Экспериментально показано, что если в состаренных под нагрузкой образцах после 5 циклов охлаждение/нагрев под действием внешних сжимающих напряжений от 75 до 250 МПа снова провести цикл охлаждение/нагрев при минимальных внешних напряжениях $|\sigma_{вш}|=1$ МПа, то при охлаждении внутренние поля напряжений приведут к росту варианта мартенсита, который приводит к увеличению размеров образца вдоль $[\bar{1}23]$-направления (рис.1(в)). Величина ДЭПФ составляет $\varepsilon_{ДЭПФ}=+1,1(\pm 0,3)\%$, деградация обратимой деформации при проявлении ДЭПФ в пределах погрешности измерений. Таким образом, термоциклирование через интервал прямых и обратных МП под действием противодействующих напряжений до 250 МПа не приводит к подавлению ДЭПФ в состаренных под растягивающей нагрузкой $[\bar{1}23]$-монокристаллах $Co_{35}Ni_{35}Al_{30}$.

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ИЗМЕНЕНИЕ МЕХАНИЧЕСКИХ СВОЙСТВ ЦИРКОНИЕВОГО СПЛАВА ПОСЛЕ ЭЛЕКТРОНО-ИМПУЛЬСНОЙ ОБРАБОТКИ

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CHANGES OF MECHANICAL PROPERTIES OF ZIRCONIUM ALLOY TREATED BY PULSED ELECTRON BEAM

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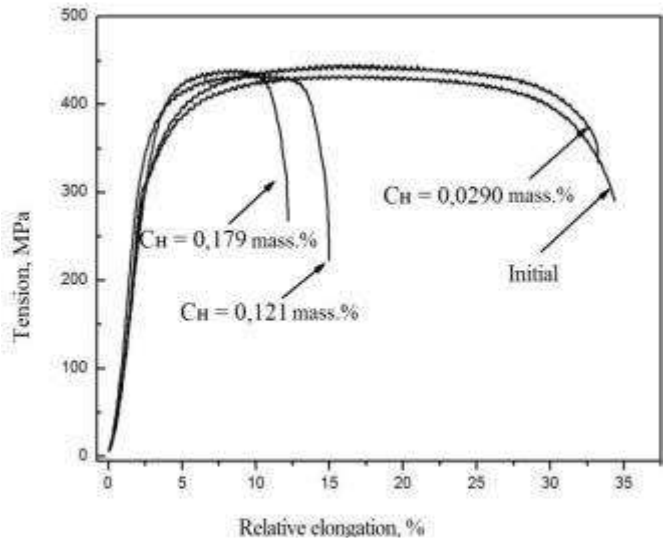
Experimental results are presented according to changes in the mechanical properties of zirconium-alloy evogo Zr-1Nb from modifying its pulsed electron beams (IEP) at different exposure settings and hydrogenation. The results show that the hydrogen saturation of the starting sample and irradiated IEP increases strength and hardness, but decrease the plasticity.

There arise many problems studying zirconium products protection. It is connected with requirements to a products surface (for example, for components operating in an active zone of nuclear reactors) and criteria of the material choice [1]. One of the promising directions in designing of materials with a high quality level of a surface layer is the use of pulsed low-energy electron beams (PEB). The submicrocrystalline structure is formed during irradiation by concentrating flaxes of energy, which influences the improvement of mechanical and structural properties and creation of new and unique material characteristics.

A thin surface layer of a solid can achieve melting temperature, melt and evaporate during the irradiation in the wide range of parameters, such as initial electron energy and density of energy. At that, heating occurs with very high speeds and subsequent high-speed cooling, which is followed by high-speed crystallization of melt and quenching phenomena. Finally, all these processes lead to the change of physical-mechanical properties of the material. The choice of beam parameters plays an important role in treatment by high-current pulsed electron beam: initial electron energy, density of energy, duration of pulse and quantity of pulses. Beam density of energy and quantity of pulses influence on mechanical properties of zirconium alloy were studied in this work.

