Irradiation resistance of $W_xTaTiVCr$ high entropy alloy for fusion plasma facing material.

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1. Introduction

Tungsten (W) is favorite plasma facing material for future fusion reactors due to its high melting point, good mechanical properties, good thermal conductivity and low sputtering erosion [1, 2]. The applications of pure W in service conditions of forthcoming fusion power plants are constrained due to its high brittleness and irradiation induced embrittlement [3]. Therefore, a high entropy alloy WxTaTiVCr, which (i) satisfies reduced activation criteria, (ii) exhibits promising strength and hardness and (iii) shows significant ductility when reinforced with W-based reinforcements, is being exploited [4]. These promising characteristics don't only shed the light on its applications in a future fusion reactor, but also emphasized upon a thorough analysis of its irradiation resistance. A certain level of irradiation damage can alter material's properties thereby risking the safe operation of a fusion power plant. Therefore, the irradiation behavior of WxTaTiVCr, via analysis of He+ ions [5], H+ ions [6] and electrons [7] irradiated samples is under–way. The progress of our study is being presented in this paper, which will be useful for the researchers working on fusion reactor materials as the fusion reactors (DEMO and ITER) contains mixture ionized and energetic neutral hydrogen isotopes (D and T) and He ash [8].

2. Methods and Results

2.1 Experimental

The highly pure elemental powders of W, Ta, Ti, V and Cr were mixed via a 3D mixer to prepare powder mixtures of $W_xTaTiVCr$. The sintering of powder mixtures was done by spark plasma sintering (SPS) under 50 MPa axial pressure in a vacuum environment. The sintering temperature and time were 1600^{o}C and 10 minutes, respectively. The room temperature irradiation of mirror polished WxTaTiVCr samples, with 200KeV He+ and 50KeV H+ ion irradiations were carried out at Korea Atomic Energy Research Institute (KAERI). The fluence of He+ and H+ ion irradiation was up to $1x10^{17}$ ions/cm^2 and $1x10^{15}$ ions/cm^2, respectively. A TEM sample was prepared via JET polishing. The electron irradiation under 1.24 MeV electrons up to a fluence of $1.12x10^{26}$/m^2 and in-situ TEM analysis, was done via High Voltage Electron Microscope (HVEM) at Korea Basic Science Institute (KBSI). The analysis of irradiation damage on the surface was carried out via scanning electron microscope (SEM). Interior of the irradiated material was characterized via transmission electron microscopy (TEM). The ~~E~~effect of irradiation on mechanical behavior was studied~~s~~ by ~~Nanoindentation~~ nanoindentation hardness test. The nanoindentation test was done with a Berkovich diamond tip (radius: 50 nm) in the load control manner by iNano (Nanomechanics, Inc., USA). The 45 mN was applied and loading rate and dwell time were 2 nm/sec and 15 s, respectively.

2.2 Results

Pure W shows a rough surface when subjected to 50 keV He+ ions up to a fluence of $3.55x10^{18}$/cm^2 [9], whereas the SEM microstructure of $W_xTaTiVCr$ doesn't show~~s~~ any damage, as shown in Fig. 1. The H+ ion irradiated samples also shows undamaged microstructure of the irradiated surface.

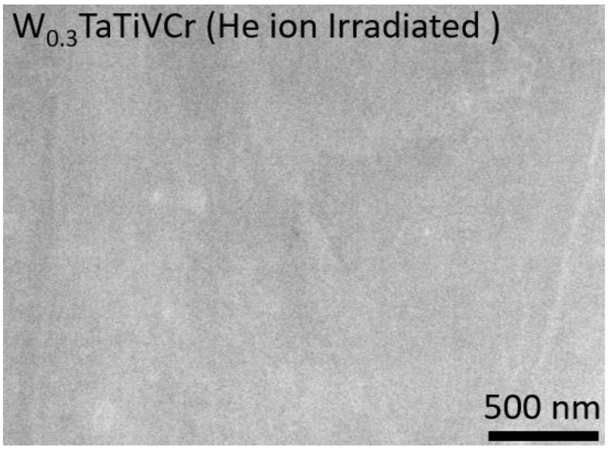

Fig. 1. The m~~M~~icrostructure of He+ ion irradiated $W_xTaTiVCr$ sample.

The TEM analysis of the irradiated materials shows a layer of irradiation damage in $W_{0.3}TaTiVCr$ up to ~200nm depth. The $W_{0.5}TaTiVCr$, having higher tungsten content in matrix material shows relatively less irradiation damage, as represented in Fig. 2.

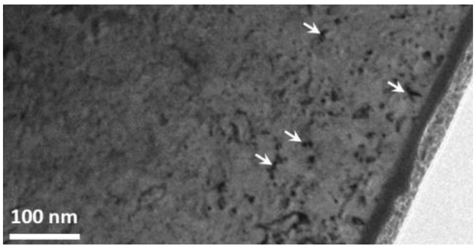

Fig. 2. TEM microstructure of He+ ion irradiated $W_{0.5}$TaTiVCr.

The variation in hardness due to irradiation was analyzed via nanoindentation test. Fig. 3 shows 10 GPa hardness of bulk $W_{0.3}$TaTiVCr, whereas the hardness of He+ ion irradiated material (near surface) is relatively higher (up to 14 GPa).

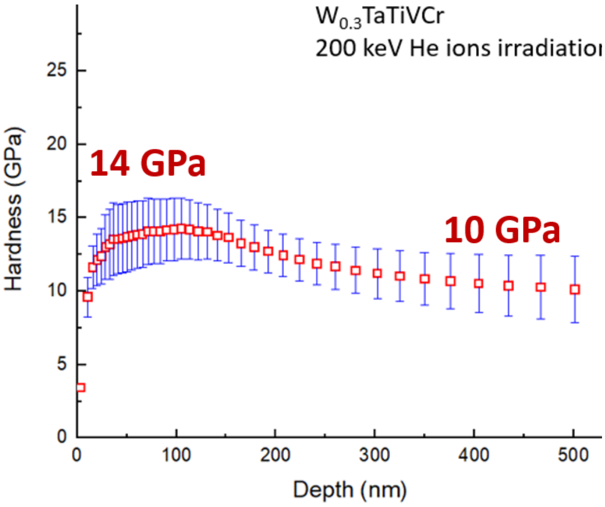

Fig. 2. Effect of 200 KeV He+ ions irradiation on the hardness of $W_{0.3}$TaTiVCr.

The electron irradiation of $W_{0.5}$TaTiVCr shows no dislocation loops due to its high resistance to electron irradiation unlike W, which shows development and growth of dislocation loops under similar irradiation conditions [7].

Irradiation damage in nanometer range in the interior of the material, no presence of irradiation induced surface roughness, a minor increase in hardness after He+ ion irradiation and high resistance to electron irradiation emphasize upon the potential applications of W_xTaTiVCr as fusion plasma facing material.

3. Conclusions

The analysis of electron and He+/H+ ion irradiation of WxTaTiVCr reveals enhanced irradiation resistance as compared to pure W. No surface roughness was observed due to ion irradiation. He+ ion irradiation produced a irradiation damage up to 200nm depth and increased hardness. No formation and growth of dislocation was observed under electron irradiation. The higher irradiation resistance highlights the potential fusion plasma facing application of this novel composites.

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