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TiN COATING ETCHING FROM A SURFACE OF THE INSTRUMENT IN BEAM-PLASMA SYSTEM

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The results of reactive ion-plasma etching of *TiN* coatings from a surface of the tool in a beam-plasma system are submitted. The researches were made on the industrial set-up of a type «the Plasma boiler» with a magnetic field of the plug configuration. The electron guns on the basis of magnetron discharge injected from magnetic plug in a magnetic trap volume oncoming electron beams with a current density up to $2\,A/cm^2$, energy $350 \div 550\,eV$. At pressure $1 \cdot 10^{-3} \div 5 \cdot 10^{-3}\,Torr$ in a magnetic trap the beam-plasma discharge was fired from which one crosswise magnetic fields an ion flow on items was extracted. As working gases the mixture *Ar* and *CF₄* were used. The given beam-plasma system allowed selectively to remove from a surface of the tools *TiN* coating at speed of etching $1 \div 2\,\mu m/h$ on the area of $12000\,cm^2$.

Introduction

Now in an industry, engineering, the technologies and medicine a *TiN* coating are widely used. It is conditioned by well spent technology of obtaining of such coatings and their unique properties [1, 2]. Such coatings have high hardness and strength, that allows, in particular, essentially to increase resource of activity of the mechanical tools. However acutely there is a problem on removal from a surface of the waste coating rests before its repeated deposition. The existing liquid-chemical technology of removal of *TiN* coatings is characterized by poor efficiency and ecological harmfulness. The vacuum ion-plasma technologies have not such demerits. In the present work the results of researches on usage of a plasma-beam system for removal of *TiN* coatings from a surface of the tool are submitted. Selection of plasma-beam discharge, as source of ions for etching coatings, is caused by volume nature of discharge that provides uniformity and purity of an ion flow on a job surface, and feasibility side by side with physical sputtering using of plasma-chemical effects. Besides the plasma-beam discharge is characterized by high concentration of plasma at low pressures with a high degree of ionization and dissociation of working substances [3-5]. In the present work the results of mining of a beam-plasma system and technologies of reactive ion-plasma etching of *TiN* coatings from a surface of a cutting tool with high efficiency are submitted.

Experimental set-up

The researches were carried out on the industrial set-up of a type «the Plasma boiler» with vacuum chamber dimensions of $900\,mm \times 1010\,mm \times 1300\,mm$. Inside the chamber the rotated holder of treated tools was placed, on which the negative potential, value up to $U = -650\,V$ is fed. The holder with tools was in a longitudinal magnetic field of the plug configuration with a plug ratio 1:5, retaining fast electrons being injected along magnetic field lines from two inverse ends of the set-up.

As electron sources the designed electron guns on the basis of direct current magnetron discharge were used. The design features of the set-up have allowed to make electron sources with the changeable output aperture, and with changeable cross-sectional area of generated electron beams. If necessary it was possible to receive a solid electron beam with diameter of $50\,mm$ on outlet of a source, or tubular electron beam with an external diameter of about $160\,mm$.

The scheme of electron sources is shown in a Fig. 1. The sources consist of cylindrical chilled cathodes of two diameters with spent inserts made from a non-magnetic stainless steel (*1, 2*), end earthed anode (*3*) and shield (*4*) under a floating potential, placed between cathodes and anode of a source. Between sources and working area of the set-up the screens (5) under a floating potential, for an avoidance of ignition of spurious discharge between a holder of tools and earthed anodes of sources were placed.

Shield, end anode and screen had the apertures conforming to diameter of the working cathode. Sources were supplied in parallel connection from one power source having a dropping volt-ampere characteristic. Between an anode and one of cathodes of a source the voltage by value $U_{dm} = (0 - 1000)V$ was applied. Near the surface of spent cathodes with the help of the external solenoid the magnetic field of the arch configuration by value $H = (200 \div 300)Oe$ was formed. With chamber pressure $p = 5 \cdot 10^{-4} \div 3 \cdot 10^{-3}\,Torr$ in the field of spent cathodes the magnetron discharge with parameters $U_d = (400 \div 460)V$, $I_d = (2 \div 12)A$ was ignited. The wide range of operating pressures of sources was caused by that inside sources in a burning area of magnetron discharge pressure was higher than in the chamber and was regulated with the help of gas (*Ar*) injection through a source.