Blade-shaped samples of the zirconium alloy Zr1Nb (brand E110) were made for the research. All surface defects (dents, scratches, rough risks) were removed by grinding and polishing operations. The irradiation of zirconium alloy surface was carried out with the help of the electron beam system «SOLO». The treatment was performed at $\tau = 50$ µs, energy density (E_s) was varied from 5 to 25 J/cm^2, quantity of pulses (N) - from1 to 10. Sample saturation by hydrogen was realized with equipment PCI «Gas Reaction Controller» using the Siverts method. Mechanical properties (strength, plasticity and microhardness) of zirconium alloy were studied in the tests for uniaxial tension with the help of device DFM-5000 with speed $v = (2 \times 10^{-7})$ m/s before destroying at room temperature and Micro Durometer PMT-3M with Vickers indenter and load 0,3, 0,5 и 1,5 N. Fractography of fracture surface of samples after tests for tension were performed by the scanning microscope method (microscope Philips SEM 515).

To study mechanical properties of zirconium alloy Zr-1Nb one carried out tests for uniaxial tension of the samples of the following series: unirradiated by PEB, after irradiation by PEB, containing hydrogen and after hydrogenation. It is out from results (pic.1) saturation by hydrogen leads to degradation of mechanical properties of samples, the relative elongation decreases to 53 % in comparison with the initial material. The implantation of hydrogen almost does not influence the limit of the sample strength. It is connected with the reason of hydride formation in the result of saturation by hydrogen from gas medium. Zirconium hydride is characterized by high strength and low plasticity [2].

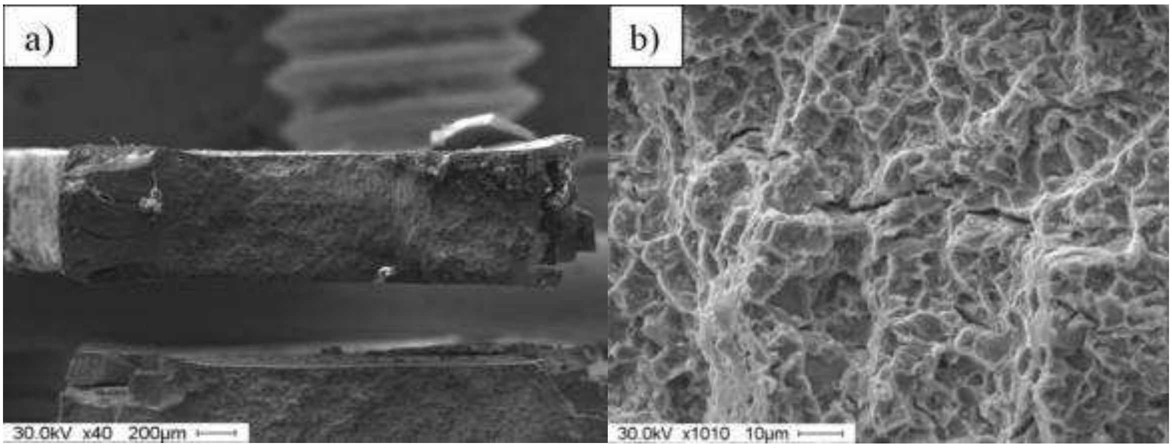


Pic.1. The diagram of zirconium alloy (Zr-1Nb) tension depending on hydrogen concentration

It is established, that hydrogenation from gas medium causes surface strengthening of samples under study, at that, the hardness of material increases with the growth of hydrogen concentration to 0,179 mass %. According to earlier results [3], after irradiation of samples Zr-1Nb by PEB the formation of martensite of a complex morphology occurs, that leads to the increasing of hardness (on the surface HV = 3160 MPa, initial – 1600 MPa). Submicrocrystalline martensite plates, formed at $E_s = 10$ J/cm^2 and N = 3 and internal stresses in zirconium alloy, caused by them, make a significant contribution to the strengthening of a material. The irradiation of a sample surface by PEB almost does not influence the limit of strength and plasticity value. This is due to the fact that the depth of modification (a melt is about 10 µm, the heat-affected zone is about 40 µm) is much smaller than the thickness of the samples (0, 7 mm).

