APPLICATION OF MICROPLASMA SPARK TREATMENTS FOR CREATING STABLE HEAT-RESISTANT BARRIERS ON THE SURFACE OF JACKETS OF THERMIONIC TRANSDUCERS IN NUCLEAR REACTORS

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Methods for developing protection for the jackets of thermionic transducers in nuclear reactors from overloading are proposed and validated. Some properties of the thermal barriers, produced by microplasma spark methods, on the surface of zirconium and tantalum jackets of thermionic transducers are investigated. The microstructural state and phase composition are analyzed. The results of preliminary thermal-cycling tests performed on the alloys, indicated above, with heat-resistant barriers are presented.

A necessary condition for a nuclear reactor to operate safely is reliable monitoring of the temperature of the fuel assemblies, especially under conditions of anticipated and unanticipated accidents where a corrosive steam-gas medium is produced. Small (1.5–2 mm in diameter) high-temperature tungsten-rhenium thermionic transducers in protective zirconium with tantalum jackets can be used to monitor the temperature [1]. Such transducers can be used in the range 20–2200°C. However, during catastrophic oxidation which occurs in an accident the zirconium and tantalum jackets rapidly break down and lose their protective properties [2–4]. This results in rapid malfunctioning of the thermionic transducers. The problem of high-temperature corrosion of tantalum and zirconium jackets can be solved by forming heat-resistant coatings on the working surface. Such coatings should remain functional under periodic heat transfer in the presence of carbon dioxide or carbon monoxide gases [5]. The protective properties of the coatings produced can also be obtained by the interaction of the jacket material with oxygen in the surrounding or a specially prepared medium with formation of dense oxide films with a high content of aluminum, chromium, or silicon [6].

It is also known [5–7] that under the conditions indicated above the most promising coatings could be coatings based on oxides and heat-resistant intermetallide phases based on aluminum, nickel, and chromium. The functioning of coatings in a corrosive gaseous medium at high temperatures depends on the properties of the protective films based on the high-temperature compounds $\alpha$-$\text{Al}_2\text{O}_3$, $\text{NiAl}_2\text{O}_4$, and $\text{NiCr}_2\text{O}_4$ which are formed [8, 9].

Microplasma spark treatment, specifically, microplasma spark alloying with ultrasonic modification [9] and anodic microarc oxidation [10], is one of the promising and most effective methods for producing the type of heat-resistant barriers indicated above. The choice of these methods is also dictated by the desire to achieve the required adhesion and a high continuity of the coating. The first method is based on microplasma alloying of the substrate by the electrode material in pulsed discharges. The simultaneous action of the ultrasonic oscillations of the electrodes increases coating adhesion and continuity and also smooths the stress gradient in the coating and substrate materials so as to ensure stability under sign-changing loads. The second method of producing coatings from thermodynamically stable oxides of the material being treated is associated with the action of microarc discharges with anodic polarization in solutions of electrolytes [10].

Considering the special features of zirconium and tantalum oxides, it is of interest to combine the forms of microplasma spark technology proposed above.

In the present paper, examples of heat-resistant coatings on the surface of zirconium and tantalum alloys and certain results of high-temperature tests of the compositions produced in an oxidative medium and in air at temperatures above 1200°C are examined.

The surface topography and the microstructure of the coatings were assessed using Mef-3 and Polyvar optical microscopes and a CamScan scanning electron microscope with an AN 10000 energy-dispersion spectrometer. The microhardness was measured using the Knoop method. X-Ray structural analysis was conducted using a DRON-3,0 diffractometer in