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Ph D proposal

Metallurgical microstructure characterisation of U-Mo alloys used in monolithic MTR fuel plate production

Description and objectives of the project

Background

In the search for a suitable fuel to replace the high enriched UAl_x fuel generally used in Research and Materials Test Reactors (MTR) with a lower enrichment fuel (<20% $^{235}U/U_{tot}$), one viable candidate is a U-Mo alloy. Mo is added to metallic uranium to extend the stability domain of the gamma phase, since this phase is stable under the desired irradiation conditions in contrast to the room temperature alpha phase. 7-10 wt% Mo is sufficient to avoid transformation to the alpha phase during the production process.
The highest fuel density can be reached with so-called "monolithic" fuel plates, in which a foil of U-10wt% Mo is sandwiched in between 2 Al alloy cladding plates. If the foil is in direct contact with the cladding during its stay in the reactor, the foil will interact with this Al cladding, resulting in the formation of a brittle interface layer [1]. The interaction product, which is also amorphous [2], has poor characteristics as a host for fission products (FP), particularly gaseous FPs (Xe) and poor mechanical resistance. To improve the behaviour of the foil during manufacturing and in the reactor, interlayers are applied to provide a better bonding and to reduce the interaction between the foil and the cladding. Zr and Si are the most promising candidates for the interlayers, where Zr layers are corolled during the foil production and Si is plasma sprayed on the finished foil. In the final production step, the foil is bound to the cladding by a welding process, such as Friction Stir Welding (FSW) or Hot Isostatic Pressing (HIP).
A lot of issues still exist in the reliable, industrial production of monolithic fuel plates, most of which are related to the foil production itself and the debonding of the foil and the cladding, either during manufacturing or during their use in the reactor. Until now, most research was focused on the production process and a better understanding of the basic microstructural characteristics (eg. dislocation structure, surface chemistry, texture, stress, etc.) of the U(Mo) foil during all steps of the production process and finally as a component of the fuel plate is required to advance the development and the qualification of U(Mo) fuel as a viable alternative for the existing fuel types. The obtained knowledge will also serve as a backbone for the qualification of the dispersion U(Mo) fuel, since the interaction phenomena will be the same.

Project description

This research project is aimed at improving the metallurgical knowledge on the U-10wt% Mo alloy used in monolithic fuel production. A full microstructural characterisation of typical foils (crystallography, grain structure and orientation, lattice defect structure, surface chemistry, etc.) needs to be performed, mainly using Transmission Electron Microscopy (TEM) and X-ray Photoelectron Spectroscopy (XPS), particularly concentrating on the interface of the fuel with the interlayer and the interlayer with the cladding. Thermal treatments offer a way to systematically assess the evolution of the interface with time and temperature. If required, the results will be complemented by the other characterisation techniques (Optical Microscopy (OM), Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), etc.). The mechanism by which the interlayers improve the bonding of the foil to the cladding and reduce the interaction between fuel and cladding, both during fabrication and during irradiation, will be studied. Aside from work on interfaces of real foils in fuel plates, model systems of interfaces can be manufactured and treated in our laboratory by sputter

deposition. This effectively allows a separate effects study of the fuel/cladding interface. Furthermore, TEM sample preparation procedures will have to be developed, building on existing knowledge, but optimising for the specific goals.
As-produced materials are available at LHMA (foils and miniplates, made with Zr and Si, both using HIP and FSW) through a collaboration with Idaho National Labs (INL), who are manufacturing monolithic fuel plates. The candidate will get the opportunity to perform several stays at their facilities. Efforts are also being made to allow transports of irradiated monolithic test plates or samples thereof to our laboratory for analysis. Furthermore, the candidate will have opportunities to interact with the University of Central Florida (Prof. Y.Sohn), who are performing characterisation of diffusion couples in the same systems, using FIB/TEM [3].

[1] A. Leenaers, S. Van den Berghe, E. Koonen, C. Jarousse, F. Huet, M. Trotabas, M. Boyard, S. Guillot, L. Sannen and M. Verwerft, J. Nucl. Mater. 335 (2004) 39-47.
[2] S. Van den Berghe, W. Van Renterghem and A. Leenaers in: Proceedings of the 29th International Meeting on Reduced Enrichment for Research and Test Reactors (RERTR), Prague, Czech Republic (2007).
[3] E. Perez, A. Ewh, J. Liu, B. Yuan, D. D. Keiser Jr. and Y. H. Sohn, J. Nucl. Mater. 394 (2009) 160-165.

<u>Targeted profile</u>

Master in Sciences, Master in Applied Sciences

<u>Administrative details</u>

The first round for applications proceeds via the *aspirant* channels of the FWO with a deadline on Feb. 1, 2010. Please check out www.fwo.be and follow "subsidiewijzer" – "predoctorale mandaten" – "Aspirant". If this is not clear, please contact Dr. Van Renterghem.

The work will be performed at the nuclear center SCK in Mol and the University of Antwerp.

<u>Contact persons</u>

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