Advanced Physical Research
Vol.2, No.1, 2020, pp.48-55

SURFACE DYNAMICS OF TUNGSTEN MULTILAYERS ALLOYS UNDER HELIUM ION IRRADIATION

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Abstract. We have used the surface morphology of tungsten composite has been investigated under helium ions irradiation (2.5 MeV $^3He^+$ ions or 5.0×10^{20} ions/cm^2 at room temperature at Frank Laboratory for Neutron Physics Joint Institute for Nuclear Research (JINR) in Dubna, Russia). AFM results showed that the incident radiation resulted in elongated protrusions and happened surface degradation after ion irradiation. The results showed for the multilayers compounds before and after irradiation there are no indications of difference in crystallographic symmetry. The virgin samples contained the as the only electrically active defects. After irradiation the defects were introduced.

Keywords: *Tungsten composite, helium ions irradiation, defect formation, defect migration, surface morphology.*

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Received: *16 February 2020;* ***Accepted:*** *22 May 2020;* ***Published:*** *30 June 2020.*

1. Introduction

Today, all concepts of energy and energy extension have strategic importance. Increasing energy demand and limited energy resources have the whole world to seek clean and safe energy (Yıldırım *et al.*, 2016; Beril Tugrul *et al.*, 2016; Buyuk *et al.*, 2013). In today's world where energy is used as a criterion of development, the correct use of energy resources is always the main item for all developed or non-developed world states (Buyuk et al., 2014; Tashmetov et al., 2019). World energy consumption is increasing mainly through the series of activities that people want to do to ensure their well-being (Mirzayev, 2020; Mirzayev *et al.*, 2018). Considering in this context, with the increase in population, industrialization and technological development, energy demand is increasing day by day (Hashimov *et al.*, 2019). Today, energy sources that are not highly renewable are used in the world. When we look at the persentage of the world's primary energy consumption resources, it is seen that oil, coal and natural gas are the first places behind it (Buyuk & Beril Tugrul, 2014; Mirzayev *et al.*, 2020; Ozyurt *et al.*, 2015; Mirzayev *et al.*, 2018). When we evaluate the fossil fuels in terms of the sustainability of environmental and habitable world conditions within the framework of the future, the increase in greenhouse gases and carbon emissions, especially in the last century, cannot be ignored (Mirzayev *et al.*, 2019; Demir *et al.*, 2019; Mirzayev *et al.*, 2019). In this context, global climate changes constitute a separate issue that should be emphasized (Mirzayev, 2020). These global problems raise nuclear power plants as power generation plants other than fossil fuel power plants, which are base power plants and provide availability conditions in this context (Mirzayev *et al.*, 2019, Zaim *et al.*, 2016). Today, new technological applications are needed for fission-based nuclear power reactors and advanced nuclear power plants, which are commercialized power plants (Mirzayev *et al.*, 2020). With the increasing population in the 21st century as well as the developing industry and technology and in this context, it brings nuclear power plants as power generation plants other than fossil fuel power plants, which fulfill the availability conditions. For this reason, new technological applications are needed for fission-based nuclear power reactors and advanced nuclear power plants, which are commercialized power plants today (Beril Tugrul *et al*., 2015; Mirzayev *et al.*, 2019). More than 440 nuclear power reactors with a capacity of approximately 350 GWe have been operated in 31 different countries since the first commercial nuclear power reactors have been in operation since 1950 (Demir *et al.*, 2019). In addition to these facilities, there are 245 research reactors in 55 countries in total, which make up approximately 11% of the electricity produced reliably worldwide without releasing carbon and 60 reactors are currently under construction (IAEA, 2018). In the USA, there are 99 nuclear reactors in operation which meets 20% of its electricity generation from nuclear facilities in 2017 and 2 Nuclear reactors are still under construction (Demir et al., 2019; Agayev *et al.*, 2020; Aliyev *et al.*, 2020; Demir *et al.*, 2019). In Russia, which provides approximately 18% of the electricity generation from nuclear power plants, 35 nuclear reactors are in operation and 7 nuclear reactors are under construction. On the other hand, in France, which is one of the leading countries of Europe in terms of nuclear technology, 58 Nuclear power reactors are in operation and constitute 71.6% of the electricity production in the country (NUCLEAR Power Reactors in the world, IAEA, 2018). After the Fukushima nuclear accident, it closed 7 nuclear reactors and has 7 nuclear operations in Germany, and 13% of the electrical energy produced consists of nuclear power plants (IAEA, 2018).

