INTERDIFFUSION BETWEEN U-Mo ALLOYS AND Al OR Al ALLOYS AT 340 ºC. IRRADIATION PLAN

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ABSTRACT

Out of reactor interdiffusion experiments between U-Mo alloys and Al alloys made close to fuel operation temperature are needed to validate the results obtained above 500 ºC.
A study of interdiffusion between U-Mo and Al or Al alloys, out and in reactor, has been initiated. The objective is to characterize the interdiffusion layer around 250 ºC and study the influence of neutron irradiation. Irradiation experiments will be performed in the argentine RA3 reactor and chemical diffusion couples will be fabricated by Friction Stir Welding (FSW) technique.
In this work out-of-pile diffusion experiments performed at 340ºC are presented. Friction Stir Welding (FSW) was used to fabricate some of the samples. One of the results is the presence of Si, in the interaction layer, coming from the Al alloy. This is promising in the sense that the absence of Al rich phases may also be expected at low temperature.

1. Introduction

The dispersion of U-(7wt% to 10wt%)Mo alloy particles in Al matrix considered to perform well under irradiation in miniplates experiments [1], showed non desirable behaviors in full-size qualifying experiments [2, 3]. They were attributed to a large interaction between U-Mo particles and the Al of the matrix. The extent and properties under irradiation of the reaction (due to interdiffusion) are important in U-Mo /Al dispersion fuel. It has been suggested that the modification of the Al matrix by a convenient alloying of the Al could change the interaction layer and improve its irradiation behavior [4].
Out-of-pile interdiffusion experiments between U-Mo and Al have been performed at temperatures above 300 ºC [5,6,7], for the case of Al alloys the temperatures were above 500 ºC [6]. The reduction in the annealing temperature implies very long term experiments. Nevertheless, these kind of experiments, made close to fuel operation temperature, are needed to validate the results obtai ned at high temèratures.
A long term study of interdiffusion between U-Mo and Al or Al alloys, out and in reactor, has been initiated, to characterize the interdiffusion layer at low temperature (around 250 ºC) and to study the influence of neutron irradiation.
In this work out-of-pile diffusion experiments performed, in a first stage, at 340ºC are presented. Friction Stir Welding (FSW) was used to fabricate some of the samples to corroborate the use of this technique in diffusion couples at low temperatures. This technique appears to be more suitable to fabricate couples to be irradiated than the ones made with clamps because it enables to encase a foil of U-Mo alloy in Al alloy as in the case of monolithic fuel elements (MFE) [8,9]. In the fabrication of a MFE, two cladding of Al plates are welded face to face with the metallic foil in between them. In this

way, the foil is bonded to the cladding. The smear of the Al onto the surface of the foil gives a good interfacial contact without stirring the fuel foil into the Al.
The irradiation device to perform the experiments in the RA3 reactor, Argentina, is also presented. First experiments will be done using depleted U and future experiments will include the use of 20% enriched uranium.

2. Experimental

Diffusion experiments
Materials employed in this study were an arc-melted U–7wt% Mo alloy, pure Aluminium and two commercial Al alloys: Al6061 (1wt%Mg and 0.6wt%Si) and AA635 (0.4wt%Mg and 7wt%Si). The U-Mo alloy was homogenized in composition by a thermal treatment of 2 hs at 1000°C.

Three chemical diffusion couples were prepared, two by FSW and the other one using a mechanical clamp. Diffusion anneals were performed at 340°C during 52 d, Table I.
Optical Microscopy (OM), SEM and EDAX were used to characterize the reaction layers´s constituents.

	Components	Preparation	Temp (ºC)	time (d)
Sample 1	Al6061/U-Mo/Al6061	FSW	340	52
Sample 2	AA635/U-Mo/Al	FSW	340	52
Sample 3	AA635/U-Mo/Al	Clamp	340	52

Table 1. Experimental details

Irradiation experiments
The irradiation will be made in the RA3 reactor and the selected position is in the bottom of the core, in a box where the thermal flux is $1x10^{14}n/cm^2s$. Samples to irradiate will be fabricated by FSW. A foil of U-Mo alloy of (10x3x0.5) mm will be encased in Al alloy. The final size to accommodate in the irradiation box will be (130x35x3) mm with a guide to slide in position.
FEM simulation codes were used to calculate the temperature profile in the samples during the irradiation. Samples under this flux and with an enrichment of 0.2% were estimated to reach, nearly, the cooling water temperature (40ºC).
It is planned to irradiate at different fluencies and to perform PIE in hot cell in due time.
It is expected to evaluate the effect of neutron irradiation on interdiffusion at low temperature.

3. Results

At 340º C interdiffusion was observed at both interphases on *sample 1* made by FSW with a thickness no large than 3 □m. No voids or debonding were observed, Fig.1.
XRD could not be performed to determine the structures in the interaction layer due to its small thickness. Concentration measurements made by EDAX on *sample 1* indicated the presence of silicon in the interaction layer, Fig.2. The Si content in it, ~3 wt%, was greater than the one in the alloy, 0.6wt%, table I. *Samples 2* and *3* are being subjected to a diffusion anneal till 03/04/05. Results will be presented at the meeting.

