DLC DEPOSITION BY PECVD AT PLASMA CATHODE BASED LOW-PRESSURE DISCHARGE

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ABSTRACT

The characteristics of a-C:H coatings prepared by acetylene decomposition in non-self-sustained discharge with a plasma cathode have been studied. The initial energy of electrons injected into the plasma was 0,1 – 0,7 keV, energy of ions bombarding the coating was 0,1 – 0,7 keV and the pressure of Ar + C_2H_2 gas mixture was 0,2 – 1 Pa. Microhardness and wear resistance of coatings were measured by methods of kinetic indentation and ball abrasion. The coatings with high microhardness (40 – 60 GPa) and high wear resistance were deposited on conditions that ion energy exceeded 300 eV. It was shown that coating's microhardness and internal stresses in the coatings deposited on chamber walls could be reduced by concerted change of voltage accelerating injected electrons and bias voltage applied to samples placed into the plasma. This allows to avoid delamination of coating particles from the walls and to provide high quality coating on samples.

Key words: diamond-like coating, plasma cathode, glow discharge.

INTRODUCTION

Gas-discharge system consisted of the plasma cathode with grid stabilization (GPC) and electrode system providing electrostatic confinement of fast electrons injected into the anode plasma was used. This type of plasma generator ensures independent variation of low pressure non-self-sustained discharge parameters and space homogeneity of plasma generated in Ar + C_2H_2 mixture. A hydrocarbon coating (DLC) was deposited on the walls of the cathode electrode of electrostatic trap (EST) and on the surface of samples. The DLC's properties strongly depends on the discharge parameters and ion energy [1]. This technique allows deposition of a-C:H coatings with high microhardness (H_m) and low friction coefficient [2] on samples placed in $3 \cdot 10^4$ cm^3 plasma volume with a deposition rate of ~1-10 μm/h. In case when EST walls and samples are equipotential DLC is formed on their surfaces whereas only the samples were preliminary treated to improve the coating adhesion. Therefore particles of coating may flake away from the walls and hit on the sample's surface worsening coating quality. The aim of this work was search for the way

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to prevent coating exfoliation by reduction of the coating hardness on the walls while keeping optimal conditions of the coating deposition on the sample surface.

EXPERIMENTAL TECHNIQUE

GPC based on d.c. glow discharge with a hollow cathode was used in the experiments [3]. The design of EST includes a hollow cathode (d = l = 150 mm) and rod anode. Argon was let into the GPC discharge system, acetylene (C_2H_2) – into the EST volume. The total pressure of gas mixture (Ar+C_2H_2) was 0,2 Pa, the ratio of Ar:C_2H_2 flows – 4:1, glow discharge current was 0,2 – 0,5 A. Non-self-sustained discharge was ignited by application of a pulse voltage (10 μc, 50 kHz, 100 – 700 V) to EST electrodes. Pulse-repetitive mode of plasma generation provided removal of positive charge from DLC surface.

Injected electrons were accelerated by voltage U_a applied between EST anode and GPC grid connected with grounded EST walls. Negative (relative to EST walls) bias voltage U_b applied to the samples was synchronized with U_a voltage. Energy of ions bombarding the wall surface was equal to eU_a, energy of ions bombarding samples surface was e(U_a + U_b).

The coatings microhardness and modulus of elasticity were determined through the nanoindentation tests with Nanotest 600 device using Berkovich indenter. Wear resistance of the samples was estimated on "Calotest" device in dry friction conditions.

RESULTS AND DISCUSSION

Microhardness of DLC weakly depends on initial energy of electrons (*Fig. 1*). The value of U_b was changed with variation of U_a voltage in such a way that the sum U_a + U_b determining ion energy remained constant and equal to 300 V.

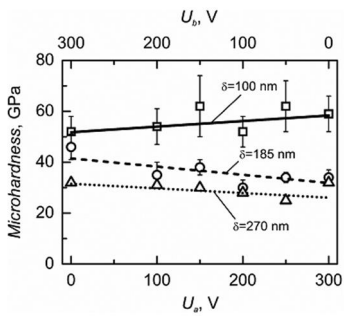

Fig.1 – Dependence of H_m on U_a under constant energy of ions

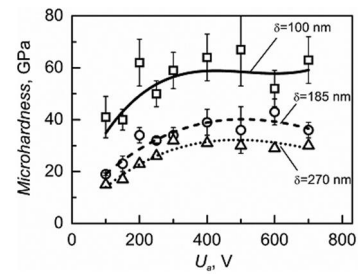

Fig.2 – Dependence of H_m on U_a under energy of ions proportional to U_a

The DLC microhardness strongly increased with ions energy at the range of 100 – 300 eV (*Fig. 2*). In these experiments energy of the ions was determined by U_a value under $U_b = 0$. Wear rate of DLC inversely depends on DLC microhardness (*Fig.3*).

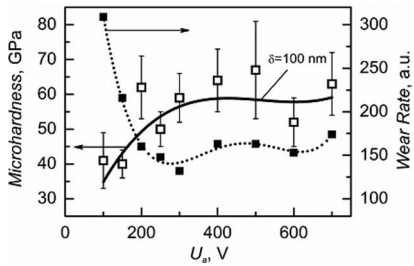

Fig.3 – Dependence of H_m and wear resistance on U_a under energy of ions proportional to U_a

DLC microhardness weakly depends on gas pressure. The rate of DLC growth increases linear with the current of plasma cathode. Linear extrapolation of the $\log(H_m\text{-}H_s)$ dependence on the indenter penetration depth, allowed to exclude the influence of substrate microhardness on the results of DLC microhardness measurement. The extrapolated H_m value for DLC deposited on the tungsten carbide substrate (BK8) at the ion energy ~ 300 eV was 76 GPa. Here H_m means results of microhardness measurement and H_s –microhardness of substrate (~17 GPa).

CONCLUSIONS

The main factor effecting on microhardness and wear resistance of DLC's deposited by acetylene decomposition in non-self-sustained discharge with a plasma cathode the energy of ions bombarding the coating during deposition. When the ions energy was >300 eV microhardness of DLC reaches ~76 GPa.

It is possible to create such deposition conditions when the properties of the Coating deposited on the chamber walls will differ drastically from the properties of DLC deposited on the sample's surfaces, that is necessary for improvement of the coating deposition technology.

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