2. Method of calculation

Tungsten composites were fabricated in the Particulate Material Laboratories of Istanbul Technical University using the mechanical alloying (MA) technique. The green bodies were sintered at 2550 °C for 2 h in a Linn™ HT-1800 high-temperature controlled atmosphere furnace with a heating and cooling rate of 5 °C/min under vacuum followed by inert Ar and reducing H_2 gas conditions. All the samples, which were irradiated during this investigation had a thickness in the range of 250±10 μm. The samples under statistical conditions (atmospheric pressure) irradiation was performed with 2.5 MeV $^3He^+$ ions (5.0×10^{20} ions/cm^2) at room temperature at Frank Laboratory for Neutron Physics Joint Institute for Nuclear Research (JINR) in Dubna, Russia. The temperature of the samples during irradiation did not exceed 50 °C (Buyuk, 2019; Ozyurt *et al.*, 2018; Buyuk *et al.*, 2012; Durmaz *et al.*, 2014; Buyuk *et al.*, 2015). The surface morphology (SEM) of samples were carried out at the room temperature using Scanning Electron Microscope (SEM) / HE-SE2 detector (ZEISS, ΣIGMA VP). SEM was also used to investigate particle size and microstructural of samples, which was performed under vacuum condition at 10^{-7} Pa generated by turbo-molecular pumps. The AFM analaysis of irradiated samples was investigated by using an atomic force microscope (Oxford Instruments, Jupiter XR, Asylum Research).

3. Results and discussion

Tungsten matrix composite materials were evaluated under four main titles as vanadium carbide (VC), titanium carbide (TiC) added tungsten carbide materials in different proportions by mass. Tungsten matrix composite materials specially produced in Istanbul Technical University Chemistry-Metallurgy Faculty, Metallurgical and Materials Engineering Department are given below. W- 6wt% VC- 2wt% TiC- 1wt% C. Vanadium carbide (VC), titanium carbide (TiC) and carbon (C) added materials added to the tungsten main matrix with different percentages are produced using mechanical alloying technique at different alloying times such as 6, 12, 24 hours (Akkas *et al.*, 2015; Ertuğrul *et al.*, 2018; Ertuğrul, 2017). The purity and initial dimensions of tungsten and additional additives used in experimental studies are shown in Table 1.

Table 1. Properties of materials used in experiments

Material	Purity %	Grain size (μm)
Tungsten (W)	99.9	17
Vanadium carbide (VC)	99.9	16
Titanium carbide(TiC)	99.9	15
Carbon (C)	99.9	21

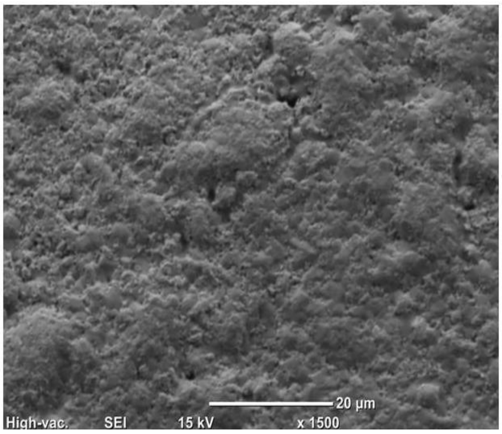
The studied materials were produced by using mechanical alloying technique in the SpexTM 8000D grinder using 1200 rpm tungsten carbide balls (6.35 mm diameter) and pressed under the pressure of 500 MPa with APEXTM 3010/4 hydraulic press. These pressed materials were sintered in LinnTM HT-1800 high temperature furnace for 1 hour at 1750 ºC (Demir et al., 2017; Beril Tugrul et al., 2015; Demir et al., 2014; Baytaş et al., 2013). Table 2 shows the codes, weight percentages, mechanical alloying times and properties of composite materials obtained by adding VC and VC-TiC to the tungsten matrix.

