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IRON SURFACE CELLULAR STRUCTURE FORMED BY ACTION OF COMPRESSION PLASMA FLOWS

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1. Introduction

Nowadays the variety of methods for modification of material surface involving the implementation of concentrated energy flows are widely used /1-4/. Thermoelastic stresses arising from exposure of a sample to shock wave produce variations in a number of surface layer properties accompanied with considerable changes in morphology of processed surface.

As shown earlier /5/, compression plasma flows are suitable for the formation of submicron cylindrical structures on the surface of semiconductor materials.

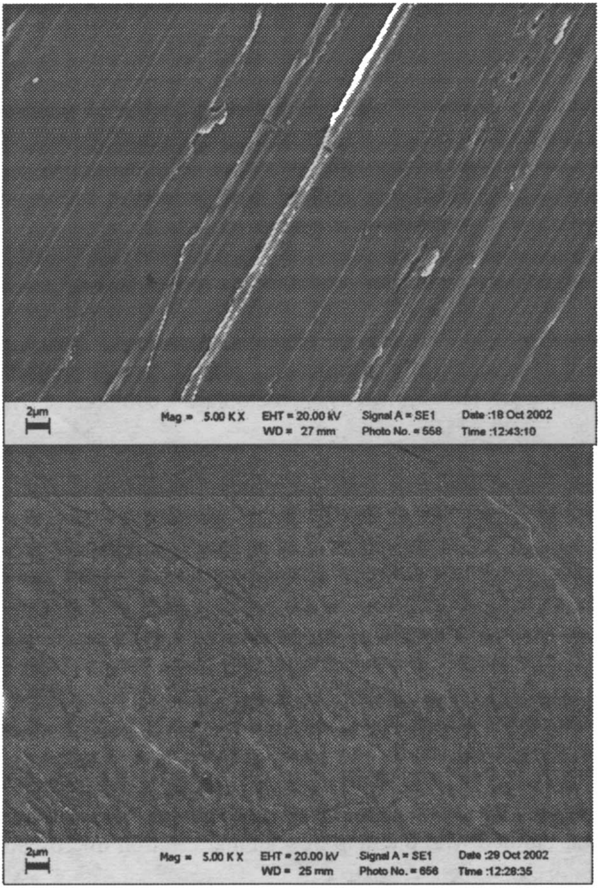
The paper presents results of electron-microscopic investigations of armco-iron surface processed by compression plasma flow generated by quasi-stationary plasma accelerator known as magnetoplasma compressor (MPC).

2. Experimental

Iron samples (0,025 wt. % C) were processed by varied-power compression plasma flows in the Institute of molecular and atomic physics, NAS of Belarus, using gas-discharge MPC of compact geometry /6/. Power density per pulse received by a sample, was measured immediately at a sample surface by calorimetric method. Depending on processing conditions it amounted to 4÷20 J/cm^2 /5/ at discharge duration of approximately 100 μs /7-8/. Studies of elemental composition were carried out using Perkin Elmer PHI-660 Auger spectrometer. The setup was equipped with an ion gun for both surface cleaning and obtaining impurity concentration profiles against depth. Energy of argon ions used for cleaning is 3.5 keV, ion current density – 50 μA/cm^2, incidence angle of ion beam – 60 to 70°. Etching area measured 2 mm × 3 mm. Surface morphology was studied with the help of scanning electron microscope Hitachi SEM S-806.

3. Results and discussion

Results of conducted research show that melting and subsequent solidification of the surface layer occur in the course of compression plasma flow action (Fig. 1). At the same time implantation of particles from plasma flow into the workpiece material takes place. This fact is confirmed by Auger-electron spectroscopy data according to which in the surface layers (those located immediately below the processed sample surface) nitrogen concentration amounts to 20 at. % (Fig. 2).



a

b

Fig. 1. Micrographs of armco-iron surface before (a) and after (b) processing.

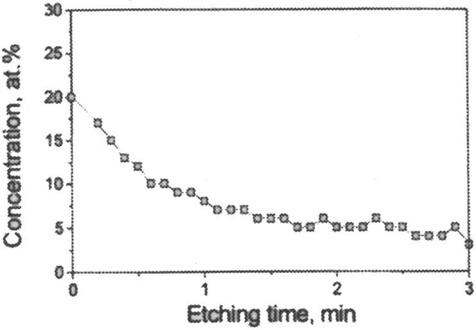


Fig. 2. Concentration profile of nitrogen in processed samples of iron.

When studied at higher magnifications, all of the processed samples turned out to possess a cellular structure consisting of polygonal cells, predominantly regular hexagons separated from each other by grooves several tens of nanometers wide (Fig. 3). The size of the cells slightly varies within 300-400 nm.

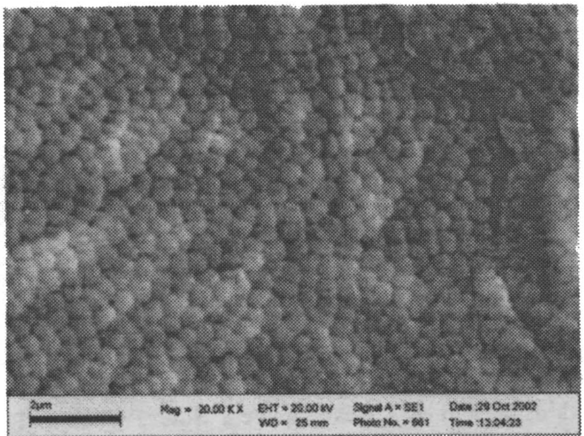


Fig. 3. Image of cellular structure at the processed sample surface.

One of the reasons why such structures are produced is the existence of concentrated and undercooled melt in which the crystallization proceeds at temperatures below solidification point because of the presence of impurities (in our circumstances – interstitial nitrogen). According to conventional models /9-10/, in this case, macroscopically flat interface becomes unstable relative to interface with cellular structure. So accidental changes in shape of the interface tend to develop, rather than to disappear. Thus, the transformation of smooth surface into the cellular one will take place if extending regions of cells (ridges) are capable to grow out more intensely than smooth interface. Then surface irregularities of the melt will result in the lateral diffusion of impurities, and, as a consequence, concentration of impurities near a ridge will decrease, whereas the melting point will increase correspondingly. At the certain extent of concentration supercooling, resulting cellular structure becomes stable.

On the other hand, similar cells can also develop due to so called Benar's effect /11/ when upon reaching critical value of temperature gradient in supersaturated solution convection current appears. This current features a structure composed of hexagonal cells. In this case, finite state of surface is conditioned by internal regularities of the process considered, rather than by external conditions.

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