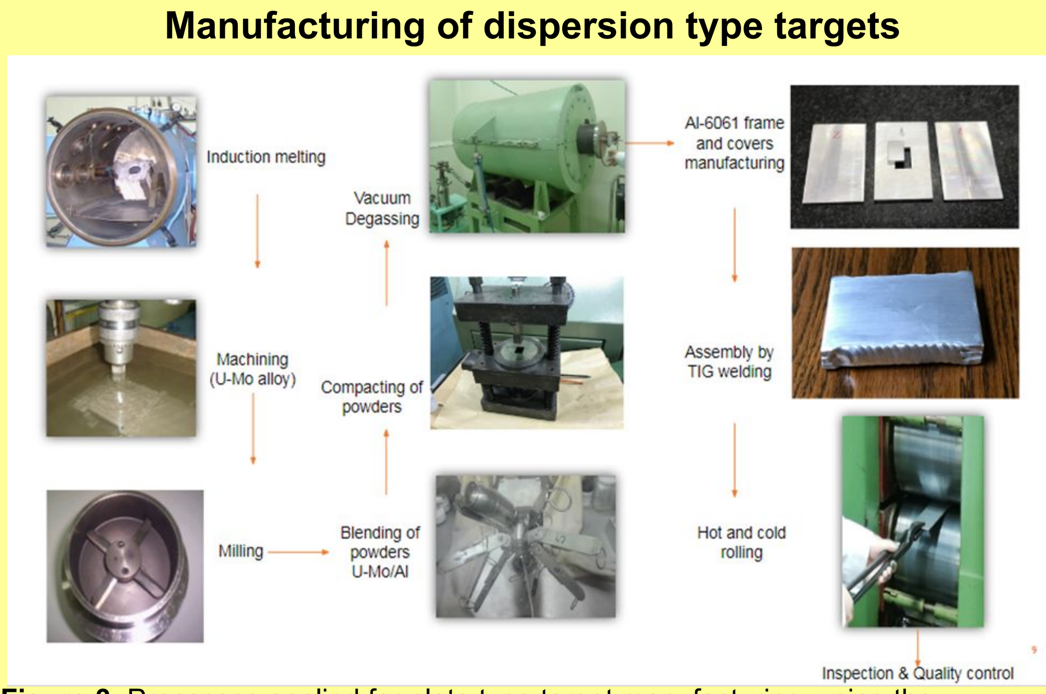
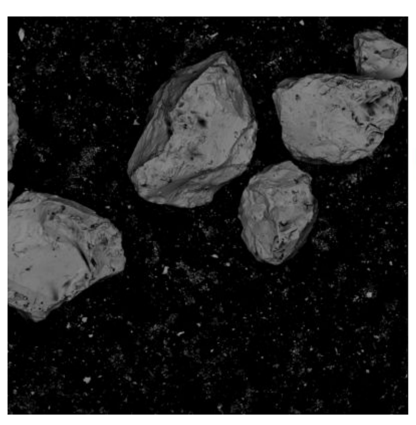
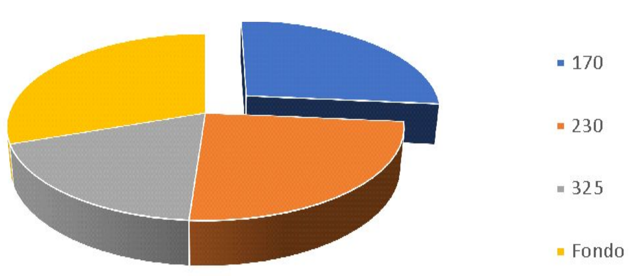
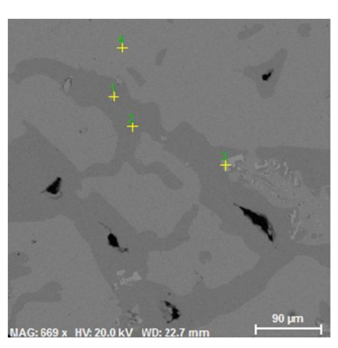


Figure 3. Processes applied for plate type target manufacturing, using the picture-frame technique usually applied for plate type nuclear fuel production

