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A METHOD FOR EXTINGUISHING MICRODISCHARGES IN THE PLASMA SURFACE TREATMENT PROCESSES

Key words

Arc microdischarges, extinguishing microdischarges, the bias power supply, the magnetron power supply.

Summary

This paper presents an original method for extinguishing microdischarges formed on workpieces treated in the process of plasma surface treatment PAPVD. The method is based on the recognition of the state just before the micro discharge, rapid turn-off of the arc, and the analysis of the quantities occurring during microdischarges. As a result of this analysis, the amount of electricity supplied by the power supply is dynamically adjusted into the vacuum chamber in which the charged details are located.

The method protects the workpieces against destruction and the vacuum chamber against the gradual degradation. It allows one to reduce the incidence of microdischarges, which eliminates excessive local temperature rise during the process.

The method is implemented in the bias power supply and the magnetron power supply, which are used in the process of plasma treatment of the surface. These devices are manufactured in Institute for Sustainable Technologies – NRI.

Introduction

Hard coatings in the plasma surface treatment processes PAPVD are an effective way of increasing the durability of workpieces. This allows one to achieve a significant increase in the service life of the treated object. In addition to receiving a coating of selected physical and chemical parameters, it is possible to obtain high adhesion strength of the coating to the surface of the coated component. The standard and the most effective way to increase these properties is the use of the process of sputtering before the deposition step [1, 2].

This process, also known as "ion beam," is carried out by applying a high order of 1 kV DC to the workpiece. An unfavourable phenomenon in the process of ion etching is the formation on the surface of the workpiece "arc microdischarges," which are produced by local changes in the electrical properties of the surface.

These changes lead to the occurrence of fluctuations of electric charge on the surface [3, 4]. The result of their occurrence are characteristic marks on the surface of the workpieces. The location of the microdischarges give rise to considerable energy, which leads to local remission of workpiece material or its edges are dulled. The unit supplying electricity in the process should not only withstand the sudden shock current during microdischarges, but the unit should ensure the elimination of the adverse event to the process of plasma surface treatment.

1. Power devices for plasma surface treatment processes PAPVD

In the processes of plasma surface treatment, PAPVD, specialized power supplies are used to provide electricity with specific parameters. The power modules are customizable to the requirements of specific objects in the control systems of plasma processes. These requirements are in addition to the need to provide controlled waveforms of sufficient power and responses to specific conditions for the plasma environment, including dynamic and static load impedance change, fading glow discharge, and the occurrence of microdischarges [5]. Therefore, the power supply units are separate complex sub-systems of the process control plasma (Fig. 1).

For the surface treatment processes, in which the first step is to apply ion etching, a bias power supply is used, which allows one to produce a regulated voltage of 1500 V in accordance with the requirements of the current stage of the process. The current yield is 40 A.

The arc microdischarges phenomenon also occurs in the plasma process with the use of magnetron plasma sources.

The magnetron power source should provide a current capacity up to 5 A with a voltage up to 800 V [6]. There is a need for adequate protection of outputs against short circuits and sudden surges in current caused by the arc microdischarges with these power supplies.

