Changes of Structure and Surface Properties of Metal Alloys after Pulsed Plasma Processing

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Abstract – The physical properties and changes in structure of vanadium alloy, common quality carbon and stainless steels were investigated. It is shown that character of structure changes depends on working gas used and accelerators' operation mode. The microhardness of plasma processed steels can increase 1,5–3 times depending on the energy density and introduced doze. Wear resistance of steel after plasma processing increased up to 4 times.

1. Introduction

The purpose of the research was the study of influence of pulsed plasma flows on durability superficial properties (in particular, microhardness of a surface) of metal alloys used as applicant material for controlled thermonuclear installations and different industrial technology.

The pulsed plasma accelerators are used for obtaining the powerful concentrated fluxes. Accelerator's construction features allow obtain plasma flows in a wide range of energy: from several units up to hundreds of keV. It gives the opportunities to use them for a wide range of applications in various fields of plasma physics and material science. In the present work the pulsed plasma accelerator KPU with coaxial electrodes is used. The technological applications of this accelerator for a semiconductors surface structure modification were submitted by the authors in [1]. In order to improve the surface properties of metal alloys, such as carbon and stainless steels, the method of plasma processing is most acceptable. This work is devoted to investigation of the influence of plasma flows on a various constructional materials.

2. Equipment

The accelerator KPU has two cylindrical electrodes with diameters of 90 mm (external) and 24 mm (internal). Energy of the capacitor bank is 32 kJ. Discharge current of KPU represents a decreased harmonically signals with the period of 14 μs and 100–500 кA. The work of this accelerator in two modes has been investigated in details. In the first mode, the gas is filled through the pulse fast valve, in the second mode the working chamber is filled by gas up to the pressure in a range between 0,01–10 torr. Plasma flow energy density has made 2–60 J/cm^2. The concentration of electrons in plasma, determined by various methods, has made ~10^{12}–10^{14} cm^{-3} in different modes. The velocity of plasma flows was up to 10^5 m/s. The detailed description of this accelerator is given in work [2]. In the Figure 1 a principal scheme of accelerator is given.

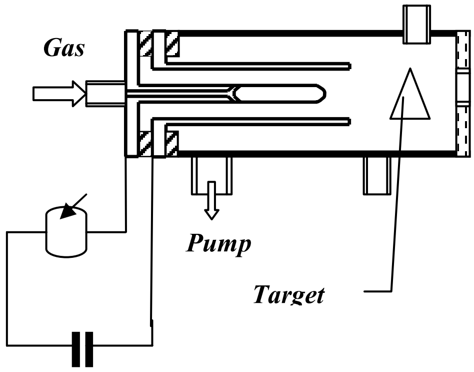

Fig. 1. Scheme of KPU coaxial pulsed plasma accelerator

For research of structural changes in a subsurface layer PMT-3 microscope metallographic methods and the X-ray analysis were used. Samples X-ray spectra were obtained by D8 ADVANCE diffractometr by means of copper radiation with monochromator.

3. Experimental results

The physical properties and changes in the structure of vanadium alloy, common quality carbon and stainless steels were investigated. The formation of the modified layer on a surface is usual for metals. However, the large density of energy results in formation of a non-uniform relief of a surface and blisters. This undesirable phenomenon can be avoided if one uses small density of energy. In all cases when the value of melted energy achieved 15–25 J/sm^2, the recrystallization of the surface area and structure modification took place on the depth about 10–30 μm (it depends on materials). The character of structural changes in metals depends on the energy density and the introduced doze. Also character of structure changes depends on working gas used and from accelerators operation mode. When vanadium alloy surface processing with Argon and Helium two different reliefs formed.

For carbon steel, which has the ferrite as a basic structure, the formation of austenitic and martensitic phases is observed after processing. At the same time for stainless steel the formation of nitride hardening phases is usual at processing by nitric and air plasmas. The microhardness of common steels processed with plasma increase 1,5–3 times when one repeats the processing (Fig. 2.)

