COATING IN THE ARC DISCHARGES WITH PLASMA FLOW FILTRATION

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Experimental results of coating deposition with application of an "open architecture" filter to reduce the dropwise component in the discharge [1,2] are presented in this paper. The filter is located in a separate chamber conjugate with the presented system. A curvilinear (with an angle 90°) solenoid creating a transporting magnetic field [3] is used as the "open architecture" filter. Performing probe measurements of the ion saturation current dependences on the current of focussing coil, pressure of inert gas (argon) and reactionary gas (nitrogen). The measurement results of substrate temperature, deposition rate of coating.

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1. INTRODUCTION

The vacuum - arc discharge in technologies of modifying a surface is actively used in various areas of the industry due to the unique characteristic of deposition coatings. The important advantage of the vacuum - arc method is full reproduction of the chemical compound deposition coating.

One of defects of the vacuum - arc method of deposition PVD - coatings is the presence in erosive plasma of a stationary vacuum arc, and therefore in a condensate, the considerable content of macroparticles (up to 50 %) with the size drops from 0.1 up to 10 microns and more than [1]. Such quantity of drops in a condensate breaks uniformity of coatings, increases a coarseness that does not allow applying this method in nanostructure technologies. The presence of drops reduces service characteristics, especially anti-corrosion, antierosive, decorative, optical, etc.

These defects can be removed by various constructions of magnetic filters. There is a series of papers devoted to research and applications of magnetoelectric filters, which technically simplifies realization of the task to decrease the drop phase in a condensate. In this report we present one of the versions of "open architecture" filter, which allows us to reduce the drop phase in the condensate under the task.

2. EXPERIMENT

To increase purity of the vacuum - arc plasma and to expand possibility of the standard «Bulat - 6» system, the filter is used, which is placed in the L-shape metal (iron) tube, one end of which is connected to the working chamber of the system, while another one is connected to the source of plasma. A solenoid creating a curvilinear (with an angle 90°) transporting magnetic field plays a role of the filter. The solenoid is made of aluminium bar with the cross-section S = 1.5 cm^2 and number of twist being equal 18. Its average diameter is $D_{ave.}$ = 17 cm. A power of the solenoid implements from individual source of direct current by connection of it consistently to the arc discharge interspace of the source plasma (Fig. 1). The substrate temperature is measured by a cylindrical copper probe with the diameter of 8mm and length 10mm, inside of which the chromel-allimel thermopair is inserted. Measuring of ion current is carried out with a metal probe (collector) made of stainless steel with defined diameters.

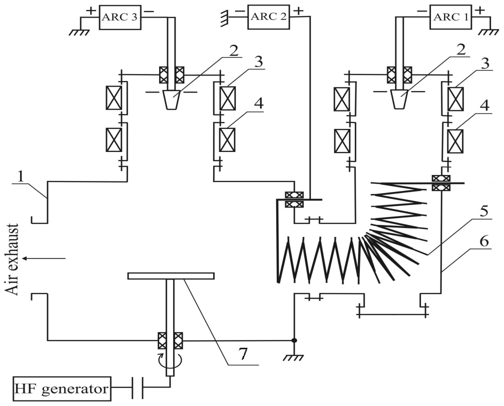


Fig. 1. 1) vacuum chamber, 2)cathode, 3)stabilizing winding, 4)focusing solenoid, 5)solenoid, 6)chamber of solenoid, 7) substrate

3. RESULTS AND DISCUSSIONS

Particle passing through the MEP (magnetoelectric plasmaguide) of the metal plasma is provided by the presence of the longitudinal magnetic and traversal electrical fields. Electrons of the magnetized plasma move along spiral lines of the magnetic field. Ions also move electrostatically retained by electrons. The ion component of the plasma goes due to these fields to the filter exit towards the collector (substrate), while macroparticles moving straight on get to the wall of L-shape tube in the trap through the intervals between the solenoid winding. The particle motion character through the MEP is described in detail in paper [2].

Dependence of the ion current at the system exit on the focussing coil current is shown in Fig. 2. Dependence of ion current at the system exit on the focussing coil (solenoid) current is measured for the case of injection of titanium plasma inside the solenoid. The collector is placed at the distance l = 3 cm from the end of solenoid. The absence of magnetic field of the focussing coil and the presence of the maximum field of the solenoid coil show that the part of ion component of metal plasma goes to the system exit (I_i = 125 mA). But at $I_{f.s}$ = 0 and I_s = 0 ion component at the exit is almost absent (I_i = 0). It allows, before forthcoming process of a deposition coating, to clear the cathode.

Next stage of the experiment was measurement of the ion current dependence on gas pressure of argon and nitrogen.

