STUDIES OF THE DISTRIBUTION OF MICROHARDNESS BY THE DEPTH OF ZIRCONIUM ALLOY E110 AFTER IRRADIATION WITH PULSED ELECTRON BEAM AND HYDROGENATION

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ИССЛЕДОВАНИЕ РАСПРЕДЕЛЕНИЯ МИКРОТВЕРДОСТИ ПО ГЛУБИНЕ ЦИРКОНИЕВОГО СПЛАВА Э110 ПОСЛЕ ОБЛУЧЕНИЯ ИМПУЛЬСНЫМ ЭЛЕКТРОННЫМ ПУЧКОМ И НАВОДОРОЖИВАНИЯ

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Annotation. *Проведено исследование влияния облучения импульсным электронным пучком и последующего наводороживания на распределение микротвердости по поперечному шлифу циркониевого сплава Э110. Показано, что наводороживание приводит к незначительному росту твердости только на небольшой глубине, что говорит о том, что водород не проникает в глубину образцов, а локализуется в тонком поверхностном слое. Такой результат подтверждается исследованием распределения водорода по глубине циркониевого сплава после облучения и наводороживания.*

Zirconium and its alloys are some of the most important elements of the core nuclear power reactors. Also, zirconium has a low neutron capture cross section and good corrosion resistance. However, during operation of the nuclear reactor components,zirconium products exposed to such hydrogenation and hydrogen embrittlement can be destructed. To prevent the penetration of hydrogen in zirconium alloys surface modification of zirconium alloys with pulsed electron beams (IEP) is used. This is due to the fact that after inoculation the surface layer of material is formed of about 10 microns, which stores hydrogen under hydrogenation [1, 2]. To confirm this effect the distribution of microhardness of the depth of the samples of zirconium alloy E110 after irradiation by a pulsed electron beam and hydrogenation is investigated in the present study.

Material and methods of research. For the purpose of study the samples of zirconium alloy E110 were made with the dimensions 20 × 20 × 0,6. Irradiation of the samples was carried out on the "Solo" in ISE SB RAS, with the two sides at the energy density of 18 J / cm2, pulse number 3, and pulse duration 50 ms. Hydrogenation was performed at installation Gas Reaction Controller [3] at 2 atm., temperature of 350 ° C and the concentration of 500 ppm. Analysis of the distribution of hydrogen in the prepared samples was carried out on a glow discharge plasma spectrometer Profiler 2. Microhardness of a series of 40 measurements at a load of 50 g was measured with a hardness HV-1000 diagram which is shown in Figure 1.

The micro-hardness on Vickers HV-1000 consists of a table (1) on which the sample is placed up to a height with 40X objective (2). Then a test load with the handle adjustment test force is set up (3).

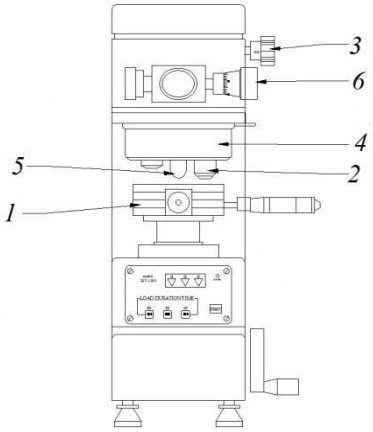

Fig. 1. Scheme for Micro-Hardness Vickers HV-1000: 1 - table; 2 - 40X lens; 3 - handle adjustment test force; 4 - rotating head; 5 - indenter; 6 - measuring flywheel

After moving the rotating head (4) on the indenter (5) begin to carry out surface diamond pyramid indentation.After this change the position of the rotating heads on the 40X objective lens and eyepiece lens to find the imprint of diamond pyramid on the sample surface. Then the length of the diagonal of the resulting print with a flywheel is measured(6). Next the length of the diagonal in the 40X lens is defined on the scale flywheel. Then the hardness is determined by the formula (1):

$$HV = 1{,}8544 * \frac{F}{\left(\frac{d}{40}\right)^2}, \qquad (1)$$

where d - diagonal indentation in the 40X lens; F- test force in kilograms; 40 - lens magnification.

The results of the studies. Figure 2 shows the distribution of micro transverse sections of zirconium alloy E110 after irradiation with pulsed electron-beam irradiation and after the IEP and hydrogenation.

