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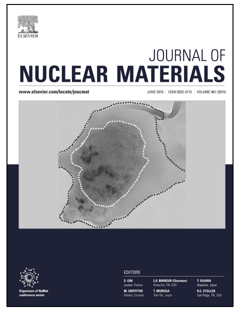

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Characterization of Dose Dependent Mechanical Properties in Helium Implanted Tungsten

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Abstract

In this work, we utilized spherical nanoindentation to investigate the mechanical property changes of helium (He) implanted tungsten (W) at different damage doses. According to the indentation stress-strain curve, two dose dependent phenomena were revealed: one is an increase in yield stress with increasing damage dose, and the other is enhanced softening following yield. Experimental measurements such as transmission electron microscopy (TEM) and positron annihilation spectroscopy (PAS) techniques, as well as molecular dynamics (MD) simulation were combined to explore the intrinsic mechanism of the dose dependent phenomena. This study proposed an efficient and promising way to measure the damage of the plasma facing materials and established an effective correlation between the mechanical property changes of He implanted W and its microstructure evolutions.

Keywords: Tungsten, He implantation, Mechanical properties, Spherical nanoindentation, Molecular dynamics

1. Introduction

With its favourable physical properties, such as low sputtering yield, high thermal conductivity and high melting temperature, tungsten (W) has become one of the most promising candidates for plasma facing materials (PFMs) in the ITER and DEMO [1]. In a deuterium-tritium (D-T) fusion reaction, a 14.1 MeV neutrons is produced and leads to continuous production of both helium (He) and hydrogen (H) by (n,p) and (n,α) nuclear reactions [2, 3]. A damage level of 0.6 displacements per atom (dpa) would be reached in 3 months in DEMO, which is expected to do tremendous damage on surrounding materials [2, 3]. It is well known that an important role is played by He, which is formed by transmutation and is implanted directly into the tungsten [3, 4]. To investigate damage effects, He implantation experiments with keV He ion energy and fluencies from 10^{14} to 10^{17} ion/cm^2 are usually applied to simulate particle irradiation effects on materials in fusion reactors [4-7]. Noteworthy, He implantation is prone to induce significant degradations of serve performances, such as a decreased thermal conductivity [5] and a degradation of mechanical properties [6]. Hardening and embrittlement, which are the main mechanical performance of irradiated materials, are supposed to cause a steep increase in yield stress and a decrease in ductility [8]. Consequently, the materials tend to fail by brittle cleavage fracture once