INFLUENCE OF HYDROGEN IMPLANTATION AND OXIDATION ON AIR ON THE STRUCTURE AND MECHANICAL PROPERTIES OF NICKEL BASED COATING PG-19-01

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Influence of oxidation on air and hydrogen implantation on the structure and mechanical properties of nickel based coating PG-19N-01 deposited on iron and stainless steel C0.12Cr18Ni10Ti substrate and also of iron with plasma treatment of surface were studied. It is shown, that implantation by protons with energy from 0.6 to 1.6 MeV up to doze $3\cdot10^{18}$ proton/cm^2 lead to insignificant changes of structure and strength properties of PG-19N-01 coating. In the samples oxidized on air at temperatures 500 °C, 700 °C and 900 °C during three hours increase in microhardness and strength of the material at mechanical tests on static bend is observed.

INTRODUCTION

Actual way of improvement of physical and mechanical properties of metal materials is the treatment of its surface by laser, electron and ion beam or by deposition on its surface of protective coating. In such way, it is possible to increase such properties of materials as hardness, wear resistance, corrosion resistance, etc. By present time various ways of protective coating deposition on the material surface – electrochemical, magnetron, detonation are developed [1, 2]. The detonation method is widely used, rather simple and inexpensive. As lack of this method it is possible to note necessity of preliminary preparation of deposited material i.e. preparation of powders of the necessary composition. Furthermore, quality and homogeneity of coatings depends on the sizes of the powder fractions and on conditions of deposition [3].

The powder nickel base coating PG-19N-01 (Cr – 8 ÷ 4%, B – 2.3%, Si – 1.2 ÷ 3.2%, Fe – 5%, C – 0.5%) is the material with high hardness, heat resistance and is perspective for application in those products where such properties are required [4].

In the given work, results of studying of structure and mechanical properties of iron with PG-19N-01 coating and also influences of oxidation on air and hydrogen implantation on structure and mechanical properties PG-19N-01 coating are presented.

MATERIALS AND EXPERIMENTAL TECHNIQUE

Substrates for deposition of PG-19N-01 coatings were made from massive bar of α – iron (purity – 99,8) and stainless steel C0.12Cr18Ni10Ti. Samples represented thin plates with sizes 30×30×(0.8 ÷ 1) mm. Plasma treatment of the surface and deposition of protective coating by plasma-detonation method from powder of alloy PG-19N-01 on the base of nickel (Cr – 8 ÷ 4%, B – 2.3%, Si – 1,2 ÷ 3.2%, Fe – 5%, C – 0.5%, Ni – 83 – 87%) are described in detail in [1] and carried out in the Sumy Institute for Surface Modification.

Study of structure and mechanical properties of the material of substrate and coating were carried out by methods of optical metallographic, X-ray difractometry, measurements of microhardness and mechanical tests on static bend.

Oxidation of samples of iron, steel, iron and steel with PG-19N-01 coating and iron with plasma treatment surface were carried out in muffle furnace at temperatures 500 °C, 700 °C and 900 °C within three hours.

Radiation treatment of samples was carried out by protons with energy from 0.6 to

1.6 MeV up to dose 3×10^{18} proton/cm^2 on the electrostatic accelerator UKP-2-1 of Institute of Nuclear Physics.

RESULTS AND DISCUSSION

Experimental results of influence of oxidation on air at high temperatures and proton irradiation on structure and mechanical properties of iron with plasma treated surface and iron with the PG-19N-01coating deposited by plasma-detonation method represented below.

1. *Iron with plasma treated surface.* Structure of initial material (iron), plasma treated iron, plasma treated iron after oxidation at 700 °C and proton irradiation is shown on fig. 1. Characteristic feature of initial iron structure is big mean grain size – 200 μk (fig. 1a). After plasma treatment the mean grain size become much smaller and consist 50 μk (fig. 1b). After oxidation mean grain size practically does not change, but grain boundaries revealed as figures of etching (fig. 1c). Apparently precipitation of some phases on grain boundaries occurred during annealing and their traces after electrolytic etching are observed. After proton irradiation mean grain size become large in comparing with plasma treated surface and consists 100 μk (fig. 1d).

