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The research of structure and mechanical properties of superhard electro-spark coatings for hardwearing mining tools

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Abstract. The development of low cost and hardwearing mining tools is one of the most important areas in mining industry. It is especially important for technologies of rare and rare earth metals mining due to high hardness of related ores. Coatings for electrodes, produced by extrusion of self-propagating high temperature synthesis (SHS) products from hard-alloyed materials with nanosized structure, for further application in processes of electrospark alloying and deposition were studied in this work. The results of microstructure and properties of deposited layers, interaction of support with SHS produced electrodes, comparison of frictional properties of obtained materials as well as some industrial testing results are presented in this work.

1. Introduction

Electrospark alloying (ESA) methods are widely used for hardwearing mining tools protection and repairing after deterioration. Novel method of SHS extrusion for production of electrodes for ESA and electrospark deposition (ESD) can be used in order to improve existing technological process [1]. The method includes exothermic combustion of initial components mixture and shear deformation of still hot products of synthesis. Application of SHS extrusion method for electrodes production substantially simplifies the process since the synthesis of materials takes only several seconds (instead of hours) in one technological stage. Detailed studies of compositions, properties (density, hardness, electrical resistivity etc.), grain size of electrodes and ranges of their variations at fixed parameters were performed in previous works [1, 2]. The results of application of ESA electrodes produced by HSH extrusion method from hard-alloyed materials with nanosized structure are presented in this work. The microstructure of layers and study of interaction between support material and SHS electrodes as well as frictional properties were done.

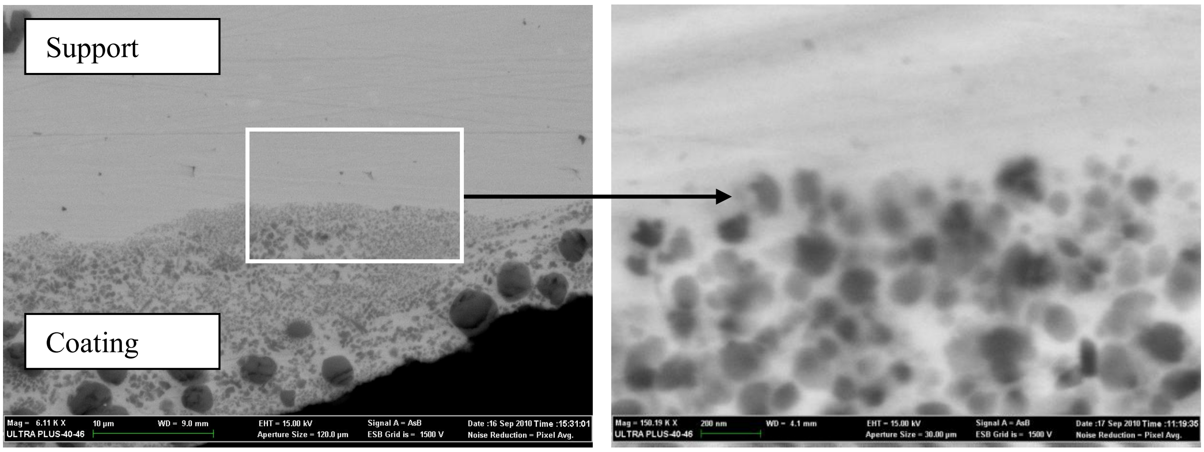
2. Materials and methods

Nowadays more than 50 different compositions of electrode materials for different applications have been synthesized by SHS extrusion method [1]. Coating deposition by ESA method with electrodes synthesized via SHS extrusion was done on SE-5.01 device (Tomsk, Russia). The device allows to prepare coatings with up to 0.2 mm thickness depending on deposition parameters, electrode material and support. Carbon steel 45 was used like model support material. In order to compare frictional characteristics of coatings, obtained with SHS electrodes, commercially available tungsten titanium carbide electrodes were also used for coatings deposition.

Study of structure was done on scanning electron microscope (SEM) JSM 6610LV (Jeol, Japan) using 20kV accelerating voltage.

