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STUDY OF A PULSE ARC DISCHARGE USED FOR DIAMOND-LIKE COATING DEPOSITION

I. P. Smyaglikov[1], E. I. Tochitsky[2], V. G. Tatur[2], N. I. Chubrik[1]
S. V. Goncharik[1], A. I. Zolotovsky[1], M. V. Bel'kov[1]

[1] *Institute of Molecular and Atomic Physics, National Academy of Sciences of Belarus, Independence Av. 70, 220072 Minsk, Belarus,*
e-mail: ips@imaph.bas-net.by
[2] *Scientific Engineering Centre "Plasmoteg"*
Academician Kuprevich Str. 1, Building 3, 220141 Minsk, Belarus

Abstract. Carbon plasma flows for deposition of diamond-like films are generated with the help of four-electrode system with graphite cathode and self-recovering thin-film conductor of an ignition device in a vacuum chamber with residual pressure down to $5\cdot10^{-5}$ Torr. The pulse-periodic carbon arc discharge is considered at discharge current of 4–10 kA, duration of pulses of 100–200 ms and the pulse repetition rate of up to 30 Hz. The form and amplitude of voltage and current of pulses of igniting, supporting and main discharges, and the form of light pulse in various zones of the discharge were measured. The information on reproducibility of the arc discharge of short duration was obtained as well.

1. INTRODUCTION

Diamond-like films find wide application in different fields of engineering and microelectronics. Such films are characterized by a high surface hardness comparable to natural diamond, but have a quasi-amorphous structure consisting of nano-sized areas of different carbon phases. The physicochemical and mechanical properties of diamond-like coatings and films depend strongly on a technique and conditions of their production. Therefore, studying the correlation of coatings' characteristics with parameters of heterogeneous plasma flows used for their depositing is in demand. The present work is aimed at studying high-current arcs of short duration in vacuum to optimise the technology relevant to diamond-like coating deposition.

2. EXPERIMENT

The investigations were carried out on an experimental setup, allowing to get pulsed erosive plasma at a discharge current amplitude of up to 10000 A, the pulse duration of 100–200 μs, and a repetition frequency of pulses of up to 30 Hz as well as to study the plasma by optical and spectroscopic techniques with a time resolution of down to 0.1 μs, spectral resolution of down to 0.01 nm and spatial resolution down to 0.1 mm. The setup incorporates the pulsed plasma accelerator (PPA) [1], the optic-spectral unit for multifunction diagnostics, and the equipment of computer recording of plasma parameters on basis of analog-to-digital converters (ADC). The functional scheme of experimental setup is represented in Fig. 1.

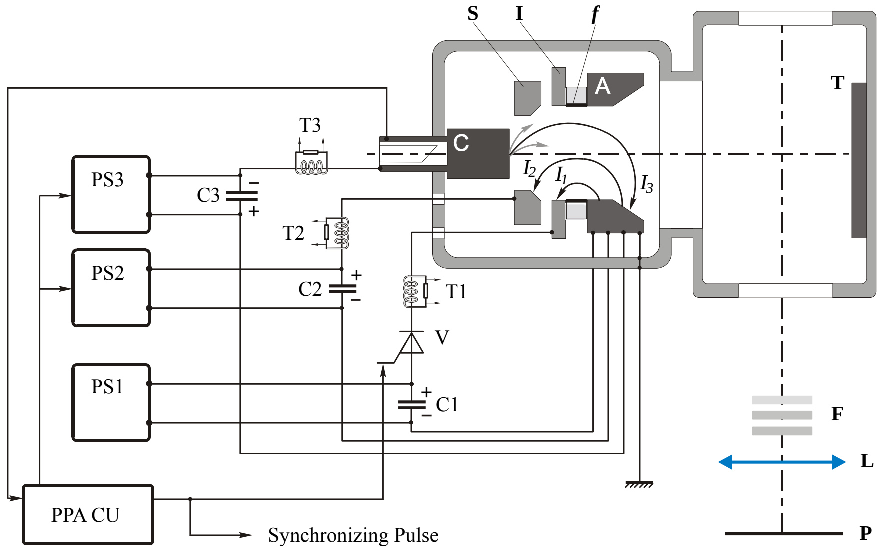

Fig. 1. The functional scheme of experimental setup to study carbon erosive plasma. PPA CU – control unit of PPA; PS1, PS2 and PS3 – power supplies of igniting, supporting and main discharges, respectively; C1, C2 and C3 – capacity storages; V – thyristor; A – anode; C – graphite cathode; S – support electrode; I – ignition electrode; *f* – self-recovering thin-film conductor; T1, T2 and T3 – sensors to measure the amplitude and shape of current pulses; T – target; F –filter set; L – quartz objective; P – image plane of plasma flow. Directions of electron currents of igniting I_1, supporting I_2 and main I_3 discharges are indicated by arrows.