Saturation of samples irradiated at $E_s = 18$ J/cm^2, N = 10, N = 5 and at $E_s = (5 – 25)$ J/cm^2, N = 3 leads to reduction of plasticity (to 12 %), like in the case of the initial material saturation. It is important to note, that saturation by hydrogen from a gas medium of samples irradiated at $E_s = 18$ J/cm^2, N = 1 does not influence the deformation behavior of alloy Zr-1Nb.

Microscopic research has shown that saturation of modified samples during 60 minutes leads to the formation of microcracks on the fracture surface. At that the largest density and crack length (100 µm) is observed at an energy density Es = 18 J/cm^2 and N = 5 and $E_s = 5$ J/cm^2 and N = 3 (Fig. 2). Earlier it has been found that one feature of the samples data is a high density of craters having a wide spread of dimensions (from 1 to 5 µm) [3]. Obviously, such defects accelerate sorption of hydrogen by samples. This conclusion has been confirmed by the results of absolute hydrogen content measurements in zirconium alloy. Thus, at $E_s = 18$ J/cm^2 and N = 5 the content of hydrogen is 0,20 mass %, at $E_s = 5$ J/cm^2 and N = 3 – 0,55 mass %, at $E_s = 18$ J/cm^2 and N = 1 – 0,11 mass. %.



a) increase 40; *b) increase 1000*

Pic.2. The failure surface of zirconium alloy samples after irradiation by PEB ($E_s = 5$ J/cm^2 u N = 3) and saturation to Cн = 0,55 mass *%*

The study of influence of the high-current pulsed electron beam impact on mechanical and structural-phase properties of zirconium alloy Zr-1Nb has ascertained:

1. The saturation by hydrogen leads to the increase of surface hardness of initial samples (to 1,5 times) and abrupt decrease (to 53 %) of material plasticity .

2. The formation of martensitic plates in the surface layer considerably increases microhardness of samples (maximum increase during at $E_s = 10$ J/cm^2 and N = 3). But irradiation of sample surface by PEB does not influence the limit strength and plasticity.

3. A specific feature of the samples previously irradiated at $E_s = 18$ J/cm^2, N = 1 is that the saturation by hydrogen from gas medium has no effect on the magnitude of strength and plasticity of the material.

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ВЛИЯНИЕ ЭЛЕКТРОННО-ПУЧКОВОЙ ОБРАБОТКИ НА СТРУКТУРНО-ФАЗОВЫЕ СОСТОЯНИЯ СПЛАВА TiNi С ПОКРЫТИЕМ ИЗ Ta

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THE EFFECT OF ELECTRON BEAMS ON THE STRUCTURE-PHASE STATE OF NITI WITH TANTALUM COATING

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After the electron beam processing on the alloy TiNi with tantalum coating it was developed, that the amount of β-Ta phase increases in modified layer, the phase state changes with the appearance of B19' martensite phase.

Никелид титана как конструкционный материал широко применяется в современной имплантологии, что делает его объектом множества исследований, направленных на улучшение биосовместимости сплава. В частности, одной из проблем, возникающих при контакте имплантов с биосредой, может быть выход ионов никеля, провоцирующих повышение вероятности возникновения злокачественных новообразований. Наиболее привлекательным для решения такой задачи представляется метод магнетронного нанесения покрытий, использование которого в комплексе с электронно-пучковыми поверхностными обработками обеспечивает формирование однородных покрытий с заданными химическим составом и толщиной [1]. Известно, что тантал, обладающий высокими показателями биосовместимости и рентгеноконтрастности, необходимой при проведении эндоскопических операций,