3. RESULTS & DISCUSSIONS







Punto	Fase	U (% peso)	Al (% peso)	O (% peso)	Compuesto	Sistema
1	Óxido	91,22	0,09	8,68	UO2	Cúbico
2	Gris oscuro	73,82	25,24	0,95	UAl3	FCC
3	Gris claro	77,35	21,13	1,51	UAl2	FCC
4	Gris	80,75	18,32	0,93	UAl2	FCC

Figure 4. SEM image and particle size distribution. Cross section of U-Al alloy sample before dispersion. Punctual microanalysis results

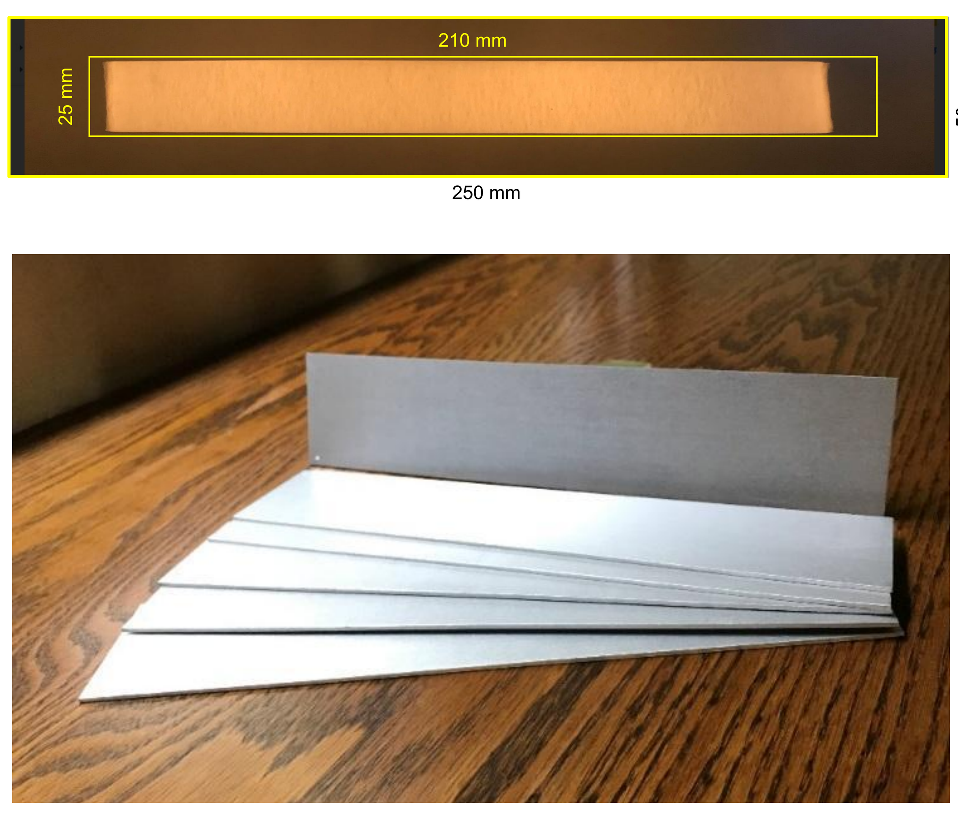
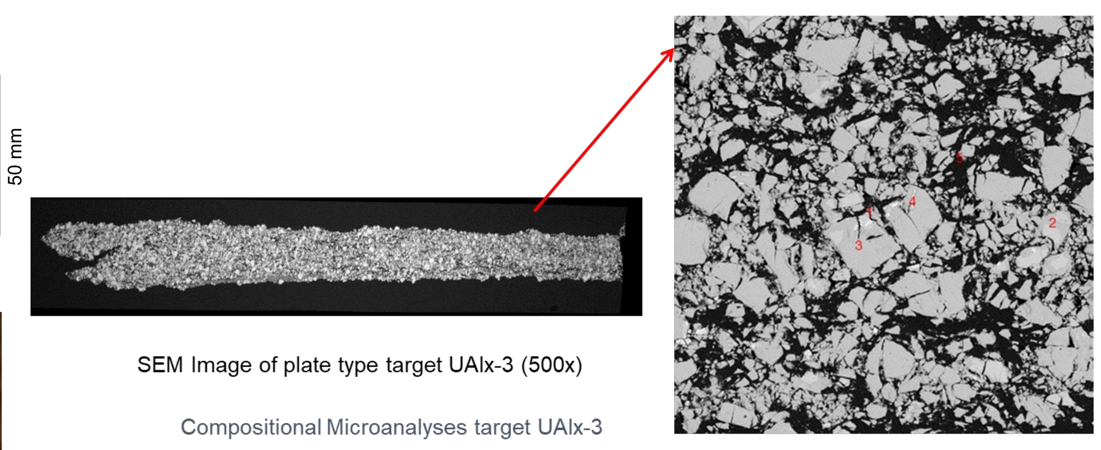


