Use of Diamond Stock in Chromium Plating


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Abstract—Cathodic deposition of a chromium coating from the standard electrolyte in the presence of a diamond stock was analyzed. The microhardness and wear resistance of chromium–diamond coatings and the effect of the diamond stock on the electrical conductivity and throwing power of the electrolyte were studied.

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Chromium plating is one of the most commonly employed electroplating processes. Chromium coatings are widely used to impart a decorative appearance to articles, to protect parts subject to wear (shafts and pistons) and molds that should have a high surface hardness, and to restore worn components. As a rule, articles of this kind are coated with a thick chromium layer (200–500 μm).

Because the deposition of thick chromium layers is a rather high-cost process, a topical task is to develop a procedure for deposition of composite chromium–diamond coatings (CDC) with the use of nanodiamonds (ND) in order to diminish the thickness and improve the physicochemical properties of chromium coatings. The possibility of codeposition of chromium and ND was first reported in [1], with the amount of ND in the chromium plating electrolyte varied from 5 to 40 g l⁻¹.

A method for CDC deposition on blade tools has found wide use. This method was industrially implemented at Elektrokhimpribor combine (Lesnoi), Cherепovets steel works, and others. Therefore, this process has been the subject of extensive research work with rather contradictory results, from enthusiastic to negative [1–3].

At present, composite electroplated coatings (CEC) with ND are not widely used because of the high cost of diamond synthesis. Therefore, it is suggested to consider, in order to lower the production cost of chromium–diamond coatings, use of the raw material from which ND are obtained, diamond stock (DS). Detonation conversion of high-power explosives with a negative balance in a nonoxidative medium (i.e., in that with an oxygen content lower than the stoichiometric value) yields a condensed ND-containing carbon phase. Such a condensed carbon, named the diamond stock, may contain up to 75% ND [4]. DS exhibits adsorption capacity and high chemical activity.

The aim of this study was to examine the effect of DS on the mechanism of the chromium plating process, electrical conductivity and throwing power of the electrolyte, physicochemical properties of coatings (microhardness, wear resistance), and outward appearance of chromium coatings obtained in various modes.

EXPERIMENTAL

A versatile chromium plating electrolyte of the following composition (g l⁻¹): CrO₃ 230–260 and H₂SO₄ 2.3–2.6 (electrolyte no. 1), was chosen for the study.

This choice was due to the following: its composition is more stable than that of a diluted chromium plating electrolyte; can be used to produce both wear-resistant and hard chromium deposits; has a rather high throwing and covering power; causes no difficulties in determination of the ND and DS content of the electrolyte (in contrast to the self-regulating electrolyte).

The deposition was performed from the above-mentioned solution, with DS introduced in amounts of 1, 2.5, 5, and 10 g l⁻¹ (electrolyte nos. 2, 3, 4, and 5, respectively). The optimal DS concentrations in the chromium plating electrolyte was determined by...
analyzing the quality of the outward appearance of coatings and physicomechanical properties of chromium–diamond coatings obtained in various electrolysis modes. Experiments were carried out in the following modes: cathode current density (A dm$^{-2}$): 30, 40, 50, 60, 70; electrolyte temperature ($^\circ$C): 45, 50, 55, 60. The cathodic polarization curves were measured in a three-electrode cell with separated 50-ml electrode spaces with a P-5848 potentiostat by the potentiostatic method. A silver chloride reference electrode was used. The potentials were recalculated to the hydrogen scale. The current was measured with an M1104 milliammeter with an accuracy of 0.2%. The experiments were performed at 50$^\circ$C.

The throwing power (TP) of the electrolyte was evaluated using an indirect method by calculating the electrochemical similarity coefficient ($\Gamma$) defined as a product of the electrical conductivity of the solution ($\chi$) and the electrode polarizability ($\Delta E/\Delta i_c$), which is a secondary distribution in determining the TP of an electrolyte [5, 6]. For this purpose, polarization curves were measured and the electrical conductivities of the solutions in the presence of DS and without it were determined. The electrical conductivity was found by measuring the voltage with a V7-40/4 voltmeter. Steel coated with chromium with a thickness of no less than 40 $\mu$m served as the working electrode (cathode), a lead plate was used as an auxiliary electrode (anode), and a silver chloride electrode served as reference.

The microhardness was measured with a PMT-3 microhardness meter. To obtain comparable data, the hardness was measured at a coating thickness of 45–50 $\mu$m and a constant load of 100 g. St. 20 steel plates were used as a support. The hardness was measured not earlier than 24 h after a coating was deposited.

Wear-resistance tests were performed on a machine with a reciprocal motion of samples under dry-friction conditions. The friction pair had the form of a brass disc with a 3.5–5-$\mu$m-thick coating to be tested, which rubs against a plane-parallel steel plate covered with hard chromium. All the tests were made under a constant load of 130 g in the course of 20 h, the wear resistance was evaluated by the mass loss by the samples upon abrasion [7].

The potentiostatic curves obtained in electrolytes in the presence of a diamond stock and without it, which reflect the overall electrode processes, are shown in Fig. 1a. Upon introduction of DS into the standard chromium plating electrolyte, the polarization curves somewhat shift in the positive direction (the polarization shift is up to 30 mV, which lies within the experimental error).

Figure 1b shows partial polarization curves of chromium deposition in solutions with and without DS additives. It can be seen that the slope of the polarization curves remains virtually unchanged. To plot partial polarization curves of chromium deposition from the standard chromium plating electrolyte with and without DS additive, the current efficiencies were measured at working current densities and a temperature of 50$^\circ$C (Table 1). As seen from Table 1, addition of DS leads to a slight increase in the current efficiency (CE) by chromium. The maximum increase in CE relative to that for an electrolyte