PULSED MAGNETRON SPUTTERING SYSTEM POWER SUPPLY WITHOUT LIMITATION AND FORCED INTERRUPTION OF THE DISCHARGE CURRENT

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The solution for the planar MSS power supply has been found as a pulsed power supply. A scheme for the pulsed power supply has been proposed and investigated (without discharge current forced restrictions and terminations). The scheme had been shown to be well-proven at technological range of magnetron discharge glow range. Pulsed discharges with 10 ms duration and magnetron discharge currents up to 60 A were obtained at background gas pressure \((2\ldots5) \times 10^{-3}\) Torr.

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INTRODUCTION

The coating technology by magnetron sputtering systems (MSS) is widely used in the manufacture of microelectronic devices, displays, obtaining functional and decorative coatings of different types of materials [1]. The size of the treated surface can vary from a few millimeters to several meters, for example, glass panels and roll materials. The performance of MSS is proportional to the power input to the discharge and the discharge current. The technological task of coating on the roll materials requires a substantial increase in the rate of deposition, and thus increasing the discharge current. In MSS exceeding the discharge current of a certain critical value leads to the transition from glow discharge to the arc one and formation of cathode spots of the second kind. As a result, the deposited films contain a droplet formation, which significantly worsens the quality of coatings.

The application of pulsed operation modes of MSS would greatly reduce the impact of negative factors on the quality of the coatings [2]. Particularly, the pulsed plasma treatment of surfaces provides lower thermal load on the product, improves the uniformity of coating thickness on the surface of the substrate with a complex morphology and suppresses the formation of stress in the films. Running the standard planar MSS in pulse mode operation requires the development of special pulsed power supplies. It must provide supply to the electrodes sufficient for the breakdown and initiation of the magnetron discharge voltage pulses with varying frequency and duration. In addition the discharge current magnitude must be sufficient to implement the process of deposition of coatings with required rate of mass transfer [3].

Voltage pulses of unipolar or asymmetric bipolar rectangular waveform are usually used to supply MSS with single power supply. These pulses cause the conditions for the energy transmission time complete usage. Real voltage and current pulses are of complicated shape which looks like rectangular.

Different modulator schemes are used to generate pulses [4, 5]. They can be divided in three groups:
- voltage generators with low internal resistance and ability of providing preset voltage during the load;
- current generators with huge internal resistance and ability providing preset current during the load;
- mixed type power supplies.

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A scheme for the pulsed power supply has been proposed and investigated (without discharge current forced restrictions and terminations). The scheme had been shown to be well-proven at technological range of magnetron discharge glow range. Pulsed discharges with 5…10 ms duration and magnetron discharge currents up to 60 A were obtained at background gas pressure \((2\ldots5) \times 10^{-3}\) Torr. High voltage on the power supply clamp was kept during the pulse. Sputtered MSS target surface photo registration showed cathode spots of second kind absence during the pulses.

1. EXPERIMENTAL EQUIPMENT

Experiments were performed using the installation of UVN-71 type with installed planar MSS with copper sputter target with dimensions of 45×180 mm [6]. The magnetic field of arc configuration was created using permanent magnets located under the target. The working pressure was maintained by argon gas inlet in the range of \((1\ldots8) \times 10^{-3}\) Torr directly to the region of the discharge.

For pulse regimes, the pulse power supply of capacitive type \((C_1\ldotsC_{10})\) with a thyristor commutation \((T_1)\) was developed. The simplified scheme of the power supply is shown in Fig. 1, where \(C_1\ldotsC_{10}\) is a set of capacitors \((1000 \mu F)\). This set of capacitors was charged up to 1.5 kV through the transformer \(T_0\) and resistor \(R_t = 10 \, k \Omega\). The short-circuit current was limited by resistor \(R_1\) with magnitude varied from 0.5 to 20 Ω.
The measurement of the pulse current was performed using Rogovsky coil. The initiation of the magnetron discharge was performed using Bosticks gun, which scheme is shown in Fig. 1. Pressing “K” button, the Bostick gun, thyristor T1 and oscilloscope were launched simultaneously.

The current-voltage characteristics of the pulse power supply are shown in Fig. 2, where lines 1, 2 and 3 correspond to load resistance $R_L$ values of 30, 10 and 5 Ω.

2. RESULTS AND DISCUSSION

There were performed the measurements of the pulse discharge characteristics with a copper target at Ar background gas ($P_A = (2…5) \cdot 10^{-3}$ Torr). Developed pulse power supply provides steady-state MSS operation during 10…12 ms. Magnetron discharge current reaches 60 A and high voltage remains at 350…450 V. Photo registration of pulse discharge as well as obtained coatings shows droplet phase absence. Constricted discharge current shape absence between the cathode and anode and sparking presence on the target surface shows that discharge didn’t transforms to low-voltage high-current regime. Cathode spots of a second kind are absent during the pulse. Short-time cathode spots of a first kind formation didn’t transform the discharge to arc regime but increases average magnetron discharge current and intensified target sputtering. Magnetron discharge transmission to arc-type discharge didn’t fused and breakdown power supply. Developed power supply allows obtaining arc discharge with predefined duration and 200 A amplitude or more.

Current pulse amplitude depends on the value of non-inductive resistor $R_L$ and background gas pressure. The fast bright cathode spots moving along the erosion zone and constricted shape of discharge current on the target surface were observed at this operating mode.

CONCLUSIONS

Present work has proposed scheme of the pulsed power supply (with no restrictions and forced interruption of the discharge current), which works well in the burning process of the magnetron discharge. The pulse discharges duration up to 10 ms with a magnetron discharge current of 60 A at pressures in the chamber in the range of $(2…5) \cdot 10^{-3}$ Torr was obtained. Photometric study of the sputtering target during the discharge pulse indicates the absence of cathode spots of the second kind.

REFERENCES

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ИМПУЛЬСНЫЙ СИЛЬНОТОЧНЫЙ ИСТОЧНИК ПИТАНИЯ МРС БЕЗ ОГРАНИЧЕНИЯ И ПРИНУДИТЕЛЬНОГО ПРЕРЫВАНИЯ РАЗРЯДНОГО ТОКА

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Предложен вариант решения электропитания планарной магнетронной распылительной системы с помощью импульсного блока питания. Предложена и исследована схема импульсного источника питания (без принудительного ограничения и прерывания тока разряда), которая хорошо работает в технологической области горения магнетронного разряда: получены импульсные разряды длительностью до 10 мс с током магнетронного разряда до 60 А при давлениях в технологической камере (2…5)·10⁻³ Торр.

ИМПУЛЬСНЕ СИЛЬНОСТРУМОВЕ ДЖЕРЕЛО ЖИВЛЕННЯ МРС БЕЗ ОБМЕЖЕННЯ ТА ПРИМУСОВОГО ПЕРЕРИВАННЯ РОЗРЯДНОГО СТРУМУ

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Запропоновано варіант рішення електропитання планарної магнетронної розпилювальної системи за допомогою імпульсного блоку живлення. Запропонована та досліджена схема імпульсного джерела живлення (без примусового обмеження та переривання струму розряду), яка добре працює в технологічній області горіння магнетронного розряду: отримані імпульсні разряди тривалістю до 10 мс зі струмом магнетронного розряду до 60 А при тисках у технологічній камері (2…5)·10⁻³ Торр.