Figure 5. Final products: Plate type targets based on UAlx particles dispersed in aluminum matrix. Radiograph of plate



SEM Image of plate type target UAlx-3 (500x)

Compositional Microanalyses target UAlx-3

	Punto	Fase	U (% peso)	Al (% peso)	O (% peso)	Compuesto	Sistema
Placa UAl-3	1	Blanco	96,57	0,52	2,91	Uα	Ortorrómbico
	2	Gris claro	74,26	24,78	0,96	UAl3	FCC
	3	Gris	67,94	31,10	0,96	UAl4	Ortorrómbico
	4	Gris	69,50	28,57	1,93	UAl4	Ortorrómbico
	5	Matriz	0,72	93,21	5,80	Al	FCC

Figure 6. SEM images. Cross section of target UAlx-3, end zone showing dog-bone area. Minimum cladding thickness: 0.32 mm. Zoom image and microanalysis results.

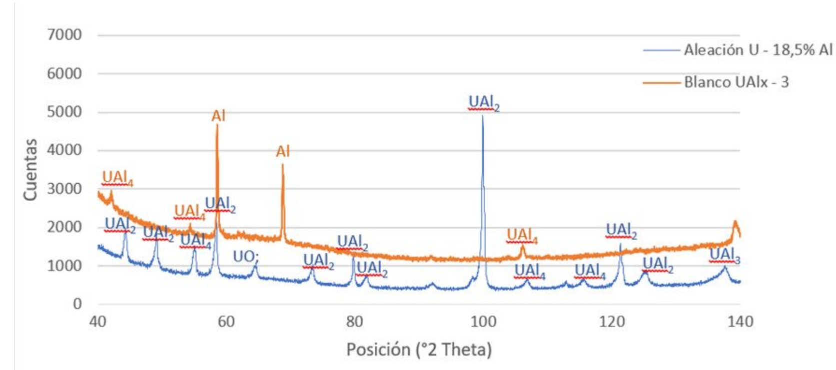


Figure 7. XRD patterns comparison between as-cast UAlx alloy and cross section sample of UAlx-3 plate type target.

4. CONCLUSIONS

It was possible to obtain a dispersion of particles of the U-7%Mo alloy in an aluminium matrix with proper characteristics for dispersion type targets for fission Mo-99 production.

Both in the centre of the particles and in the interface, it was possible to verify the formation of uranium aluminides such as UAl_2, UAl_3, and UAl_4 in thermal treatments carried out at 550°C, from 2 to 48 hours.

Observing the evidence of the formation of aluminides, it is concluded that, by means of a thermal treatment carried out at 550°C for around 14 hours, an equilibrium is achieved between the formation of aluminides at the centre of U-Mo particles and the presence of UAl_2, UAl_3, and UAl_4 in all its volume.

At times greater than 24 hours, the UAl_4 compound is the predominant constituent, and then the reactions in the particles have already reached a stable state.

By means of induction melting was possible to obtain stoichiometric (U-18.5wt% Al) and hypo stoichiometric (U –10 wt% Al) alloys, from which particles could be obtained by mechanical comminution with proper characteristics for plate type targets.

Using validated methodologies for nuclear fuel production, it was possible to design and manufacture targets in miniplate format with different uranium densities. Using non-destructive testing methodologies, supplemented with a metallographic study and SEM and XRD analysis, it was possible to characterize and verify the compliance and specifications of the manufactured targets. The results of the characterization are consistent with the reports of other manufacturers of this type of target.

CCHEN can offer and supply tube and plate types targets for fission Mo production, manufactured according to technical specifications and the own requirements of users.