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Structure of electro-explosion resistant coatings consisting of immiscible components

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A R T I C L E I N F O

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A B S T R A C T

The composite coatings consisting of immiscible components of TiB_2-Cu and Mo-Cu systems are formed by method of electro-explosion spraying. The structure of coatings is studied by method of transmission electron microscopy. It is established that the coatings are the particles of titanium, tungsten or molybdenum diboride in copper matrix. The coatings range in thickness from 90 to 100 µm.

1. Introduction

The development of physical bases of increase in the operational characteristics of different materials is one of the priority tasks of condensed state physics and physical material science. In development of electro-switching equipment for electro-technical machine-building the topical task is creation of new electro-erosion resistant materials. These materials, in most cases, govern the electro-physical characteristics of the equipment as well as its capacity to switch the electric current in a reliable and long-term manner. The combination of diverse requirements, sometimes incompatible for conventional metals and alloys is characteristic of materials for electrical contacts. The high hardness and high-melting are necessary for them and these should be combined with high values of electro – and heat conductivity, electro-erosion and corrosion stability, resistance to welding and bridge formation. The solution of these tasks, in particular, can be accomplished by application of pulse methods of deposition of coatings [1–12].

In this case, widening the scope of electro-explosion spraying (EES) application requires thorough examinations of interrelationship of sprayed multi-component compositions, regimes of their deposition as well as the structure being formed and properties of coatings. In connection with it, the purpose of the research is to study the structure, phase composition and properties of coatings consisting of immiscible components of Mo-Cu and TiB_2-Cu systems formed by pulse method of electro-explosion spraying (EES). From the point of view of their application (pseudoalloys and coatings of TiB_2 – Cu system) as electric contacts the common property to the formed coatings is high electro-erosion resistance.

2. Material and method of study

Spraying of coverings was done using electro-explosion setup EVU 60/10M [13]. It includes a capacitive accumulator of energy and pulse plasma accelerator consisting of coaxial-edge system of electrodes with a conductor displaced on them, a discharge chamber localizing the explosion products and passing into the nozzle along which they outflow to vacuum technological chamber with residual pressure of 100 Pa. When accumulator discharges the electric current of high density through a metallic foil causes its explosion [13]. From products of explosion a supersonic multi-phase plasma jet is formed serving for spraying the coatings during 100mcs pulse time. The details of EES method of coatings are presented in [13].

The coatings were deposited on substrates made of electro-technical copper M00. In this case the composite electrically explosive conductor (CEEC) being a two-layer foil with previously weighed powder of molybdenum, tungsten and titanium diboride placed inside was used. The application of CEEC makes it possible to achieve the mixing of foil explosion products and powder in the process of formation and distribution of the jet. The powder particle size of molybdenum, tungsten and titanium diboride amounted to 0.5–5 µm. The masses of weighed powders and copper foil measured 800 and 200 mg respectively.

The sample preparation for electron-microscope studies included

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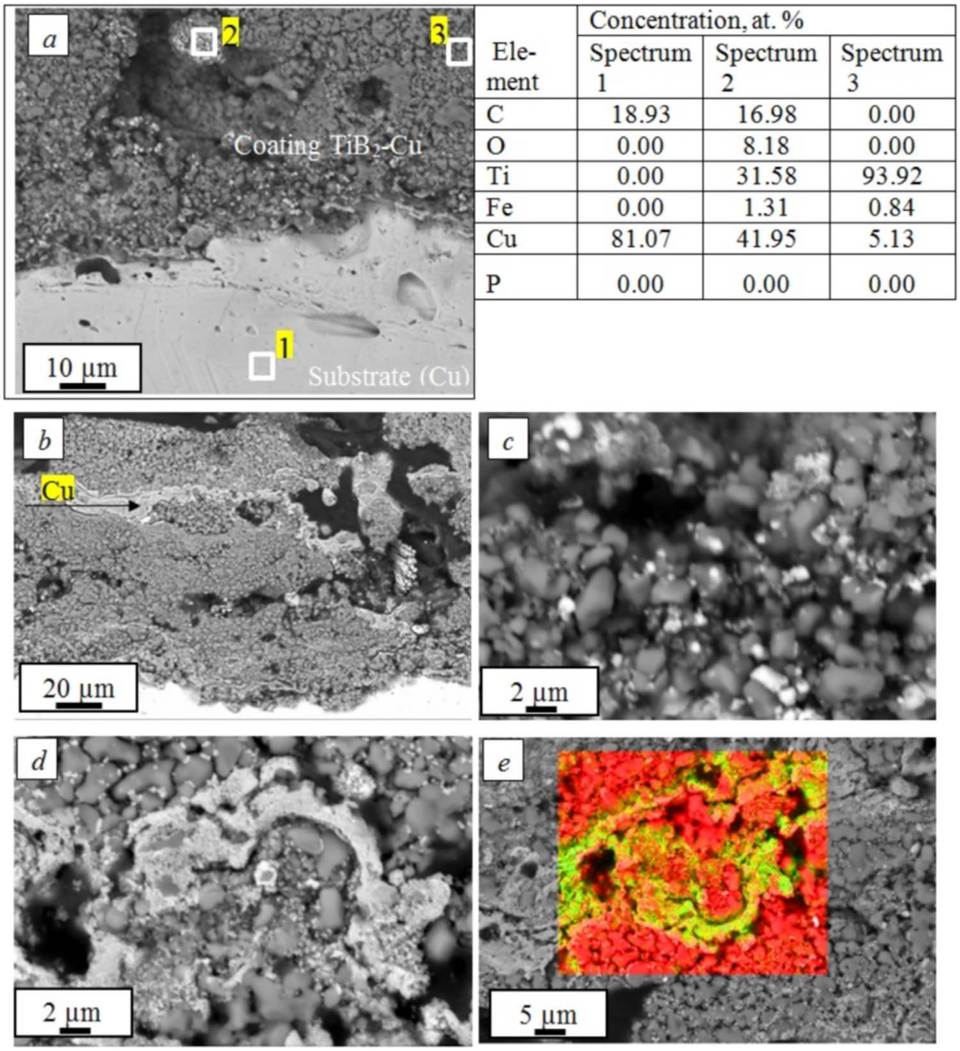

