Effect of organic additives in the structure and functional properties of Ni-P composite coatings reinforced by nano-SiC and MWCNTs

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ABSTRACT

Wear and corrosion of materials cost up to 3-4% of developed countries' national income (GDP) [1]. Every year, billions of Euros are spent on capital replacement and control methods for wear and corrosion infrastructure, hence, prevention of wear and corrosion is of crucial importance for the European economy. For several decades hard chromium plating has been the most used coating method to protect components operating in high wear environment. This is due to its superior hardness and corrosion inhibiting qualities arising thanks to chromium's natural ability to react with elements such as oxygen. However, hard chromium coatings are applied from electrolytic baths containing Cr^{+6} (hexavalent chromium). Public and government agencies having already recognized the extremely harmful impact of Cr^{+6} in both human health and environment (cancers, respiratory problems, contamination of aquifer etc) have begun to enact legislations and regulations against hard chromium plating in order to protect public health and workers involved with handling chromium plating (i.e. chromium platers) [2].

Composite coatings used as protective surface coatings of engineering components to improve their wear resistance and service life are the one of alternatives to hard chromium [3]. Particularly, electrolytic composite coatings based on a Ni–P alloy matrix containing fine particles of SiC, WC, B_4C, MWCNT, or TiO_2 have attracted attention due to their good mechanical and chemical properties including high hardness and enhanced wear resistance combined with a good corrosion resistance [4]. However, homogenous dispersion of the reinforcing particles in the metallic matrix is a prerequisite in order to enhance their mechanical/tribological properties [5].

In the present work, the effect of organic additives in the structure and functional properties of Ni-P based composite coatings has been studied. Specifically, a standard sulfate based Ni-P bath reinforced with nano-SiC particles (45-55 nm) or MWCNTs have been investigated. Various organic additives such as SDS, lactic acid, saccharin and CTAB have been introduced into the electrolytic bath in order to achieve excellent dispersion of the reinforcing particles as well as to improve the deposition of compact and functional coatings. Mild carbon steel specimens have been used as substrates. The effect of the additives combination and the current density on the structure, morphology and functional properties has been evaluated.

Depending on the applied conditions and proper combinations of organic additives it has been achieved to produce a wide range of coatings with P content in the range of 4–16 wt%. The structure of the coatings has been proven to be strongly affected by the organic additives and the current density. Thus, by altering the bath composition it was able to transform the structure of the coatings from the completely amorphous phase to nano-crystalline with the presence either Ni or $Ni_{12}P_5$ and Ni_8P_3 phases. The morphology of the coatings is also correlated to the electrolysis conditions. Thus, for example, at low current density spherical formations and pyramidal or polyhedron crystallites have been presented, while in higher current density smoother surfaces with refined grain boundaries have been produced.

Finally, functional properties of coatings such as micro hardness and surface roughness have been measured in the as plated form. Pure Ni-P coatings exhibited hardness in the range of 550 to 650 HV depending on their structure. In general amorphous structure has as a result lower micro-hardness values. Addition of SiC nanoparticles or MWCNT has as a result the increase of micro-hardness up to 800 HV. This increment can be attributed to both the presence of the particles (even in low concentration) in the matrix of the coatings as well as in the modification of the Ni-P matrix due to the presence of the nano-particles.

Overall, it has been proved that functional Ni-P matrix composite coatings can be produced from modified nickel sulfate baths with the addition of proper combination of organic additives.

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