Express Method for Diagnosing Microwave Plasmatron Work Stability within the Range of Plasma-Inducing Gas Pressures

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An express method of microwave plasmatron work stability diagnostics within the range of gas at low pressure has been worked out. Its use makes possible to reduce the duration of process of defining gas pressure value characterized by high repetition in time of the impulse plasma forming process.

Keywords: microwave plasma, stability, optimal gas pressure

1 INTRODUCTION

Non-steady state conditions of magnetron feeding may lead to unstable plasmatron work connected with the operation of magnetron as well as caused by plasma instability because of electronic-ionic drift, space anisotropy and other phenomena. The investigation of microwave discharge at various plasma forming modes is of scientific as well as practical interest because of the necessity to provide reproducibility and control of plasma effect on the material surface from one treatment cycle to another [1].

2 THEORY

As the construction of microwave discharge equipment is practically completely closed in order to prevent leakage of electromagnetic radiation [1-3], the method of optical emission analysis, as a means of plasma processes control, is the only contact-free diagnostic tool enabling us to get immediate true and objective information about many processes of plasma treatment of materials, gas discharge composition and its properties. The interest to this diagnostic method is explained by two main factors. First of all, the method is non disturbing, i.e. not requiring introduction of probe devices into plasma, provision of gas recovery from reaction zone etc. Second, it provides high informativity and reliability of data.

In order to determine the pressure range of stable microwave plasmatron work faster and to raise the reliability of data about the character and stability of microwave discharge within this range of gas pressure, an optical diagnostic system for microwave plasmatron work stability was developed.

3 EXPERIMENTAL SYSTEM

Figure 1 shows the diagram of a diagnostic complex for investigating microwave discharge optical characteristics.

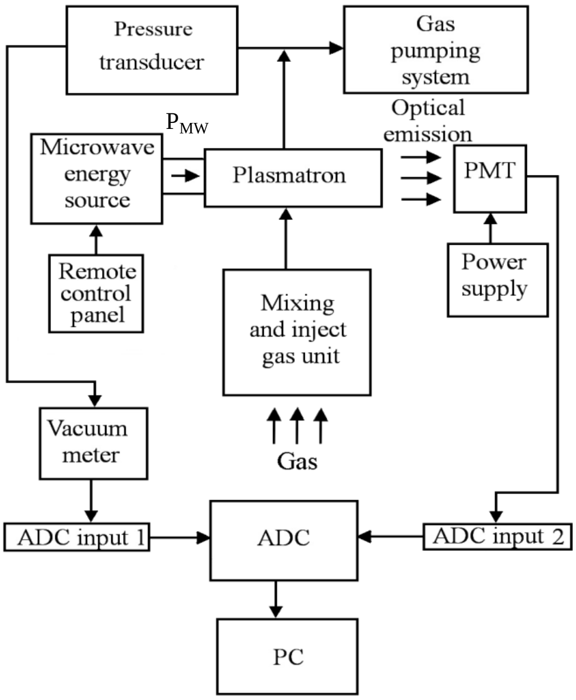

Fig. 1: Diagram of a diagnostic complex for investigating microwave discharge optical characteristics

Plasma was initiated in a cylindric vacuum quartz discharge chamber with diameter 200 mm and the length 310 mm placed in the centre of a rectangular resonator with dimensions 345x250x380 mm. Microwave power (frequency of electromagnetic field f ≈ 2.45 GHz) was fed into the resonator through the rectangular connection hole placed with its long side along the discharge chamber axis. Microwave power fed into the plasmatron was $P_{MW} \approx 700$ W.

The experiments were held with atmospheric air at different pressures. The air was continuously pumped through the vacuum chamber of the plasmatron.

A photomultiplier tube (PMT) with spectral sensitivity region 0,23 - 1,1 µm was used as a sensor for registration of plasma optical emission.

Signals from PMT were fed to input 2 of an analog-to-digital converter (ADC) and then to a personal computer (PC). Pressure measurements in the discharge chamber of the plasmatron were carried out with a thermal type vacuum meter. The pressure transducer of the vacuum meter was set in the gas pumping system next to the discharge chamber. The electrical signals from the output of the vacuum meter were fed to input 1 of an ADC and then to a PC.

4 METHOD

The development of the optical diagnostic system was based on the method of express analysis of microwave plasmatron work stability within the range of gas pressure.

The essence of the method consists in simultaneous registering with a PC the signal from analog output of the vacuum meter, corresponding to the gas pressure in the discharge chamber, and the signals of a photoregistering device (in our case photomultiplier (PMT)), corresponding to the intensity of microwave discharge optical emission.

The registration was performed while the pressure in the discharge chamber was continuously decreasing. The upper and lower levels of gas pressure values are determined by the condition of maintaining plasma in microwave plasmatron at a specified microwave power value. The pressure has changed in the result of stopping gas supply into the plasmatron discharge chamber, the gas being continuously pumped out with a vacuum pump.

After that, synchronized oscillograms of registered signals of plasma optical emission and signals equal to the pressure in the discharge chamber are analysed.

Based on the obtained data we determine the pressure characterized by higher amplitude and pulse form repeatability of the plasma optical emission. As the experiments have shown, microwave plasmatron will work most stably at this pressure.

5 RESULTS

Figure 2 shows the data on the changes of plasma optical emission character depending on the pressure in the discharge chamber, obtained with express method of microwave plasmatron work stability diagnostics.