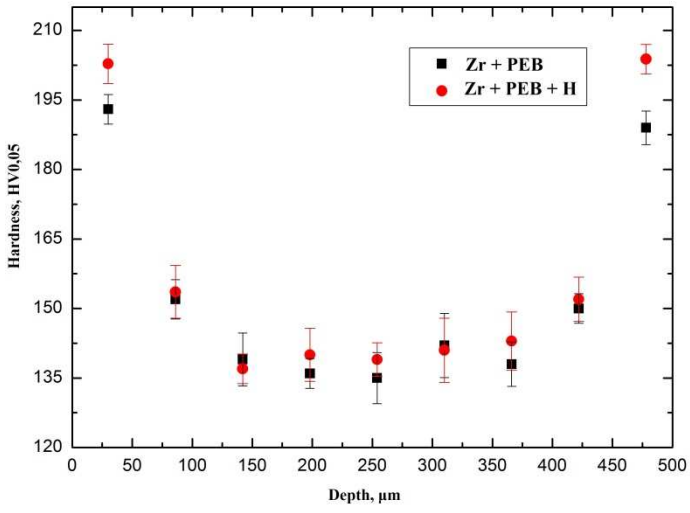

Fig. 2. Distribution of Micro transverse sections of zirconium alloy E110 after irradiation and after irradiation IEP IEP and hydrogenation

Pulsed electron beam irradiation at an energy density of 18 J / cm2 and 3 pulses 50 microseconds each leads to surface hardening of zirconium alloy E110, which is associated with structural-phase changes in the surface layers of the material as a result of high-speed heating and rapid cooling during irradiation [1-2] . As shown in

Figure 2 microhardness value is ~ 195 HV0,05to a depth of 50 microns and it decreases with further increase in depth to ~ 140 HV0,05. Subsequent hydrogenation at 350 ° C and a hydrogen pressure of 2 atm. withtheconcentration of 500 ppm hardness increases only to a depth of 50 microns. This result is due to the fact that after the irradiation of EPI hydrogen zirconium alloy at the above settings hydrogenation is localized in the surface layer and does not penetrate into the depth of the material.

To determine the localization of hydrogen after the hydrogenation of the samples before and after irradiation IEP the distribution of hydrogen in depth with a spectrometer Profiler-2 is investigated. The results of the study are presented in Figure 3. As it was shown by the studies hydrogen is concentrated in the surface layer of the material after modifying zirconium alloy E110 with a pulsed electron beam [2].

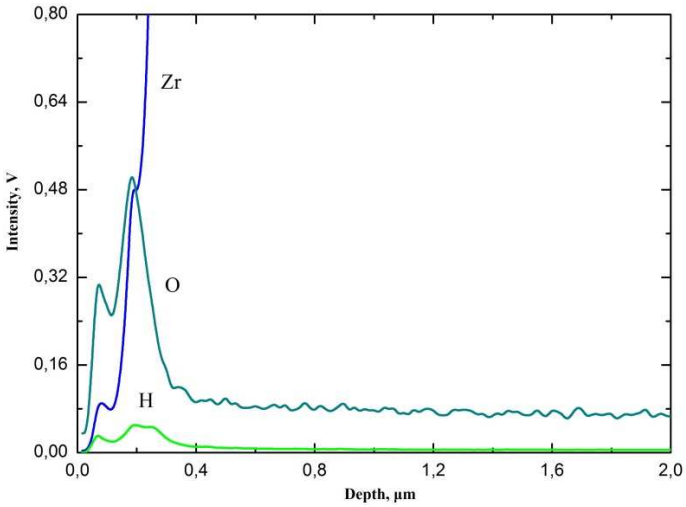

Fig. 3. The distribution of elements in the depth of zirconium alloy E110 after irradiation IEP and hydrogenation

Conclusion. In this paper we investigated the distribution of Micro transverse sections of zirconium alloy E110 after pulsed electron beam irradiation and subsequent hydrogenation. Studies have shown that pulsed electron beam irradiation at the energy density of 18 J/cm^2 for three 50 ms pulses each increases the microhardness of the layer 50 to a depth of about 1.5 microns in time. Subsequent hydrogenation to a concentration of 500 ppm leads to the increase of hardness at a depth of 50 microns, which is associated with the localization of hydrogen in the surface layer during hydrogenation. This result is confirmed by the study of the hydrogen distribution in the depth of zirconium alloy E110 after irradiation and hydrogenation.

References

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