Table 2. Codes and properties of W-C-VC-TiC composite materials

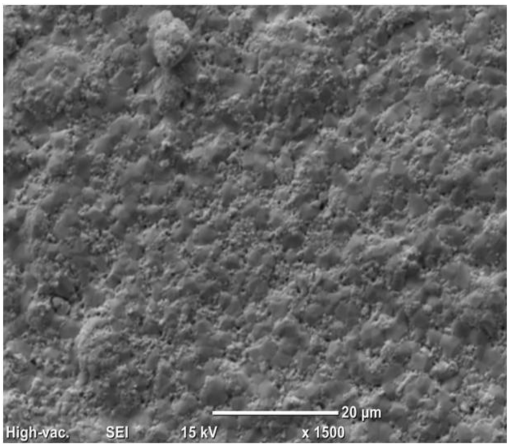
Material code	W (weight%)	VC (we.%)	TiC (we.%)	C (we.%)	Density (g/cm^3)	Duration of M.A (hour)	Diameter of samples (cm)
6V	93	6	-	1	16.80	6	1.2
12V	93	6	-	1	16.50	12	1.2
24V	93	6	-	1	16.46	24	1.2
6VT	91	6	2	1	16.21	6	1.2
12VT	91	6	2	1	15.56	12	1.2
24VT	91	6	2	1	15.44	24	1.2

Images of these studied materials were obtained and examined by scanning electron microscope (SEM). In this context, basic physical properties such as dispersion and homogeneity of powders were evaluated. Fig. 1 shows the images obtained by scanning electron microscopy (SEM) of W- 6wt% VC- 1wt% C and W- 6wt% VC- 2wt% TiC- 1wt% C composite materials produced by 6- hour mechanical alloying.

Fluctuation dynamics on the surface of samples were determined. The distributions on the surface of samples for irradiation doses are shown in Fig. 1. The results revealed that the distributions of sample were homogeneous on the surface. On the other hand, the distribution of elements on the surface was more homogenous compared to carbon alloys. In addition, it has also been reported to be technically difficult to completely remove these elements during the synthesis of samples. HE-SE2 detector was used to determine the chemical structure of the irradiated materials. As can be seen in Figure 1, although there is some homogeneity in the distribution of the elements, it is not the case for each element. Furthermore, although the sample has a high degree of purity, the emergence of the oxygen element in the analyses after ion irradiation concludes from the result of the chemical reactions forming the molecular oxygen. It should be noted that the SEM images of the samples were not taken during the ion irradiation. All measurements were performed at room temperature after irradiation. In the Figure 2 shows the 2D surface morphology images of tungsten alloys compounds initial and high energy helium ions irradiated dose at room temperature: A-initial part and B-irradiated part sample.



A-initial part



B-irradiated part sample

Fig. 1. SEM images of tungsten alloys compounds A-initial and B-after high energy helium ion irradiation

AFM images of tungsten alloys compounds samples are shown in Fig. 2. It should be noted that the AFM images of the alloy's samples were not taken during the ion irradiation. All measurements were performed at room temperature after irradiation. Degradation on the surface of the ion-irradiated tungsten alloys compounds was observed as can be seen from Fig. 2. The occurrence of amorphization of tungsten alloys compounds was seen in ion irradiation dose. The size of white clouds was measured and was found to be 20 µm while the particle size of tungsten compounds was 5 µm.