We have experimentally defined the possibility of applying the developed diagnostic system and the method of diagnostics. For this purpose, we carried out experiments to compare the results obtained with the express diagnostic method, i.e. in the conditions of continuously changing gas pressure in the discharge chamber; with those obtained while diagnosing at a steady gas pressure. The pressure in the discharge chamber of the plasmatron is kept constant by applying a constant gas flow rate at the inlet and at the outlet of the chamber.

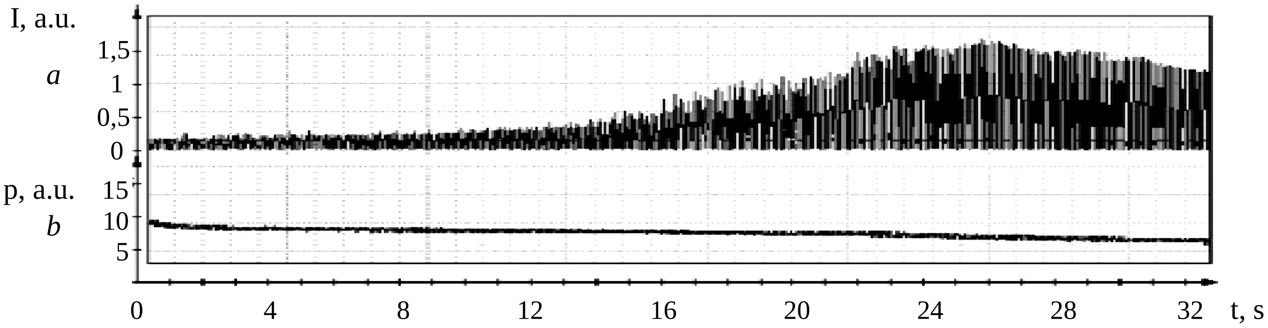

Fig. 2: Synchronized oscillograms of registered signals: a) changes in the amplitude of plasma optical emission I *from discharge in air; b) changes in the signal equal to pressure* p *inside the discharge chamber*

During diagnosis of the microwave plasmatron, the pressure of atmospheric air in the discharge chamber was a varying parameter.

During the first stage of the experiment we studied the reproducibility of the express diagnostics results. The investigation was carried out repeating the experiments several times at equal conditions. It showed that the method of express diagnostics is characterized by reproducibility of results in the extent sufficient for successful application. The deviation of the measured amplitudes of optical pulses remained within the admissible measurement error limits.

The next stage of the experiment concerned the definition of reliability of the express diagnostics. For this purpose, we carried out experiments to compare the results obtained with the express diagnostic method, i.e. in the conditions of continuously changing gas pressure in the discharge chamber; with those obtained while diagnosing at a steady gas pressure. Figure 3 shows comparative data on the magnitude of plasma optical emission pulses I_{max} for certain levels of atmospheric air pressure. These data illustrate a quite good degree of correspondence of experimental results while using the express method and the method of microwave plasmatron work stability diagnostics at fixed air pressure levels.

The analysis of the investigation results showed that the method of express diagnostics of microwave plasmatron work stability in the range of gas pressure has a sufficient degree of results' reliability and may be used for express examination of microwave plasmatron work characteristics.

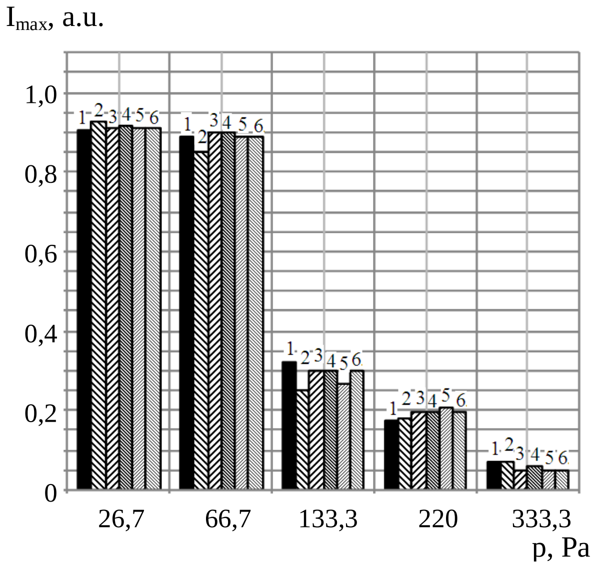

Fig. 3: Comparative data on the magnitude of plasma optical emission pulses I_{max} *for atmospheric air at different low pressure levels (1 – express method data; 2…6 – data for steady magnitudes of pressure during repetition of experiment five times)*

6 CONCLUSION

The developed diagnostic method of microwave plasmatron work stability in the range of gas pressure provides the opportunity to reduce significantly the duration of defining the peculiarities of microwave plasmatron work at different gas pressures.

REFERENCES

[1] Bordusov S. Microwave plasma technologies in the production of electronic devices / Minsk: Bestprint, 2002. 450 p.

[2] Microwave plasma generators: physics, technics, applications / V.M. Batenin [et al.] M.: Energoatomizdat, 1988. 224 p.

[2] Microwave Discharges: Fundamentals and Applications. 3 – rd International Workshop, Abbaye Royale de Fontevraud, France, 20 – 25 April, 1997 // Journal de Physique IV, 1998. Vol.8. Pr 7. 421 p.