INTRODUCTION

Microplasma (micro-, arc, plasma-electrolytic, and anodic spark) anodizing of value metals, such as aluminum, titanium, tantalum, magnesium, and zirconium, enables one to produce compact oxide layers with a high hardness, as well as heat and wear resistance on their surfaces [1–3]. This method is based on using high anodic voltages, which cause the generation of plasma discharges on the treated surface and a local increase in temperature up to several thousand degrees in microdischarge channels followed by the rapid cooling of the breakdown sites to a temperature close to that of the electrolyte. The high temperature at the breakdown sites and the high intensity of the electric field promote the appearance of noticeably nonequilibrium conditions and the involvement of the electrolyte components in the formation of the oxide coating. All of these factors, along with the electrophoretic processes provide not only the formation of coatings composed of individual oxides, but also their alloying and the production of composite materials [4–7].

We previously showed that it is principally possible to carry out the microplasma deposition of coatings on the surface of not only value metals, but also iron (low-carbon steel) due to the formation of a thin surface layer composed of aluminum oxide as a result of the decomposition of aluminate ions involved in the bath composition [8]. A substantial part of the potential drop is localized within this layer, and microarc discharges appear and cause the subsequent growth of the aluminum-oxide coating. It is quite natural that these coatings are very porous and do not provide sufficient corrosion protection [9]. In order to develop the approach with the goal to improve the protective properties of the coatings, we consider the possibility of modifying them with polyethylene introduced as a dispersion in the working aluminate bath.

EXPERIMENTAL

Microplasma anodic treatment of a low-carbon steel was carried out using a stabilized constant voltage source controlled within the range of 50–360 V in a two-electrode electrochemical cell with a volume of 500 ml supplemented with systems of stirring and water cooling. Sodium aluminate solution (0.1 mol/l) stabilized by NaOH additive (0.05 mol/l) was taken as a supporting electrolyte [8]. The treated electrode (anode) with an open surface of $20 \times 5 \times 1$ mm was cut off from a plate of an St3 low-carbon steel with the following admixture composition (wt %): 0.35 C, 0.8 Mn, < 0.05 S, and < 0.05 P. The cathode was made of 9Kh18N10T stainless steel. The surface ratio of the cathode to anode was 20 : 1. Before anodizing, the electrodes were sandpapered, treated with acetone, and washed in distilled water. When preparing the suspension, PEND 273-83 low-pressure polyethylene powder was introduced in the aluminate electrolyte as a polymer additive.

Electron microscopy and the local elemental analysis of specimens were carried out with an LEO-1455 VP scanning electron microscope supplemented by an X-ray fluorescent attachment for microprobe analysis. The thickness of coatings was determined by the cross-
The infrared reflection spectra of the specimen surfaces were recorded with a MIDAC-2000 Fourier transform infrared spectrophotometer. The corrosion resistance of the coatings was estimated from the data of potentiodynamic polarization measurements in a test 0.5-mol/l aqueous NaCl solution at room temperature. For this purpose, a PI-50-1.1 potentiostat supplemented with a PR-8 programmer and an Endim 620.00 two-coordinate potentiometer was taken. The electrochemical cell was thermostated at 25±1°C and involved a platinum counter-electrode and a saturated silver-chloride reference electrode. In this work, all potential values are given with respect to the reference electrode. The potential was changed in the range of −0.6 to +1.5 V at a rate of 2 mV/s (quasisteady-state polarization conditions). Before carrying out electrochemical measurements, the electrode was exposed to a working solution for 10 min to achieve the stabilization of the electrode immersion potential to a level not exceeding 3–5 mV/min.

RESULTS AND DISCUSSION

During the microplasma treatment of the iron electrode in the aluminate bath, the anodic current density decreases rapidly within the first 1–1.5 min, then more slowly (Fig. 1). It is worth noting that an increase in the polyethylene dispersion concentration promotes not only the decrease of the initial current density (Fig. 2a), but also the decrease in its steady-state value. Note that the pronounced effect of the polyethylene additive on the current value is even observed at low concentrations (tenths of a percent) and, with an increase in the concentration above 0.7%, the effect reaches the limiting value. It is important from a practical point of view that the aforementioned decrease in the current density promotes a substantial decrease in the power consumption and, hence, in the heat release during the formation of coating. In particular, under the experimental conditions used, upon the introduction of 0.5–1.0% polyethylene dispersion into the electrolyte, the electrolyte temperature remained nearly constant at about 20–25°C for 10 min. At the same time, at a polyethylene content of 0.1–0.2%, as well as in its absence, the electrolyte was warmed to 60–80°C under the same conditions. The decreased warming caused by the presence of polyethylene dispersion is obviously determined by the decrease in the electric power consumption by the electrode system. The effect can be quantitatively estimated by integrating the curves shown in Fig. 1 and multiplying the obtained electric charge density by the electrode surface area and the applied voltage. As Fig. 2b shows, the electric power consumption decreases by a digit of seven to eight upon the introduction of a 0.5–1.0% polyethylene dispersion.

It is worth noting that, although the current and power dependences on the polyethylene content in the electrolyte are smooth (Fig. 2), a similar dependence of the coating weight has a maximum at a polyethylene content of 0.5–0.6% (Fig. 3). The investigation showed that, during the microplasma treatment of an