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MODERNIZATION FEATURES OF A VACUUM INSTALLATION BASED ON LOW-PRESSURE ARC DISCHARGE FOR FORMING COMPOSITE TiN-Cu LAYERS

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Abstract. A hybrid technology for forming composite TiN-Cu layers under the combined influence of a magnetron and low pressure arc discharges has been designed. The parameters of the plasma generator have been studied. The technological parameters for layer deposition in the conditions of coordinated action of the vacuum arc evaporator and the planar magnetron have been studied. This report describes the phase composition of TiN-Cu layers and the structure on fused silica substrates.

Keywords: arc evaporator; planar magnetron; layers; structure; phase composition; nanocomposite.

1. Introduction

In this paper, we propose a hybrid technology for forming composite layers. The main feature of this technology lies in the coordinated action of a vacuum arc and magnetron discharges. Coverings such as TiN, TiAlN, TiCrN and others that are widely used in mechanical engineering and in metal working are characterized by high hardness and low friction coefficients. However, their main disadvantage lies in their substantial fragility, which greatly narrows the areas in which they can be applied [1].

Intensive research work in the field of nanostructured and nanocomposite coatings of transitional metals is currently being carried out intensively around the world, but much work still remains to be done. Significant success in applying nanostructured and nanocomposite coatings, in particular of TiN-Cu, has been achieved by vacuum plasma processes [2,3,4,5].

For this reason, studies of new technologies for making composite layers with good plasticity and high hardness are of interest. To work on this task, we combined a vacuum arc evaporator and a planar magnetron in a single chamber. This combination provides the following advantages: coatings can be applied on details of various geometric forms, high deposition speeds and low temperature of the substrate can be achieved, and an impurity component can be introduced.

2. Experimental part

The experiments were performed on the VU-1M vacuum installation (Figure 1).

Figure 1. General view of the installation.

The TiN-Cu layers were deposited by simultaneous reactive magnetron sputtering of the copper target and arc evaporation of the titanium target. The industrial VU-1B installation was modernized to carry out the deposition process. Modernization involved placing the planar magnetron in the vacuum chamber. This planar magnetron works on the basis of an abnormal smoldering discharge of the direct current. The magnetron is installed vertically on the side wall of the vacuum chamber. The power supply for the magnetron is up to 3 kW.

The magnetron (Figure 2) consists of a cathode in the form of a copper target and an annular anode. The magnetic system is produced by constant (cobalt-samarium) magnets, a magnetic conductor and a polar tip. These make a toroidal magnetic field with the induction of 0.2–0.8 Tl above the surface of the target. The plate was supplied to the grounded anode (positive potential) and to the isolated target (negative potential).

The cathode unit (Figure 3) consists of the welded case, the cathode, the magnetic coil, the additional anode, and the electrostatic screen isolated both from the cathode and from the additional anode. The magnetic coil ensures that the cathode burns evenly. Inside the chamber there is a rotating substrate holder,

Number	Current of the arc discharges, A	Current of the magnetron discharges, A	Voltage on the magnetron target (Cu), V	Pressure in the chamber, 10^{-2} Tor
a	80			0.2
b	90	0.8	35	0.2
c	60	0.6	40	9
d	60	0.6	40	9

Table 1. Composite TiN-Cu layer formation parameters

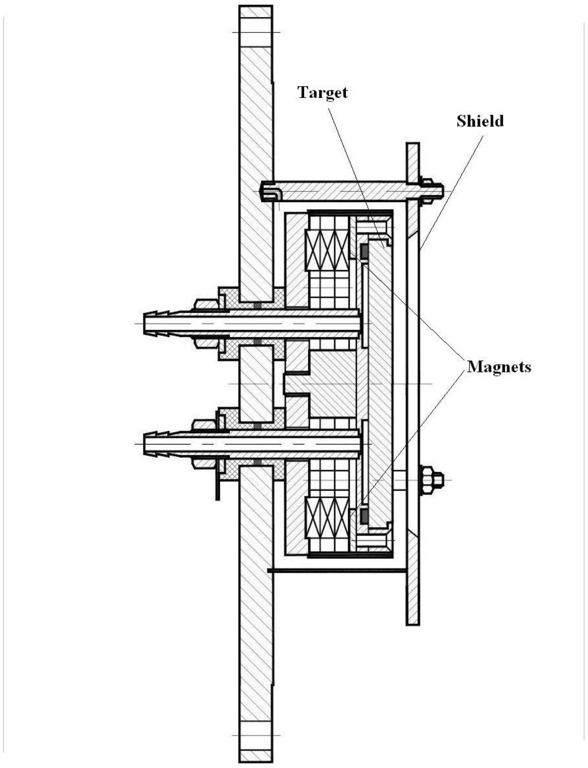

Figure 2. Design of the magnetron.

which distributes the gradually thickening coating evenly.