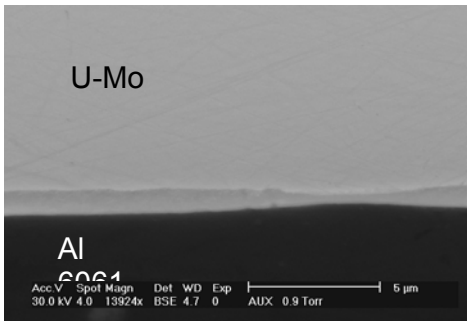

Fig. 1: Sample 1. Interaction layer between U-7w%Mo/Al 6061. 340ºC, 52 d. Backscattered image.

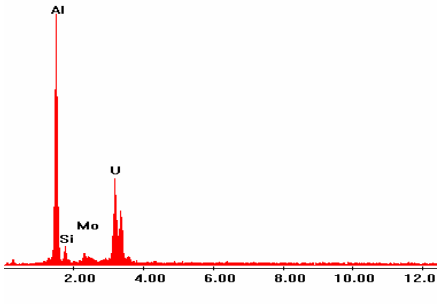

Fig. 2: Sample 1. EDAX spectrum on the interaction layer shown in Fig.1.

The irradiation plan has been presented to the Regulatory Authority and its approval is being awaited to start the irradiations.

4. Discussion and summary

In a previous work [9] FSW was successfully used to prepare diffusion couples which annealed at 550ºC gave satisfactory results. This work indicates that FSW remains valid for low temperature diffusion anneals.
In diffusion experiments performed between U-Mo and Al alloys, at 550ºC [10] the presence of Si in the interdiffusion layer, was associated to the existence of the phase $(U,Mo)(Al,Si)_3$ and the absence of $(U,Mo)Al_4$. Although in this work no structure identification of the phases that constitute the interaction layer was made, the presence of Si is promising in the sense that the absence of Al rich phases may be also expected at low temperature.

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6. References

[1] M. K. Meyer, G.L Hofman, S.L. Hayes, C.R. Clark, T. C. Wiencewk, J.L. Snelgrove, R. V. Starin, K.H. Kim, "Low temperatures irradiation behavior of Uranium- Molybdenum Alloy Dispersion fuel". J. Nucl.Mat.,304, (2002), 221-236.

[2] L.M. Hamy, P. Lemoine, F. Huet, B. Guigon, C. Jarousse, J. Emin, "Status as of March 2004 of the French Umo Group Development Program". 8th International Topical meeting Research Reactor Fuel management (RRFM), Munich, Germany, March 21-24, 2004.

[3] A. Leenaers, S. Van den Berghe, E. Koonen, C. Jarousse, F. Huet,, M. Trotabas , M. Boyard, S. Guillot, L Sannen , M. Verwerft, "Post-irradiation examination or Uranium-7wt%Molybdenum Atomized dispersion fuel". J. Nucl. Mater.335 (2004) 39-47.

[4] G.L. Hofman, M.R. Finley, Y-S. Kim. “Post-irradiation analysis of U-Mo/Al dispersión fuels miniplate test, RERTR 4 & 5”. 2004 International Meeting on Reduced Enrichment for Research and Test Reactors, Vienna, Austria, November 7-12, 2004[5] Ho Jin Ryu, Young Soo Han, Jong Man Park, Soon Dal Park, Chang Kyu Kim. “Reaction layer growth and reaction heat of U-Mo/Al dispersion fuels using centrifugally atomized powder”. Journal of Nucl. Mater. 321 (2003) 210-220.

[6] M. I. Mirandou, S. N. Balart, M. Ortiz, M. S. Granovsky. “Reaction layer in U- 7wt%Mo /Al diffusion couples”. J. of Nucl. Mater, 323, (2003), 29-35.

[7] D.Sears, A.Davidson, J.Mason, C.Buchanan and P.Ryan. 2004 International Meeting on Reduced Enrichment for Research and Test Reactors, Vienna, Austria, November 7-12, 2004]

[8] C.R. Clark, T. C. Wiencewk, M.R. Finlay, R. L. Briggs, D. M. Wachs, S.L. Hayes, G.L Hofman, C. J. Mothershead. “Update on fuel fabrication development and testing at Argonne National Laboratory”. 2004 International Meeting on Reduced Enrichment for Research and Test Reactors, Vienna, Austria, November 7-12, 2004.

[9] P. Cabot, A. Monglioni, M. Mirandou, S. Balart. “CNEA experiments to apply Friction Stir Welding to encase U-Mo foils in Al”. 2004 International Meeting on Reduced Enrichment for Research and Test Reactors, Vienna, Austria, November 7-12, 2004.

[10] M. Mirandou, M. Granovsky, M. Ortiz, S. Balart, S. Aricó and L. Gribaudo. “Reaction layer between U-7wt%Mo and Al alloys in chemical diffusion couples”. 2004 International Meeting on Reduced Enrichment for Research and Test Reactors, Vienna, Austria, November 7-12, 2004.