Journal of Nuclear Materials 494 (2017) 165–171

Contents lists available at ScienceDirect

Journal of Nuclear Materials

journal homepage: www.elsevier.com/locate/jnucmat

TEM and XAS investigation of fission gas behaviors in U-Mo alloy fuels through ion beam irradiation

Hang Zang [a], Di Yun [a, b, e, *], Kun Mo [b], Kunpeng Wang [d], Walid Mohamed [b], Marquis A. Kirk [b], Daniel Velázquez [c], Rachel Seibert [c], Kevin Logan [c], Jeffrey Terry [c], Peter Baldo [b], Abdellatif M. Yacout [b], Wenbo Liu [a], Bo Zhang [a], Yedong Gao [a], Yang Du [a], Jing Liu [a]

[a] Department of Nuclear Science and Technology, Xi'an Jiaotong University, Xi'an, 710049, China
[b] Argonne National Laboratory, Argonne, IL 60439, USA
[c] Illinois Institute of Technology, Chicago, IL 60616, USA
[d] Nuclear and Radiation Safety Center, No. 54 Hongliannancun, Haidian District, P.O. Box8088, Beijing 100082, China
[e] State Key Laboratory of Multi-phase Flow in Power Engineering, Xi'an Jiaotong University, Xi'an, 710049, China

ARTICLE INFO

Article history:
Received 12 December 2016
Received in revised form
29 June 2017
Accepted 15 July 2017
Available online 17 July 2017

Keywords:
Metallic alloy fuels
U-Mo alloy
Fission gas behaviors
Xe bubble
Ion irradiation
XAS

ABSTRACT

In this study, smaller-grained (hundred nano-meter size grain) and larger-grained (micro-meter size grain) U-10Mo specimens have been irradiated (implanted) with 250 keV Xe^+ beam and were in situ characterized by TEM. Xe bubbles were not seen in the specimen after an implantation fluence of 2×10^{20} ions/m^2 at room temperature. Nucleation of Xe bubbles happened during heating of the specimen to a final temperature of 300 °C. By comparing measured Xe bubble statistics, the nucleation and growth behaviors of Xe bubbles were investigated in smaller-grained and larger-grained U-10Mo specimens. A multi-atom kind of nucleation mechanism has been observed in both specimens. X-ray Absorption spectroscopy showed the edge position in the bubbles to be the same as that of Xe gas. The size of Xe bubbles has been shown to be bigger in larger-grained specimens than in smaller-grained specimens at the same implantation conditions.

1. Introduction

U-Mo metallic alloys have been extensively used for the Reduced Enrichment for Research and Test Reactors (RERTR) program, which is now known as the Office of Material Management and Minimization under the Conversion Program, as research and test reactor fuels [1–5]. These fuels are in forms of either monolithic plates or dispersion plates in which U-Mo fuel particles are embedded in Aluminum cladding. U-Mo alloys have also been proposed as metallic fuel candidates for fast reactors due to their ideal thermal properties [6]. In addition, an ongoing effort is investigating the behavior of these alloys along with U-Zr alloys under fast reactor irradiation conditions [7]. U-Zr binary alloy fuels and U-Pu-Zr ternary alloy fuels exhibit zoned microstructures according to their relatively complicated phase diagrams [8]. In contrast, U-Mo alloy fuels stay in a single irradiation stabilized γ phase. As such, the use of U-Mo alloy fuels have the potential to eliminate some of the issues related to zone formation in U-Zr alloy fuels.

However, there is a significant lack of experimental data of this fuel form under fast reactor operation conditions. An early work by a French team has investigated the behaviors of U-8Mo (8 wt percent Mo) annular fuels under fast neutron irradiations [6]. This is, as far as we know, the only relevant data set available to date. Consequently, in order to qualify U-Mo alloy fuels as fast reactor fuel, systematic assessments need to be carried out. The necessary assessments would need to include investigations on the fission product migration behaviors within the fuel, the chemical compatibility of the fuel with the designated cladding material, the fission gas swelling and release behaviors, etc. These assessments would be unavoidably associated with in-reactor tests which are

* Corresponding author. Department of Nuclear Science and Technology, Xi'an Jiaotong University, Xi'an, 710049, China.
E-mail address: diyun1979@xjtu.edu.cn (D. Yun).

http://dx.doi.org/10.1016/j.jnucmat.2017.07.033
0022-3115/