The reference voltage applied to the substrate holder is 1.5 kV. It preheats the details and provides ionic removal of gas inclusions from the growth surface. The gas mixture is prepared in a separate vacuum mixer. The installation has a unified vacuum system based on a N400 diffusive pump.

The TiN-Cu layers are set while both devices are working simultaneously. The parameters used in this experiment are presented in Table 1. Plates of fused quartz (amorphous SiO_2) 1 mm in thickness were used in order to avoid the influence of focusing the substrate material on the structure of the composite layer. X-ray phase analysis was carried out on a 2D Bruker Phaser (Cu $K\alpha_1$-radiation). The microstructure of the layers was investigated using a METAM PB-22 microscope with the NEXSYS Image Expert program. Knoop (HK) hardness measurements were made by pressing a diamond indenter of a specified shape into a surface with a known force.

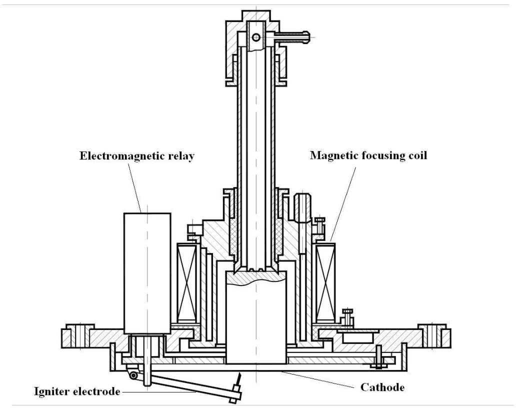

Figure 3. Design of the cathode unit.

3. Results and Discussion

Figure 4 shows the X-ray diffraction (XRD) patterns of the TiN-Cu films coated on fusing quartz. Polycrystalline TiN-Cu layers are obtained with column crystallite and preferred orientation on the plane [111] perpendicular substrate surfaces of the sample (Figure 4a).

Although X-ray analyses showed no fixed reflexes of α-Ti phase impurities in a layer, drops 700–800 nm in size were observed. Deposition of composite TiN-Cu led to the formation of a layer containing TiN, partially orientated on a plane [111], though other planes (200), (220) can be allocated to the reflexes (Figure 4b). As an impurity, X-ray analysis was able to detect the presence of nitride Ti2N and an α-Ti drop phase. The decrease from 90 to 60 A in the arc discharge current when titanium was evaporated led to a considerable reduction in the quantity and in the sizes of the titanium drops in a layer. According to X-ray analysis (Figure 4c), there are reflexes of TiN in the composite layer. In addition, the X-ray pattern contains a pure Cu peak. Note that intensity of the Cu reflexes on the roentgenogram is only slight. A change in the distance from the arc cathode (a change in deposition speed, and, hence, in the thickness of the composite layer that is formed, etc.) to substrates 220 to 280 mm in thickness led to increased Cu in the composite layer. The X-ray patterns reveal copper intensity varying from 10 % (Figure 4d).

The parameters of a TiN crystal cell (Fm3m) are defined for all composite TiN-Cu layers. A considerable reduction in parameter a with $a = 0.4318$ nm to