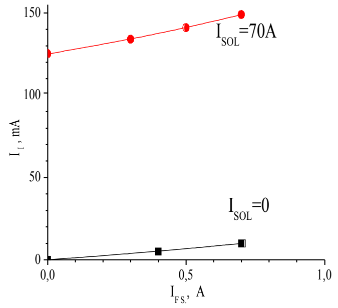
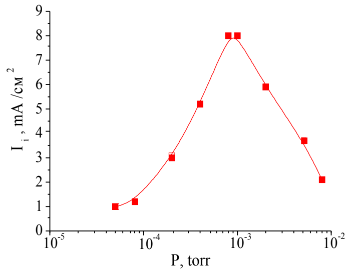
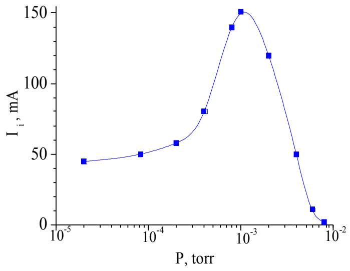


Fig. 2. Change of the ion current at the system exit depending on the focussing coil current I_{arc} = 110 A; U_{subs}= - 150 B, P = 4×10^{-5} torr, l=3 cm

The research was carried out for streams of titanium plasma. The results of the measurement are shown in (Fig. 3a, b).



a) density current



b) ionik current

Fig.3. Change of ionic current from pressure a) Ar and b) N_2. I_{arc} = 110 A; $I_{f.s}$ = 0,7 A (120 Oe); I_{col} = 70A (40 Oe); $U_{subs.}$ = - 150 B. l=3 cm

Experiments were carried out with identical parameters for each gas. One can see from figure that the ion current (density) at pressure P = 1×10^{-3} torr has a strongly pronounced maximum for both gases. The increase in the ion current is caused by interaction of the products of cathode erosion with gas. The decrease of I_i in the region P > 10^{-3} torr occurs in the connection with recombination of the charged particles, as well as with dissipation of the stream on the gas target.

Measurements of the probe temperature dependence on time of metal titanium plasma effect on it at pressure of the residual gas P = 4×10^{-5} torr, and at the atmosphere pressure of argon P_{Ar} = 1×10^{-3} torr are shown in Fig. 4. Readout of the temperature was performed from the beginning of arc activation. One can see from figure that at the same time of deposition probe heating at high is about 30°C. It is much less than it is at argon atmosphere (180°C). Measurement of the probe temperature with clearing time in HF-plasma was carried out as well. The parameters of HF-clearing as follows P_{Ar} = 2·10^{-3} torr; U_{HF} = - 1 kV; time t = 10 min. The probe temperature has decreased up to 30°C.

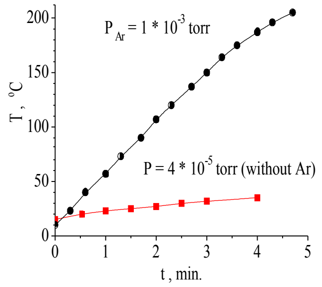


Fig. 4. Measurement of the probe temperature dependence on time of Ti deposition in argon atmosphere. I_{arc} = 110 A; $I_{f.s}$ = 0,7 A (120 Oe); I_{col} = 70 A (H=40 Oe); $U_{subs.}$ = - 150 B. l=3 cm

To show the distribution of the coating thickness at the system exit over radius, the glass sample was placed in the chamber center (10 cm from the solenoid end) behind which the metal screen is placed. The sample size is 210 x 240mm. The metal screen was under HF-voltage through the capacity. Before deposition of coating, clearing of glass sample in field of HF-discharge in an atmosphere of argon was performed. The obtained titanium coating had a good adhesion and full absence of drops in a condensate, they were not observed in optical microscope at the increase of 225 times. Translucent coating has allowed with the light source and pyrometer to obtain the coating thickness distribution at the system exit on radius (Fig. 5).

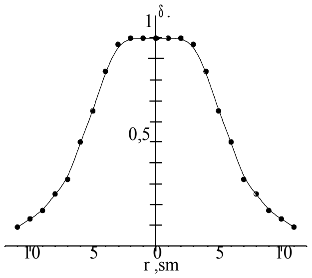
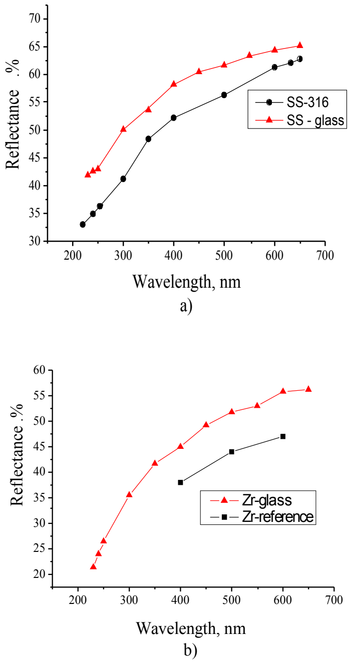


