DYNAMICS OF HYDROGEN ACCUMULATION IN THE ALLOY TiNi AT ELECTROCHEMICAL HYDROGENATION

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ДИНАМИКА НАКОПЛЕНИЯ ВОДОРОДА В СПЛАВЕ TiNi ПРИ ЭЛЕКТРОХИМИЧЕСКОМ НАВОДОРАЖИВАНИИ

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***Аннотация**. Авторами статьи сделан литературный обзор по темам взаимодействия и проникновения водорода в титановые сплавы. Также в статье представлен анализ закономерностей взаимодействия системы металл-водород, и анализ исследования методики изучения водородной проницаемости через металлическую фольгу.*

Introduction. In modern technology and science, one of the main objectives is the development of structural and functional materials with improved technological and operational properties. In the past two decades, a scientific direction for obtaining bulk nanostructural state in metals and alloys has been actively developing. [1] Currently, the main direction of obtaining bulk nanostructured (NS) and ultra fine-grained (UFG) states are the methods of intensive plastic deformation (IPD). From the large class of shape memory alloys the most well-known are binary TiNi alloys. Such alloys are widely used not only in mechanical engineering (thermo-mechanical coupling, thermal actuators, temperature sensors, bolts and rivets to create permanent connections), but also in other branches of engineering and medicine, thanks to a complex of physical and mechanical properties: high strength and ductility, corrosion resistance in various corrosive environments. [2,3,4]. It can be concluded that TiNi is often in contact with water. For instance, medical equipment that has been serving as a support for the human body for decades is constantly surrounded by body fluids. In order to solve the problem of hydrogen embrittlement, it is necessary to study in more details the physical and chemical properties of the NiTi under operating conditions with hydrogen.

Hydrogen significantly affects physical and chemical properties of titanium alloys. Its penetration into materials cannot be excluded, since hydrogen is present in the aqueous medium and in the atmosphere in large quantities, and due to technical conditions of materials operation. Therefore, structural materials of titanium alloys must have the necessary strength and plastic properties stored in a wide temperature and pressure range, high corrosion resistance, resistance to hydrogen embrittlement.

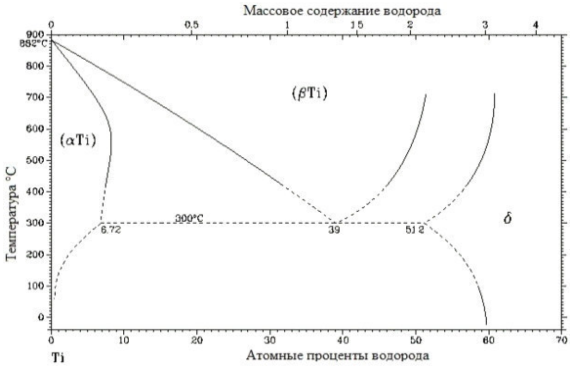


Fig 1. Phase diagram of the titanium-hydrogen system

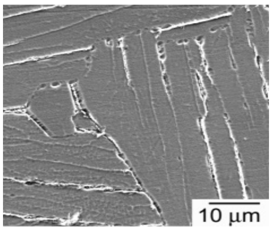


Fig 3. Sample of titanium nickelide

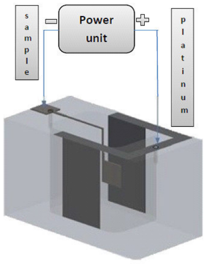
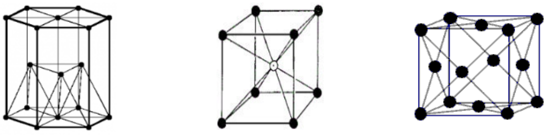


Fig. 4. Stand for electrolytic hydrogen saturation

Phase diagram of the titanium-hydrogen system is shown in fig. 1. The abscissa axis shows hydrogen content in atomic percent in titanium, hydrogen content in weight percent in titanium, and the ordinate axis shows the temperature dependence in degrees Celsius.

