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DEPOSITION OF HARD, WEAR- AND OXIDATION-RESISTANT COATINGS BY HIPIMS AND PCAE METHODS USING CERAMIC CATHODES: APPLICATION FEATURES AND MAIN ADVANTAGES*

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Coatings based on refractory compounds of transition metals demonstrate high hardness, wear-, corrosion-, and oxidation resistance, good thermal stability. The use of high-power impulse magnetron sputtering (HIPIMS) methods for coating's deposition has a number of significant advantages, among which it can be noted: high adhesive strength and crack resistance of coatings, high density and low defectiveness, low surface roughness, high resistance to thermal shock, etc. The main effects are associated with an increase in the degree of ionization of the flow and an increase in the energy of the deposited particles. Another way to obtain a highly ionized flow is cathode-arc evaporation traditionally. However, when ceramic cathode materials evaporate, difficulties arise due to the high temperature gradient in the material, leading to rapid destruction of the cathode. The solution to this problem is the supply of energy in short pulses, which is implemented in the pulsed cathodic arc evaporation (PCAE) method.

Present work is devoted to the study of the deposition features and the identification of a positive effect on characteristics during deposition of coatings by these methods when using multicomponent ceramic cathodes. Cathodes were manufactured using self-propagating high-temperature synthesis (SHS).

The molybdenum silicide and zirconium boride targets as well as multicomponent MoSiB, MoHfSiB, MoZrSiB, MoSiB/Y, ZrMoSiB, ZrTaSiB SHS-electrodes were sputtered/evaporated in Ar, Ar-N_2, and Ar-C_2H_4 gas mixtures. Plasma diagnostics was performed by optical emission spectroscopy using Plasmascope (Horiba Jobin Yvon) unit. The metal and non-metal model materials (alumina, silicon) were used as the substrates. To evaluate the oxidation resistance and anti-diffusion properties the coatings were annealed in air or in vacuum at T=500-1700°C. The structure of as-deposited and annealed coatings was studied by X-ray diffraction, scanning and transmission electron microscopy, X-ray photoelectron spectroscopy, glow discharge optical emission spectroscopy, FTIR, and Raman spectroscopy. The samples were characterized using nanoindentation, impact-, RT/HT tribo- and scratch-testing.

The results obtained show that critical load of adhesive failure of HIPIMS coatings exceeded 70 N, whereas for samples deposited at direct current (DCMS), the values did not exceed 10 N. The highest level of mechanical properties was achieved for MoZrSiB coatings deposited at a frequency of 200 Hz. At the same time, for coatings obtained at a frequency of 50 Hz and annealed in vacuum at 1000°C, the maximum values were fixed at the level of 40 GPa due to self-hardening effect. The transition from DCMS to HIPIMS led to an increase in resistance to thermal cycling, as well as to thermal shocks, which was confirmed by experiments on heating followed by cooling in water. PCAE coatings based on MoSiB had satisfactory mechanical properties, however, the presence of a droplet phase significantly reduced oxidation resistance, the maximum operating temperatures did not exceed 900-1000°C. DCMS and HIPIMS coatings had high oxidation resistance at 1500-1700°C

Combination of relatively high mechanical properties, remarkable thermal stability, and oxidation resistance makes new materials promising candidates for protective coatings to be used in high-temperature applications.

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