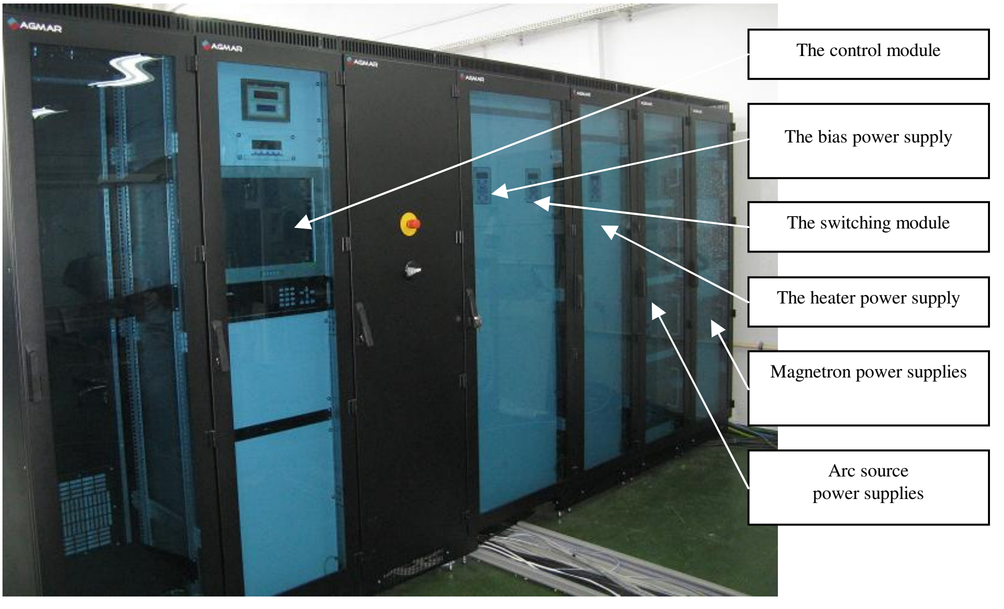

Fig. 1. Equipment for plasma surface treatment with the control modules and power modules

2. Arc microdischarges detection

The duration of the microdischarges is counted in microseconds and is associated with a very large dynamic processes occurring on the surface of the workpiece and in the plasma. By measuring the time, the current, and voltage characteristics, it is possible to determine the state in which the glow discharge in the arc discharge proceeds, causing damage to the etched surface of the workpiece.

Figure 2 shows the current and voltage waveforms in the vacuum chamber during the occurrence of microdischarges. When analysing waveforms, it can be seen that power grows rapidly during the microdischarges. The voltage decreases, which is caused by the existence of a non-zero output impedance of the power supply. In about 3 μs, current increases to 120 A, and if there is no short-circuit protection circuit output, the current of the power supply unit would reach a value several times larger.

The safety system cuts off the power supply, resulting in a further drop in voltage, and the current changes the direction of flow. This is due to the inductive nature of the plasma. Because the system reacts to the power-off with a delay, the value of the current is so high that the energy of the microdischarge causes visible marks on the surface of the etched parts. In order to limit the discharge current, the power supply should respond faster when the maximum current is exceeded. A sufficient source of information for the control unit of power supply about an impending microdischarge is the measurement of current [7]. The voltage change, i.e. the voltage drop at the time of microdischarge, is due to the flow of large current. As a result, the voltage is deposited on the impedance of the entire circuit.

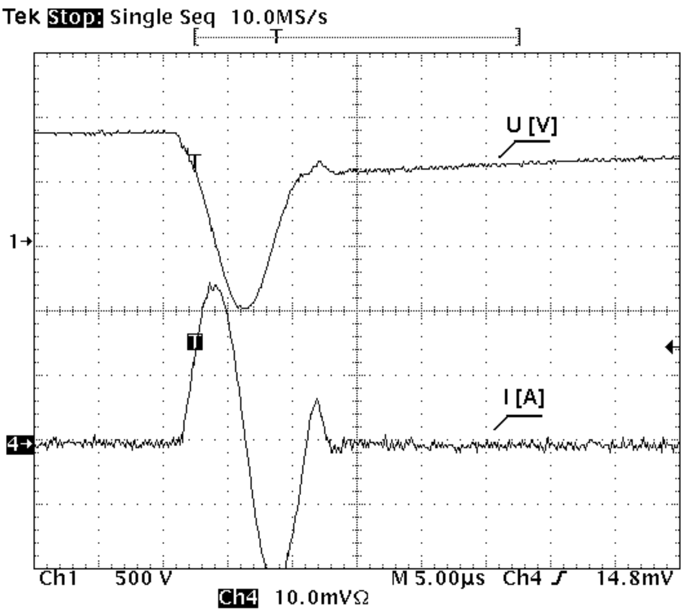

Fig. 2. Waveforms of current (50 A/dz.) and voltage (500 V/dz.) glow discharge at the microdischarge

3. The extinguishing microdischarges method

The method extinguishing arc microdischarges combines two functions. The first is to extinguish microdischarges formed as soon as possible, and the second is analysis of the quantities occurring during microdischarges. As a result of this analysis, the quantity of electricity supplied by the power supply device into the vacuum chamber is determined in which charged details are located.