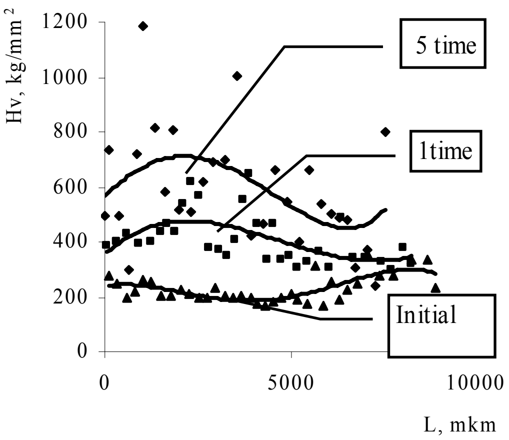

Fig. 2. Microhardness of common steel along surface space L

In any case, the degree of hardening is proportional to the introduced doze. Wear resistance of steel after plasma processing increased up to 4 times. This parameter determined by abrasive method.

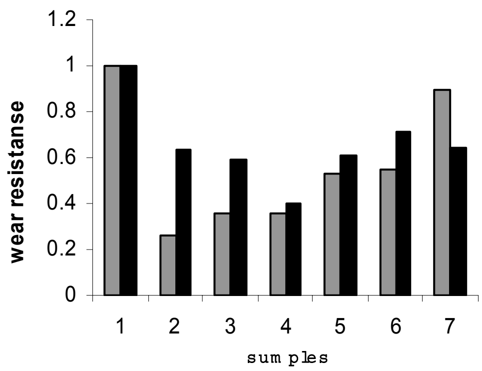

Fig. 3. Wear resistance of common steel samples, treated by different energy density. On left – linear parameter, on right – mass parameter

The stainless steel samples were treated by several pulses. The processing of stainless steel samples with energy density about 25–30 J/cm^2 at once was carried out 10, 20 and 30 times (N). In all cases the influence of plasma leads to the surface melting and the homogeneous relief with blisters is forming. As the number of influences increase the quantity of blisters increase, too. They unite into groups and form complexes. The surface of the processed sample is not etched in usual solutions of acids.

The microhardness is higher 3 times, and Hv size has a directly proportional dependence on quantity of pulses N observed. The generalized result on microhardness presents on Figure 4.

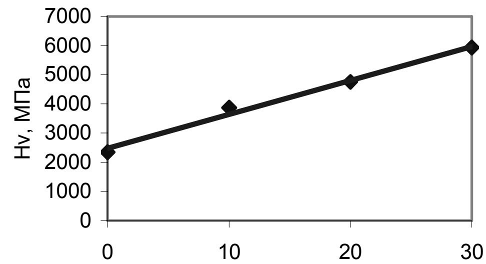

Fig. 4. Microhardness of stainless steel, processed several times

To specify the metallographic data, the X-ray analysis of all three samples of stainless steel processed by different quantity of time was carried out.

The basic phase of an initial sample is austenitic stainless steel. With the help of the automated program parameter of a austenite crystal lattice was determined; it is equal a=(3.58980±0006) Å. The Roentgen data and phase structure of the processed samples show the presence of two basic phases: iron nitride and austenite in the processed layer of a surface. For iron nitride and austenite phases the parameters of a crystal lattice were determined. Parameter for nitride is equal to a=(3.6104±0.0011) Å, parameter for austenite – a=(3.5896±0.0015) Å. From comparison of austenite phase parameters for various samples it is seen that within the limits of a mistake of definition this parameter almost remains the same after processing. Only weak deformation of a crystal lattice is possible for these samples. The iron nitride structure can be expressed by the following formulas: Fe N0.056 or Fe N0.059.

References

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[2] B.M. Ibraev, Rus. J. of Engineering Thermophysics. 12, 2, 65, (2003)