Research of plasma radiation of low pressure dc arc gas discharge

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Abstract. A spectroscopic analysis of a plasma arc discharge in helium was carried out. In the obtained emission spectra in the wavelength range from 380 to 1100 nm, lines of molecular band systems, such as Swan C₂ systems and C I.

1. Introduction
Sputtering of graphite and composite electrodes in an arc discharge is effectively used for the synthesis of carbon nanostructures [1-2] and nanoparticles in a carbon matrix [3-4]. Main advantages of arc spraying: chemical purity of synthesized materials in a discharge in an inert gas atmosphere; the possibility of modifying materials in a chemically active atmosphere; size control of nanostructures by selecting discharge parameters; and simplicity of the process. The deposition products of composite electrodes in an electric arc are nanoparticles surrounded by carbon, which prevents the coagulation of nanoparticles without stopping the access of gas or liquid to the particle, which allows using such composites as highly efficient catalysts.

Varying the parameters of the arc gas (pressure, current, voltage, composition of the buffer gas, the chemical composition of the electrodes) one can change the composition and morphology of the materials obtained. Various methods are used to control the physical processes occurring in the discharge, namely electrical, mass spectrometric, and optical methods. In this article, the experimental results of spectrometric measurements in an arc discharge in helium during the sputtering of a graphite anode are carried out.

2. Experimental Setup
The experimental setup shown in figure 1 was a cylindrical vacuum chamber, which was previously pumped out and then filled with working gas.

An arc discharge was ignited between two graphite electrodes, which were located on the axis of symmetry of the chamber. Negative voltage was applied through a high-current sealed ceramic-metal inlet to a movable graphite electrode (1), which was a cylinder of 3 cm in diameter. A grounded stationary composite electrode (2) was attached to the camera body. The replaceable composite anode was a graphite rod with a diameter of 0.8 cm and a length of 8 cm. The arc discharge was ignited and supported by a constant current source, which enabled experiments at a current of 80 to 200 A. When spraying the anode, the bellows transmission unit allowed the cathode to move for maintaining the constant voltage across the discharge gap.
In the process of burning the discharge, atomic atomization of the anode and the formation of a fan flow occurring from the interelectrode gap to the chamber walls occur. When approaching the chamber walls, the carbon vapors were cooled and condensed. As a result, larger agglomerates appeared and deposited on a cooled removable stainless steel screen (3), covering the surface of the chamber walls. After spraying with an electric arc, the synthesized material could be collected from a removable screen. The kinetics of the formation of nanomaterials during condensation in an arc discharge strongly depends on conditions such as the level and pressure of the buffer gas, the electrical characteristics of the discharge, and the geometry of the chamber. Typical materials for electric arc spraying are metal or carbide nanoparticles encapsulated in carbon with varying degrees of crystallization.

The discharge radiation passing through quartz glass (4) was detected by a spectrometer in the wavelength range from 190 to 1100 nm. The light transmittance $k$ of quartz glass was measured using an ultraviolet lamp and an incandescent lamp (figure 2). Further experimental results are given taking into account the coefficient $k$. 

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**Figure 1.** The experimental setup: 1 – movable graphite cathode, 2 – composite anode, 3 – cooled removable screen, 4 – quartz window.
3. Result and Discussion

The spectrometer allows measuring radiation in both the visible ultraviolet and infrared ranges. Below are the results of measurements in each of the ranges in an arc discharge in a helium atmosphere at a pressure of 25 Torr at a current and discharge voltage of 150 A and 20 V, respectively.

3.1. UV wavelength measurements

The emission spectrum of gas discharge in the UV region is shown in figure 3. In the emission spectrum in the range from 190 to 380 nm, a carbon line of 247.86 nm can be distinguished [5], and a less noticeable one is 193.09 nm.

![Figure 3. Optical emission spectra in the UV band reception plasma arc discharge in helium at a pressure of 25 Torr, 150 A of the discharge current, discharge voltage 20 V.](image)

3.2. Visible wavelength measurements

The emission spectrum of gas discharge in the visible region is shown in Figure 4. In the emission spectrum in the range from 380 to 730 nm, Swan bands can be distinguished [6-8]. Swan systems result from transitions between the electronic states of C_2 molecules. The strongest band of the Swan system emits a green color spectrum (about 510 nm, 515 nm and 520 nm), which can be used to determine the vibrational temperature [8]. These emissions correspond to the bands (0,0), (1,1), (2,2).
3.3. IR wavelength measurements

The emission spectrum of a gas discharge in the IR region in the range from 550 to 1100 nm is shown in Figure 5.

Figure 4. Spectra of optical emission of arc plasma in helium at a pressure of 25 Torr, discharge current of 150 A, and discharge voltage of 20 V.

Figure 5. Optical emission spectra in the infrared range of plasma of an arc discharge in helium at a pressure of 25 Torr, discharge current 150 A, and discharge voltage 20 V.

Conclusion

This article presents the results of experimental studies of radiation of a direct current arc discharge in a helium atmosphere during sputtering of a graphite anode. It is shown that the main lines for these parameters are Swan bands in the visible range and C I lines in the ultraviolet region of the spectrum. In the future, these results can be used to determine the vibrational temperature for C₂.

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