Fig. 5. Distribution of the thickness of coating at the system exit on radius

As one can see from the figure, the cross-sectional distribution of the density of the output plasma stream is nonuniform, and only a segment with the radius of 3 cm, located symmetrically relatively to the solenoid axis, has the uniform coating. If one takes the radius at which the coating decreases in two times (R = 6 cm), then the effective cross-sectional area of the stream will be S = 113 cm^2. This parameter has a practical significance of coating deposition with uniform distribution of the properties on products of the relevant sizes.

Velocity of coating deposition was studied for the sample made of stainless steel with the size 20×20 mm, fixed at the distance l = 3cm from the solenoid end. Clearing was produced in HF - discharge during t = 10 min. Deposition of coating was carried out in atmosphere of residual gas P = 5×10^{-5}torr, and the cathode of evaporated material (Ti) was used. At the time of process HF-bias was applied to the sample. The coating was deposited in pulse mode for 40 minutes

(10 seconds of deposition + 10 seconds of pause): t_{ef} = 20 min. Thickness of coating measured by interferometer is δ = (1.5…2) μkm, corresponding to the deposition velocity of 5 μkm /hour.



a)

b)

Fig.6. Measurement of coating deposition with optical reflector for a) SS-316, b) Zr

Amount of coating deposition on drop-free with application the filter of "open architecture" was studied with optical reflector. To compare, we took the polished metal samples (12 class of cleanliness) and glass samples with coating of research metal in range of lengths waves from 200 up to 700 nm. The metals were Zr, SS-316 stainless steel, the deposition was produce on substrates from glass by the sizes 20×60 mm. Results of measurement are shown in Fig. 6 a, b One can see from both figures that a reflected power polished metal samples less than at the deposition coating through the filter of «open architecture», in a condensate presence of drops is not observed. Therefore, coatings have excellent reflecting properties. They may be applied in optical and nanostructures technologies.

4. CONCLUSIONS

We have shown that measurement of the ion current dependence on gas pressure for argon and nitrogen was conducted for the streams of titanium plasma. We have found that under the pressure P = 1×10^{-3} torr ion current (density) has the maximum for both gases. Decreasing of I_i in the area P > 10^{-3} torr, occurs in the connection with recombination of charged particles, and stream dissipation in the gas target.

When the currents of the focusing coil and solenoid are absent, the ion current at the output of the filter tends to zero. It allows, before forthcoming process of the coating deposition, to make preliminary clearing of the cathode and to reduce all operations to unified work cycle. In the presented experiment, the velocity of deposition was 5 μkm /hour. Coatings on the glass samples with application of the cathodes made of SS-316, Zr are obtained and explored on reflectivity in the range of wave lengths from 200 up to 700 nm. Therefore, the coatings have excellent reflecting properties and may be applied in optical and nanostructures technologies.

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ПОКРЫТИЯ В ДУГОВОМ РАЗРЯДЕ С ФИЛЬТРАЦИЕЙ ПЛАЗМЕННОГО ПОТОКА

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Представлены экспериментальные результаты нанесения покрытий PVD методом с применением фильтра «открытой архитектуры» для уменьшения капельной составляющей в разряде [1,2]. Представлен фильтр «открытой архитектуры», помещённый в отдельную камеру, сопряжённую с установкой. В качестве фильтра применяется соленоид, создающий криволинейное (с углом 90°) транспортирующее магнитное поле [3]. С помощью зондовых измерений получены зависимости ионного тока коллектора от изменения: тока фокусирующей катушки, давления инертного газа (аргона) и реакционного газа (азота). Представлены результаты измерения температуры подложки, скорость осаждения покрытия.

ПОКРИТТЯ В ДУГОВОМУ РОЗРЯДІ З ФІЛЬТРАЦІЄЮ ПЛАЗМОВОГО ПОТОКУ

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Представлено експериментальні результати нанесення покрить PVD методом із застосуванням фільтру «відкритої архітектури» для зменшення краплинної складової в розряді [1,2]. Представлено фільтр «відкритої архітектури», який знаходиться в окремій камері, що сполучена з установкою. Як фільтр застосовується соленоїд, що створює криволінійне (з кутом 90°) транспортуюче магнітне поле [3]. За допомогою зондових вимірів отримані залежності іонного струму колектора від змін: струму фокусуючої котушки, тиску інертного газу (аргону) і реакційного газу (азоту). Представлено результати вимірів температури підкладки, швидкість осадження покриття.