Formation Features of Strengthening TiN Coatings at Joint Action Magnetron and Arc Discharge of Low Pressure

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Abstract – The hybrid technology of reception functional coatings TiN at joining action magnetron and arc discharge of low pressure is developed. The generator of plasma has been developed and observed mutual influence of magnetron and arc discharge on processes stability of coating formation. The generator's plasma basic electro physical and technological parameters are studied; it was shown the opportunity of strengthening TiN coatings drawing on copper (BrKMn 3-1) and titanic alloys (OT4-1). The basic advantages in offered overlapping processes of sputtering in the magnetron and arc discharge are the expanded opportunities in management on structure and coating properties also the reduction of formation temperature.

1. Introduction

The opportunity of combination of two different growth processes in one installation leads to new receptions of films cultivation, for example it is possible to try to unite method CIB (a method of condensation with ionic bombardment) and magnetron dispersion.

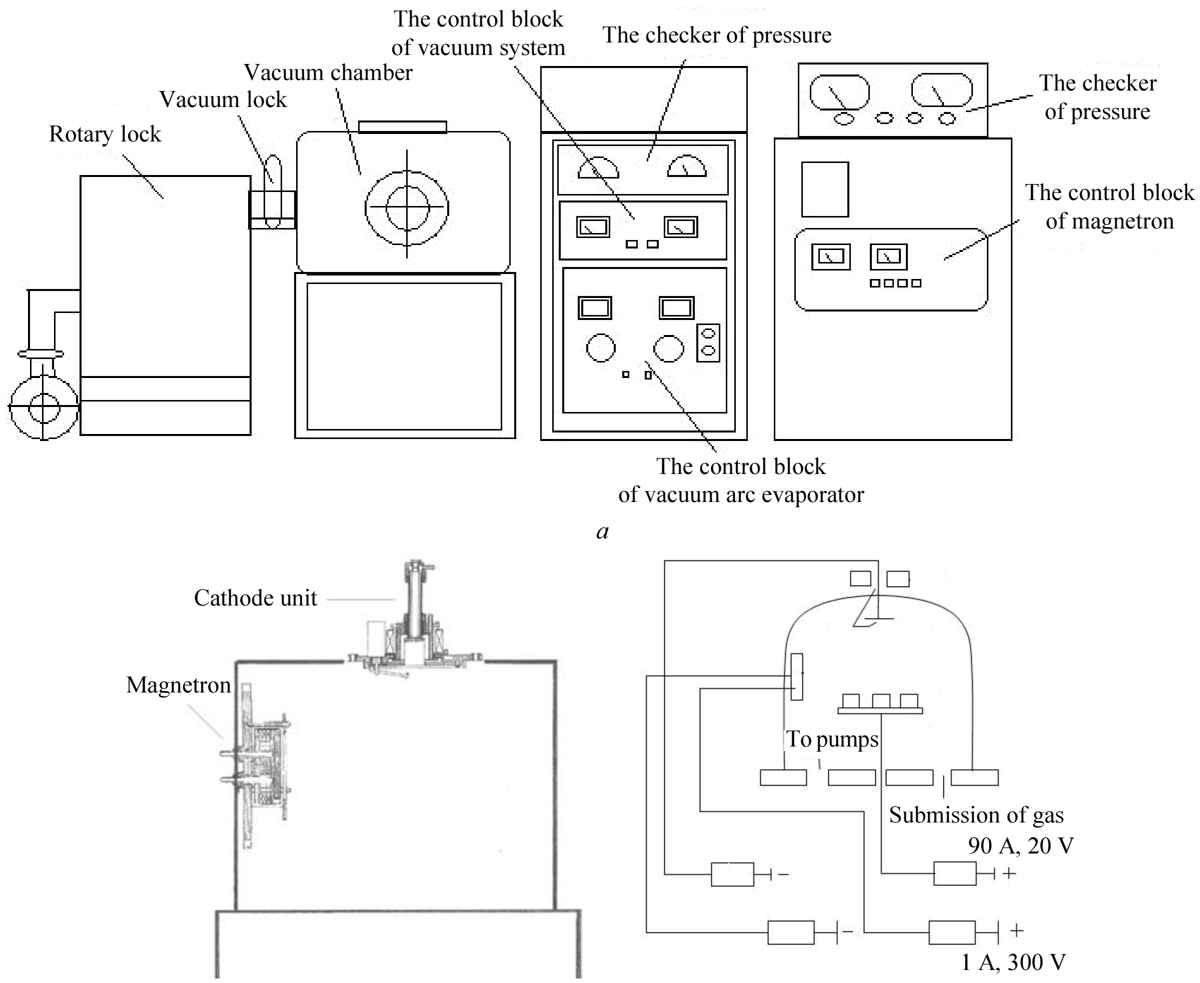

Fig. 1. The design of installation and intrachamber equipment: *a* – an arrangement of mainframes of installation; *b* – arrangement magnetron in the vacuum chamber; *c* – the basic scheme

These methods are universal because they give possibilities to receive wide scale of mono- and multilayered and composite coatings, which have the unique operational characteristics [1]. As the basic advantages of planar magnetron use it is possible to allocate the following: high speeds of dispersion, low temperature of substrates, small degree of film impurity with extraneous gas inclusions [2].

