THE VOLUME OF THE NANOCLUSTER AND ITS DEPTH AT ACTION OF IONS OF DIFFERENT ENERGIES, VARIETIES AND CHARGES ON TITANIUM ALLOY VT-4

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This paper discusses the volume of the nanostructured cluster and the depth of its occurrence in a magnesium alloy, which will provide a high resource of parts made of magnesium alloys. The volume of nanostructures under the single action of an ion on a titanium alloy makes it possible to predict the required density of the ion current in the flow for the complete filling of the layer, where it is possible to form nanostructures for this ion of the corresponding grade, energy and charge.

It is obvious that with the growth of ion energy and their charges, a significant increase in the volume of nanostructures is realized, and the charge for boron and carbon ions also affects the volume of $V_{max} = 1.1\cdot10^{-22}$ m^3 and the depth of occurrence of nanostructure volumes $h_{max} = 8.7\cdot10^{-8}$ m; $h_{min} = 7.3\cdot10^{-8}$ m ($E = 2\cdot10^4$ eV).

For the case of the action of nitrogen and aluminum ions on the titanium alloy is determined by the energy and charge of the ion, and the depth of its occurrence increases significantly with the growth of energy and ion charge. The maximum depth at which there is a nanocluster is $6.6\cdot10^{-8}$ m, while the minimum is $5.3\cdot10^{-8}$, and the maximum volume of nanocluster is $5.5\cdot10^{-23}$ m^3 at $E = 2\cdot10^4$ eV.

Similar dependences for the case of action of vanadium and chromium ions are found. It is obvious that the energy, as well as the ion charge affect significantly, while the transition from vanadium to chromium practically did not change the nature and numerical values.

The same is observed for the depths of the nanocluster, and the depth of occurrence is significantly affected by the energy and charge of ions. In the case of oxygen and iron ions, the volume of the nanocluster also significantly depends on energy and charge, and the depth of the nanocluster (maximum and minimum),. The maximum volume of nanocluster - $4.27\cdot10^{-23}$ m^3, and the maximum and minimum depth – respectively $6\cdot10^{-8}$ and $4.71\cdot10^{-8}$ m ($E = 2\cdot10^4$ eV).

The action of nickel and cobalt ions makes it possible to obtain nanoclusters of quite significant size, and their value depends significantly on the energy and charge of the ions. The same effect is experienced by the maximum and minimum depth of the nanocluster, but the transition from nickel to cobalt practically does not change either the volume of the nanocluster or the depth of its occurrence. The maximum volume of the nanocluster is $6.32 \cdot 10^{-24}$ m^3, and $h_{max} = 2.95 \cdot 10^{-8}$, $h_{min} = 1.91 \cdot 10^{-8}$ m ($E = 2 \cdot 10^4$ eV; Z = 3). Similar dependences for the case of action of yttrium and zirconium ions are shown in Fig. 1, also there is a determining dependence of the volume (Fig. 1, *a*) and depths of its occurrence (Fig. 1, *b*, *c*) from the energy and charge of the ion, whereas the transition from yttrium ion to zirconium ion does not change these dependences.

Under the action of molybdenum and hafnium ions on magnesium alloy volume and depth of nanoclusters depend essentially on the energy and charge of the ion. For these ions the values volumes and depths of occurrence are almost identical.

For the case of the action of tantalum and tungsten, the influence of the ion variety is practically absent, and the determining influence of the ion energy and charge is observed. The maximum volume of nanocluster – $4.38 \cdot 10^{-24}$ m^3, and the maximum and minimum depth of its occurrence – $2.69 \cdot 10^{-8}$ and $1.69 \cdot 10^{-8}$ m, respectively.

Under the action of platinum on the titanium alloy, a high influence of energy and ion charge on the volume and depth of its occurrence is also noted. In this case the volume of nanocluster – $4.97 \cdot 10^{-24}$ m^3 and the depth of occurrence is $h_{max} = 2.71 \cdot 10^{-8}$ m, $h_{min} = 1.7 \cdot 10^{-8}$ m.

The obtained dependences will be necessary to determine the required current density of the corresponding grade, charge and energy for the complete filling of the layer with nanostructures, and choosing the necessary energies, charges and ion grades to obtain nanostructures of the mainly required thickness, we similarly assess the required current densities in each layer.

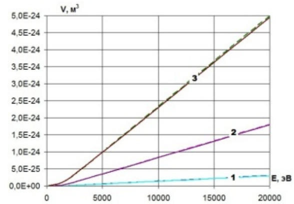
Knowing the volume occupied by the nanostructure at the corresponding energies, grades and charges of ions and the range of depths at which this volume is located, it is obviously possible to estimate the density of the ion current.

Then, according to the known ranges of the depth of the zones where nanostructures are formed, we choose the energy, grade and charge of the ions to completely fill the volume in depth, i.e. so that they complement each other. Next, we determine the current density of each of the ion and charge grades in order to fill the required volume of the surface layer of the part with nanostructures as much as possible (it is desirable that the end of the first layer is the beginning of the second, the end of the second – the beginning of the third layer, and so on).

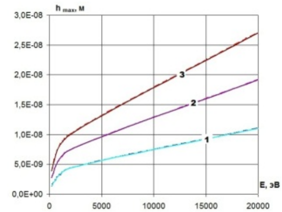
Then for any *i*-th layer the current density is defined as:

$$j_i = \frac{h_{i2} - h_{i1}}{V_{HCi}} z_i e,$$

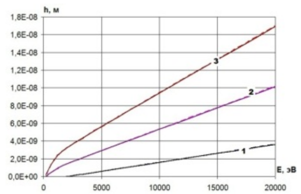
where h_{i1} and h_{i2} are the initial and final coordinates of the zone where nanostructures for the *i*-th ion are realized; V_{HCi} is the volume of the zone where nanostructures are formed; z_i is the charge number of the *i*-th ion: *e* is the electron charge.



a



b



c

Fig. 1. The volume of the nanocluster *V* (*a*), the maximum h_{max} (*b*) and minimum *h* (*c*) depth of its occurrence depending on the ions' energy of yttrium (--) and zirconium (–) on titanium alloy (1–*Z* = 1, 2–*Z* = 2, 3–*Z* = 3)

Knowing j_i, V_{HCi}, h_{i1}, h_{i2}, and z_i and by choosing E_i,, we can form the required number of ion flows, allowing to obtain a nanostructured layer of the required thickness, and taking into account the technical problem of the formation of non-monoenergetic-charged ion flows, it is possible to solve the problem of technological parameters of ion processing.

1. The principal possibility of designing the surface layer in a titanium alloy by creating nanostructures of different composition and physical and mechanical characteristics is shown.

2. It is obvious that the ion energy and its charge have a determining influence on the volume of the nanocluster, while the ion mass, however, is not so significant.

3. The depth of the nanocluster reaches tenths of a micrometer, that is, a layer of material experiencing significant changes, quite significant, and if we consider the possibility of ion diffusion and even anomalous diffusion, it is possible to obtain layers with altered characteristics within a few micrometers.

4. It is obvious that for a number of ion pairs (under their action on a magnesium alloy) the dependences of the nanocluster volume and the depth of its occurrence on energy and charge are the same. Such pairs are: "vanadium-chromium", "nickel-cobalt", "yttrium-zirconium", "tantalum-tungsten" and "molybdenum-hafnium".