3. Results and discussions

Study of microstructure of coatings deposited by ESD using SHS electrodes showed that hardened layers had complex structure and consisted of at least two regions. Sizes of wear resistant structural components on the surface of coating corresponded to the ones of initial electrodes (figure 1a). Coating region located closer to the support consisted of smaller structural components with sizes of 20 – 100 nm (figure 1b). This can be explained by different heat removal rates. The support cools down more intensively and consequently cooling rate of structural components is higher on support/coating boundary. Thus there is not enough time for grain sizes to increase substantially. Constant action of sparks on the surface decreases heat removal rate, temperature of melt is higher and grain sizes reach values up to 1 – 2 µm. Also one can see grains broken off electrode surface with initial sizes. Wear-resistant grains uniformly distributed inside metallic support along whole region of support/coating interface which increases adhesion of electrode material with the support.



a) *b)*

Figure 1. Microstructure of SHS electrodes: a – STIM-2/30, b – STIM 3/10H, c – STIM-4

The presence of transition layer with inclusions of coating material indicates that ESD process proceeds throw the diffusion of cathode and anode materials at the interface. We observed processes of electrode material particles penetration inside steel support on the depth of 15 - 20 µm (figure 2 a, c, d) as well as outward diffusion of iron into the coating material (figure 2 b). Thus interdiffusion processes positively affect adhesion which in turn provides high sustainability of coated instrument against abrasion in extreme conditions.

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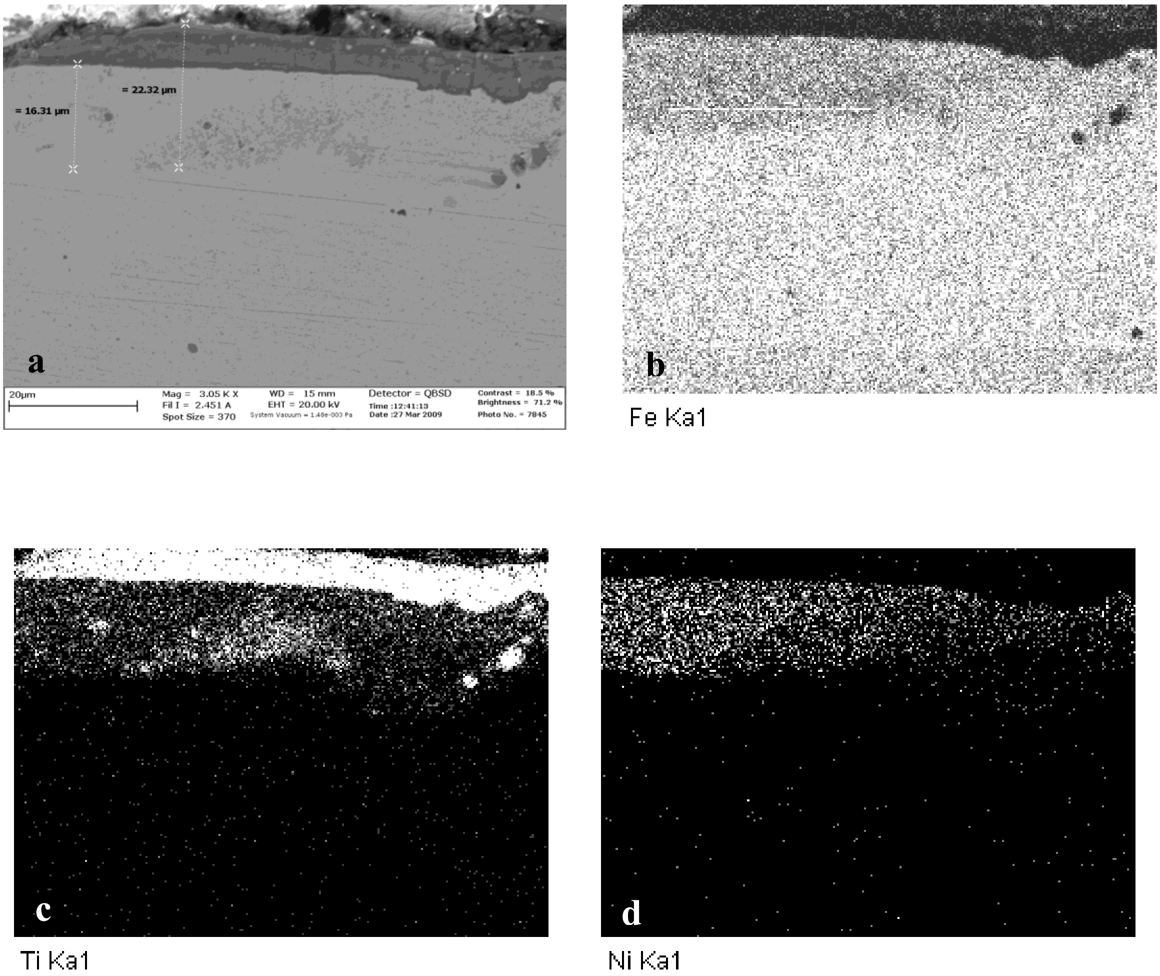

Figure 2. a – Microstructure of coating STIM – 2/30 on steel 45. Distribution of elements in the coating: b – Fe, c – Ti, d - Ni

Microhardness measurements were done for coated material from the surface down to the core of the support under the loading of 50 g. Sample with traces of indenter as well as plot of microhardness vs. depth are shown in figure 3.

