СЕКЦИЯ 5
ВЛИЯНИЕ ИЗЛУЧЕНИЙ НА СТРУКТУРУ И СВОЙСТВА ПОКРЫТИЙ

SECTION 5
RADIATION INFLUENCE ON COATINGS STRUCTURE AND PROPERTIES

THE STRUCTURE AND PHASE COMPOSITION STABILITY OF AMORPHOUS ZIRCONIUM IRRADIATED WITH HELIUM IONS

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Amorphous alloy samples based on Zr with additional metals were irradiated using He ions at operating energy of 40 KeV under room temperature conditions with fluence from $5\cdot10^{17}$ to $7\cdot10^{17}$ cm^{-2}. The phase analysis of the samples is conducted using an X-ray diffractometer (Rigaku). XRD analysis revealed formation of amorphous, crystalline and amorphous+crystalline structure of Zr base foils. It was found that irradiation with helium ions does not lead to a change in the structure of the foils. It was found that irradiation with helium ions leads to a shift in the diffraction peaks of crystalline phases to the region of smaller angles for all crystalline and crystalline amorphous foils. And irradiation with helium ions leads to a decrease in the angular position of the amorphous halo.

***Keywords*:** Amorphous foils; Zirconium; Ion irradiation; Phase composition; lattice parameter.

Introduction

The development of nuclear energy in the world places high demands on the structural materials used, their production technology, and performance monitoring. Under the action of irradiation, these materials undergo structural-phase transformations that have a negative effect primarily on mechanical properties. Therefore, the development and creation of materials with high radiation resistance are relevant.

In this generation, most upcoming research shows that this problem can be solved if the metallic alloy glass has or possesses some nanocrystals with some radii or a few nanometers.

Amorphous alloys are defined as a combination of a metal with at least two or more metal. Amorphous alloys which are known as metallic glass [1], are important materials for different sector applications. Typically amorphous alloys exhibit unique physical and mechanical properties which cannot be reached in materials with crystalline structures. Zirconium (Zr) alloy consider type of amorphous alloys which have several types of feature [2].

The paper aims to explain the features of amorphous alloys after helium ion irradiation with different dose.

The main idea of work focus on how the elemental composition and amorphous structure of the alloys influence on its radiation stability after ion irradiation.

Materials and methods

The initial samples based on zirconium alloy were obtained by ultrafast quenching from the melt in the form of ribbons with a thickness of 30-60 μm. The main element of samples is based on Zr with Cu and some additional metals with several compositions for each element (Table 1).

Table 1. Elemental composition of samples based on zirconium alloy

Sample	Elements	Composition, at. %
Zr-1	Fe	8.11
	Ni	1.43
	Zr	88.32
	Sn	2.15
Zr-2	Ti	17.54
	Ni	15.18
	Cu	14.61
	Zr	51.32
	In	1.35
Zr-3	Ti	19.6
	Ni	17.41
	Cu	15.37
	Zr	47.63
Zr-4	Ti	65.23
	Zr	34.77

After preparing the samples, they had two different sides: the inner side, which was adjacent to the drum, and the outer side of the foil. The inner side was visually observed as mirrored, and the outer side as matte.

X-ray Diffraction (XRD) analysis was employed for structural identification using an Ultima IV Rigaku X-ray diffractometer operating in parallel configuration and equipped with CuK_α wavelength (0.15418 nm).

Ion implantation of the HEAs was carried out using 40 keV He^{2+} ions at the DC-60 heavy ion accelerator of the Astana branch of the Institute of Nuclear Physics at the fluence from $5.0 \cdot 10^{17}$ to $7 \cdot 10^{17}$ cm^{-2}. The implantation temperature was 300 K. The beam current was 200 μA, and water cooling of the target substrate was used.

Results and discussion

The results of studying the phase composition showed that the initial samples are in three different states which are amorphous, amorphous with crystalline, and crystalline (Table 2).

Figure 1 shows the XRD spectrum of a typical amorphous and crystalline sample (Zr-1-inner). As can be seen from Fig. 1, the spectrum contains narrow diffraction peaks corresponding to the crystalline phase and wide halos corresponding to the amorphous phase. The crystalline peaks correspond to the fcc-zirconium phase modified mainly with iron.

Table 2. Structure of samples based on zirconium alloy

Sample	Side of sample	Structure
Zr-1	inner	amorphous +crystalline
	outer	amorphous
Zr-2	inner	amorphous
	outer	amorphous
Zr-3	inner	amorphous
	outer	amorphous
Zr-4	inner	amorphous +crystalline
	outer	crystalline

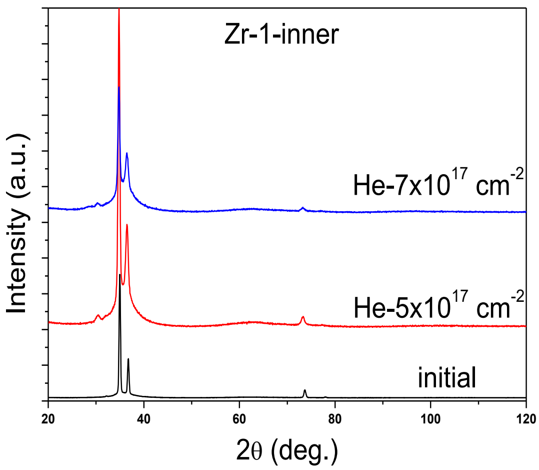

Fig. 1. XRD spectra of initial Zr-1-inner sample and after He (40 keV) irradiation with fluence of $5 \cdot 10^{17}$ and $7 \cdot 10^{17}$ cm^{-2}

Figure 2 shows the XRD spectrum of the crystalline sample (Zr-4-outer). Only crystalline peaks are visible. In this case, a solid solution (Ti, Zr) with a preferred orientation (200) is formed. Figure 3 shows the XRD spectrum of a typical amorphous sample (Zr-3-outer). Only wide amorphous halos are present.

