Journal of Nuclear Materials 442 (2013) S251–S255

Contents lists available at SciVerse ScienceDirect

Journal of Nuclear Materials

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

Effects of helium and deuterium irradiation on SPS sintered W–Ta composites at different temperatures

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ARTICLE INFO

Article history:
Available online 14 March 2013

ABSTRACT

Energetic He^+ and D^+ ions were implanted into different W–Ta composites in order to investigate their stability under helium and deuterium irradiation. The results were compared with morphological and chemical modifications arising from exposure of pure W and Ta. Special attention was given to tantalum hydride (Ta_2H) formation due to its implications for tritium inventory. Three W–Ta composites with 10 and 20 at.% Ta were prepared from elemental W powder and Ta fibre or powder through low-energy ball milling in argon atmosphere. Spark plasma sintering (SPS) was used as the consolidation process in the temperature range from 1473 to 1873 K. The results obtained from pure elemental samples and composites are similar. However, Ta_2H is easily formed in pure Ta by using a pre-implantation stage of He^+, whereas in W–Ta composites the same reaction is clearly reduced, and it can be inhibited by controlling the sintering temperature.

1. Introduction

The high melting point, high sputtering threshold and low tritium inventory of W rendered it as a potentially suitable material for extensive use in high-flux components and structural applications in fusion devices [1–3]. However, W is brittle at low and moderate temperatures, which results in intense thermal stress during operative thermal cycling events or plasma disruptions [4], in component fracture and high-Z contamination of the plasma. The development of new W alloys involving other refractory metals is an attractive way to solve this problem [1]. A parallel approach involves the production of W refractory composites with improved ductility and toughness with respect to pure W by adding a Ta component in a W matrix. Ta has low neutron activation and high radiation resistance, ductility and toughness relative to those of W, and transmutes to W under high-energy neutron irradiation, retarding the formation of the brittle *sigma* phase of the W–Os–Re diagram [5]. Metastable W–Ta composites are expected to provide optimized irradiation performance and higher fracture toughness at low temperatures than that of pure W. Hydrogen diffusion in Ta is also higher than in W at RT and the diffusion gap will increase at higher temperatures. W and Ta have body-centred cubic (bcc) structures, thus presenting low activation energies for hydrogen diffusion [6]. Nevertheless, the lattice parameter is larger in the Ta crystalline structure, leading to higher diffusivities [6–8] and, possibly, to low hydrogen retention.

W–Ta composites with improved toughness, high densities and, as a consequence, higher thermal conductivities were recently produced by alloying Ta short fibres in a W powder matrix (W–Ta_f fibre composites) [9]. The use of coarse components, low milling energies during mechanical alloying (MA) and consolidation via spark plasma sintering (SPS) at temperatures lower than 1573 K minimizes W and Ta interdiffusion and formation of the equilibrium solid solution [10] thus preserving phase separation and the individual properties of the components [9]. As a consequence, the behaviour of the individual phases in the consolidated composites should be comparable to those expected for pure W and Ta targets under the same irradiation conditions. Despite the promising features of the new W–Ta composites, the behaviour of these materials under irradiation remains unknown. In this work, two W–Ta_f fibre composites and one W–Ta powder composite produced with coarse elemental components and Ta contents of 10 or 20 at.% were irradiated by energetic He^+ and D^+ ion beams in or-

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http://dx.doi.org/10.1016/j.jnucmat.2013.02.068