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# THE SOURCE OF CHARGED PARTICLE BEAMS FOR IMPLEMENTATION OF THE COMBINED EFFECTS ON MATERIALS

***PAVEL SOLDATENKO, DMITRIY ANTONOVICH***
**Polotsk State University, Belarus**

*Presents some results of an experimental study of realization the combined ion-electron effects on the material surface using a single source.*

**Introduction.** Ion-plasma technologies are promising for the controlled modification of materials surface properties [1]. Moreover, for mechanical and corrosion modification of surface with ion beams are applied ions with energy typically lower than 1 keV and a flux density of about 1 mA/cm$^2$. Since the electron beams with power density up to $10^8$ W/m2 in addition to the heat, can have modified (hardening) impact. The effectiveness of ion impact is dependent on the temperature of the modified material support which is not advisable around the product. The promising direction is submitted electron-beam assisting ion influence by plasma electron sources (PES) that can emit electrons and ions with the polarity of the accelerating voltage.

In this paper we present some results of an experimental study of realization the combined ion-electron effects on the material surface using a single PES.

**Results and discussion.** As an experimental PES used the structure shown in Figure 1. In this source the main gas ionization processes take place in the area bounded by external and internal cathodes 1 and 2 and the anode 3. The magnetic field is generated by using permanent magnets 6 disposed between the cathodes. The direction of the magnetic induction vector is a necessary condition for the structure. It should have a perpendicular direction relative to the working surface of the cathodes because this leads to restriction of the electrons mobility from the plasma to anode, resulting in increased plasma density in that area. Plasma penetrates the expander 9 through the upper hole in expander. The plasma-forming gas lets into the discharge structure through the channel 8 in the socket 5 and cathode 1. The construction of this gas-discharge structure provides the location of workpieces and the feeding mechanism in the volume of plasma expander 9 within the vacuum chamber which communicates with the discharge structure via the base flange 11. The use the additional electrode 7 located between the internal cathode and expander provides increased extraction efficiency and stability of the emission current [2].

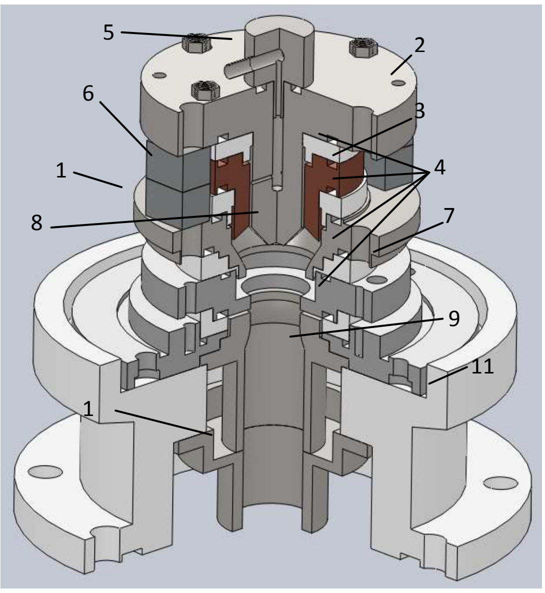
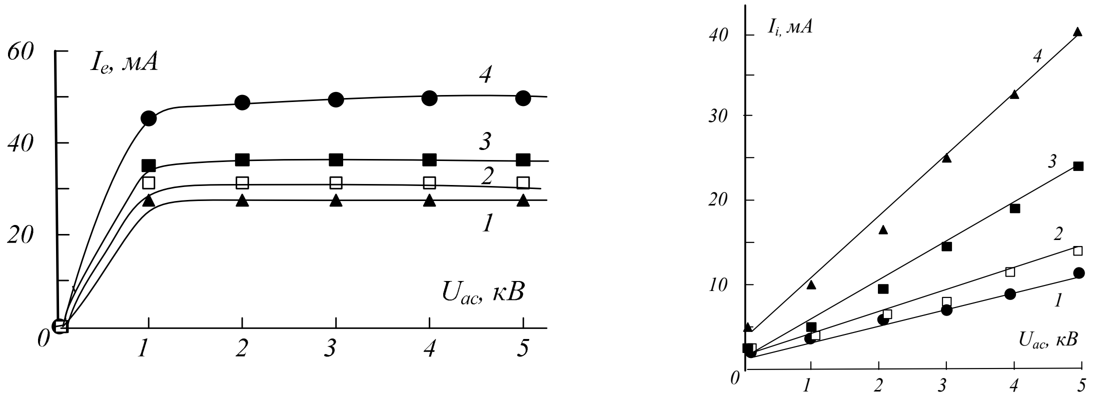


