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Blistering of W–Ta composites at different irradiation energies

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ABSTRACT

Pure tungsten and tantalum plates and tungsten–tantalum composites produced via mechanical alloying and spark plasma sintering were bombarded with He^+ and D^+ energetic ion beams and deuterium plasmas. The aim of this experiment is to study the effects caused by individual helium and deuterium exposures and to evidence that the modifications induced in the composites at different irradiation energies could be followed by irradiating the pristine constituent elements under the same experimental conditions, which is relevant considering the development of tailored composites for fusion applications. Higher D retentions, especially in tungsten, and superficial blistering are observed in both components after helium exposure. The blistering is magnified in the tantalum phase of composites due to its higher ductility and to water vapour production under deuterium irradiation. At lower irradiation energies the induced effects are minor. After plasma exposure, the presence of tantalum does not increase the D content in the composites.

1. Introduction

Tungsten (W) was select for an extensive use in fusion devices due to its excellent properties as high melting point, sputtering threshold or low tritium retention [1]. Nevertheless, it also presents unsolved limitations arising from inappropriate ductile-to-brittle transition temperatures (DBTTs). It is crucial to improve the ductility in W materials in order to avoid intense thermal stress in operative plasma scenarios. An obvious way to solve this problem is to alloy W with other ductile refractory metals which also present low neutron activation [2] and recently refractory W composites were pointed as a promising alternative to pure W [3]. Depending on the processing parameters used the phases of a composite can remain quite separated within the microstructure. Notably when a moderate sintering time/temperature is used during the consolidation route, extensive interdiffusion between the components can be avoided [4]. As a result, a composite should reveal the individual properties of the pristine phases, as ductility, DBTT, toughness, thermal conductivity, fuel retention or radiation resistance. This feature seems to be obvious and is important viewing the future development of tailored composites for fusion applications.

Besides other promising features, tantalum (Ta) presents the superior ductility of group V-B [5,6]. The addition of a small amount of Ta in a W composite structure could improve the ductility of a W based material. Thus, the use of W–Ta composites are promising for applications in fusion devices as in different helium cooled divertor concepts [2,7]. It is mandatory to evaluate the behaviour of the materials under irradiation. This is commonly performed in irradiation campaigns involving energetic deuterium (D) and helium (He) beams and D plasmas [8–11].

The aim of this experiment is to assess the behaviour of W–Ta composites as PFM and as structural materials by evaluating chemical and structural changes arising from individual He and D irradiations in a wide impinging energy range and to compare them with the effects induced in pure W and Ta plates exposed under the same irradiation conditions.

2. Experimental procedure

W–Ta composites presenting Ta contents of 10 and 20 at.% were fabricated by alloying W powder (99.95% with a particle size of 1 μm) with Ta powder (99.9+%, particle size of 75 μm, powder

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