2. Description of modernized installation BU-1B

Below there is the basic scheme of two devices allocation and principle of functioning: the vacuum arc evaporator accommodation and planar magnetron, and blocks of magnetron and cathode units management, vacuum maintenance, an electric and gas supply.

Figure 1 shows the general view, an arrangement of mainframes and the basic scheme of the modernized installation.

Modernization of initial installation BU-1B has been made by configuration of planar magnetron in the vacuum chamber. Capacity of the power supply magnetron is up to 3 kW. The high-voltage generator is calculated on a voltage up to 1000 V. By means of the magnetron's block of management, adjustment of capacity of the discharge can be made in any mode.

Magnetron (Fig. 2) consists of a ring target, a constant ring magnet, a polar tip, and the central anode.

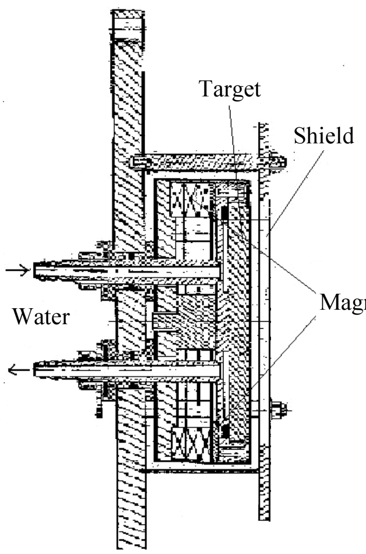

Fig. 2. A design of magnetron

The magnetic system is formed by constants (cobalt-samarium) magnets, magnetic conductor and a polar tip, which are forming above a surface of a target a toroidal magnetic field with an induction equal from $2 \cdot 10^1 - 8 \cdot 10^2$ mTl. An electric supply on magnetron moves through the earthed anode (positive potential) and the isolated target (negative potential).

Cathode unit (Fig. 3) consists of the welded case which has a cavity for cooling by water, the magnetic coil providing uniform burning out of the cathode, the additional anode, the electrostatic screen isolated both from the cathode, and from the additional anode.

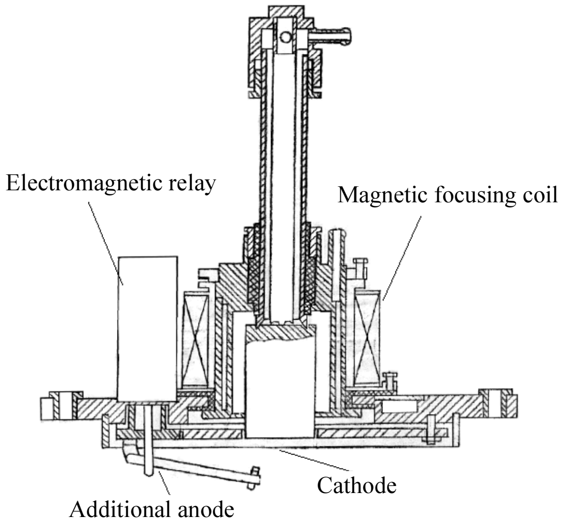

Fig. 3. A design of cathode unit

A material of the cathode is titan of mark "BT-1-0" with diameter 60 mm serves. The cathode also is cooled by water. In order to receive plasma in vacuum, the evaporator is equipped by the setting fire device representing the electromagnetic relay, which anchor in the form of a rod, moves turn again and forward and moves molibden bar, short circuiting an interval the anode-cathode. Capacity of the power supply of cathode unit is up to 2 kW. Inside of the chamber rotating base sheet header is located, providing uniformity of distribution increased films on thickness. The basic voltage submitted on a rack provides preliminary heating details. Gas mix for planar magnetron in the separate vacuum amalgamator is prepared. The lap of working gases is made through special needle leak. Limiting residual pressure in the vacuum chamber $6.6 \cdot 10^{-3}$ Pa. Installation has uniform vacuum system based on diffusive pump N400\700.