Analysis of tables 1 and 2 showed that at a Zr concentration of about 50 at.% And the presence of Ti, Ni and Cu in the same concentration, only an amorphous structure is formed. At a high concentration of zirconium (more than 88 at.%) Or low (about 35 at.%), A crystalline or amorphous crystalline structure is formed.

XRD studies of irradiated samples showed that irradiation with helium ions at a fluence of $7 \cdot 10^{17}$ cm^{-2} does not lead to a change in

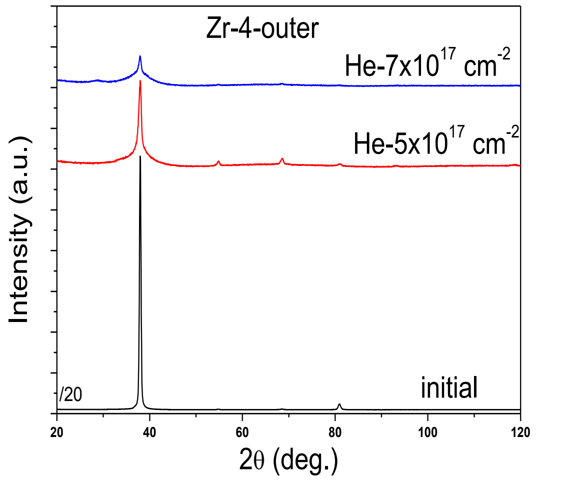

Fig. 2. XRD spectra of initial Zr-1-outer sample and after He (40 keV) irradiation with fluence of $5 \cdot 10^{17}$ and $7 \cdot 10^{17}$ cm^{-2}

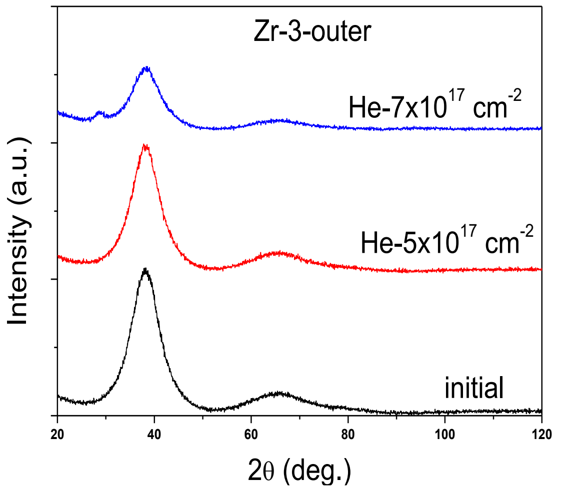

Fig. 3. XRD spectra of initial Zr-3-outer sample and after He (40 keV) irradiation with fluence of $5 \cdot 10^{17}$ and $7 \cdot 10^{17}$ cm^{-2}

the structure of zirconium-based foils (Fig. 1-3). It was found that irradiation only leads to a change in the lattice parameter of the crystalline phases and a shift in the angular position of amorphous halos (Fig. 1-3).

It was found that irradiation with helium ions leads to a shift in the diffraction peaks of crystalline phases to the region of smaller angles for all crystalline and crystalline amorphous foils. This is due to an increase in the lattice parameter of crystalline phases as a result of defect formation processes. An increase in the irradiation fluence to $7 \cdot 10^{17}$ cm^{-2} does not lead to a change in the lattice parameter of the crystalline phases.

Table 3 shows the results of determining the angular position of the amorphous halo of the initial samples and samples irradiated with helium ions.

As can be seen from Table 3, the angular position of the amorphous halo depends on the concentration of elements in the sample, as well as on the side of the sample (which is associated with the ultrafast cooling rate). Irradiation with helium ions leads to a

Table 3. Angular position of the amorphous halo of initial and after He (40 keV) irradiation with fluence of $5 \cdot 10^{17}$ and $7 \cdot 10^{17}$ cm^{-2} samples based on zirconium alloy

Sample	Side of sample	2θ, degrees		
		initial	$5 \cdot 10^{17}$ cm^{-2}	$7 \cdot 10^{17}$ cm^{-2}
Zr-1	outer	35.85	35.70	35.60
Zr-2	inner	37.50	37.40	37.05
	outer	37.15	37.10	37.05
Zr-3	inner	38.15	38.05	37.70
	outer	38.10	38.10	38.20

decrease in the angular position of the amorphous halo (Table 3). For Zr-3-outer specimen only, the angular position does not change. An increase in the fluence of irradiation with helium ions leads to a further decrease in the angular position of the amorphous halo. Table 3 indicates the stability of the amorphous structure of the Zr-3-outer sample.

Conclusions

XRD analysis revealed formation of amorphous, crystalline and amorphous+crystalline structure of Zr base foils.It was found that irradiation with helium ions does not lead to a change in the structure of the foils. It was found that irradiation with helium ions leads to a shift in the diffraction peaks of crystalline phases to the region of smaller angles for all crystalline and crystalline amorphous foils. And irradiation with helium ions leads to a decrease in the angular position of the amorphous halo.

References

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