THE INFLUENCE OF PLASMA TREATMENT OF DIFFERENT CATHODE MATERIALS ON CURRENT-VOLTAGE CHARACTERISTICS OF MIRROR DISCHARGE IN AIR

G.P. Glazunov, M.N. Bondarenko, A.L. Konotopskiy

Institute of Plasma Physics of NSC "Kharkov Institute of Physics and Technology", Kharkov, Ukraine

E-mail: glazunov@ipp.kharkov.ua

The behavior was investigated of current-voltage characteristics of Penning discharges in air atmosphere. Such materials were used as cathodes: stainless steel 12KH18N10T, iron, nickel, titanium, copper, aluminum, tungsten. It had been shown the behavior of current-voltage characteristics of Ti, Cu, W is typical for Penning discharges. But, if to use stainless steel or Al cathodes, no typical behavior of current-voltage characteristics was observed, namely, the discharge current abrupt increase after threshold value of discharge voltage. The physical-chemical mechanism is suggested and discussed to explain this effect.

PACS: 52.40.Hf

INTRODUCTION

Desorption of the essential quantity of heavy impurity gases (water vapor, CO, N_2, O_2, CO_2 , hydrocarbons, etc.) is observed at the RF- or UHF-discharge cleaning of non heated vacuum chamber wall surfaces of plasma devices during their preparing for plasma experiments. This can lead to serious change of work gas composition and, in turn, adversely effect on vacuum-plasma characteristics of plasma facing materials (erosive, emissive etc.). Really, there are about $\sim 10^{19}$ particles in the Uragan-2M (U-2M) vacuum chamber (volume ~5 m^3) at the pressure of $\sim 10^{-4}$ Torr. If to suppose only 0.1 desorbing monolayer from the plasma facing surfaces (~25 m^3) during plasma pulse, we will obtain $\sim 10^{19}$ impurity particles. In other words, no pure hydrogen plasma interacts with plasma facing materials (mainly stainless steel), but plasma with high quantity (~50 %) of impurities. So, it was of interest to study behavior of stainless steel (SS) and others materials, used in plasma devices, in conditions of the impact by plasma discharges in air atmosphere. It had been shown earlier [1], in particular, that treatment of SS by magnetron type plasma discharges in air stimulates forming of modified layer (thin films) on the cathode surface. In this work the behavior was investigated of current-voltage characteristics (CVC) of mirror discharges in air atmosphere with cathodes made of SS and others materials.

1. EXPERIMENTAL AND RESULTS

The experiments were carried out on the diagnostic stand of materials DSM-1, operating in regime with mirror discharges [2]. The work gas pressure for all experiments was $2 \cdot 10^{-3}$ Torr, discharge duration 10…15 min. Magnetic field in the centre of plasma column was 500 Oe. Discharge voltage varied in the range of -300…2000 V. At the same time discharge current was changed from 5 to 90 mA. The scheme of the experiment is presented in Fig. 1. Cathodes (1) were polished disks made of stainless steel 12KH18N10T 22 mm in diameter and 2 mm thickness. Plasma column diameter was 20 mm, the distance between cathodes was 200 mm. Current-voltage characteristics were measured as dependencies of discharge current on absolute value of negative voltage on cathodes (Figs. 2-8).

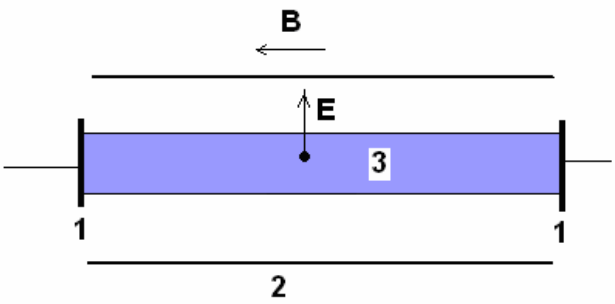

Fig. 1. Scheme of the experiment: 1 – cathode; 2 – anode, 3 – plasma column

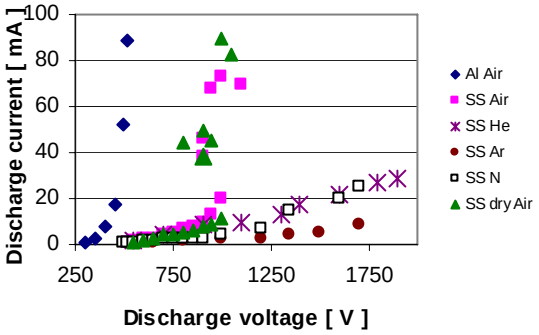

Fig. 2. Current-voltage characteristics of mirror discharges with SS-cathodes

It was founded that the discharge current abruptly increases from few muliampers to 90 mA, when discharge voltage value runs up to threshold magnitude (in case of SS it is ≈950 V). At the same time in mirror discharges with SS-cathodes in helium, nitrogen or argon atmosphere such effect was not observed.

