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CHARACTERISTICS OF THE ANNIHILATION OF POSITRONS IN NANOSIZED METAL COATINGS ZR/NB AFTER HE^{+} ION IRRADIATION

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ОСОБЕННОСТИ АННИГИЛЯЦИИ ПОЗИТРОНОВ В НАНОРАЗМЕРНЫХ МЕТАЛЛИЧЕСКИХ СЛОЯХ ZR/NB ПОСЛЕ ОБЛУЧЕНИЯ ИОНАМИ HE^{+}

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Аннотация. *Новые технологии получения конструкционных материалов, устойчивых к водородным и радиационным повреждениям, являются актуальными проблемами материаловедения. Водородное повреждение и радиационная деградация являются важными факторами, ограничивающими усталостную долговечность конструкционных материалов. Одной из перспективных альтернатив при разработке радиационно-водородостойких материалов с улучшенными физико-механическими свойствами является нанесение наноразмерных металлических покрытий (НМП). Настоящая работа посвящена изучению аннигиляции позитронов в НМП Zr/Nb с различной толщиной отдельных слоев Zr и Nb после облучения ионами* He^{+} *с дозами от* $3\cdot10^{16}$ *ионов/см*^{2} *до* $3\cdot10^{17}$ *ионов/см*^{2}.

Introduction. Nanoscale multilayer coatings (NMCs) are increasingly used in power engineering, electronics, mechanical engineering, optics, biotechnology, and other industries. The reason for this is the possibility of a significant change in the physical and mechanical properties and corrosion resistance of structural materials. Changes in the thickness and composition of layers can lead to an increase in strength, hardness, and the formation of a nanocomposite with a wide range of functional purposes. The hexagonal-cubic systems (hcp/bcc and hcp/fcc) have the greatest structural mismatch of crystal lattices. In addition, hcp/bcc systems have the potential to create radiation-resistant composites. The large divergence allows incoherent and semi-coherent boundaries of hcp/bcc systems to be an effective absorber of radiation defects and a barrier to dislocation propagation during deformation, as shown in recent studies [1, 2].

The aim of this work was a comparative analysis of the characteristics of positron annihilation in a Zr/Nb NMCs with a thickness of individual layers of 100 ± 10 nm after irradiation with He^{+} ions.

Research methods. The samples were analyzed by means of annihilation line Doppler broadening (DB) spectrometry using variable positron energy at the AIDA - Helmholtz Center Dresden-Rossendorf, HZDR. A monoenergetic positron beam 4 mm in diameter was used; the positron energy varied from 0.01 keV to 35 keV. Annihilation γ radiation was recorded by the HPGe detector with an energy resolution of 1.09 + 0.01 keV, interpolated for an energy of 511 keV. The obtained DB spectra were analyzed by estimating the parameters S and W of the annihilation line, as well as graphical representation of the R parameter as a function of S = f(W). The prepared samples were irradiated with He^+ ions using a PION-1M plasma ion source with a non-incandescent cathode. The energy of the accelerated ions was 25 keV. The irradiation time was chosen to cover a wide dose range from $3*10^{16}$ to $3*10^{17}$ ions/cm^2. During irradiation, the temperature of the samples did not exceed 200 °C.

Results. Figure 1 shows the dependence of the S, W parameter on the positron energy for Zr/Nb NMCs with an average layer thickness of 100 ± 10 nm and an irradiation dose range from $3*10^{16}$ to $3*10^{17}$ ions/cm^2.

