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Structure and phase composition of tungsten alloys modified by compression plasma flows and high-intense pulsed ion beam impacts

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ABSTRACT

The results of structure and phase composition change in tungsten after compression plasma flow and high-intensive pulsed ion beams impacts are discussed. The compression plasma flows with the absorbed energy in range 35–70 J/cm^2 were used for the sub-surface modification. The preliminary Ti coating deposition on the tungsten surface allowed us to form W-Ti alloys by plasma flows treatment. The layer of the W-Ti alloy consists of solid solutions W(Ti) and β-Ti(W) as well as nitride phase (Ti,W)N. The high-intensive pulsed ion beam impact provides the tungsten carbide W_2C formation in the sub-surface layer. When forming the W-Ti alloy the carbon ions implanted into the tungsten take part in the carbo-nitride (Ti,W)(N,C) formation without brittle W_2C phase.

1. Introduction

Tungsten is considered as a main plasma facing material for ITER and DEMO because of its low sputtering yield, high melting point and high thermal conductivity [1–3]. During the operation of a fusion reactor the tungsten-contained parts will be subjected to high thermal influences and mechanical loads during the plasma disruptions and the plasma direct interaction with the first-wall material. Besides, the tungsten will be irradiated with neutrons or different ions, like helium, deuterium, tritium, that are produced in the thermonuclear reactions. A lot of radiation effects like blistering, flecking or bubbles formation take place during the irradiation [4–6]. As tungsten possesses a low temperature of brittle-to-ductile transition, the surface will be cracked and eroded that will promote to the plasma contamination with the eroded products. The tungsten atoms transport to the plasma and retard the reaction [7]. So, it is necessary to minimize the high-Z elements ejection into the plasma for the reaction stabilization. The formation of the tungsten-based alloys with additional elements can be considered as a promising approach for this purpose. The addition of other elements into the tungsten matrix changes the elastic and ductile properties influencing on the crack formation and surface erosion processes. However, to produce a tungsten-based alloy by any tradition methods connected to heating, melting and casting is a rather difficult problem because of the high melting point of tungsten. The powder technologies are unsuitable for the first-wall materials production.

In the present work the problem of tungsten-based alloys synthesis is solved by mean of high-energy compression plasma flow application. Such plasma flows with a high directly speed, high energy and pulse duration about 100 μs are generated by quasi-stationary plasma accelerators. Directed dense plasma flows with small divergence and high energy (up to several tens of J/cm^2) allows one to modify a layer with a thickness of tens of micrometers in an extremely short time 100 μs. The previous results showed the possibility to use the compression plasma flow (CPF) impact for alloying of the sub-surface layers of materials with other metals deposited as a thin coating on the surface [8–10]. The energy of the plasma flow is enough for melting of both the coating and a part of the substrate. The melted state of two (or more) metals is mixed in hydrodynamic mode and fixed after solidification.

The main purpose of the work is to produce the tungsten-titanium alloy by CPF impact on the bi-layered Ti/W system. Ti was used as an alloying material because of decreasing in Young's modulus in W-Ti alloys comparable to that of pure tungsten. Moreover, the ductility of the W phase is reported to be improved through Ti alloying and metallic bonding [11]. As the main aim of producing the tungsten-based alloy is to improve its mechanical properties under the ion irradiation, the obtained alloys were testing on the structure and phase composition

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