Fig. 1. Plasma electron source with crossed E × H fields and the additional electrode: 1 – external cathode; 2 – internal cathode; 3 – anode; 4 – insulators; 5 – socket for inlet plasma-forming gas; 6 – permanent magnets; 7 – additional electrode; 8 – gas outlet; 9 – expander; 10 – accelerating electrode; 11 – flange

Besides the application of additional electrode, to control the source extraction efficiency is possible due to the magnitude of the magnetic field [2]. The presence of a magnetic field in the gas-discharge structure is due to the conditions of the discharge formation and the order of 0.1 Tesla. However, since source structure elements (expander and accelerating electrode) is also made of a magnetic material (steel), the magnetic field goes from gap between cathodes, which provides additional mechanisms to improve emission efficiency in the expander by increasing the plasma concentration and the creation of conditions for the movement of electrons in the plasma along lines of the magnetic field in the area of emissions. Basic characteristics of the source and pictures of electron and ion beam are shown in Figures 2-3.



*a* *b*

Fig. 2. Characteristics of electron extraction a) and ion extraction b) for different expander potentials: Expander potential: 1, 2 – anode, 3, 4– cathode; discharge current: 250 mA

*a* *b*

Fig. 3. Appearance of electron (a) and ion (b) beams if charged particles

To determine the most promising modes of operation provided gas-discharge construction were carried some experiments of the implementation of effects on the samples steel in various modes: electronic, ionic, combined. Research hardening process carried out by the example of tool steels (steel X12BM) used for the manufacture of die tooling. In this changed the current density in discharge structure and the temperature of the samples heating. The measurement results of the hardness (HV), and microhardness ($H_{0,19}$) after different electron-ion treatment conditions shown in Table 1. Determination of HV is conducted on unimplanted the sample surface, and characterized the change in the hardness of steel during high temperature impact during ion implantation. Using the measurement $H_{0,19}$ is estimated hardening implanted surface layers of steel.

Figure 4 is a graph of the distribution of microhardness depth of the modified layer. The implantation of nitrogen ions at 670 K leads to an increase in the depth of the modified layer to ~ 10-15 microns. The microhardness of the layer significantly increases and reaches a level $H_{0,19}$ = 16000 MPa.

Table 1 – The hardness HV and microhardness $H_{0,19}$ X12BM treated steel before and after treatment with an electron-ion ($j \approx 2$ mA·sm$^{-2}$) at different temperatures

| X12BM steel | | | | | |
|---|---|---|---|---|---|
| Measured characteristics | Processing mode | | | | |
| | The initial state | The temperature of electron-ion influence, K | | | |
| | | 620 | 670 | 720 | 770 |
| Surface microhardness $H_{0,19}$, MPa | 6100 | 9600-10000 | 16000-16500 | 14000-15000 | 10500-11000 |
| Steel hardness HV, MPa | 5950 | 5800 | 5700 | 5300 | 4900 |

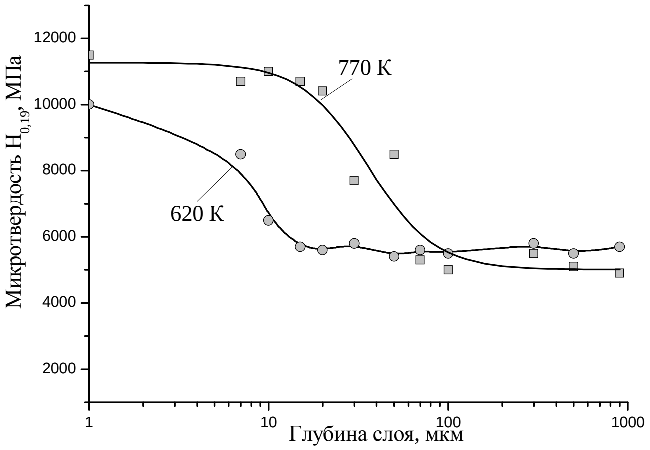


Fig. 4. Microhardness distribution in the depth of modified layers of steel X12BM

**Conclusion.** These results demonstrate the possibility of alternate electron and ion extraction from the gas discharge plasma and the combined implementation of the ion-electron impact onto the material surface using a single PES with parameters sufficient for a number of surface modification techniques.

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