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**INFLUENCE OF DEUTERIUM PLASMA IONS ON
Zr₅₇Cu_{15.4}Al₁₀Ni_{12.6}Nb₅ AMORPHOUS ALLOY¹**

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The aim of this work is to study effects of an intense action on metal glasses – in this case, on the Zr₅₇Cu_{15.4}Al₁₀Ni_{12.6}Nb₅ alloy – of deuterium plasma particles of several tens of eV. The peculiarity of this approach reflects more closely some problems of thermonuclear energy than diffusion and even electrochemical saturation with hydrogen or deuterium.

¹ Thanks to V.G. Konovalov Researcher, for active participation in this work.

Blessed memory of Vladimir Sergeevich Voitsenya Doctor of Science, ideological leader of the work.

A sample of $Zr_{57}Cu_{15.4}Al_{10}Ni_{12.6}Nb_5$ alloy, high mirror quality, $20 \times 10 \times 3 \text{ mm}^3$, was cleaned at the DSM-2 stand [1] with Ar plasma ions (300 eV) obtained under conditions of electron cyclotron resonance (ECR) [1]. During the experiment, the sample was placed in D-plasma obtained under similar ECR conditions. Then it was exposed (at room temperature) by D^{2+} deuterium ions with a flux density of $1 \cdot 10^{26} \text{ ions/cm}^2 \cdot \text{s}$ ($2 \cdot 10^{26} \text{ D/cm}^2 \cdot \text{s}$) and an ion energy of 100 eV, at which the mass gain of the sample of this kind is maximum [2, p. 144].

Ten treatment sessions were carried out for 3 hours every day, excluding weekend, until a fluence of $1 \cdot 10^{21} \text{ ions/cm}^2$ ($2 \cdot 10^{21} \text{ D/cm}^2$) was reached.

After each session, the weight gain of the sample was measured and, since the sample was bent during exposure [2, p. 145], its curvature was obtained optically by measuring the focal length.

During the experiment, a study of the relative changes in the average interatomic distance ($\Delta r/r_o$) was also carried out for the irradiated near-surface layer of the material. This was determined from the shifts of the CuK_α X-ray reflection halo from this surface, what was carried out on the DRON4-07 diffractometer.

Simulation of experimental data with an estimate of the diffusion coefficient and determination of the volume of deuterium atoms in the material was also carried out.

During the entire experiment, the mirror quality of the sample and the amorphous state of its working surface practically did not change without visible signs of crystalline formations. However, after a fluence of $9 \cdot 10^{20} \text{ ions/cm}^2$, a fragment chip off from the edge of the sample working surface.

It has been established that the content of absorbed deuterium increases in proportion to its fluence, and its fraction is 27...32% of the atomic fluence.

Figure 1 shows the changes in the curvature $1/R$ and the interatomic distance of the sample $\Delta r/r_o$ ($a(T)$) with increasing of the fluence (R is the curvature radius of the sample). As Figure 1a shows, the $1/R$ changes are proportional to fluence.

The initial changes in $\Delta r/r_o$ (Fig. 1b) exhibit nonlinearity, which is associated with the diffusion of deuterium. Different relaxation processes in the sample explain the irregularity of subsequent changes. Such processes are associated with the action of high stresses, initiating the interatomic redistribution of deuterium and acts of chipping, visually observed near the working surface at $9 \cdot 10^{20} \text{ ions/cm}^2$.

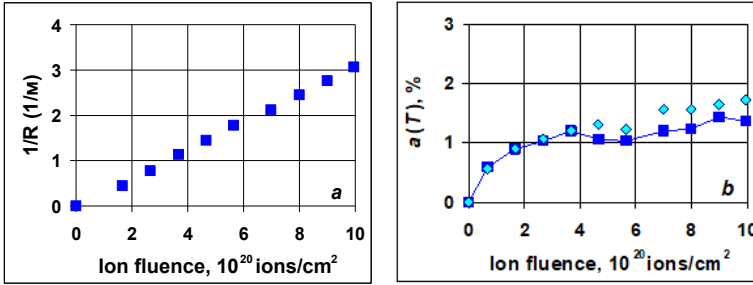


Fig. 1. Changes in the sample curvature (a) and the interatomic distance in the material (b) with ion fluence. The simulation results are presented (♦)

Simulation of the results obtained has been carried out. To simulate the dynamics of the sample curvature, a centrally symmetric model of curvature of a plate with a thickness T under the action of surface volumetric dilatation $3a$ ($T \ll L \ll R$; L is the size along the plane of the original plate) is considered. In this case, the condition of elastic equilibrium for normal distortions of the plate is reduced to the equation $2\varepsilon_{xx} + \varepsilon_{\rho\rho} = 3a$, where ρ is the coordinate along the radius vector R ($0 \leq \rho \leq T$), and x is the designation of a pair of coordinates along a spherically curved plane of plate. For ε_{xx} , the solution is sought in the following form: $\varepsilon_{xx} = (\rho - \rho_0)/R$.