2. DISCUSSION

To clear up the mechanism of the process of abrupt current increase in the case of mirror discharges with SS-cathodes in air atmosphere CVC behavior had been studied under impact of plasmas of mirror discharges in various gases (air, nitrogen, helium, argon) on the metals, which are in SS composition: Fe (steel-3), Ni, Ti, and, also on Cu, Al, W. It turn out, that plasma CVC behavior for such metals as Ti, Cu, W is typical for Penning discharges, i.e., monotone current increasing with discharge voltage increase (see Figs. 3-5). The similar CVC behavior for these cathodes is observed in plasmas of mirror discharges in others gases: helium, nitrogen, argon. For cathodes made of Ni and Fe the increase of discharge current had been measured at the another discharge voltages and has the different character in compare with SS (Figs. 6, 7).

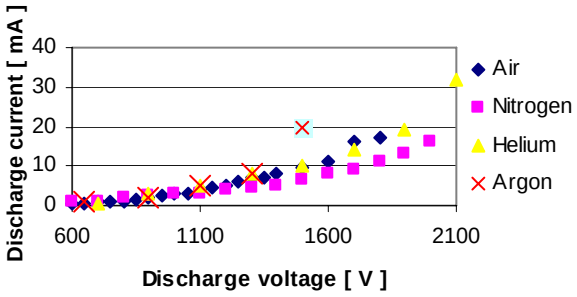

Fig. 3. Current-voltage characteristics of mirror discharges with Ti-cathodes

But for Al (Fig. 8) the effect of abrupt increasing discharge current has the similar character as for SS, but it is observed at the low value of discharge voltage (~300 V) and for all work gases, except argon.

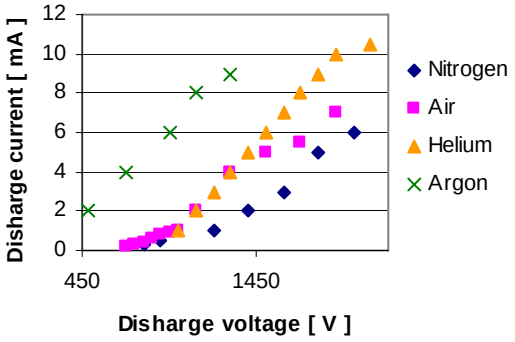

Fig. 4. Current-voltage characteristics of mirror discharges with Cu-cathodes

Note, the air freeze out drying in liquid nitrogen did not effect on the behavior of CVC of mirror discharges with SS-cathodes, i.e. it is not founded the water vapor influence. The cathode temperature increase during discharge could be the reason of above mentioned effect, but its absence for SS in case of helium, nitrogen and argon plasmas is the evidence of highly unlikely such explanation.

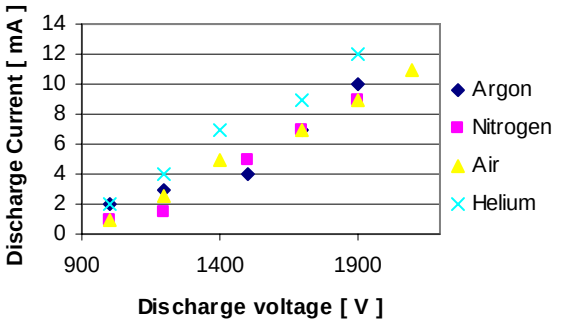

Fig. 5. Current-voltage characteristics of mirror discharges with W-cathodes

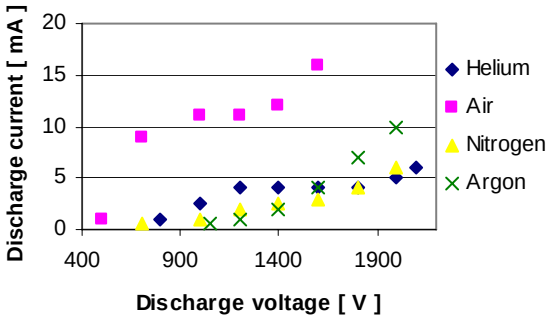

Fig. 6. Current-voltage characteristics of mirror discharges with Ni-cathodes

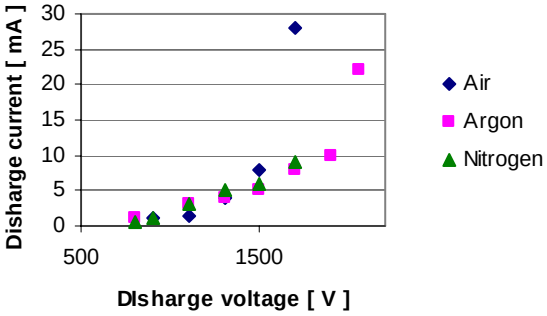

Fig. 7. Current-voltage characteristics of mirror discharges with Fe-cathodes

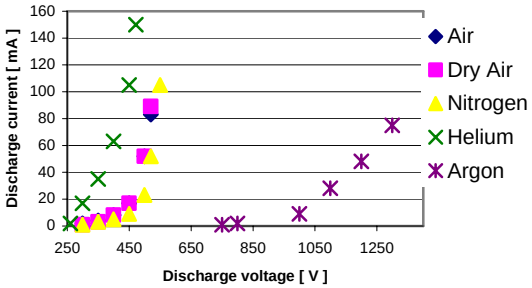

Fig. 8. Current-voltage characteristics of mirror discharges with Al-cathodes

The analysis of the obtained data has shown that discharge current abrupt increase could be caused by plasma-chemical reaction behavior on the cathode surface [1], which can lead to surface modification (thin