Extinguishing microdischarges is to turn off the flowing current as fast as possible when you exceed the reference value at a certain level. This value is chosen so that there is no accidental, unwanted interruption in the supply of energy to the process. Microdischarge extinguishing time, or the time to restart the current, can be determined dynamically, depending on the frequency, or statically by microdischarge operation. If the extinguishing time is too short, it was observed that there is a faster formation of the next microdischarges. If the extinguishing time is too long, there is an increase in adverse effects to the product. Experimentally, it was found that the optimal time for extinguishing microdischarges is about 10 ms. This time is measured by a microprocessor controlled power supply. The controller measures and stabilizes the voltage at a certain level and measures and controls the current flowing.

The use of a microprocessor can be implemented in the method of the second function microdischarge firing. The microprocessor collects and analyses information on the number of microdischarges occurring in a given period. On this basis, the quantity of electricity supplied to the vacuum chamber is determined dynamically. This energy is directly related to the voltage of the power supply, according to the relation E = U*I*t. This voltage is reduced automatically at the specified time, when the number of microdischarges exceeds the allowable limit. The voltage rises automatically to a preset level, when the quantity of microdischarges decreases. To implement this method, the microprocessor uses the following parameters:

$\mathbf{t_{mw}}$ – dead time, the extinguishing microdischarges time (about 10 ms);

U – preset voltage of the power supply, the voltage supplied to a process determined by the technologist depending on the phase of the process (the ion etching is 900–1000 V);

$\mathbf{U_{min}}$ – the minimum voltage of the power supply, which can be achieved by an algorithm extinguishing microdischarges (at about 200 V ion etching);

$\mathbf{U_{mw}}$ – actual voltage delivered to the process, determined dynamically due to the presence of microdischarges (for $\mathbf{U_{min}} \ldots$U);

$\mathbf{N_{mw}}$ – the total number of microdischarges from the beginning of the process;

$\mathbf{n_{mw}}$ – the counter of microdischarges in a given period of time;

$\mathbf{N_{mw\Delta U}}$ – the number of microdischarges in a given time interval $\mathbf{t_{\Delta U}}$ beyond which the lowering of the value of the voltage **ΔU** occurs;

$\mathbf{t_{\Delta U}}$ – the time interval after which the voltage reduction on the value of **ΔU** (about 3 seconds);

ΔU – the voltage at which voltage is reduced or increased **U** (approximately 50 V);

Rn_{mw} – reduction microdischarges counter during a time interval by a percentage value (around 10%).

Output parameter of the algorithm is implemented **U_{mw}** voltage that is supplied to the plasma process (Fig. 3). This voltage is calculated on the parameters **U, U_{min}, $N_{mw\Delta U}$, $t_{\Delta U}$, ΔU, Rn_{mw}** determined by the operator or by default during manufacture of the device. Figure 4 shows an algorithm executed by a microprocessor. It shows the interconnection between the set parameters and explains the method for extinguishing microdischarges. The input parameter is the number of microdischarges **N_{mw}**, which implies the parameter **n_{mw}** in interval time **$t_{\Delta U}$**. This value is appropriately modified by the parameter **Rn_{MW}**, when microdischarges do not appear in **$t_{\Delta U}$** time.

