INVESTIGATION OF CHARACTERISTICS OF NON-SIMULTANEOUS ARC DISCHARGE IN TITANIUM VAPORS IN GLOW DISCHARGE ELECTRON EVAPORATORS

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Investigations of simultaneous applying of high voltage glow discharge (HVGD) and non-self-maintained low-pressure arc discharge for obtaining high-quality titanium nitride coatings are provided. Obtained results are compared with experiments, provided on experimental technological equipment. Provided investigations showed, that using of glow discharge electron guns (GDEG) in installations for obtaining of chemically-complex compounds with plasma activation lead to simplifying of technological equipment and to improving the films quality. For investigated electrical parameters there are no necessary special technical measures for providing both HVGD and arc stability, early considered simple technical solutions are enough. Using of simple mechanical pumps for realizing binary films deposition in the range of operation pressure 10^{-2} – 1 Pa with joint pumping of electron gun and technological chamber is also possible. Necessary technological equipment can be elaborated in correspondence with the customers' requirement.
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INTRODUCTION

Among the modern methods of coatings deposition in the vacuum, important place is occupied by the electron beam evaporation, which find application in such important branches of industry as electronic, instrument-making, machine-building and other. Main advantage of such technologies is direct heating of evaporated material by the powerful electron beam and its evaporation from the water-cooled crucible, which provided the high purity of coatings with high deposition rate. In such conditions of obtaining of coatings its microstructure and properties are noticeably improved by ionizing of vapor flows with controlled ions concentration. Such kind of deposition is called plasma activated deposition, where chemical compound are created from evaporated metal and residual gases [1]. In this paper the method of evaporation, based on combining of electron beam heating by the high voltage glow discharge electron gun and plasma activation of vapors in the vacuum non-self-maintained arc discharge is described. Main singularities of realizing of this method on the technological equipment and required technical means are described. As a conclusion main obtained experimental discharge characteristics are presented and branches of profitable using of such evaporators are pointed out.

THE STRUCTURE AND PRINCIPLE OF OPERATION OF ELECTRON BEAM EVAPORATOR WITH PLASMA ACTIVATION

Scheme of construction of glow discharge electron beam evaporator is presented at Fig. 1. The main element of this construction is glow discharge electron gun 1, which formed the electron beam with large convergence angle 2 and connected with technological chamber 5 by guiding cannel 3, on which located the focusing magnetic lenses 5 [2].

Geometry parameters of guiding system is depended on required pressure in technological chamber and allowable losses of beam current. Interdependence of those parameters was analyzed in paper [3], where the methodic of calculation of guiding system geometry also have been proposed [3]. The ordinary parts, located in the technological chamber, included water-cooled crucible 6 with evaporated material 7, and substrates 10 where ionized vapour 9 condensates. As for rules of electrical connection, crucible in such systems is usually located at zero potential, and the substrates are electrically isolated from chamber for its treatment in discharge plasma by using ion bombarding [4,5]. Ring-like electrode 8 is used as anode for lighting of non-self-maintained vacuum arc discharge and for plasma-activation of vapours and residual gases for increasing the rate of chemical reaction between metal's and gas components [5]. In the main principles such construction of evaporator is coincide with similar evaporators, where hot cathode electron guns are used [1], but using of high voltage glow discharge electron guns is lead to combination of two form of discharges in one technological equipment. Therefore, for realizing of deposition of binary compounds with using GDEG, experimental investigation of physics of used discharges is necessary.

Plasma-activated deposition of binary compounds with including of gas components is usually realized in relatively high operation pressure range of 10^{-1}–10^{-2} Pa with inputting of active gases. Clearly, those traditional electron guns with hot cathodes are not profitable to using in such vacuum conditions [1]. But the best way to complex solution of this technical problem is using of other types of electron guns, which are stably operated in required physical conditions. Among such novel types of guns the glow discharge electron guns, based on HVGD, perspective to using for plasma-activated deposition of coatings in the soft vacuum [2].

