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Investigation Studies of WNbMoVTa and WNbMoVTaCr$_{0.5}$Al Refractory High Entropy Alloys as Plasma-Facing Materials

Authors : Burçak Boztemur, Yue Xu, Laima Luo, M. Lütfi Öveçoğlu, Duygu Ağaoğulları

Abstract : Tungsten (W) is used chiefly as plasma-facing material. However, it has some problems, such as brittleness after plasma exposure. High-entropy alloys (RHEAs) are a new opportunity for this deficiency. So, the neutron shielding behavior of WNbMoVTa and WNbMoVTaCr$_{0.5}$Al compositions were examined against He^+ irradiation in this study. The mechanical and irradiation properties of the WNbMoVTa base composition were investigated by adding the Al and Cr elements. The mechanical alloying (MA) for 6 hours was applied to obtain RHEA powders. According to the X-ray diffraction (XRD) method, the body-centered cubic (BCC) phase and NbTa phase with a small amount of WC impurity that comes from vials and balls were determined after 6 h MA. Also, RHEA powders were consolidated with the spark plasma sintering (SPS) method (1500 ºC, 30 MPa, and 10 min). After the SPS method, (Nb,Ta)C and $W_2C_{0.85}$ phases were obtained with the decomposition of WC and stearic acid that is added during MA based on XRD results. Also, the BCC phase was obtained for both samples. While the Al_2O_3 phase with a small intensity was seen for the WNbMoVTaCr$_{0.5}$Al sample, the Ta_2VO_6 phase was determined for the base sample. These phases were observed as three different regions according to scanning electron microscopy (SEM). All elements were distributed homogeneously on the white region by measuring an electron probe micro-analyzer (EPMA) coupled with a wavelength dispersive spectroscope (WDS). Also, the grey region of the WNbMoVTa sample was rich in Ta, V, and O elements. However, the amount of Al and O elements was higher for the grey region of the WNbMoVTaCr$_{0.5}$Al sample. The high amount of Nb, Ta, and C elements were determined for both samples. Archimedes' densities that were measured with alcohol media were closer to the theoretical densities of RHEAs. These values were important for the microhardness and irradiation resistance of compositions. While the Vickers microhardness value of the WNbMoVTa sample was measured as ~11 GPa, this value increased to nearly 13 GPa with the WNbMoVTaCr$_{0.5}$Al sample. These values were compatible with the wear behavior. The wear volume loss was decreased to 0.16×10^{-4} from 1.25×10^{-4} mm^3 by the addition of Al and Cr elements to the WNbMoVTa. The He^+ irradiation was conducted on the samples to observe surface damage. After irradiation, the XRD patterns were shifted to the left because of defects and dislocations. He^+ ions were infused under the surface, so they created the lattice expansion. The peak shifting of the WNbMoVTaCr$_{0.5}$Al sample was less than the WNbMoVTa base sample, thanks to less impact. A small amount of fuzz was observed for the base sample. This structure was removed and transformed into a wavy structure with the addition of Cr and Al elements. Also, the deformation hardening was actualized after irradiation. A lower amount of hardening was obtained with the WNbMoVTaCr$_{0.5}$Al sample based on the changing microhardness values. The surface deformation was decreased in the WNbMoVTaCr$_{0.5}$Al sample.

Keywords : refractory high entropy alloy, microhardness, wear resistance, He^+ irradiation
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