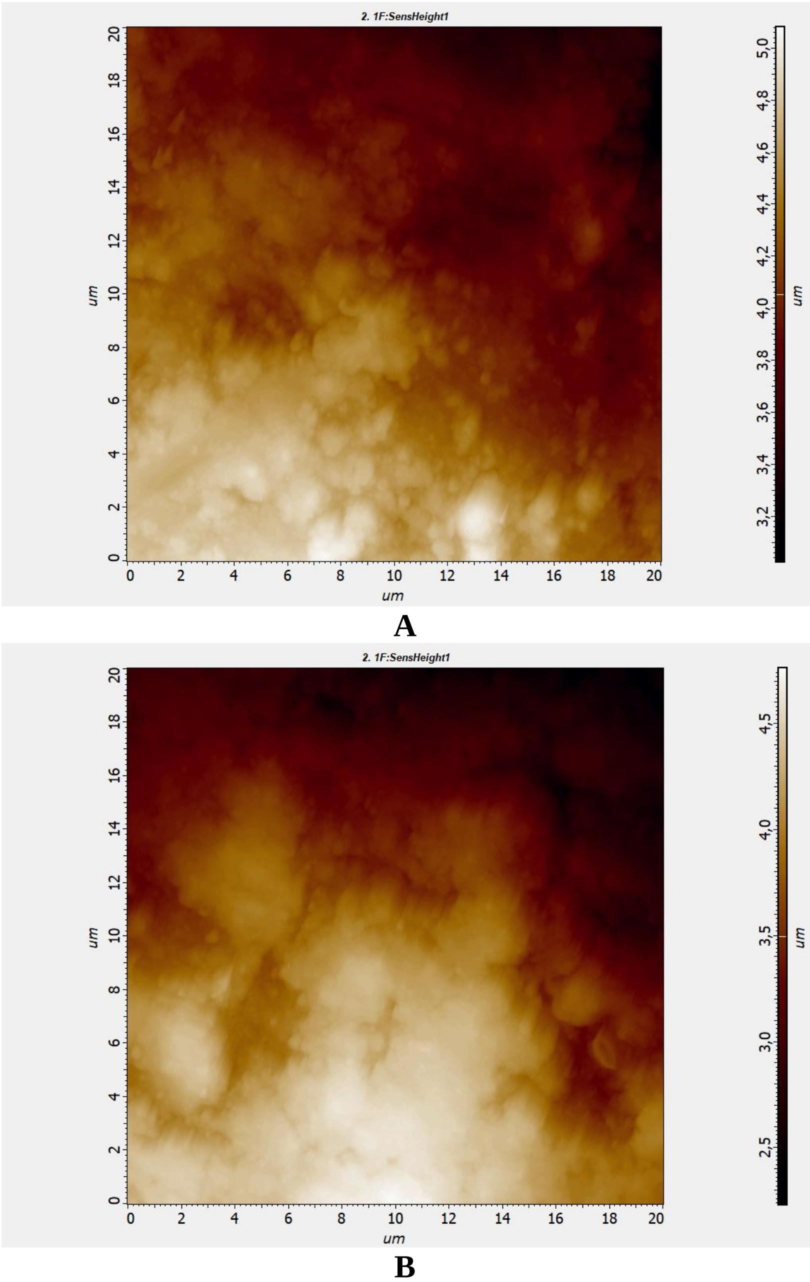


Fig. 1. AFM images of tungsten alloys compounds A-initial and B-after high energy helium ion irradiation

4. Conclusion

In the present work, W-C-VC-TiC composite materials samples were irradiated ~2-3 MeV with high energy ions beams of 5.0×10^{20} ions/cm^2 at the room temperature and density of ions beams was 0.03 μA. Specific surface area of the tungsten sample at a room temperature range for the non-irradiated sample the dimension of grains of different sizes in local locations is visible. Obviously, the initial sample contains swelling of different sizes and after irradiation increased of grains sizes. During helium irradiation, the large grains were "adsorbed" by small and medium grains. This process for multilayers samples is named "effects of grains transition". As a result, different size irradiation swelling was a formation of a larger affected cascade.

Acknowledgments

Author would like to thank Dr. E. Demir and Dr. Matlab N. Mirzayev for useful support in writing this article. The author also would like to thank Prof. E.Popov from the Flerov Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research.

References

Agayev, F.G., Jabarov, S.H., Ayyubova, G.Sh., Mirzayev, M.N., Trukhanov, S.V., Trukhanova, E.L., Darwish, M.A., Podgornaya, S.V., Vinnik, D.A., Hoang, T.P., Dang, N.T., Trukhanov, A.V. (2020). Structure and thermal properties of $BaFe_{11.1}In_{0.9}O_{19}$ hexaferrite. *Physica B: Condensed Matter*. 580, 411772.

