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The structure changes on a steels surface after pulsed plasma processing

Abstract. The structure changes on steels surface, modified by plasma processing, are researched. The nano size structure, formed after plasma processing, is investigated by X-ray analysis and metallographic methods. Is shown, that phase consist of surface define by plasma parameters and the size of formed crystallites strongly influence on physical properties of materials.
Keywords: the pulse plasma accelerator, a plasma flow, surface of materials, carbon steel, microhardness, crystallite.

Introduction

The pulsed plasma processing, as one of ways of high-intensity influence on a surface of materials, is one of perspective methods for creation of materials with the special properties [1-3]. Feature of the given method is the opportunity of a combination of hot plasma thermal influence together with doped by particles of a plasma flow. However, good physical properties of surface processing can be achieved at the certain regimes of influence, as large density of energy flow, can result not only in improvement of properties, but also to destruction of a material. Therefore, the correct choice of processing regimes plays the important role for purposeful treating of materials surface.

As shown in our work [4], the pulse plasma accelerator with coaxial system of electrodes has high enough power parameters for processing a metal alloys surface $0,5-10\ MW/cm^2$. The work of this accelerator in a pulse regime is well investigated [5], when the working gas is injected between electrode space before apply of a high voltage. In this regime the dense plasma flow with high speed is formed. Lack of the given mode is the weak dependence of plasma parameters, concentration and temperature on a voltage of the discharge. In the other regime, at constant initial pressure of gas in the working chamber, the same parameters change over a wide range. This mode named “continuously filled” [6].

For metal alloys such as carbon and stainless steels, the basic result of plasma influence is the hardening [7]. Therefore, in this work the influence of plasma processing regimes on changes in structure and as a consequence, on steel hardness is investigated. Energy density at one time influence was chosen as basic parameter of processing.

Samples which had been cut out as plates of $15\times15\times5\ mm$ were investigated. The processing was carried out at different energy density of air plasma. The roentgen analysis of the processed samples is carried out on “D8 Advance” diffract meter, the microhardness is measured on the device “Metaval”.

Parameters of processing of carbon steel are given in the table 1. A basis of an initial sample of carbon steel is ferrite with crystal lattice parameter $a = 2.8684 \pm 0.0004$ Å. The feature of processing for all samples is the presence of an austenite phase. As it is shown on the table 1, there is the maximal crystallite size of austenite $L =$ 240 Å contains in the sample №5, processed by $32\ J/cm^2$. The basic phase of a sample is the ferrite with parameter of a crystal lattice

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$a = 2.8630 \pm 0.0005$ Å. Austenite has parameter $a = 3.6212 \pm 0.0037$ Å. Phase diagram of the processed sample №3 is given in figure 1.

The obtained results show, that influence of energy density on structural parameters has not trivial character. The quantity of austenitic phase reaches a maximum at energy density equal $32\ J/cm^2$, thus the maximal crystallite quantity is observed. Structural features also clearly influence on the value of a material microhardness, which are given in figure 2.

Table 1 – The summary data on all carbon steel samples.

Pattern	Energy dense, J/cm^2	Ferrite L, Å	Austenite L, Å	Parameter Fe-α, ±0.0005 Å	Austenite parameter, ±0.0005 Å	Int. of austenite phase
Initial	0	1160	-	2.8691	-	-
№ 3	16	730	175	2,8631	3,6172	24.2
№ 4	22	610	160	2,8622	3,6141	19.8
№ 5	32	460	240	2,8630	3,6212	26.0
№ 7	44	115	110	2,8630	3,6184	13.6
№ 9	48	145	140	2,8610	3,6223	12.7

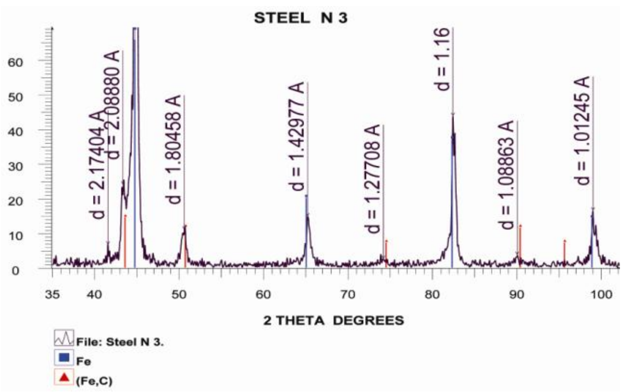

Figure 1 – Phase diagram of a №3 carbon steel sample.

