INVESTIGATION OF THE STABILITY OF MICROWAVE DISCHARGE IN OXYGEN IN A RESONATOR TYPE PLASMATRON

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Microwave generators with simplified magnetron supply circuit, powered from rectified unfiltered commercial-frequency voltage, are widely used as microwave power sources in experimental research and industrial equipment for vacuum plasma material processing. Such type of magnetron supply circuit implies quasi-continuous operation mode resulting in a pulsating of microwave output power. As a result, pulsating microwave discharge is ignited in the discharge chamber of the plasmatron /1/.

Stability of the microwave discharge is an important characteristic from the aspect of obtaining reproducible technological results of microwave plasma material processing.

Discharge instability, especially due to the pulsating nature of the discharge, might be caused by the specific character of the magnetron operation during the generation of the microwave power under varying supply conditions, as well as various plasma instabilities, caused by emerging charged particles, electron-ion drift, space anisotropy and other phenomena. Despite the fact that the dynamics of the discharge behavior in its initial stage has repetitive nature, the location of the discharge emergence in an empty reactor chamber and the trajectory of the luminous area towards the edge of the vacuum volume are unique for each new plasma-formation cycle /2/.

Therefore, researching the stability of the microwave discharge during various plasma-forming conditions is of scientific as well as practical interest arising from the necessity of providing reproducibility and control over the character of the effect of exposing the surface of materials to plasma for each new operating cycle.

Analysis of the stability of pulsating microwave discharge was carried out by registering and processing the signal of plasma discharge luminescence during different time intervals of the plasma formation process. O_2 was used as a plasma-forming gas. Pressure inside the discharge chamber – 133 Pa. Pumping speed and gas consumption were constant.

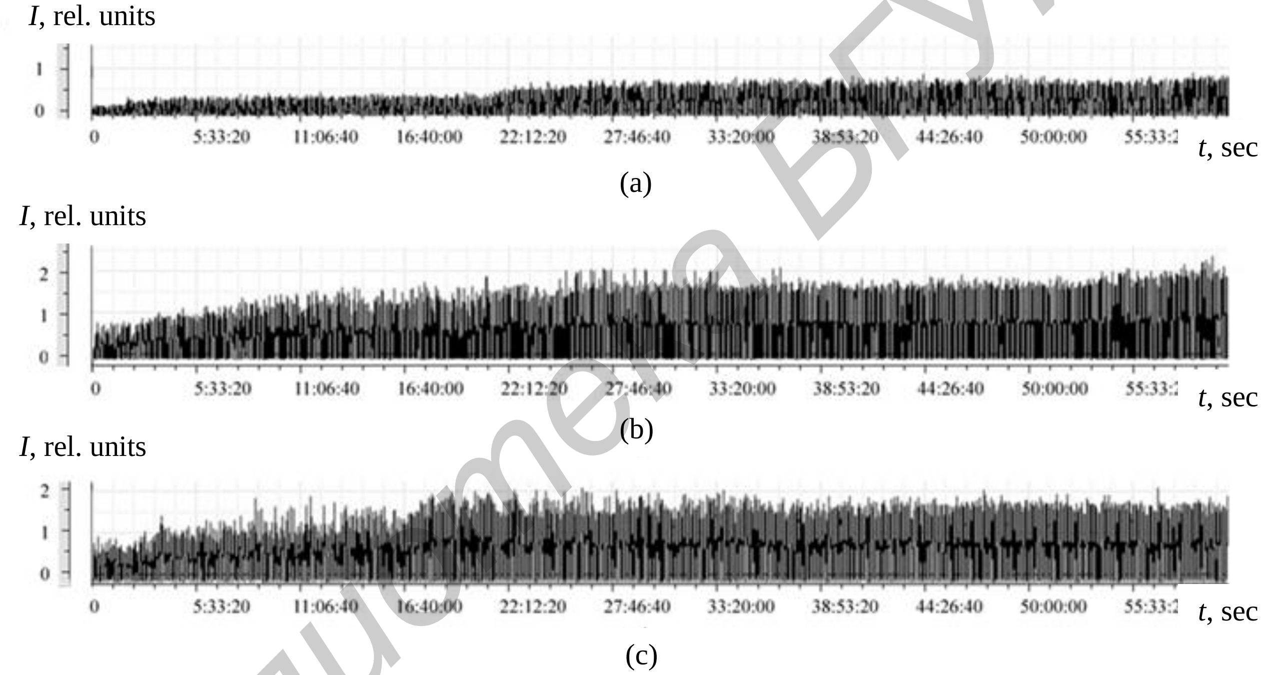
Waveforms were recorded with LA-1.5 ADC. Results of measurements of the signals were transferred to a PC for further processing in PowerGraph 4.0 under Windows OS.

During the experiments were used two types of magnetron’s power sources. The first power source was based on a half-wave rectifier circuit with a voltage doubler. A signal registration was performed while the output power of the magnetron power source was changed within the ±50% range of the nominal power of the microwave magnetron. Another type of the magnetron's power source was based on a full-wave rectifier with a voltage doubler /3/.