Element	Concentration, at. %		
	Spectrum 1	Spectrum 2	Spectrum 3
C	18.93	16.98	0.00
O	0.00	8.18	0.00
Ti	0.00	31.58	93.92
Fe	0.00	1.31	0.84
Cu	81.07	41.95	5.13
P	0.00	0.00	0.00

Fig. 1. Electron-microscope image of structure of electro-explosion coating of TiB_2-Cu system. The table shows the results of X-ray spectrum microanalysis of the regions shown in (a). The arrow in (b) designates the copper interlayer in the coating. In (e) titanium is designated with red colour, copper – with green colour. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

the preparation of transverse metallographic section, its electrolytic etching in solution of HF (5%)+H_3PO_4 (95%) at voltage of 10 V during 10 s. Studies of metallographic sections of electro-explosion coatings were done using scanning electron microscope LEO EVO 50(Zeiss, Germany) by method of back-reflected electrons. Energy dispersion X-ray spectrum microanalysis was performed to identify the elemental composition.

3. Results and discussion

TiB_2-Cu, W-Cu and Mo-Cu systems belong to the systems consisting of immiscible components throughout the entire temperature and concentration interval. The investigations of transverse metallographic sections showed that thickness of coatings was several tens micrometers. The important feature of electro-explosion coatings is the formation of mesoscopic size globules (from several units of micrometers to 10–20 μm) in them (Fig. 1). One of the structural elements of the electroexplosion coatings is the dynamic rotations with characteristic sizes from 10 to 20 μm. The dispersion of the coating's material to submicron sizes takes place in formation of the rotations at their boundary. In structure of the coating the regions of mesodimentional scales (10–20 μm) being formed in rotational movement of the coating's material (dynamic rotations) are observed. At the boundaries of rotations the dispersion of the coating's material occurs. In formation of coatings by electro-explosion of copper foil with weighed portion of titanium diboride powder (Fig. 1), the part of globules up to 20 μm in size formed by titanium diboride are surrounded with copper shell. In preparing the metallographic sections some of globules are chipped with the formation of pores corresponding to the sizes of the globules. It is connected with poor solubility of copper and titanium diboride in each other and absence of their chemical compounds.

The information about the formation of the analogous globular structures in coatings with any other methods, e.g. gas-thermal spraying methods is absent in literature. As the same time it is known about the formation of globular structures of mesoscopic size in dynamically deformed materials in the conditions of shock loading [14]. It may be suggested that the physical nature of formation of such structures in EES with supersonic multi-phase plasma jets and in conditions of substrate surface treatment with shock waves as in the research [14] is a common one. On this basis, consider a possible mechanism of their formation following the ideas presented in [15]. The front of distribution of shock waves initiating in the material of the coating in their formation due to the vibrational character of the discharge of capacitive energy storage in electro-explosion device is interface of dynamically loaded medium and non-deformed material. At this interface 'chess board' distributions of tensile and compressive normal stresses arise. The strong curvatures of zones of tensile normal stresses generate the bifurcational structural states in these zones. The