The microhardness of the processed samples changes proportionally to energy density, however the certain law is observed. As it is shown in figure 3, for the first group of samples (samples №1, 2) the value of microhardness practically does not vary. For the second group (samples № 3, 4, 5, 6) the microhardness increases about two times, and for the third group (samples №7, 8) it increase more than three times.

Thus, there is an optimal value of energy density in area $20 - 40\ J/cm^2$, at which the increasing of microhardness of carbon steel is reached and crystallites with maximal size are formed. At small energy less than $20\ J/cm^2$ there is no hardening, and at large one there is a reduction of the crystallite sizes.

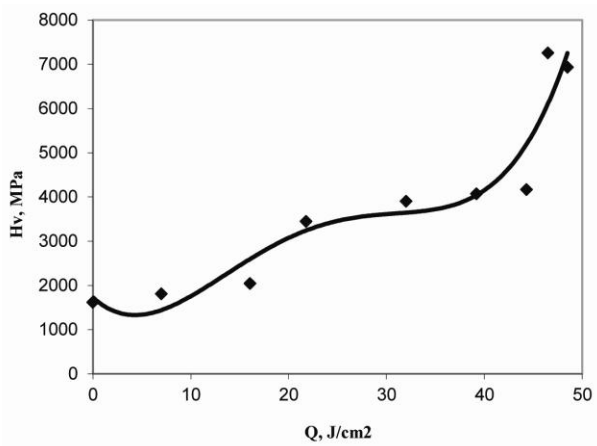

Figure 2 – Dependence of microhardness on density of energy.

Samples of corrosion-proof steel 12X18H9 were processed similarly with density of energy $5 - 50\ J/cm^2$. The result of the X-ray analysis is given in the table 2. As it is shown from the table 2, the processing of corrosion-proof steel by air plasma results in formation of carbonitride phase. This result can testify to the high enough contents of nitrogen ions in air plasma flow, as dope of metals occurs at a doze not less than 10^{15} cm^{-2}. The behaviour of microhardness of corrosion-proof steel is given in figure 3.

Table 2 – The data of the structural analysis of corrosion-proof steel.

$2\theta_{max}$	I_{max}	d	$2\theta_{cg}$	I_{int}.	
43.6310	974.3	2.0727	43.6572	11075.1	Fe
50.7635	143.2	1.7969	50.8207	2565.9	FeCrNi
74.7995	131.2	1.2682	74.7916	1548.7	$FeCrN_6C_3$

Therefore, the structural changes in steels induced by pulsed plasma processing, create the modified layers with physic -mechanical properties beyond the original surface. The formation of carbides and nitrides, austenites in the modified layer as a result plasma treatment, watched as in [1,7]. It can be said that the modification of the structure of crystalline materials is typical for pulsed plasma processing. Austenitic phases formation associated with heating above melting and rapid cooling designs during processing. Key role in this process play carbon atoms, removed from equilibrium position with a minimum potential energy. During this transformation a period of grain centered lattice is greater than the original volume centered lattice, which is also a characteristic feature.

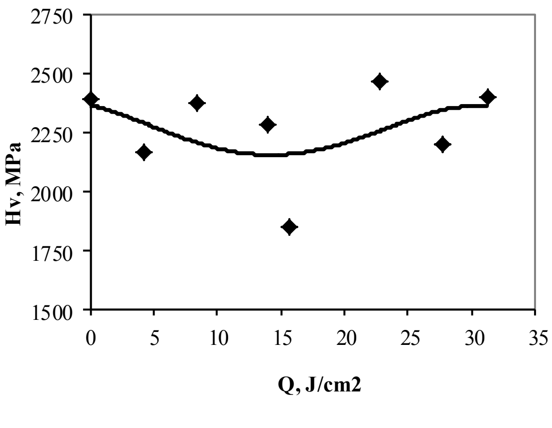

Figure 3 – Microhardness of stainless steel samples.

Conclusions

Thus, under identical conditions of plasma processing physics-mechanical properties of carbon and corrosion-proof steels have different changed. Therefore it is possible to make a conclusion, that for each material even close on physics-mechanical properties, it is necessary to develop the own way of processing. At influence of plasma there is a structural reorganization of surface area specific to each material what results to such sensitivity of this method. It leads to specific change of mechanical properties.

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