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Influence of Molybdenum and Tungsten on the Formation of Zirconium Oxide Coatings on a Steel Base

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Abstract: In this paper, we have developed conditions for the deposition of zirconium oxide coatings from solutions containing hexafluorozirconic acid as well as tungsten and molybdenum salts on a steel base. Based on electrochemical studies, it was shown that the addition of tungsten and molybdenum salts to the solution to deposit zirconium oxide coatings led to the inhibition of the anodic process of iron ionization. It was shown that the optimal conditions for the deposition of oxide-zirconium coatings on the surface of steel samples from a solution of 0.2 g/L Zr (IV) + 0.15 g/L W (VI) + 0.1 g/L Mo (VI) were a deposition temperature of 30 °C and time of 10 min. The thickness of the oxide-zirconium coatings formed under these conditions was 64.72 nm, the adhesion value was 3.17 MPa/s, and the corrosion resistance was 26 s according to Akimov's drop method. The depth of corrosive penetration, determined in the salt fog chamber, did not exceed 2 mm after 240 h of testing, meeting the requirements for adhesive layers under the paintwork.

Keywords: zirconium oxide coatings; hexafluorozirconic acid; molybdenum; tungsten; cyclic voltammetry; protective ability; surface structure; thickness; adhesion

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1. Introduction

One of the most common methods for protecting metal structures from corrosion is the deposition of anti-corrosion protective coatings. The priorities for improving anti-corrosion coating deposition processes include increasing the protective and other functional properties. In the process of deposition of anti-corrosion coatings, it is necessary to further reduce the environmental hazard that these processes involve, as well as the concentration of the solutions used and the temperature and time for deposition of protective coatings. Recently, ceramic coatings have been gaining in popularity since they have high thermal and electrical resistance and are also more resistant to oxidation, corrosion [1–8], erosion, and wear in high-temperature environments. Diamond nanoparticles, as well as those of other chemical compounds used for the deposition of hard coatings (SiC, ZrO_2, and Al_2O_3), are commercially available, with a particle size in the range of 4–300 nm. Some of the most promising ceramic coatings are nanostructured zirconium oxide layers containing zirconium dioxide (ZrO_2) [9,10]. Zirconium dioxide deposited from a solution provides the formation of chemical bonds of the produced film with both the metal base and with the subsequent paint and varnish coating. According to the literature [11,12], solutions for the formation of such coatings, in addition to hexafluorozirconic acid, should contain heavy metal ions such as nickel, copper, chromium, cobalt, and molybdenum, etc. Heavy metal ions form active centers that contribute to the deposition of zirconium oxide produced as a result of hydrolysis of hexafluorozirconic acid at pH 4.5 and 5.5 and room temperature [13–15]. In this work, we consider the combined effect of Mo (VI) and W (VI) ions on