The formation processes of carbon coatings produced by low frequency plasmatron at atmospheric pressure in matrix mode of deposition

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Abstract. In the paper, the problems of the formation of carbon coatings by low frequency atmospheric pressure plasmatron in a matrix deposition mode are considered. The influence of the main technological parameters of the process of coatings formation on the thickness and contact wetting angle are also investigated.

1. Introduction

Modern industry is interested in coatings that are resistant to environmental influences, such as microbiological pollution and humidity [1–4]. To create such a protective coating, it is necessary to form a developed surface with a special relief and chemical composition. The formation of such surfaces based on carbon thin films provides a number of advantages in creating a thin coating with required properties to protect against hazardous environment conditions [5, 6].

Due to the absence of the necessity to create and maintain low pressure, simple process control, available equipment and possibility to use different types of gas discharges, ion-plasma methods at atmospheric pressure find new applications in various fields of science and technology: for the synthesis of metal powders, for the deposition of thin films from the gas phase, processing of textile materials [1–3], as well as for biomedical applications, etc. [4–6].

One of the most promising types of gas discharges is the low-frequency (LF) arc gas discharge of low-temperature plasma. It is able to provide local formation of the coating with minimal environmental influence [7] and a low degree of degradation of the substrate material, which is especially important when thermolabile polymers have been used.

To create a coating with required characteristics over the entire area of the product or substrate, by means of LF-plasmatron, we used a matrix mode of deposition. It is a process in which to create a developed surface it is necessary to produce a local chemical vapor deposition (CVD) of the coating, followed by CVD of a new coating at fixed distance between the points of deposition shown in figure 1.

2. Materials and methods

To provide the deposition of carbon thin films by CVD, the LF-plasmatron of atmospheric pressure was used. The CVD is provided by the gas supply of a mixture of several gas streams shown in figure 2.
The formation of coatings was carried out according to the following technological parameters: plasma-forming/transport gas (He or Ar), plasmatron-substrate distance (15–24 mm), time of deposition (5–20 s), distance between vertices of an equilateral triangle (3–6 mm). The total gas flow was 7.1 ± 0.1 l/min.

The formation of coatings was carried out on monocrystalline silicon substrates for subsequent measurement of the thickness on an MII-11 microinterferometer, and on polyethylene terephthalate (PET) substrates. The contact wetting angle was studied by using a microscope with a goniometric attachment.

3. The results
The study of the thickness of the obtained coatings was carried out on samples on a silicon substrate at several points: in the center of the coating, at the points of the triangle's vertices, and in the middle of one of the triangle hips. The study showed that the growth rate of carbon coatings depends significantly on the plasmatron-substrate distance and the time of deposition. This is due to the increased energy input to the gas discharge between the plasmatron nozzle and the substrate to which the deposition was made, in addition to an increasing of diffusion of gas particles from the plasma jet into the environment. It was found that the use of argon as a plasma-forming gas makes it possible to achieve a 5-fold increase in the growth rate, which is most likely associated with more intensive ionization of the gas mixture as shown in figure 3.
Figure 3. The dependence of the average thickness of obtained carbon coatings on the distance between vertices of triangle, the distance of plasmatron-substrate and the plasma-forming gases used.

Figure 4. Contact angle of wetting of the obtained coatings depending on the distance of the plasmatron-substrate, the distance between the points of the triangle and the plasma-forming gas used. Investigations of the contact wetting angle were carried out on samples of both monocrystalline silicon and PET as it is shown in figures 4 and 5. The results indicate an increase in the hydrophilicity of PET, which is associated with the effect of etching during the deposition process. Silicon substrates exhibit a slight increase in hydrophobicity (figure 4). This is due to the fact that the process of silicon etching during CVD is practically excluded, because silicon has a different conductivity than PET, which affects the flow of LF arc gas discharge.

4. Conclusions
Thus, the paper shows the possibility of the formation of carbon coatings in the matrix mode of deposition. The influence of the technological parameters of the deposition processes on the
physicochemical properties of the formed coatings was established. The use of argon as a plasma-forming gas made it possible to achieve a significant increase in the growth rate of the coatings obtained in comparison with helium.

References

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