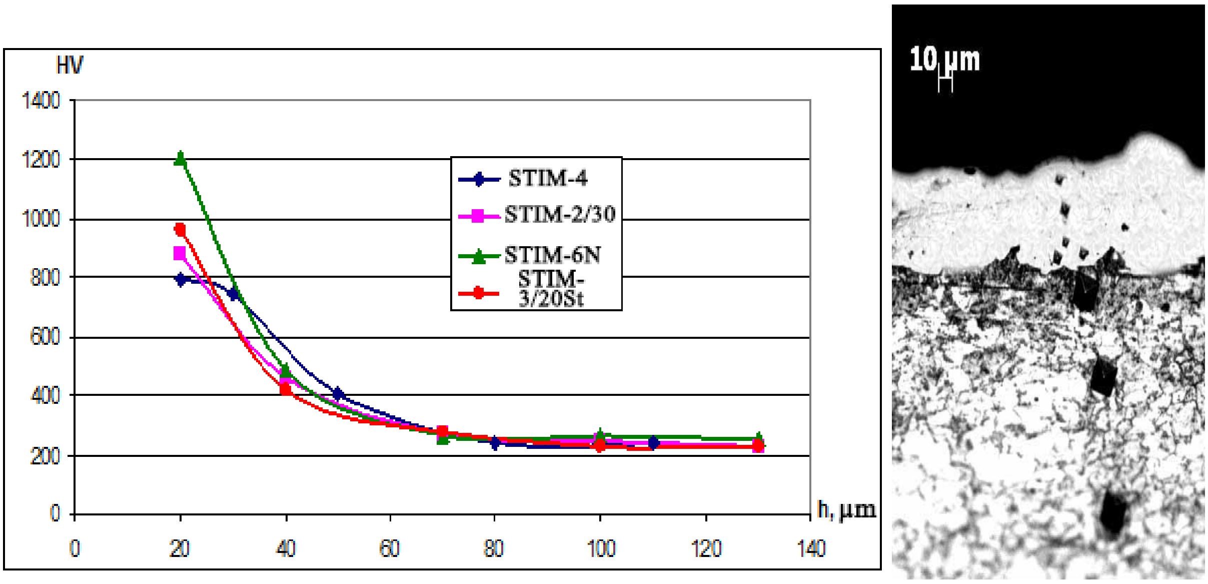

Figure 3. Sample with coating deposited using SHS electrodes and microhardness of coatings

The results of microhardness measurements showed that at the surface of the support layer with microhardness of 1200 HV forms. Microhardness decreases from the surface down to the core of the support which indicates presence of transition layer on the surface of the support with composition similar to electrode material. This ensures correlation of mechanical properties of electrode material and coating. As the result microhardness of metallic support surface increases up to 4 – 4.5 times.

In order to test industrial application of coatings obtained using SHS electrodes deposition on the surface of jaw crusher was done. Testing was performed at Nikopol Ferroalloy Plant. It was shown that deterioration rate of coated crusher surface was 1.7-2 times lower than in the case of uncoated surface made from steel grade 40X (Russian, GOST). During testing 5800 tons of manganese agglomerate was processed.

Therefore the application of electro-spark coating for longwearing mining tools is one of unexpensive and promising ways of increasing their durability. SHS extrusion method is known [3] as the effective method for production of electrodes with nanosized structure made of wear-resistant component and oxides (without metallic binder) initially in the form of micrometer-sized powders. Usually in order to obtain composite nanostructured ceramics by SHS ultrafine powders are used, or chemical and mechanical treatment is done after synthesis [4]. Another option is to add material with low melting point and make long mechanical treatment [5]. In case of SHS extrusion on the other hand nanosized structure is formed due to combination of exothermic combustion of initial components mixture with shear deformation.

4. Conclusions

High potential of SHS electrodes for coating deposition on longwearing mining tools was shown in this work. ESA and ESD treatments with SHS electrodes can be successfully applied at different mining plants where wear resistance of steel instruments is of great importance.

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