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Mini Review

Electrodeposition of Composite Ni-TiO2 Coatings from a Deep Eutectic Solvent, Ethaline

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Abstract

The electrodeposition of Ni-TiO2 composite coatings was carried out from a plating bath based on a deep eutectic solvent, ethaline (a eutectic mixture of ethylene glycol and choline chloride). The effects of electrolyte composition and electrolysis conditions on the content of Titania particles, microstructure and microhardness were investigated. The introduction of TiO2 nano-particles into Ni-matrix was shown to improve the corrosion stability and electrocatalytic activity of the synthesized composite electrodeposits.

Introduction

It is known that the electrochemical deposition of composite coatings yields finishing electrodeposited layers with improved physicochemical and service properties, such as increased microhardness, high wear, and corrosion resistances, etc. This work deals with the electrodeposition of composite Ni-TiO_2 coatings using an electrolyte based on the so-called ethaline, a deep eutectic solvent [1]. Deep Eutectic Solvents (DESs) are now considered as a promising kind of room temperature ionic liquids.

Materials and Methods

Ethaline is composed of the eutectic mixture of choline chloride and ethylene glycol in the molar ratio of 1:2, respectively. The $NiCl_2.6H_2O$ salt served as a source of Ni(II) ions in the electrolyte. Titania nano-powder (Degussa P 25, Evonik, the particle size of ca. 25-30 nm) was used as a dispersed phase in colloidal plating electrolyte. The electrodeposition of composite was performed from a plating bath described in detail in our previous studies [2,3] under the condition of continuous agitation at a constant value of current density.

Results and Discussion

Due to high viscosity and density, the colloidal electrolyte based on DESs provides excellent dispersion stability in comparison with common aqueous plating baths. No visible signs of coagulation and sedimentation were detected during one week of observations. This is one of the most important advantages of colloidal electroplating baths containing DESs. The effects of TiO_2 content in electrolyte, stirring rate and current density were investigated. The highest content of TiO_2 in composite electrodeposited coatings, equal to ca. 2.35 wt.%, was achieved at 500 rpm, 10 mA.cm^{-2} and 15 g dm^{-3} TiO_2. It was stated that the electrodeposition of Ni-TiO_2 composites well obeys known concepts on the mechanisms of composites electrochemical synthesis (Guglielmi theory, etc.) [4]. The X-ray analysis of composites revealed the reflections of face centered cubic nickel and anatase TiO_2 planes. The broad half-width values of the XRD spectra of Ni showed the nanocrystalline structure of the metallic matrix. The calculated values of crystalline size varied in a range of ca. 9-14 nm.

An introduction of TiO_2 particles into the nickel matrix results in an increase of coatings' microhardness. This is due to the so-called Orowan mechanism. It is associated with the dispersion of fine colloidal particles, which impedes the motion of dislocations in the metallic matrix and results in an increase in the material hardness. Electrochemical impedance spectroscopy showed that the insertion of Titania nano-particles in Ni matrix leads to an increase in corrosion stability of the coatings. The improvement in corrosion resistance may be caused not only by the formation of a protective physical barrier, which partially blocks the surface and is composed of TiO_2 particles, but also by the formation of corrosion micro-cells in which TiO_2 acts as cathode and nickel as anode. The electrocatalytic properties of Ni-TiO_2 composite electrodeposits were tested in the of hydrogen and oxygen evolution reactions proceeding in an alkaline solution. It was shown that the incorporation of Titania nano-particles into the Ni matrix ensures improvement in electrocatalytic performance of the electrochemically deposited layers [5].

Conclusion

The main characteristics of Ni-TiO_2 composite electrodeposition from a deep eutectic solvent, ethaline, were reported in this work. Due to higher viscosity and density, the colloidal electrolyte based on DES shows excellent dispersion stability as compared with "usual" aqueous systems. This is one of the most important advantages of colloidal electroplating baths containing deep eutectic solvents. An increase in TiO_2 content in composite coatings enhances microhardness, corrosion stability and electrocatalytic activity.

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