Characteristics of the optical luminescence pulses of the microwave discharge were studied in the initial period of the discharge excitation and after a certain amount of time from it's excitation.

Figure 1 illustrates the optical plasma discharge luminescence waveforms within one minute from the beginning of plasma formation.

It is clearly seen that the amplitude of the optical signal of plasma discharge luminescence is increasing during the initial stage. The lower the magnetron power, the longer it takes for the operating conditions to establish.

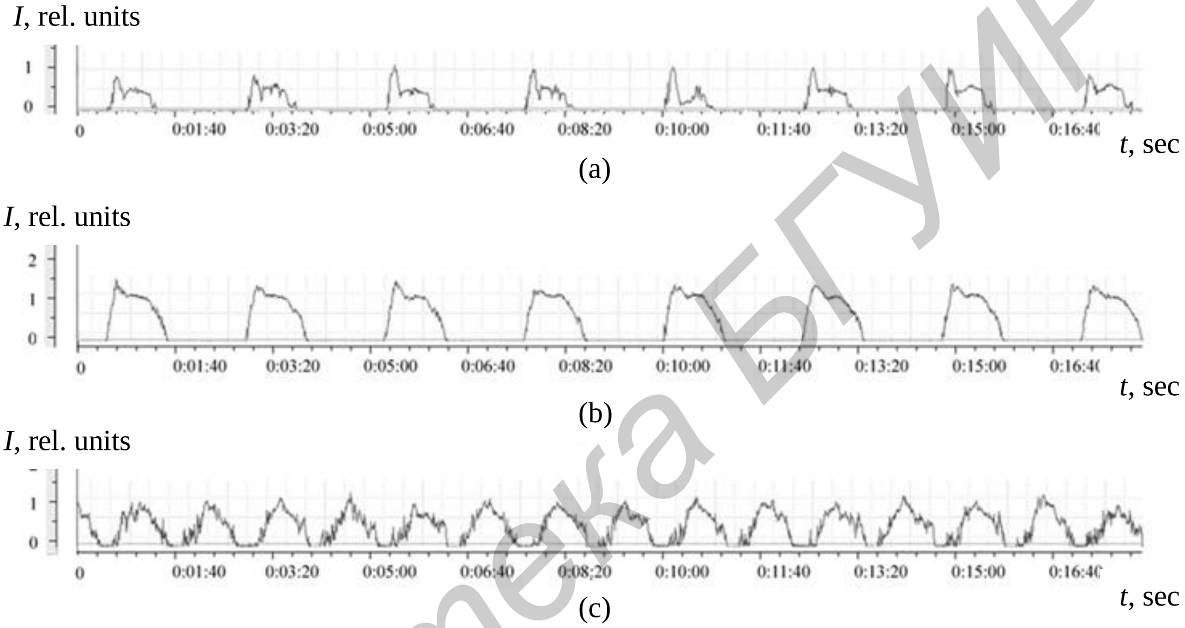


a – half-wave rectifier with voltage doubler, W_{MW} = 650 W;
b – half-wave rectifier with voltage doubler, W_{MW} = 850 W;
c – full-wave rectifier with voltage doubler, W_{MW} = 850 W

Fig. 1. Optical plasma discharge luminescence waveforms
for different microwave magnetron power

One of the factors leading to the persistence of plasma-forming process is the temperature conditions of the microwave cathode of the magnetron. Heating of the cathode and increase of the emission current happens gradually, which affects the output power of the microwave magnetron /4/. Heating of the microwave magnetron enclosure is a persistent process as well, which also affects its performance. With regard to the microwave plasma-chemical materials processing due to the persistence of the plasma-forming process, the period of time, required for material processing in microwave plasma, may varied because the persistence leads to changing the energetic component of the microwave discharge.

In order to research the reproducibility of the process of microwave material plasma processing the impulses of the optical signal from plasma of oxygen discharge were analyzed (figure 2). The impulses were selected on the time interval starting from the 30th second from the moment of the beginning of microwave generation.



(a)

(b)

(c)

a – half-wave rectifier with voltage doubler, W_{MW}= 650 W;
b – half-wave rectifier with voltage doubler, W_{MW}= 850 W;
c – full-wave rectifier with voltage doubler, W_{MW} = 850 W

Fig. 2. Optical plasma discharge luminescence waveforms in oxygen (scaled up)

The above waveforms clearly indicate noticeable repeatability of the pulses. The difference in amplitude between the pulses varies in the interval of ± 20%.

Performed experiments showed that in the conditions of changing the instantaneous output power of the magnetron within the ±50% range of its nominal power, as well as increasing the repetition rate of the microwave generation pulses, the impulses of the optical signals from microwave oxygen discharge are similar in shape for each new plasma-formation cycle. This indicates that the process of microwave vacuum plasma-chemical material processing in O_2 is supposed to have good reproducibility over time for each new operating cycle.

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