Akkas, A., Beril Tugrul, A., Marsoglu, M., Addemir, O., Agacan, B., Buyuk, B. (2015). Radiation Shielding Effect of Boron Carbide Aluminum Metal Matrix Composite. *Acta Physica Polonica A*. 127, 947-949.

Aliyev, Y.I., Asadov, Y.G., Ilyasli, T.M., Mammadov, F.M., Naghiyev, T.G., Ismayilova, Z.A., Mirzayev, M.N., Jabarov, S.H. (2020). Structural aspects of thermal properties of AgCuS compound. *Modern Physics Letters B*, 34, 2050066.

Beril Tugrul, A., Demir, E., Yılmaz, O., Sönmez, S., Öveçoğlu, M.L., Buyuk, B. (2016). An Investigation on the Mass Attenuation Coefficients of W VC C and W VC TiC C Composites for Gamma Radioisotopes. *Acta Physica Polonica A*, *129*(4), 724-727.

Baytaş, A.F., Tugrul Beril, A., Gökbulak, F., Baydoğan, N., Altınsoy, N., Hacıyakupoglu, S., Yavuz, N., Erentürk, S., Büyük, B., Demir, E., Zeynep, C. (2013). Investigation of Salt Diffusion in Soil by Using Radiotracing Technique. *Defect and Diffusion Forum,* 274-278.

Beril Tugrul, A., Erentürk, S., Hacıyakupoglu, S.,Yavuz, N., Altınsoy, N., Baydoğan, N., Baytaş, A.F., Büyük, B., Demir, E., Sonay, G. (2015). Kinetic and Thermodynamic Behavior of Selenium on Modified Bentonite and Activated Carbon using Radiotracer Technique. *Acta Physica Polonica A*, *128*(2B), 180-182.

Buyuk, B., Beril Tugrul, A., Addemir, A.O., Ay, N. (2014). Gamma Attenuation Behaviour of h-BN and h-BN-TiB_2 composites. *Acta Physica Polonica A*, 125, 420-422.

Buyuk, B., Beril Tuğrul, A., Aktop S., Addemir A.O., Investigation on the Effects of Boron Carbide Particle Size on Radiation Shielding Properties of Boron Carbide_Titanium Diboride Composites. (2013). *Acta Physica Polonica A*, 123, 177-179.

Buyuk B., Beril Tugrul A. (2014). Comparison of Lead and WC-Co materials against gamma irradiation. *Acta Physica Polonica A*, 125, 423-425.

Buyuk, B. (2019). Gamma-Ray Attenuation Properties of Flexible Silicone Rubber Materials while using Cs-137 as Radioactive Source. *European Journal of Science and Technology*, 15, 28-35.

Buyuk, B., Beril Tuğrul, A., Akarsu, A.C., Addemir, A.O. (2012). Investigation of Behaviour of Titanium Diboride Reinforced Boron Carbide-Silicon Carbide Composites Against Cs-137 Gamma Radioisotop Source By Using Gamma Transmission Technique. *Acta Physica Polonica A*, 121, 135-137.

Buyuk, B. (2015). Gamma Attenuation Behaviour of Some Stainless and Boron Steels. *Acta Physica Polonica A*, 127, 1342-1345.

Demir, E., Beril Tuğrul, A., Büyük, B., Yılmaz, O., Övecoglu, M.L. (2018). Comparison of W-VC-C Composites Against Co-60, Se-75 and Sb-125 for Gamma Radioisotope Sources. *American Institute of Physics*. https://aip.scitation.org/doi/10.1063/1.5026012

Demir, E., Karabas, M., Sönmez, S., Tugrul Beril, A., Öveçoglu, M.L., Buyuk, B. (2017). Comparison of Radiation Properties of Tungsten and Additive Metal Coatings on 321 Stainless Steel Substrate. *Acta Physica Polonica A*, *131*(1), 71- 73.

Demir, E., Mirzayev, M.N., Beril Tugrul, A., Gledenov, Yu.M., Turchenko, V.A., Yılmaz, O., Büyük, B., Öveçoğlu. M.L. (2019). Investigations on surface morphologies, microstructure and thermal properties of tungsten-based composites. *Modern Physics Letters B*, *33*(19), 1950216.