It is accepted to distinguish four phase states of the system Ti-H: 1) α-Ti – solid solution of hydrogen in the HCP lattice (Figure 2a); 2) β-Ti – solid solution of hydrogen in BCC lattice (Figure b); 3) δ-TiH_{2-y} – stoichiometric dihydride with the FCC sublattice Zr (figure 2c); 4) ε-TiH_{2-x} – dihydride with the FCC lattice.



- HCP lattice b) BCC lattice c) FCC lattice

Fig 2. The positions of hydrogen in metal lattice

Titanium nitride can be allocated in the form of plates along certain crystallographic directions, in the form of compact allocation of some form within the grains along the grain boundaries. Nature of allocation of hydrides depends on many factors: hydrogen content, grain size, hydrogenation temperature prior to heat titanium processing, stress state of the metal when allocating hydrides, impurities, etc. With the increase of total content of hydrides in titanium, their tendency to allocate a compact precipitates along the grain boundaries increases.

Methods and experiment. The object of our study is a rectangular flat titanium alloy samples BT1-0 with dimensions of 20 × 20 × 1 mm. The alloy composition is shown in Table 1

Table 1

Elemental composition of titanium alloy BT1-0

Fe	C	Si	N	Ti	O	H	Примесей
0,18	0,07	0,1	0,04	98 -99	0,18	0,12	0,3

Samples were subjected to grinding and polishing to remove surface defects. Grinding was performed using silica sandpaper having grain size of 1000, 1500 and 2000 microns.

To remove defects and removing surface stress the samples were burned under vacuum at 750 ° C for 60 minutes.

For our study we used electrolytic hydrogen saturation. Electrolysis is physical and chemical phenomenon consisting in allocation of components of soluted or other substances on electrodes that result from secondary reactions on the electrodes, which occur during the passage of electric current through the solution or melt of electrolyte.

In electrolysis, the process of hydrogenation of metals is similar to high-temperature hydrogenation, as hydrogen ions are allocated on the samples, which is similar to the action of hydrogen, dissociated at a high temperature and ionized at the metal surface.

During electrolysis, hydrogen, penetrating, is accumulated on the metal surface. Because of the low diffusion coefficient of hydrogen at room temperature it does not penetrate into the depth of sample. As a consequence, the hydrogen forms hydride phases with titanium in the surface layer.

Thus, the control of all of the above conditions is an important task in the hydrogenation of samples for the study of metal-hydrogen systems. For the electrolytic saturation of the metal samples, a special cell (Figure 6) has been developed, which allows to control such parameters as a position of sample, volume and temperature of the electrolyte. Stand for the electrolytic saturation consists of the electrolytic cell with a sample mounting unit, an anode made of platinum and a current source GPS-1830D. The cathode in the electrolytic cell is a sample saturated with hydrogen. Since the location of the samples in relation to anode has a significant effect on the saturation intensity, the special holders were made allowing to fix the sample and ensuring reliable contact.

Metal hydrogenation is affected by its chemical composition and structure. Chemical composition and structure affect the diffusion of hydrogen through metal, its solubility in metal lattice, i.e. they substantially determine the ability of metal to absorb hydrogen.

The intensity of hydrogenation of metals and alloys by the electrolytic method is determined by the following factors: composition and state of the environment, from which hydrogenation occurs; state and form of the surface of hydrogenated material; chemical composition and structure of the material; the presence of stress and strain; time of hydrogenation.

Conclusion. As a result of the work on studying the laws of interaction of metal-hydrogen system, we investigated the method and techniques of studying hydrogen permeation through a metal foil.

In the course of the present work we have carried out a literature review and analysis on the issues of interaction and penetration of hydrogen into titanium alloys. Also we have studied in detail the installation for saturation of titanium alloys by hydrogen. This is a stand for electrolytic hydrogen saturation. The installation is applied for direct saturation of samples with hydrogen at various temperatures.

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