Feature of the developed design – teamwork of magnetron and cathode unit. As the experiments have shown, magnetic field of magnetron very strongly influences to the behavior of the arc discharge which burns in the form of chaotically moving on surfaces target cathode spots. In normal conditions, there is a gradual evaporation of a material of the cathode and its uniform use. Under influence of a magnetron's magnetic field cathode's spots of the arc discharge are displaced from a target's surface on a wall of the chamber. There is a strong heating this area of the chamber and non-uniform evaporation of a cathode's material. After gaugings size of magnetic field's induction and construction the general picture of force lines distribution in the vacuum chamber the problem has been eliminated.

In Fig. 4 the three-dimensional model of force lines magnetic field magnetron distribution is shown.

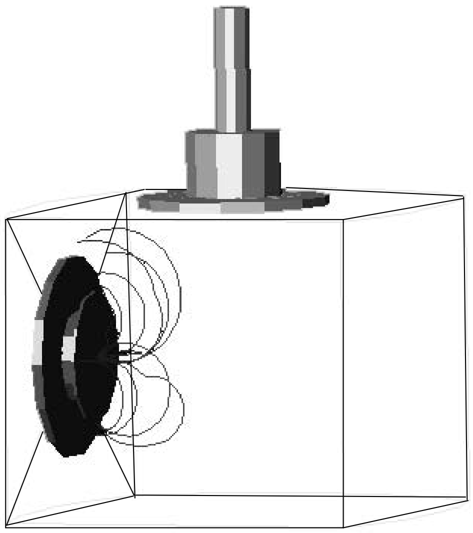

Fig. 4. A general view of force lines distribution of magnetron's magnetic field in space of the vacuum chamber

3. Principle of action

The results on separate work of the vacuum arc evaporator and planar magnetron for working of technological modes of sedimentation metal films have been received. Formation of doratively-sheetings occurred in two stages: for reception of covering by method CIB, firm substance (cathode) evaporate in vacuum under action of a low-voltage electric arch of a direct current. Higher ionization plasma of the evaporated substance is formed at evaporation in the vacuum chamber. Between the cathode and anode electrode the adjustable potential difference is created. In an electric field the charged particles of plasma are accelerated before achievement of the energy proportional to a potential difference, and direct to an auxiliary electrode, in which where processable details settle down, forming on a surface dense and uniform covering on thickness.

As reactionary gas was used nitrogen gaseous with high degree of clearing. Limiting residual pressure in the vacuum chamber – $6.6 \cdot 10^{-3}$ Pa. The mode of drawing coverings was provided reception of uniform layers in interval of thickness 1.0–4.5 μm. Preliminary ionic processing of a surface of samples spent in the decaying discharge on nitrogen.

Process of formation decoratively-sheeting coverings by method magnetron dispersions on steel products assumed jet dispersion of titan in an atmosphere of nitrogen. The structure of plasma formation gas included argon and nitrogen (3–5% on volume). Gas mix was prepared in the separate amalgamator (volume up to 3 l) which preliminary pumped out up to pressure ~10^{-2} Pa (on thermo-ionization converter PMI-3). Gases were mixed in the amalgamator entering through needle leak from cylinders with the compressed gas. The decaying discharge was lit at a voltage 250 V and a current 0.6 A for realization of ionic clearing and warming up evaporated surfaces. Further current of the discharge was lifted up to 2–3 A. On an electrode on which there were processable products, submitted a voltage 80–150 V that warmed-over surfaces of a product were not cooled and were under potential for improvement of adhesion sputter coverings. Duration of process depends on it is required to put what thickness of a layer. The distance from magnetron up to spraying surfaces made 180 mm and in all experiences did not change.

Key parameters magnetron discharge (VAC, size of a magnetic induction, pressure of working gas) for a target from Ti (99.2%) are investigated. A range of working pressure – 10^{-2} Pa, size of a magnetic induction – $2 \cdot 10^{1} – 8 \cdot 10^{2}$ mT.

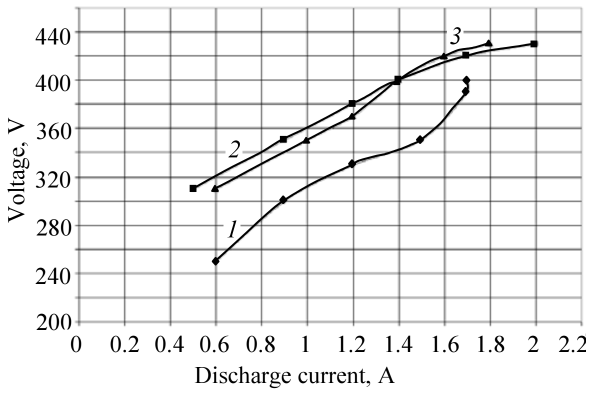

Fig. 5. Current-voltage characteristics of the magnetron at the discharge dispersion, voltage on the titan target BT-1-0: *1* – $p = 8 \cdot 10^{-2}$; *2* – $3 \cdot 10^{-2}$; *3* – 10^{-3} Pa

A series of experiments on drawing strengthening coverings TiN on copper (BrKMn 3-1) and titanic (OT4-1) alloys were lead. Influence of parameters of technological process on contents, structure and characteristics of received TiN sheeting's was studied.