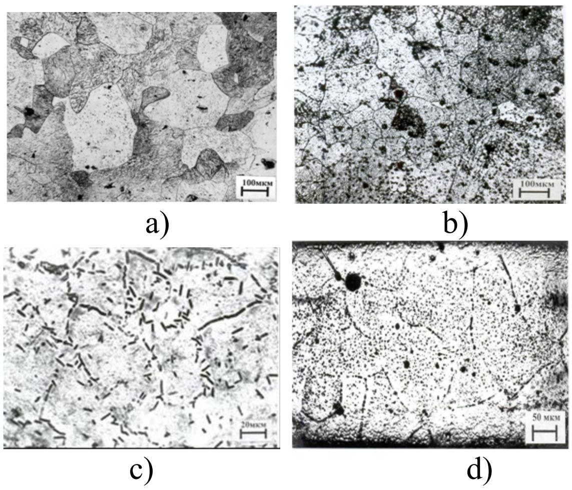


Fig. 1. Microstructure of surface layers of initial iron – a); plasma treated iron – b); plasma treated iron after oxidation at 700 °C – c) and proton irradiation – d).

Microhardness of initial material (iron), plasma treated iron, plasma treated iron after oxidation at 700 0C and proton irradiation is shown on fig. 2. As follows from dependences of Hμ on distance for treated surface the microhardness for treated material increases approximately twice (curve 1) compare to initial material (line "iron"). Oxidation at 700 °C leads to little increasing of microhardness (curve 2) and after proton implantation decreasing of Hμ in the region of hydrogen influence (3) is observed.

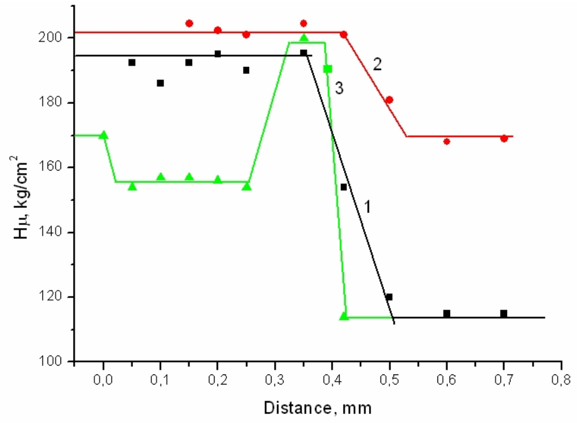
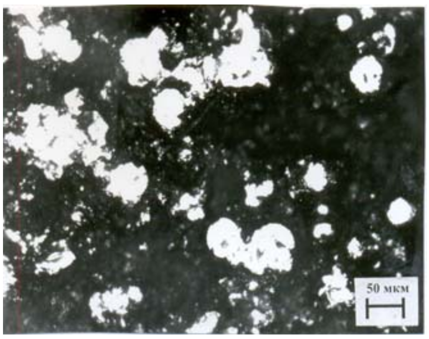


Fig. 2. Microhardness of surface layers of initial iron (iron), plasma treated iron – 1), plasma treated iron after oxidation at 700 °C – 2) and proton irradiation – (3).

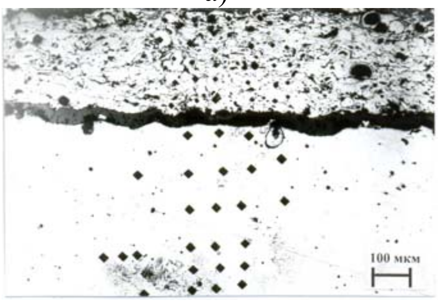
Strength of iron with plasma treated surface was determined from mechanical tests on static band, as mechanical properties of surface much more sensitive to band deformation compare to uneasily deformation. From bend test follow – plasma treatment of iron surface lead to strong increasing of iron strengthening – irreversible deformation begins at load 4 kg (maximal strength – 8 kg) while as for untreated material irreversible deformation begins at load ~2 kg (maximal strength – 4.5 kg). Oxidation at 700 °C leads to further increasing of irreversible strength. – 5 kg (maximal strength – 11 kg). Proton irradiation leads to decreasing irreversible strength value up to 2 kg and maximal strength up to 3.9 kg. It is necessary to note following: One more impotent fact: cracks on iron surface does not appear ever for band maximal band angle, while for plasma treated surface cracks forms at band angle ~ 30°, after oxidation at temperature 700 °C – at the same band angle 30°. Cracks on plasma treated surface forms at bend angle ~ 45° for material after proton irradiation.