On center of sources the capability of the installation of a massive electrode from a non-magnetic stainless steel with an insert in the form of tantalum tube (*6*), working in a regime of the hollow cathode was envi-

sioned. It allowed, if necessary, to receive narrow electron beam on an axis of the chamber.
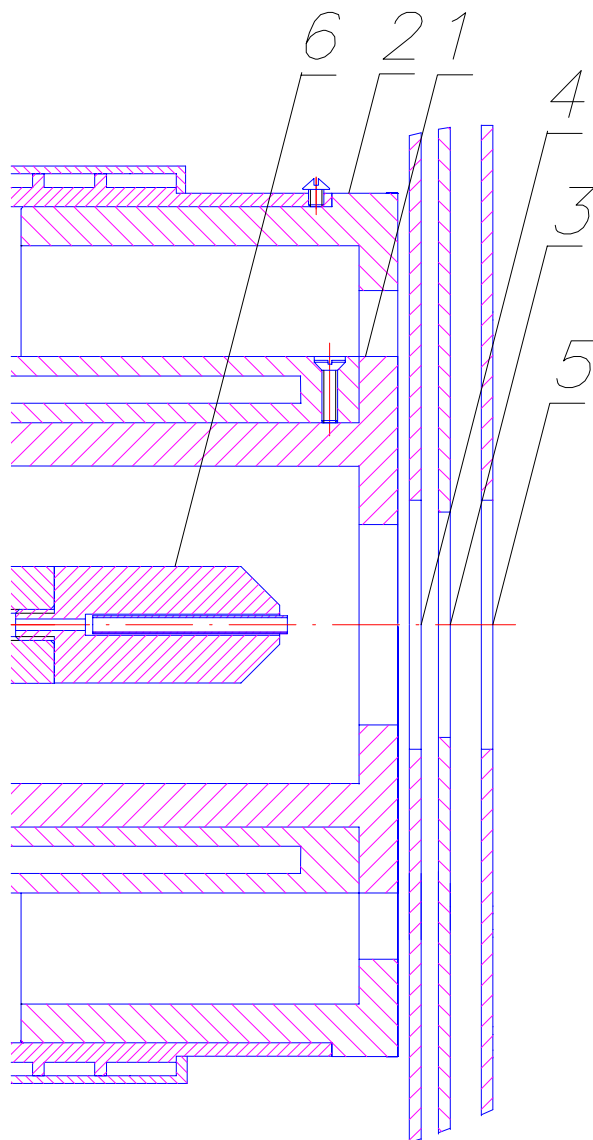

Fig. 1. The scheme of an electron source: 1- the spent cathode of a narrow-aperture source; 2- the spent cathode of a wide-aperture source,; 3- end anode; 4- shield under a floating potential; 5- screens under a floating potential; 6- hollow cathode

The electrons of magnetron discharge plasma in a source oscillating in an arch magnetic field at the expense of collisions fall on line of magnetic field, withdrawing them through the output aperture in the chamber.

The effective extraction and acceleration of electrons from a source is promoted by a direction of a magnetic field gradient, and also by difference of cross-section of a plasma column because of difference of diameters of the cathode and aperture of a source [6].

The current of electron beam from the sources makes a large part of a discharge current. The current density of electron beam from two sources in center of working chamber on an axis of a system reached value

$2\ A/cm^2$ at a value of total current of discharge in two sources about of $10\ A$.

The design features of sources did not enable hit of mist spray of the spent cathode in a volume of the plasma boiler.

In Fig.2 the volt-ampere characteristic of a narrow-aperture electron source, and also electron beam current, and attitude of a beam current to a discharge current vise versa discharge voltage in a source is shown at chamber pressure $p = 3 \cdot 10^{-3}\ Torr$.
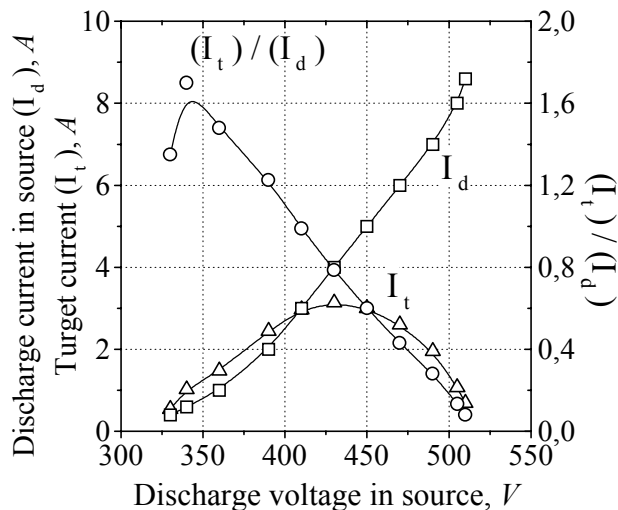

Fig.2.