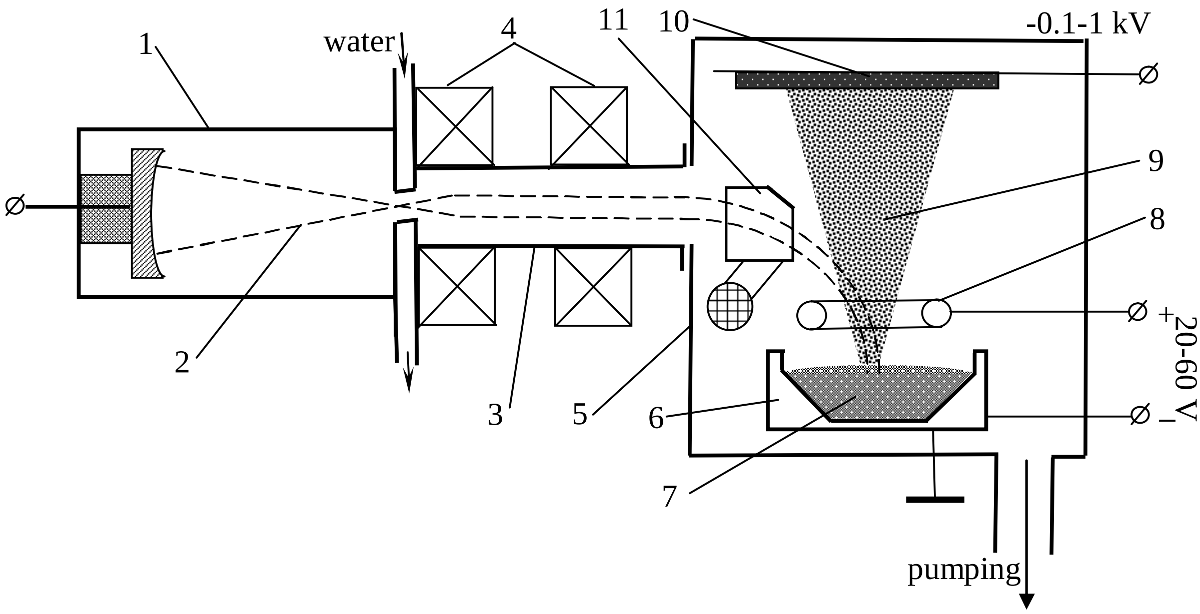

Fig.1 Scheme of construction of electron-beam evaporator with plasma activation in the arc discharge:
1 – electron gun; 2 – electron beam; 3 –beam guiding system; 4 – magnetic lenses; 5 – technological chamber;
6 – crucible; 7 – evaporated material; 8 – anode of arc discharge; 9 – vapor; 10 – substrate, 11 – deflection system

Such guns are operated in physical conditions of HVGD, which are correspond to range of pressure units or tens Pa and power density of electron beam from the cathode surface is till 10^6 W/cm^2. Another problem of electron beam evaporation is the low level of vapor ionizing by high energy beam electrons. Therefore, lighting of additional non-self-maintained arc discharge near the surface of evaporation is also necessary [1,5].

EXPERIMENTAL INVESTIGATION OF INTERINFLUENCE BETWEEN HVGD AND VACUUM ARC DISCHARGE

Current-voltage characteristic of non-self-maintained arc discharge in titanium vapor and nitrogen gas media are presented in Fig. 2 and 3, and dependence of arc current form parameters of electron gun presented in Fig. 4

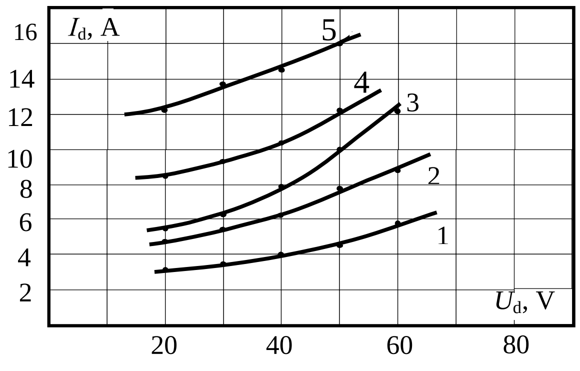

Fig. 2. Current-voltage characteristics of arc discharge for different beam power for pressure in technological chamber 10^{-2} Pa and acceleration voltage 12 kV. HVGD current: 1 – 150 mA; 2 –180 mA; 3 – 200 mA; 4 – 250 mA; 5 – 300 mA

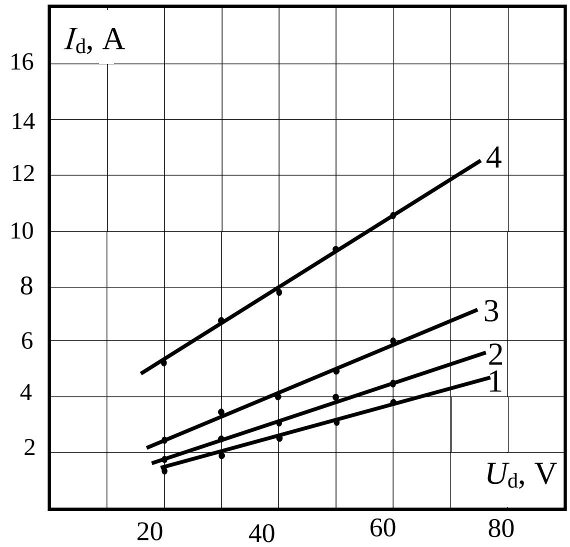

Fig. 3. Current-voltage characteristics of arc discharge for different beam power for pressure in technological chamber 1 Pa and acceleration voltage 12 kV. HVGD current: 1 – 150 mA; 2 –180 mA; 3 – 200 mA; 4 – 250 mA; 5 – 300 mA