2. *Iron with the PG-19N-01 coating deposited by plasma-detonation method.* Structure of the PG-19N-01coating deposited by plasma-detonation method, coating structure after oxidation on air at temperature 700 °C

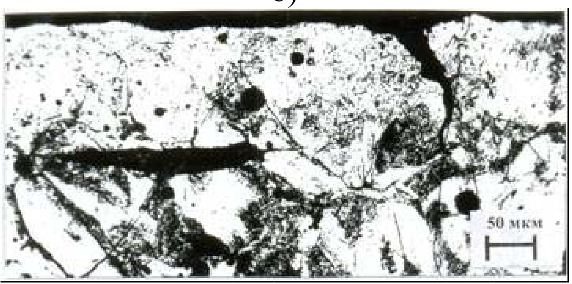
and proton irradiation is shown on fig. 3. Microstructure of PG-10N-01 coating before oxidation and proton irradiation represent the mixture of white and dark regions – probably fraction of PG -10N-01 powder (fig. 3a). After oxidation on air between deposited material and substrate appear strong boundary (fig. 3b), more over in structure of coating forms pores size of which can reach 100 μk, see fig. 3c. Proton irradiation does not produce significant influence on microstructure of coating and substrate.



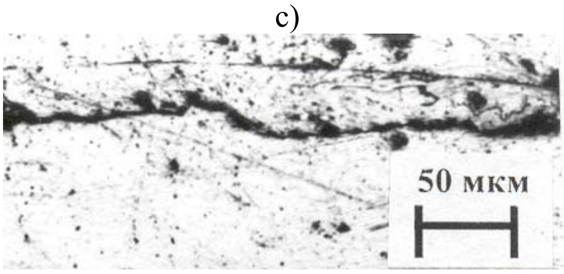
a)



b)



c)



d)

Fig. 3. Microstructure of PG-19N-01coating deposited by plasma-detonation method. a) – after deposing of coating; microstructure of PG-19N-01coating iron after oxidation at 700 °C – b); pore in coating iron after oxidation at 700 °C – c); microstructure coating after proton irradiation – d).

Microhardness value in white regions is very high and consist ~715 kg/mm^2. Average microhardness value of coating equal to ~580 kg/mm^2 and more than five times exceeds Hμ a of the substrate material. After oxidation on air at 700 °C during 3 hours microhardness of coating decrease to value ~310 kg/mm^2. Zone of microhardness decreasing consists ~80 – 100 microns from the outer surface of coating, Hμ of other part of a coating remain the same as before oxidation (580 kg/mm^2). Proton implantation leads to softening of coating on ~28%, softened zone extend on 10 – 12 μk and corresponds to projective range of protons. Microhardness value behind projective range corresponds to unirradiated material and consists ~580 kg/mm^2.

As follow from experiments on static band flexural strength of PG-10N-01 coating on iron is insignificant. For bend angle ~10° at the surface of coating appear frontal crack and at bend angle ~60° delaminating of coating is observed. Irreversible deformation begins at load 2 kg and coincides with crack formation and maximal load consist 3 kg and corresponds to delamination of coating. For oxidized material cracks forms at the same bend angle 10° and at bend angle 45° delamination of coating occur. At that weakening of material take place: cracks forms at bending stress 1.5 kg and delamination – at bending stress – 2 kg. Proton irradiation does not significantly influence on mechanical properties of Ni-base PG-19N-01 coating: cracks forms at bend angle ~10° (see fig. 4), delamination of coating occur at bend angle ~ 60°, stress level for irreversible deformation and maximal stress is the same order as for unirradiated material.