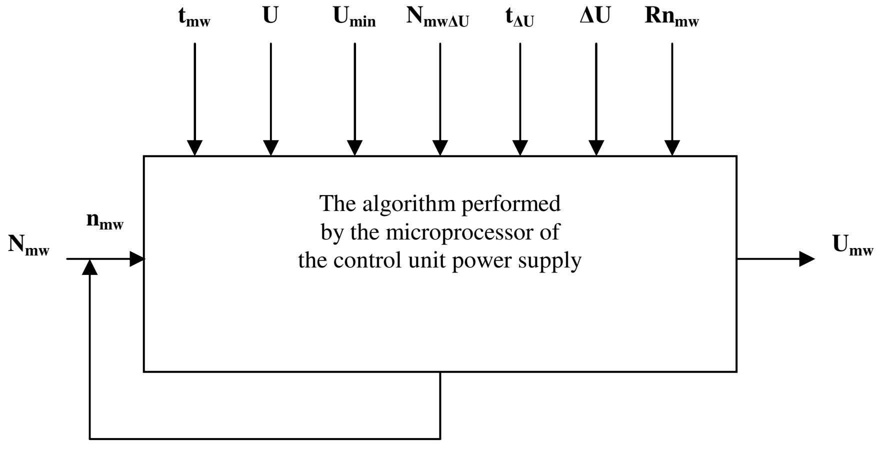

Fig. 3. Schematic diagram parameter management by the microprocessor of the controller

This algorithm actually creates a closed-loop, negative feedback. The greater the number of emerging microdischarges, the smaller the output voltage, and thus the electric power supplied to the process. This allows, in turn, a reduction in the number of microdischarges occurring in the chamber. If the growth rate of the occurrence of microdischarges drops, the output voltage automatically returns to the preset level, U, for the surface treatment process.