In Fig.3 the current density of electron beam vise versa a discharge current on different distances from an axis of a system is shown at chamber pressure $p = 3 \cdot 10^{-3}\ Torr$.
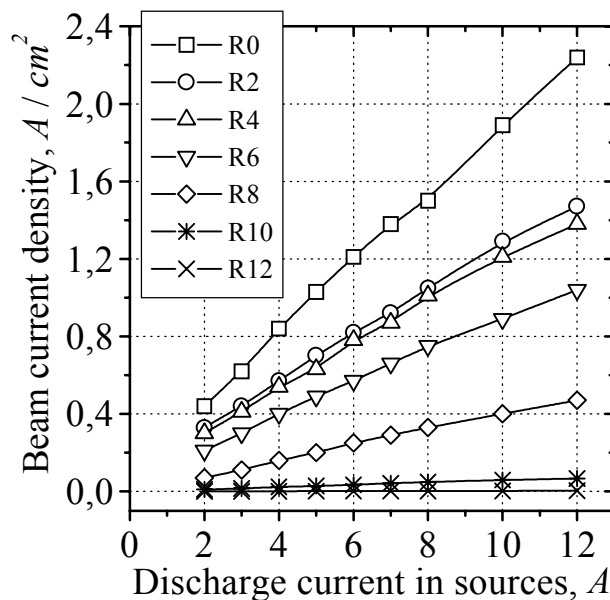

Fig.3.

In a volume of the plasma boiler the beam electrons moving along lines of a retaining magnetic field of plug configuration, made ionization of working gas. The cross sectional dimensions of a zone of effective ioniza-

tion by electron beams were determined by diameter of the operational output aperture of sources. In a case of narrow-aperture sources (diameter of the output aperture 50 *mm*) diameter of a zone of ionization in center of the chamber was about 260 *mm*, in case of wide-aperture sources (diameter of the output aperture 160 *mm*) – it was about 350 *mm*.

TiN coating etching

At supply on a holder with tools of a negative potential, in the chamber the glow discharge was fired. The cathode of this discharge was the holder with tools, and anode was column of beam-plasma discharge. The constructional parts of a holder were occluded by screens under a floating potential. From discharge in the chamber crosswise magnetic fields an ion flow accelerated in a layer of a cathode voltage drop up to energy, conforming to a bias to a holder was extracted on tools.
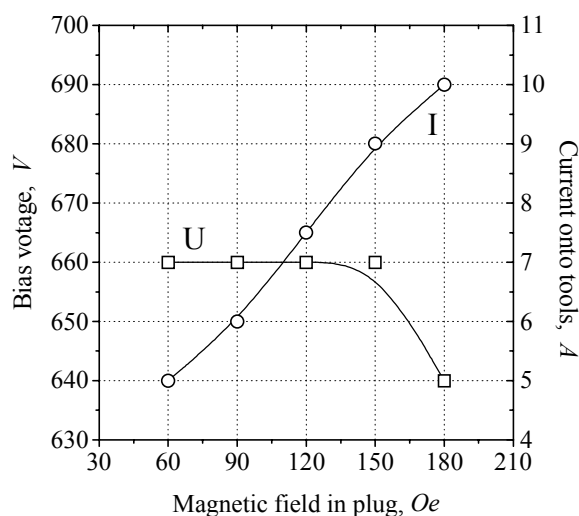

Fig. 4.

In Fig.4 the value of ion current on tools and bias voltage on tools vise versa value of a magnetic field in a plug is shown.

As working substance the mixture of argon (*Ar*) and freon (*CF$_4$*) was used. The percentage of a freon in a mixture was from 1% up to 20%.

The selection of a freon as a component of a working mixture is conditioned by stability both titanium, and titanium nitride to sputtering by ions of argon and absence of selectivity of etching *TiN* in relation to a stuff of the tool. The ions of a fluorine, which appear as a result of dissociation and ionization, bombard a surface of tools and provide formation of titanium fluoride, which is sublimated under relatively low temperature and rather easily sputtered by ions of argon [7].

At chamber pressure $p = 3 \cdot 10^{-3}\, Torr$, on a working mixture consisting of 90% of argon and 10% of a freon and at parameters of discharge in electron sources $I_d = 8\,A$, $U_d = 450\,V$, on tools it was possible to receive an ion flow with energy $\varepsilon_{et} = 660\,eV$ and current up to $I_{et} = 5\,A$. The speed of *TiN* coating etching was about $1 \div 2\,\mu m/h$ with selectivity of etching of *TiN* in relation to a stuff of tools 5:1 for one duty cycle, in which it was possible to treat up to 200 *kg* of tools, in particular 12 bulky tools.

Conclusions

The designed beam-plasma system allowed selectively to remove from a surface of the tool *TiN* coating without damage of a cutting edge at speed of removal of coating $1 \div 2\,\mu m/h$.

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