The quantities R and ρ_0 are determined from the minimization of the elastic energy $\int \varepsilon_{xx}^2 d\rho$ by their variations, which leads to the equations of equilibrium of the dilatation forces along x , and of their moments. As a result, these quantities are determined from the system of the following equations:

$$\overline{\varepsilon_{xx}} = \frac{T}{2R} - \frac{\rho_0}{R} = \frac{1}{T} \int_0^T a(\rho) d\rho; \quad \overline{\varepsilon_{xx} \rho} = \frac{T}{3R} - \frac{\rho_0}{2R} = \frac{1}{T^2} \int_0^T a(\rho) \rho d\rho. \quad (1)$$

At small thicknesses of the intercalated deuterium layer ($\tau \ll T$), there is $\rho_0 = T/3$ (note: $\varepsilon_{xx}(\rho_0) = 0$), and the dilatation associated with the volume v of the deuterium atom and their concentration c in the layer of the front side is determined by the value $c v \tau = T^2/2R$. In other words, for such layer thicknesses, the curvature changes linearly with the concentration of deuterium in it. The subsequent estimation of the deuterium diffusion made it possible to clarify the value of its atomic volume: $v = 2.6 \pm 0.2 \text{ \AA}^3$.

Based on the calculation results, the experimental value $\varepsilon_{pp}(T) = 3a(T) - 4T/3R$ (1), determined from the halo displacements, an analogue of the $\Delta r/r_0$ value on the working surface of the plate, was used to calculate the true value of $\Delta r(T)/r_0 = a(T) = c(T)v/3$. Just this value is shown in Figure 1b together with the results of modeling the effect of deuterium diffusion.

The values of $\Delta r(T)/r_0$ (Fig.1b) for the initial exposures are used to simulate the diffusion change in the deuterium concentration deep into the sample ($c(y,t)$; $y = T - \rho$), according to the general formula:

$$c(y,t) = \frac{1}{\kappa\sqrt{\pi}} \int_0^t \frac{f(t_0)}{\sqrt{t-t_0}} \exp\left(-\frac{y^2}{4\kappa^2(t-t_0)}\right) dt_0, \quad (2)$$

where $f(t)$ is the particle flux density during the time t (t_0) of the entire experiment, equal to $f_0 = 2 \cdot 10^{26}$ D/cm²·s during exposure periods and zero outside the sessions; κ^2 – diffusion coefficient. On the working surface of the sample ($\rho = T$; $y = 0$), solution (2) for $\Delta r/r_0$ takes the following form:

$$\Delta r(T)/r_0 = a(T,t) = \frac{2}{3} \frac{vf_0}{\kappa\sqrt{\pi}} \sum_i \left(\sqrt{t-t_i+\Delta t_i} - \sqrt{t-t_i} \right), \quad (3)$$

where Δt_i (3 h) is the time duration of individual sample processing sessions; t_i is the end time of a regular session, dated from the end of the first session; t is the total time from the end of the first session up to scanning the X-ray reflection profile from the exposed sample – up to passage of the halo peak.

As a result of modeling (Fig. 1b), the diffusion coefficient of deuterium in a sample of the given composition was estimated: $\kappa^2 = (1.75...2.45) \cdot 10^{-9}$ cm²/s (3). The limiting characteristics of the deuterium concentration in the sample were also estimated. So, at the border of the experimental graph regularity (Fig. 1b; fluence $3.67 \cdot 10^{20}$ ions/cm²), the numerical ratio D/M of deuterium atoms – with their penetration depth of 0.03 mm – to BMG atoms is 1.6. Before the chipping of the sample (fluence $9.0 \cdot 10^{20}$ ions/cm²) D/M = 2.3 in such a layer. However, according to Fig. 1a, possibilities of BMG saturation with deuterium are in principle much higher.

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НИЗЬКОЧАСТОТНА ДИЕЛЕКТРИЧНА СПЕКТРОСКОПІЯ РІДКОГО ФЕНІЛДИФТОРМЕТИЛСУЛЬФАТУ

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Для фізики рідин і рідинних систем значний інтерес мають фундаментальні аспекти вивчення галогенпохідних сполук: фторзаміщення в молекулі органічної сполуки часто призводить до неочікуваних змін фізичних властивостей рідини. З іншого боку, дослідження фізико-хімічних властивостей фторзаміщених сполук актуальне, оскільки такі речовини широко використовуються як холодильні агенти і теплоносії, барвники та пестициди, інгаляційні анестетики і кровозамінники, проміжні продукти органічного синтезу і мономери для отримання полімерних матеріалів [1].

Об'єктом дослідження даної роботи є рідкий фторзаміщений фенілметилсульфата – фенілдіфторметилсульфат ($C_6H_5SO_2CHF_2$), який