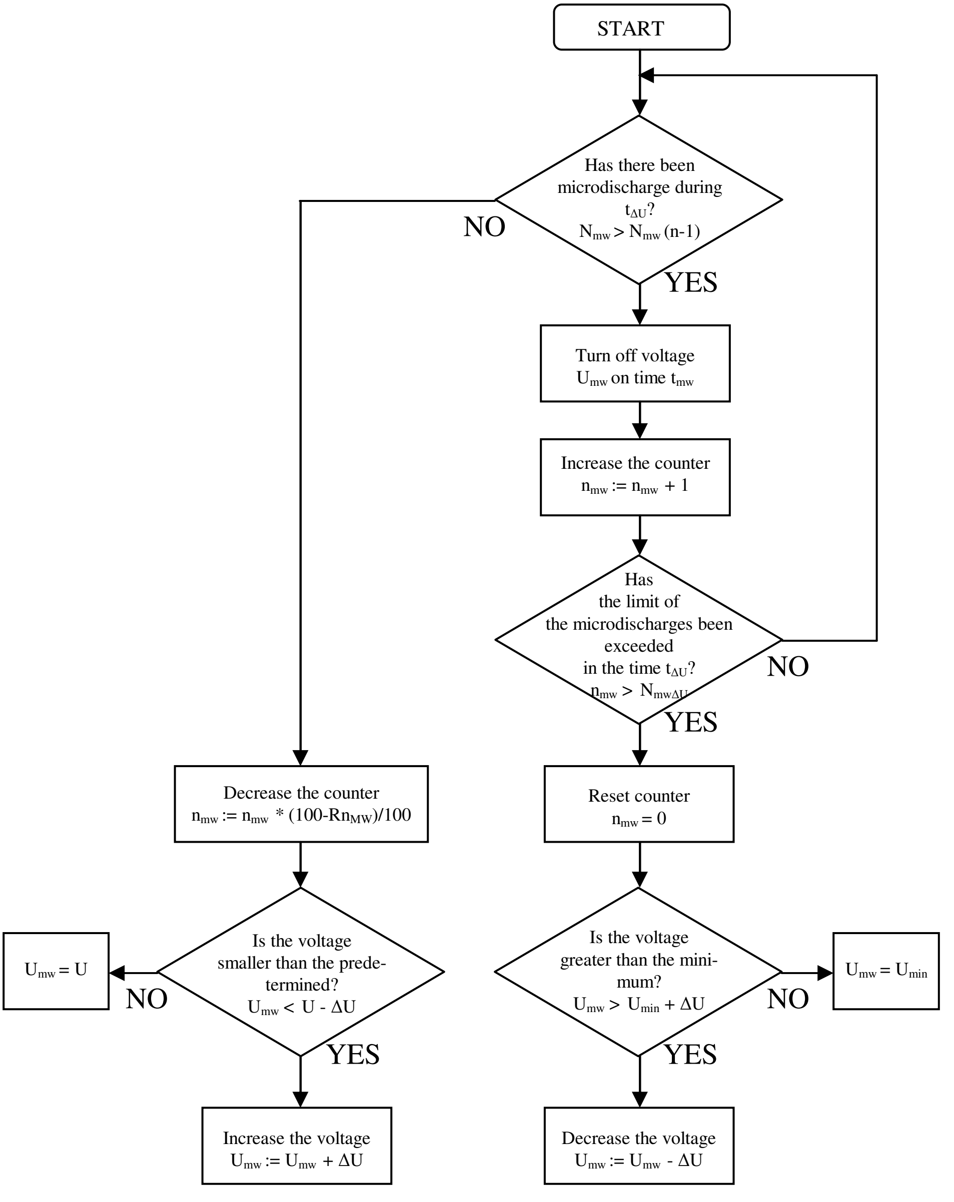

Fig. 4. Algorithm extinguishing microdischarges executed by a microprocessor controlled power supply to the plasma processes

4. Verification tests extinguishing microdischarges methods

For the initial verification, this method for extinguishing microdischarges was implemented in a bias power supply. By using specialized software, an appropriate program was developed, and the resulting code was placed in the microprocessor control unit (Fig. 5).

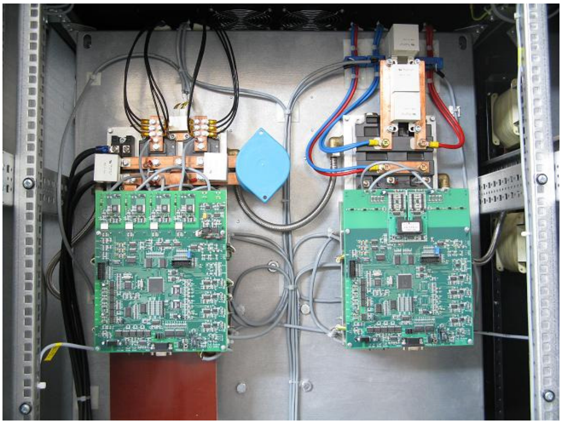

Fig. 5. A view of the bias power supply controller (left) and control switch module (pulser)

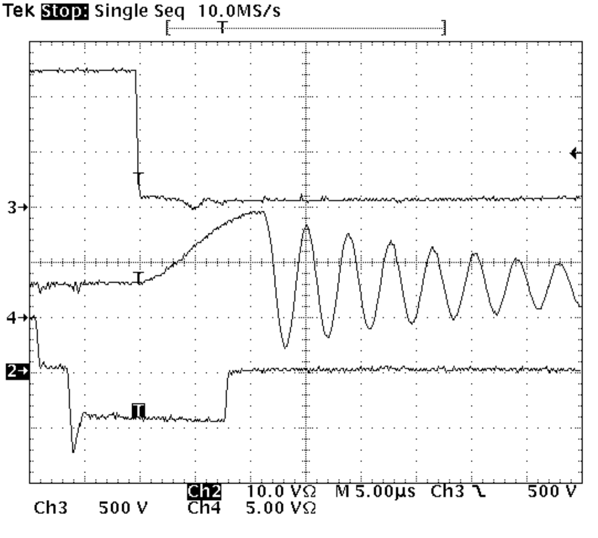

Fig. 6. The reaction of the power supply output to microdischarge during the power supply output by the short-circuit system simulator (short duration 10 µs, 400 Ω load, short-circuit 0 Ω, 2 – primary current, 3 – output voltage, 4 – output current)

The initial test of this method uses the power electronics micro short-circuit simulator. It allows a controlled output short-circuit power at the time set in the range of 1 µs to 10 ms. Figure 6 presents the output power of the short duration of 10 μs. This study verified the assumptions in the positive way only as the first function method of extinguishing microdischarges.