films forming), cathode emission current increase and, consequently, to discharge current increase. Really, well known the method of current emission increase from metal surfaces by deposition of various films [3]. For example, the electro-positive thorium deposition on W surface changes its surface electron structure, decreasing work function of electrons. In the case of oxide-coated cathodes it arises due to, e.g., BaO or others oxides deposition. In our case it could also be oxides and, perhaps, carbides forming on the surface of SS- and Al-cathodes because of O_2, CO_2 and hydrocarbons presence in discharges.

In conclusion note, that such essential change of emissive characteristics of stainless steel (main material of plasma devices) under impact of plasmas of discharges in chemical active gases can lead to serious, undesirable consequences in real plasma machines – arcs, breakdowns, increasing of SS erosion rate etc.

CONCLUSIONS

Current-voltage characteristics behavior had been investigated of Penning discharges in air atmosphere. It had been shown that current-voltage characteristics for such cathode materials as, Ti, Cu, W are typical for mirror discharges in all work gases. But if to use stainless steel or Al cathode material, CVC non typical behavior is observed, when discharge current abruptly increases after threshold value of discharge voltage. This effect could be caused by plasma-chemical reactions on the cathode surface, its modification, which leads to increase of current emission and, consequently, discharge current.

REFERENCES

1. G.P. Glazunov, A.A. Andreev, M.N. Bondarenko, A.L. Konotopskiy, V.E. Moiseenko, V.A. Stolbovoy. Erosion of vacuum-arc TiN-coatings and stainless steel under impact of stationary plasma of magnetron type discharges // *Physical surface engineering.* 2011, v. 9, № 3, p. 250-255.

2. G.P. Glazunov, E.D. Volkov, D.I. Baron, A.P. Dolgiy, A.L. Konotopskiy, A. Hassanein. Effect of Low/High Hydrogen Recycling Operation on Palladium Sputtering under Steady State Plasma Impact // *Physica Scripta.* 2003, v. T103, p. 89-92.

3. L.A. Ashkinazi, V.S. Petrov. *Materials of electron emitters . Part II. Thermal cathodes.* Moscow. 1997, p. 68 (in Russian).

Article received 03.10.12

ВЛИЯНИЕ ПЛАЗМЕННОЙ ОБРАБОТКИ РАЗЛИЧНЫХ МАТЕРИАЛОВ КАТОДА НА ВОЛЬТ-АМПЕРНЫЕ ХАРАКТЕРИСТИКИ ОТРАЖАТЕЛЬНОГО РАЗРЯДА

Г.П. Глазунов, М.Н. Бондаренко, А.Л. Конотопский

Исследовано поведение вольт-амперных характеристик (ВАХ) разрядов Пеннинга в атмосфере воздуха. В качестве катодов были использованы такие материалы: нержавеющая сталь 12Х18Н10Т, железо, никель, титан, медь, алюминий, вольфрам. Показано, что поведение вольт-амперных характеристик плазмы для таких материалов катода как титан, медь, вольфрам типично для отражательного разряда. Но при использовании в качестве материалов катода нержавеющей стали и алюминия наблюдалось не типичное поведение вольт-амперных характеристик, а именно, резкий рост тока при превышении порогового значения напряжения. Предлагается физико-химический механизм для объяснения этого эффекта.

ВПЛИВ ПЛАЗМОВОЇ ОБРОБКИ РІЗНИХ МАТЕРІАЛІВ КАТОДА НА ВОЛЬТ-АМПЕРНІ ХАРАКТЕРИСТИКИ ВІДБИВНОГО РОЗРЯДУ

Г.П. Глазунов, М.Н. Бондаренко, А.Л. Конотопський

Досліджена поведінка вольт-амперних характеристик (ВАХ) розрядів Пеннінга в атмосфері повітря. Як катоди були використані такі матеріали: нержавіюча сталь 12Х18Н10Т, залізо, нікель, титан, мідь, алюміній, вольфрам. Показано, що поведінка вольт-амперних характеристик плазми для таких матеріалів катода як титан, мідь, вольфрам типово для відбивного розряду. Але при використанні в якості матеріалів катода нержавіючої сталі і алюмінію спостерігалася не типова поведінка вольт-амперних характеристик, а саме, різке зростання струму при перевищенні порогового значення напруги. Пропонується фізико-хімічний механізм для пояснення цього ефекту.