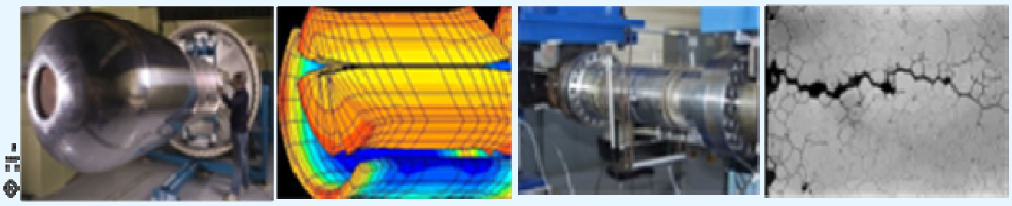
MINOS

Centre of Excellence for Nuclear Materials

Workshop

Materials Innovation for Nuclear Optimized Systems



December 5-7, 2012, CEA – INSTN Saclay, France

Rudy J. M. KONINGS et al.

JRC-ITU and University of Delft (Netherlands)

Nuclear Reactor Fuels: Materials with Highly Complex Behaviour

Workshop organized by:

Christophe GALLÉ, CEA/MINOS, Saclay – christophe.galle@cea.fr

Constantin MEIS, CEA/INSTN, Saclay – constantin.meis@cea.fr

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Nuclear Reactor Fuels: Materials with Highly Complex Behaviour

Rudy J. M. KONINGS[1, 2], Dario MANARA[1], Ondrej BENEŠ[1], Christine GUÉNEAU[3]

[1]European Commission, Joint Research Centre, Institute for Transuranium Element (Karlsruhe Germany
[2] Delft University of Technology, Faculty of Applied Sciences (Delft, The Netherlands)
[3]CEA-DEN-DPC, Service de la Corrosion et du Comportement des Matériaux dans leur Environnement, SCCME (Saclay, France)

This lecture will principally focus on the high temperature characterisation of nuclear fuel materials, which is a challenging task. Nuclear fuels are highly complex materials. They operate under extreme conditions such as high temperatures (up to 1500 K for conventional Light Water Reactors, 2400 K for Fast Neutron Reactors), in intense radiation fields and undergo significant changes in chemical composition during their life. In case of accidental conditions, the fuel may experience even more extreme conditions that may result in melting or reactions with cladding and/or coolant. This will be explained in a general introduction.

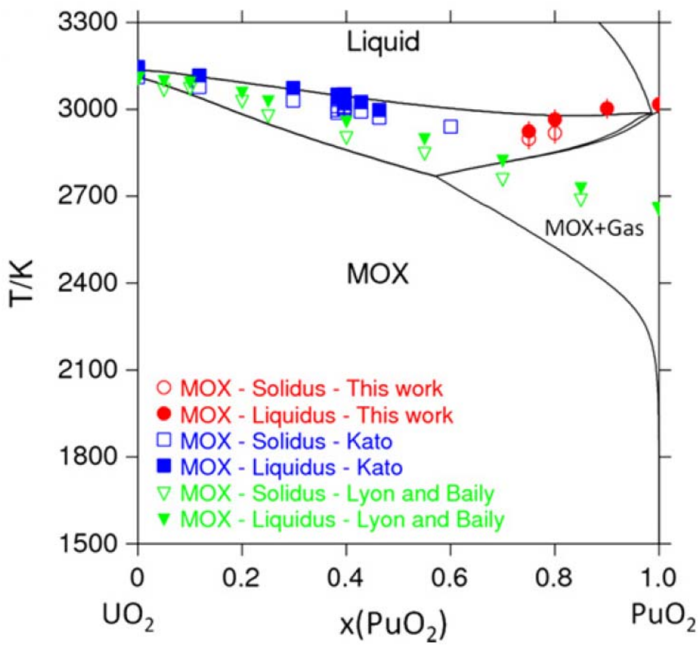

Fig. 1: The UO_2-PuO_2 section of the ternary U-Pu-O phase diagram optimized by CALPHAD [1] taking into account recent experimental results. The UO_2-PuO_2 solid solution is indicated as MOX. Empty and full red circles represent new experimental results [2].

The main part of the lecture will address the high temperature properties of UO_2 and PuO_2, the main components of current nuclear fuels, and their solid solution. Also the high temperature properties of the minor actinide oxides will be discussed, in view of their recycling in fast reactor fuels (transmutation). Extensive studies have been performed on particularly UO_2 and PuO_2 in 1950s and 1960s that have laid the foundation for our current understanding of these materials. The available data from that research has been gathered in numerous assessments but are not always conclusive. This is generally due to the high oxygen potential and the reactivity with container materials that might affect experiments at high temperatures. For that reason we have performed new experimental studies, when possible using innovative experimental approaches.

The experimental work includes melting point studies by laser heating (self-crucible), vapour pressure measurements by Knudsen effussion mass spectrometry, and calorimetry, and yielded is some cases remarkable differences with the literature [2]. For the interpretation of the results a close link with thermodynamic modelling has proven to be extremely useful, as will be demonstrated. As an example the optimised phase diagram of the UO_2-PuO_2 system, based on new results from laser heating experiments and the CALPHAD assessment, is given in Figure 1.

References

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