In Figs. 6 and 7 influence of potential displacement on microhardness of TiN layers put on copper (BrKMn 3-1) and titanic (OT4-1) alloys is shown. Thickness of layers made 3–5 μm.

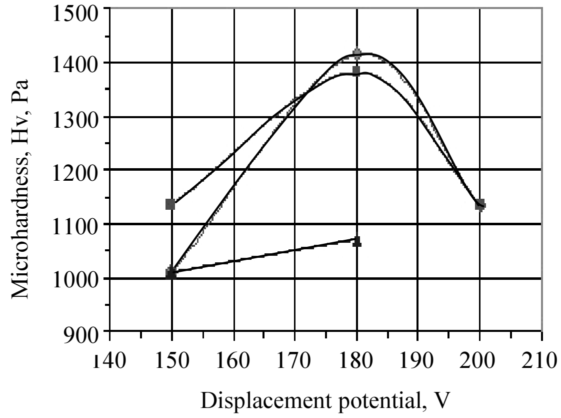

Fig. 6. Dependence of microhardness TiN on potential of displacement

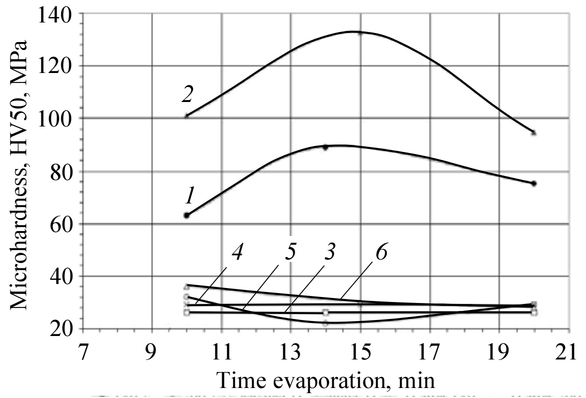

Fig. 7. Influence of potential displacement on microhardness of TiN layers: *1* – 180 V; *2* – 200 V; *3* – eatched Ti; *4* – alpha-Ti; *5* – Ti after 180; *6* – Ti after 200

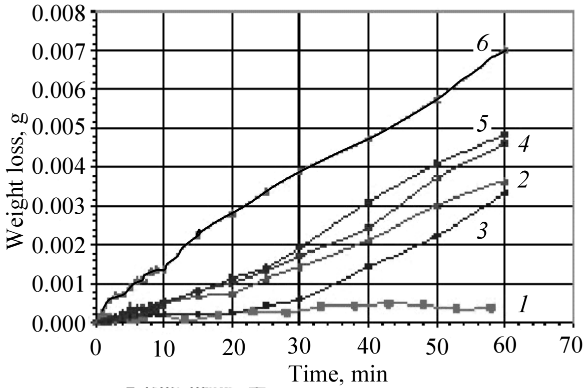

Fig. 8. Wear resistance of TiN layers (an alloy BrKMn3-1) at potential displacement 180 V: *1* – 150 V, 10 min; *2* – 180 V, 15 min (280 mm); *3* – 180 V, 20 min; *4* – 180 V, 10 min; *5* – 180 V, 15 min (300 mm); *6* – BrKMn 3-1

The results of comparative wear resistance of investigated layers are presented in Figs. 8 and 9.

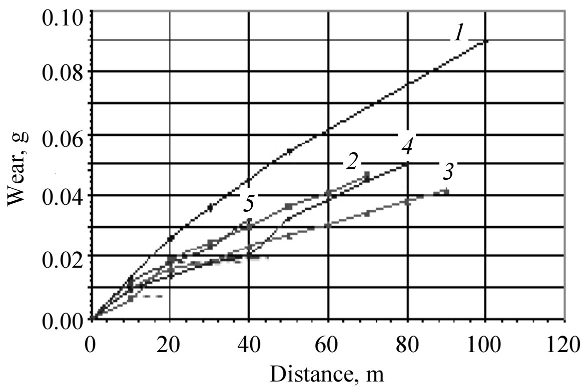

Fig. 9. Wear resistance of TiN layers (alloy OT4-1): *1* – eatched Ti; *2* – Ti/TiN 2000; *3* – Ti/TiN 440; *4* – alpha-Ti; *5* – alpha-Ti/TiN 1080

References

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[2] B.S. Danilin and V.K. Syrchin, *The magnetron's spraying systems*, Moscow, Radio and communication, 1982.