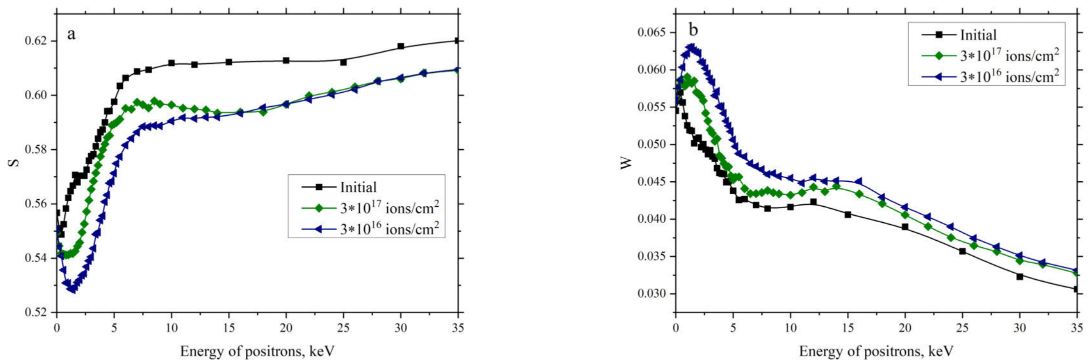

Fig. 1. Dependence of the S parameter (a) and the W parameter (b) on the positron energy of the Zr/Nb NMCs with the thickness of individual layers of 100 ± 10 nm and the range of irradiation doses from $3*10^{16}$ to $3*10^{17}$ ions/cm^2

Analyzing the obtained curves in Figure 1, we can conclude that the S parameter of the Zr/Nb NMCs decreases with increasing radiation dose, which indicates the absence of the formation of stable radiation defects. After 20 keV, the S parameter increases and the W parameter decreases, which indicates the predominant positron annihilation in the single-crystal silicon substrate. Figure 2 shows the dependence of the S parameter on the W parameter of a Zr/Nb NMCs with a thickness of individual layers of 100 ± 10 nm and a range of irradiation doses from $3*10^{16}$ to $3*10^{17}$ ions/cm^2.

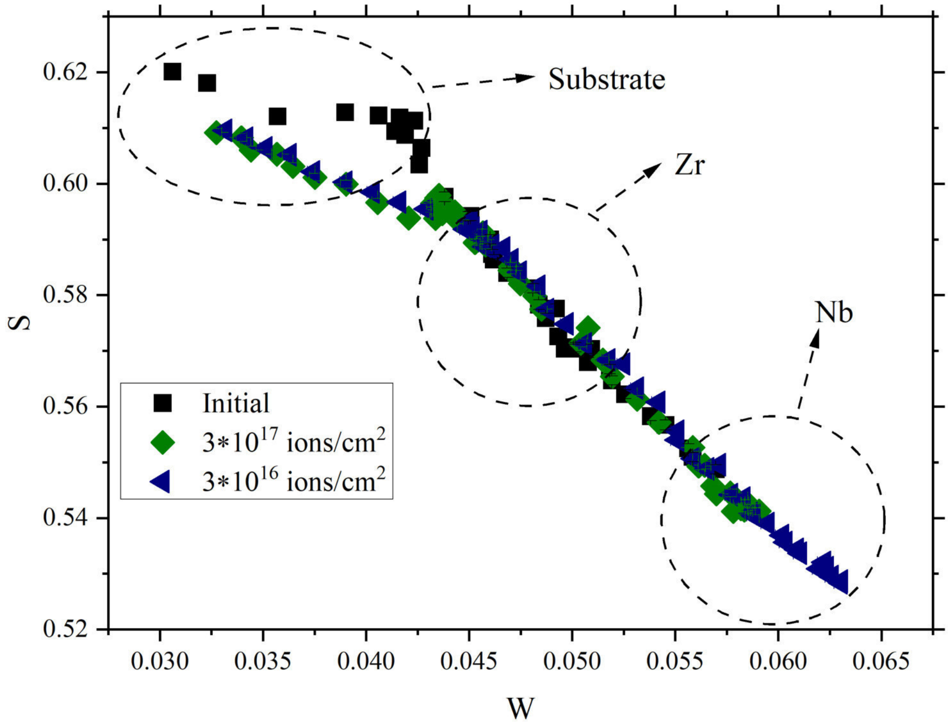

*Fig. 2. Plot of the dependence of the S parameter on the W parameter for Zr/Nb NMCs with an individual layer thickness of 100 ± 10 nm and an irradiation dose range from 3*10^16 to 3*10^17 ions/cm^2*

As can be seen from Figure 2, the graph of the dependence S = f (W) consists of 2 curves with different slope angles, this is due to the annihilation of positrons in the substrate, annihilating positrons in the substrate change the slope of the curve.

Conclusion. A layer-by-layer analysis of positron annihilation in Zr/Nb NMCs shows that increasing the irradiation dose by He^+ ions leads to the formation of stable radiation defects. Once the energy reaches 20 keV, the probability of positron annihilation in the monocrystalline silicon substrate increases.

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