Heavy Ion Irradiation of UMo/Al Dispersion Fuel

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1. Introduction

For the conversion of the FRM II fuel element from highly enriched Uranium (HEU) to Uranium of lower enrichment (MEU) Uranium-Molybdenum (UMo) alloys dispersed in an Aluminum matrix are one option. However, it has been found that the performance of dispersed UMo/Al nuclear fuel suffers from an undesired interdiffusion-layer (IL) which builds up at the interface between the UMo particles and the surrounding Aluminum. In 2006 it has been shown, that it is possible to emulate this IDL out-of-pile using a heavy ion beam (^{127}I at 80MeV) within some hours. Because the energy of the ions is below the Coulomb barrier the UMo samples are not activated during heavy ion irradiation. They are therefore easily accessible with normal laboratory equipment (SEM, EDX, XRD) [1]. Since then, considerable progress has been made to improve the reliability of this method. In collaboration with CEA-Cadarache TUM has build up a complete new irradiation setup at the tandem accelerator in Garching (Maier-Leibnitz Laboratorium) which allows to monitor and control the irradiation conditions like flux, fluency, vacuum and sample temperature automatically. The new setup allows the quick irradiation of different kinds of samples. Consequently we have started two independent irradiation campaigns.

2. Methodological approach

In 2008, it has been found that the IDL of in-pile irradiated U7wt%Mo/Al samples consists of an amorphous U-Al compound [2]. In contrast, in 2007 it has been found that the IDL of in-pile irradiated UMo/Al samples consists mainly of UAl_3 [3]. Up to now, the IDL formed during heavy-ion bombardment was found to consist of UAl3. Together CEA we started an experimental campaign to determine the irradiation conditions which lead to the formation of an amorphous and a crystalline IDL, respectively. For this reason we have irradiated 10 U7wt%Mo/Al samples provided by CERCA at different conditions (temperature, angle of the incoming ion beam, fluency). Post irradiations examinations to specify the composition of the IDL created during heavy-ion bombardment are underway at the CEA facility in Cadarache and at the beamline ID22 at ESRF which provides intensive X-ray radiation at a nanometric scale.

3. Prevention of the IL formation

To qualify UMo as a nuclear fuel the formation of the undesired IDL at the UMo-Al interface has to be suppressed. It has been found that there are in principal three possibilities to overcome this problem:

a Addition of a diffusion limiting element to the Al-matrix containing the UMo particles (e.g. Si, Ti, Bi)

b Creation of a ternary UMo alloy by adding another element (e.g. Nb or Pt)

c Insertion of a diffusion barrier between the interface UMo-Al (e.g. a thin layer of Zr or a UO2 layer)

d Any combination of a, b and c

Since the new heavy-ion irradiation setup allows the fast screening of different samples at the exact same irradiation conditions, CERCA provided in total 20 different dispersed UMo-Al samples for testing. The first batch of samples consists of U8wt%Mo particles dispersed in an Aluminum matrix which contains different concentrations of a second element (e.g. 2wt%Si, 5wt%Si, 2wt%Bi, 5wt%Bi). Each of those samples has been produced with and without an UO2 layer at the interface UMo-Al as a diffusion barrier. The second batch of samples consists of 4 different ternary UMo alloys dispersed in a pure Aluminum matrix. The aim of this irradiation campaign is to find the most promising material combination for a future in-pile test.
From the 20 miniplates provided by CERCA, in total 60 samples have been prepared for irradiation with ^{127}Iodine at 80 MeV. First irradiations have been performed since fall 2008 with an integral of $1x10^{17}$ ions/cm for each sample. This corresponds to a full burn-up of a high flux research reactor. The irradiation temperature was ≈200°C. The irradiation campaign will be finished until summer 2009. Examinations on already irradiated samples are ongoing. The full set of data will be available until end of 2009.

References

[1] N. Wieschalla *et al.* Journal of Nuclear Materials **357** (2006) 191-197
[2] S. Van den Berghe *et al.* Journal of Nuclear Materials **375** (2008) 340-346
[3] K. Conlon *et al.*, *Neutron Powder Diffraction of UMo Fuel irradiated to 60at% 235U burn up*, RRFM 2007, Lyon, France, 2007