CONCLUSION

1. Plasma treatment of iron leads to significant improvement of mechanical properties of materials surface and reaches 200 microns from the treated surface. In that region mean grain size decrease, microhardness and strength increase. Maximal increasing of microhardness and strength (~2 times) reaches up to 100 microns from treated surface. Together with increasing of bending strength formation of cracks take place at rather small band angle (~ 60°) as follow from bend test. Oxidation on air at high temperatures (500 °C and higher) of iron with plasma treated surface leads to degradation of mechanical properties. Microhardness practically left the same. Net of cracks forms at band angle ~30° as follow from bend test. Proton irradiation leads to recovery of mechanical properties: microhard-

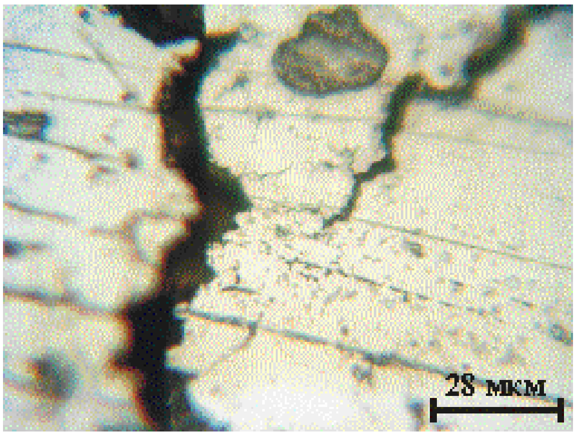


Fig. 4. Crack formation at band angle ~10° in PG-19N-01 coating after oxidation at 700 °C.

ness decrease, ben-ding strength decrease to the level of initial material.

2. Deposition of Ni-base PG19N-01 coating by plasma-detonation method allow significantly improve physical and mechanical properties of material, for example iron. PG-19N-01 coating has rather low corrosion resistance, but PG-19N-01 coating significantly increase hardness, strength, wear resistance. Bending strength of that coating the same order as for initial material and at band angle ~60° delaminating of coating take place. Oxidation on air at high temperatures (500 °C and higher) of iron with Ni-base PG-19N-01 coating leads to degradation of mechanical properties of coating. Microhardness decreases almost twice, bending strength decrease. At band angle ~10° on the surface forms cracks and at band angle ~45° delaminating of coating take place. Proton irradiation does not significantly influence on structure and mechanical properties of Ni-base PG-19N-01 coating.

ACKNOWLEDGMENTS

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ВПЛИВ ІМПЛАНТАЦІЇ ВОДНЮ ТА ОКИСЛЮВАННЯ НА ПОВІТРІ НА СТРУКТУРУ І МЕХАНІЧНІ ВЛАСТИВОСТІ ПОКРИТТІВ НА ОСНОВІ НІКЕЛЮ PG-19-01

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Вивчено вплив окислювання на повітрі й імплантації водню на структуру й механічні властивості нікелевих покриттів PG-19N-01, нанесених на залізну підкладинку та з нержавіючої сталі 30.12Cr18Ni10Ti підкдадинки, а також заліза із плазмовою обробкою поверхні. Показано, що імплантація протонами з енергією від 0,6 до 1,6 МеВ з дозою $3\cdot10^{18}$ протон/см^2 приводить до незначних змін структури й міцності характеристик покриття PG-19N-01. У зразках, окислених на повітрі при температурах 500 °С, 700 °С и 900 °С у плині 3-х годин спостерігалося збільшення мікротвердості й зміцнення матеріалу при механічних випробуваннях на статичний вигин.

ВЛИЯНИЕ ИМПЛАНТАЦИИ ВОДОРОДА И ОКИСЛЕНИЯ НА ВОЗДУХЕ НА СТРУКТУРУ И МЕХАНИЧЕСКИЕ СВОЙСТВА ПОКРЫТИЙ НА ОСНОВЕ НИКЕЛЯ PG-19-01

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Изучено влияние окисления на воздухе и имплантации водорода на структуру и механические свойства никелевых покрытий PG-19N-01, нанесенных на железную подложку и из нержавеющей стали C0.12Cr18Ni10Ti подложки, а также железа с плазменной обработкой поверхности. Показано, что имплантация протонами с энергией от 0,6 до 1,6 МэВ с дозой $3\cdot10^{18}$ протон/см^2 приводит к незначительным изменениям структуры и прочностных характеристик покрытия PG-19N-01. В образцах, окисленных на воздухе при температурах 500 °С, 700 °С и 900 °С в течении 3-х часов наблюдалось увеличение микротвердости и упрочнения материала при механических испытаниях на статический изгиб.