The full range of methods of extinguishing microdischarges was verified during many processes of the surface treatment in which a bias power supply and a magnetron power supply were used. Figure 7 shows the waveforms during the actual process of plasma surface treatment using a magnetron power source. There is a microdischarge in the waveform that is extinguished as a result of the developed method.

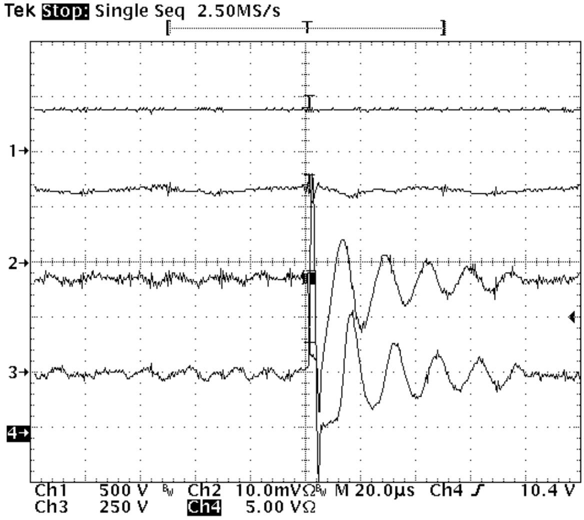

Fig. 7. A microdischarge during operation of the magnetron power source and the cathode is aluminium (1-U, 2-I (5A/dz), 3-Uwy, 4-Iwa)

Conclusions

The author's method of extinguishing microdischarges allows one to protect the technology process in PAPVD devices from the existence of local microdischarges. It protects workpieces from the damage and the vacuum chamber against the gradual degradation. It allows one to reduce the incidence of microdischarges, which protects against excessive local temperature rise during the process. It determines the efficiency of the plasma process and consequently, the possibility of its industrial application.

The method was implemented in a bias power supply and a magnetron power supply, which are used in the process of plasma treatment of a surface. These devices are manufactured in Institute for Sustainable Technologies – NRI.

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Metoda gaszenia mikrowyładowań w procesach plazmowej obróbki powierzchni

Słowa kluczowe

Mikrowyładowania łukowe, gaszenie mikrowyładowań, zasilacz polaryzacji podłoża, zasilacz źródła magnetronowego.

Streszczenie

W artykule przedstawiono autorską metodę gaszenia mikrowyładowań powstających na detalach obrabianych w procesach plazmowej obróbki powierzchni PAPVD. Metoda ta polega na rozpoznaniu stanu tuż przed wystąpieniem mikrowyładowania, szybkiego wyłączenia powstającego łuku oraz analizie

ilości występujących mikrowyładowań w czasie. W wyniku tej analizy ustalana jest ilość energii elektrycznej dostarczanej przez urządzenie zasilające do komory próżniowej, w której umieszczone są pokrywane detale.

Opracowana metoda zabezpiecza obrabiane elementy przed ich uszkodzeniem oraz komorę próżniową przed stopniową degradacją. Pozwala na ograniczenie częstości występowania mikrowyładowań, co zabezpiecza przed nadmiernym miejscowym wzrostem temperatury podczas procesu.

Metoda została zaimplementowana w zasilaczu polaryzacji podłoża oraz zasilaczu źródła magnetronowego, które są wykorzystywane w procesach plazmowej obróbki powierzchni. Urządzenia te zostały wyprodukowane w ITeE – PIB.