The photograph of microstructure of cutting cross section of obtained titanium nitride films shown at Fig. 5. This film was deposited on experimental installation with glow discharge electron gun, and combination of high-rate electron beam evaporation with plasma activation of titanium vapors in nitrogen where used. One can see that the structure of obtained films is very smooth, and including only small and negligible microcrakes, drop fractions and other defects is observed. Obtaining of better structures also may be possible with increasing arc current and the power of electron beam.

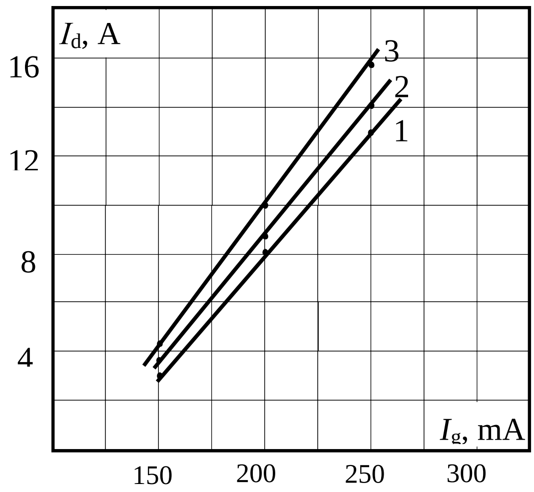

Fig. 4. Dependence of arc discharge parameters from HVGD parameters for different voltages of arc discharge: 1 – U_d =20 V; 2 – U_d =30 V; 3 – U_d =40 V

Fig. 5. Microstructure of obtained titanium nitride films in the cross section with 25000 magnification

CONCLUSIONS

Provided experimental investigation shown, that using of GDEG in installations for obtaining of binary compounds with plasma activation lead to simplifying of technological equipment and improving the films quality. For investigated electrical parameters there aren't necessary special technical measures for providing both HVGD and arc stability, early considered simple technical solutions are enough. Using of simple mechanical pumps for realizing films deposition in the range of operation pressure 10^{-2} – 1 Pa with joint pumping of electron gun and technological chamber is also possible. Necessary technological equipment can be elaborated by authors corresponding to the customers' requirement.

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ИССЛЕДОВАНИЕ ХАРАКТЕРИСТИК НЕСАМОСТОЯТЕЛЬНОГО ДУГОВОГО РАЗРЯДА В ПАРАХ ТИТАНА В ГАЗОРАЗРЯДНЫХ ЭЛЕКТРОННЫХ ИСПАРИТЕЛЯХ

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Исследуется совместное применение высоковольтного тлеющего разряда (ВТР) и несамостоятельного вакуумно-дугового разряда низкого давления для получения высококачественных покрытий из нитрида титана. Полученные теоретические результаты подтверждаются экспериментами, проведенными на технологическом оборудовании. Проведенные исследования показали, что использование газоразрядных электронных пушек (ГРЭП) в электронно-лучевом оборудовании, предназначенном для нанесения покрытий сложного химического состава, совместно с использованием дугового разряда для активации плазмы, позволяет упростить электронно-лучевое оборудование и повысить качество получаемых покрытий.

ДОСЛІДЖЕННЯ ХАРАКТЕРИСТИК НЕСАМОСТІЙНОГО ДУГОВОГО РАЗРЯДУ У ПАРАХ ТИТАНУ У ГАЗОРОЗРЯДНИХ ЕЛЕКТРОННИХ ВИПАРНИКАХ

С.В. Денбновецький, В.Г. Мельник, І.В. Мельник, Б.А. Тугай, П.В. Порицький

Досліджується сумісне застосування високовольтного тліючого розряду (ВТР) та несамостійного вакуумно-дугового розряду низького тиску для отримання високоякісних покриттів із нітриду титана. Отримані теоретичні результати підтверджуються експериментами, проведеними на технологічному обладнанні. Проведені дослідження показали, що використання газорозрядних гармат в електронно-променевому обладнанні, призначеному для осадження хімічно складних покриттів та використання дугового розряду для активації плазми, дозволяють спростити електронно-променеве обладнання та поліпшити якість отримуваних покриттів.