Demir, E., Tugrul Beril, A., Baydoğan, N., Baytaş, A.F., Altınsoy, N., Hacıyakupoglu, S., Büyük, B. (2014). Evaluation of Rubidium and Potassium Diffusion in Soil by Radiotracer Technique. *Defect and Diffusion Forum*, 353, 199-204.

Durmaz H., Beril Tugrul, A., Buyuk, B. (2014). Evaluation of Gamma penetration through plain carbon steels. *Acta Physica Polonica A*, 125, 469-472.

Hashimov, R.F., Mikailzade, F.A., Trukhanov, S.V., Lyadov, N.M., Vakhitov, I.R., Trukhanov, A.V., Mirzayev, M.N. (2019). Structure and thermal analysis of $Ba_{0.5}La_{0.5}MnO_3$ polycrystalline powder. *International Journal of Modern Physics B*, 33, 1950244.

Mirzayev, M.N., Abdurakhimov, B.A., Jabarov, S.H., Tashmetov, M.Yu., Demir, E., Tiep, N.V., Ismayilova, N.A., Aliyev, Y.I., Popov, E., Mirzayeva, D.M., Karaaslan, S.I., Georgiev, G.I. (2020). Effect of high intense electron beam irradiation on structural and Raman properties of boron carbide micro powder. *International Journal of Modern Physics B*, *34*(04), 2050008.

Mirzayev, M.N., Mammadov, Kh.F., Skuratov, V.A., Demir, E., Jabarov, S.H., Ismayilova, N.A., Biira, S., Abdurakhimov, B., Popov E. (2019). Oxidation kinetics and thermophysical properties of gamma irradiated silicon hexaboride. *Journal of Alloys and Compounds*, *801*(15), 151-157.

Mirzayev, M.N., Mehdiyeva, R.N., Garibov, R.G., Ismayilova, N.A., Jabarov, S.H. (2018). Influence of gamma irradiation on the surface morphology, XRD and thermophysical properties of silicide hexoboride. *Modern Physics Letters B*, *32*(14), 1850151.

Mirzayev, M.N., Popov, E., Demir, E., Abdurakhimov, B.A., Mirzayeva, D.M., Sukratov, V.A., Mutali, A.K., Tiep, V.N., Biira, S., Tashmetov, M.Yu., Olejniczak, K., Kristavchuk, O. (2020). Thermophysical behavior of boron nitride and boron trioxide ceramics compounds with high energy electron fluence and swift heavy ion irradiated, *Journal of Alloys and Compounds*, 155119.

Mirzayev, M.N. (2020). Simultaneous measurements of heat flow rate and thermal properties of nano boron trioxide under neutron irradiation at the low and high temperature. *Vacuum*. 173, 109162.

Ozyurt, O., Altınsoy, N., Buyuk, B. (2015). Investigation of Gamma-ray and Neutron Attenuation Coefficients for Granites Produced in Turkey. *Acta Physica Polonica A*, 127, 1268-1270.

Ozyurt, O., Altınsoy, N., Karaaslan, S.I., Bora, A., Buyuk, B., Erk, I. (2018). Calculation of gamma ray attenuation coefficients of some granite samples using a Monte Carlo simulation code. *Radiation Physics and Chemistry*, 144, 271-275.

Tashmetov, M., Abdurakhimov, B., Mirzayev, M.N., Thang T.X. (2019). The effect of electron beam to nanocrystallites size, strain and structural parameters of the silicon carbide nanopowder. *International Journal of Modern Physics B*, *33*(20), 1950223.

Yıldırım, S., Beril Tugrul, A., Buyuk, B., Demir, E. (2016). Gamma Attenuation Properties of Some Aluminum Alloys. *Acta Physica Polonica A*, *129*(4), 813-815.

Zaim, N., Beril Tugrul, A., Atlas, H., Buyuk, B., Demir, E., Baydoğan, N., Altınsoy, N. (2016). Investigation of Natural Radioactivity of Surface Soil Samples in the Vicinity of Edirne Turkey. *Acta Physica Polonica A*, *130*(1), 64-67.