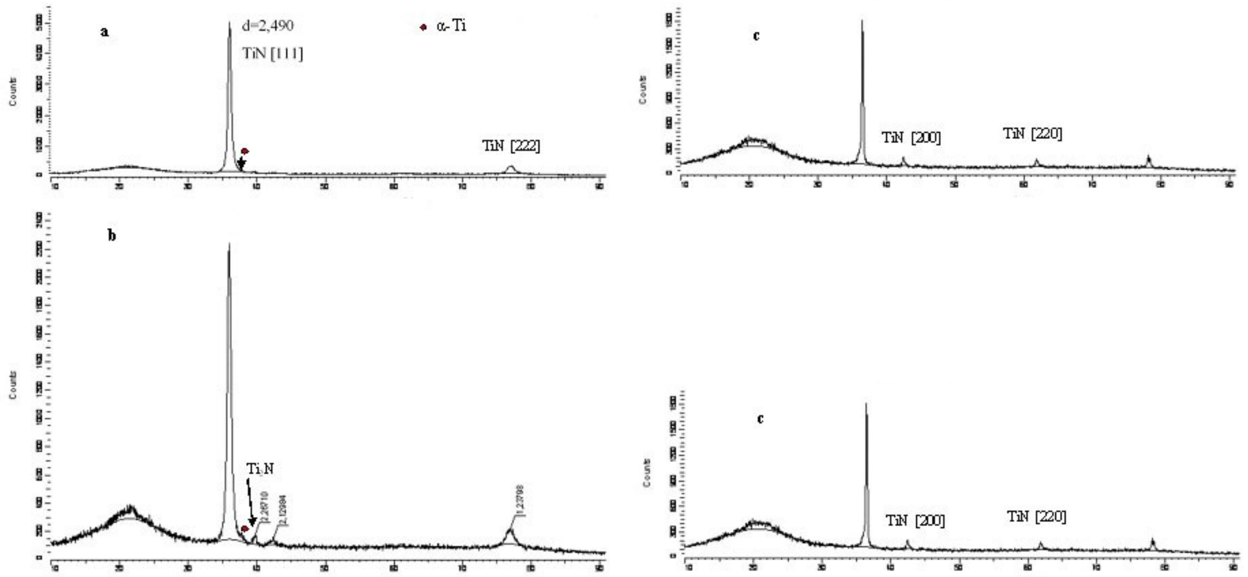

Figure 4. XRD patterns for TiN-Cu films: a) TiN, 80 A; b) TiN-Cu, 90 A; c) TiN-Cu, 60 A (220 mm); d) TiN-Cu, 60 A (280 mm).

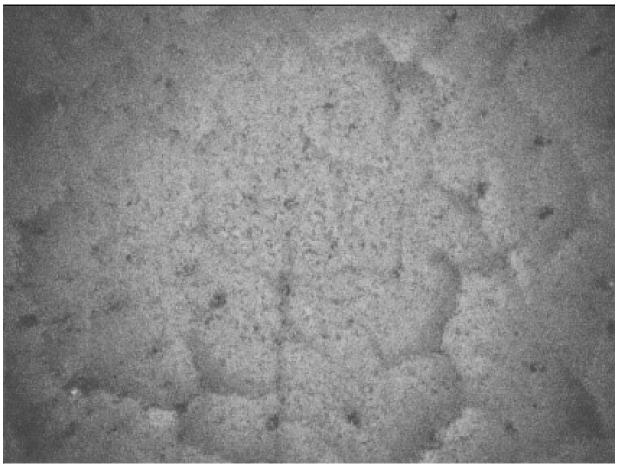

Figure 5. Microstructure of a TiN-Cu layer.

$a = 0.4254$ nm is observed (Table 2).

Figure 5 shows the microstructure of the surface layer of the pattern with copper reflections (pattern d).

A study of the microstructure of a layer surface revealed no presence of Ti drops. The layers have a homogeneous grain structure. There may be some copper on the grain borders. It can be expected that the TiN grains have a column structureThe changes in the hardness of the composite TiN-Cu films are illustrated in Table 2. The maximum hardness values for composite TiN-Cu films were measured to be 3910 MPa. The hardness of the TiN layers formed by reactive arc evaporation was 2910 MPa. This effective increase in the hardness of the composite layer may be connected with the absence of the Ti drop phase and with the discovery of Cu atoms on the borders of the TiN grains.

Thus, the structure and the phase structure of a layer of composite TiN-Cu indicates the formation of a composite material combining firm titanium nitride and plastic copper.

Number	**Crystal cell** TiN a, nm	**Micro Knoop hardness HK** Pa
a	0.4310	2560
b	0.4318	2910
c	0.4259	1680
d	0.4254	3910

Table 2. Physical properties of the TiN-Cu composite films.

4. Conclusion

Preliminary results have been obtained for a hybrid technology for forming composite TiN-Cu layers with a simultaneous combination of a vacuum arc evaporator and a planar magnetron. Composite TiN-Cu layers with different technological parameters were formed. A layer of the composite has a granular structure, and there were inclusions of copper atoms on the border of the TiN grains. The results of studies of TiN-Cu layers will be used for optimizing the technological process for forming a coating with the required properties.

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