At the beginning of each run of PPA, capacity storages C2 = 200 μF and C3 = 1200 μF are charged up to a voltage level, preset by the control unit PPA CU. Then the capacity storages are disconnected from power supplies PS2 and PS3. The voltage of capacitors C2 and C3 is adjusted in the range of 250÷500 V. Power supply PS1 maintains the voltage of capacitor C1 = 15 μF on the level of about 800 V.

An electric pulse from the control unit, serving simultaneously as a synchronizing pulse of external peripherals, turns thyristor V on. An igniting current pulse is generated owing to discharging of capacitor C1 through a localized contact of anode A with ignition electrode I, formed by a thin conducting film *f* of the cathode erosion material deposited on a surface of insulator between electrodes I and A. A portion of initiating plasma is produced as a result of flash evaporation of the film. When the above mentioned plasma reaches the interelectrode space between cathode C and support electrode S, the discharge of capacity C2 occurs resulting in strong increase of conductivity of plasma between the cathode and anode, sufficient to initiate the main discharge. Energy of capacity storage C1 is liberated on the cathode by means of a vacuum high-current arc burning in vapour of the cathode eroded in microspots. Under the impact of gas-dynamic and electromagnetic forces the formed plasma flow is accelerated toward the target T. The part of plasma is deposited on interelectrode insulator, thus recovering the thin-film conductor *f* of the ignition system. After that the PPA is ready to the next operation cycle. The repetition frequency of igniting pulses is assigned by the control unit in the range of 0.1 to 35 Hz.

Entrance slits or working sites of peripherals, necessary to carry out the investigations, are arranged in an image plane P of plasma flow. For synchronization the peripherals with the pulsed arc discharge the igniting pulse of control unit PPA CU is used. After completing the registration cycle the software of equipment of computer recording of plasma parameters copies storage contents of ADC boards on a hard disk of the computer during a pause between the igniting pulses.

3. ELECTRICAL CHARACTERISTICS OF PULSED PLASMA FLOWS

Electrical characteristics of pulsed carbon arc were measured with the help of system of recording of currents and voltages of pulsed discharges. The system is realized on the basis of a set of initial transducers (current sensors and compensated voltage dividers) and analog-to-digital converters with the personal computer. The scheme of arrangement of sensors to measure amplitude and shape of current pulses of igniting I_1, supporting I_2 and main I_3 discharges is shown in Fig. 1.

The registered current oscillograms are given in Fig. 2. Current pulses I_1, I_2, I_3 and I_4 were taken from sensors T1, T2, T3 and T4 respectively. According to the results obtained there is a good repeatability of amplitude and shape of all current pulses. For example, maximal change of amplitude of the main discharge current from pulse to pulse does not exceed 10%. The time delay between igniting and supporting pulses and between supporting and main pulses varies in the range of 1÷3 and 5÷20 μs, respectively. The difference of current pulses I_3 and I_4 shows that the considerable part of the main discharge current does not flow to the anode and dissipates on other electrodes.

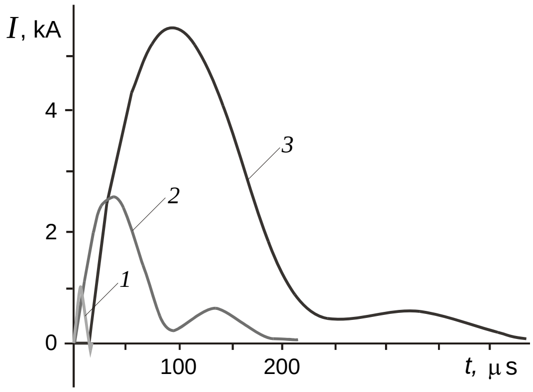

Fig. 2. The current oscillograms taken from sensors T1, T2 and T3.

In spite of steady current characteristics of the discharge in question, radiation intensity in a fixed spatial point of the plasma flow can vary by a factor of ten from impulse to impulse. The light pulse may be bell-shaped or have strong fluctuations of intensity at a frequency of 100–200 kHz. The last is due to formation and decay of cathode spot groups having lifetime of 5–10 μs.

4. CONCLUSION

The studies of carbon erosive plasma in a mode of diamond-like coating deposition have shown a good repeatability in electrical parameters of the used pulsed arc discharge with multi-step process of plasma initiation. The registered voltages and radiation intensities tend to have fluctuations at a frequency of 100–200 kHz. Such behaviour is ordinary for arc discharges with consumable electrodes [2, 3].

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