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Optimization and Characterization of Electrodeposited Coatings of Ni-Al_2O_3

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Abstract: Composite coatings suitable protection against corrosion was prepared by electrodeposition from a chloride electrolyte containing alumina microparticles maintained in suspension. The nickel-alumina composite coatings showed a better corrosion resistance in 0,6 M NaCl solution and high hardness than nickel electrodeposited under the same conditions. With increasing alumina content in the electrolyte, the amount of alumina dispersed in the deposit increased uniformly. The composite coatings deposited were uniform and adherent to the substrates. The morphology and microstructure analysis was conducted with Scanning Electron Microscopy (SEM). The effects of Al_2O_3 concentration on the microhardness and corrosion resistance properties of the composite coatings are discuted.

Key words: Electrodeposition, Ni-Al_2O_3 composite, microhardness, corrosion

INTRODUCTION

A new family of electrodeposited coatings containing occluded solid particles in a metal matrix has been developed in recent years to combine some of the desirable properties of the metals with that of solid particles[1]. Composite coatings give various functional properties, such as wear resistance, corrosion resistance and mechanical properties such as high hardness[2-5] to the plated surface[6,7]. For many practical applications, wear resistance of mechanical parts is a major property and a Common way of increasing wear resistance is the codéposition of Al_2O_3 particles on a metallic matrix, i.e., Ni-Al_2O_3 composites[2] can also be prepared by electrodeposition. Electroplating offers the advantage of low cost[8] and can be applied to the fabrication of structures with complex geometries[9].

The evolution of the degree of codéposition of solid particles on an electrode depends on many parameters of electrolyze such as the hydrodynamics along the electrode, the density of current and the concentration of particles in the bath. Here we report on the fabrication of Ni-Al_2O_3 films by electrochemical deposition where nanometer size Al_2O_3 particles are dispersed in a nickel matrix. The aim of this study is both to investigate the electrodeposition of Ni-Al_2O_3 and the effect of the Al_2O_3 concentration on the structure morphological and properties of the composite coatings will be discussed.

MATERIALS AND METHODS

The Ni-Al_2O_3 films were electrodeposited onto steel substrates. Cathode and anodes substrates were steel and Ni (99, 9%), anode was a chemically pure nickel sheet plates respectively.

Firstly, the substrates were degreased in an alkaline solution containing NaOH and Na_2CO_3 at 35°C for 3 min and then picked and activated in a solution in acid solution for 5 min. Finally, on the cleaned specimen steel by a distilled water and was performed in the following $NiCl_2.6H_2O$ 0,1 m ol L^{-1}, NaCl 0,1 mol L^{-1}, NH_4Cl 0,4 mol L^{-1}, H_3BO_3 0,3 mol L^{-1}. Boric acid was used to maintain the solution pH which found to be close to 3,8 in order to minimize hydrogen evolution. With the different concentration of Al_2O_3 particles were deposited for 60 min on steel substrate. The volume of the electrodeposition bath was approximately 200 mL. All solutions were freshly prepared with water doublydistilled. The suspensions were mixed by magnetic stirring for 48 h and the plating solution was agitated during electrodeposition with a magnetic stirrer. The morphology and microstructure of the composite coatings were analyzed using Scanning Electron Microscopy (SEM).The cathodic efficiency was calculated from weight difference according to Faraday's law. The composite coating hardness was measured using microhardness indentation. Anodic polarization tests were carried out in a conventional three electrode corrosion cell.

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RESULTS AND DISCUSSION

Many authors[10-12] think that the variation of electrolyze parameters (current density, bath's pH, granulometry of particles, solid particles concentration and temperature) can ameliorate the quality of coating. In some way and to reduce the cost price which tend the second after the quality of coating, we tried to find the optimum conditions which can satisfy our objective.

After realization of many coatings with different current density (1-10 A.dm^{-2}), we recognize that the best results are obtained with a current density between 1,2 to 2 A.dm^{-2}, a temperature of 50°C and an acid pH. These conditions were verified by analyzing the quality of coating (adhesion, brightness, thickness and corrosion resistance). Beyond these conditions especially the current density interval, the film become dendritic and with a bad adhesion to the substrates. The thickness of films determined by optical microscope, increase with increasing of solid particles of Al_2O_3 in the bath Fig. 1.

Figure 2 shows that the coatings have a good hardness. The addition of solid particles Al2O3 in Nickel matrix increase the hardness. This is due to the heterogeneity of films which consequently ameliorate the mechanical properties of coatings[13,14].

The corrosion tests by the lost weight method Fig. 3 examined in an aggressive environment (NaCl 3,5%) and ambient temperature shows that the corrosion rate decrease with increasing alumina quantity. This result is in a good accordance with literature[15].

In Fig. 4 is shown the microstructure of different films deposited with different Al_2O_3 concentration. Fig 4a shows the metallic structure of pure Nickel, it's clear that this structure is homogeneous, compact and without dendrites. Figure 4b-d present a big degree of codeposition which increases gradually with addition of Al_2O_3. All surface samples were covered with solid particles incorporated in nickel matrix[15] found the same result.

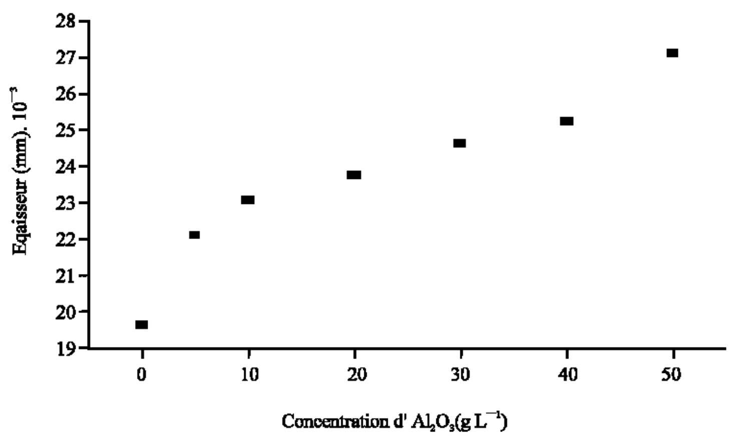

Fig. 1: Thickness of films as function of Al_2O_3 concentration

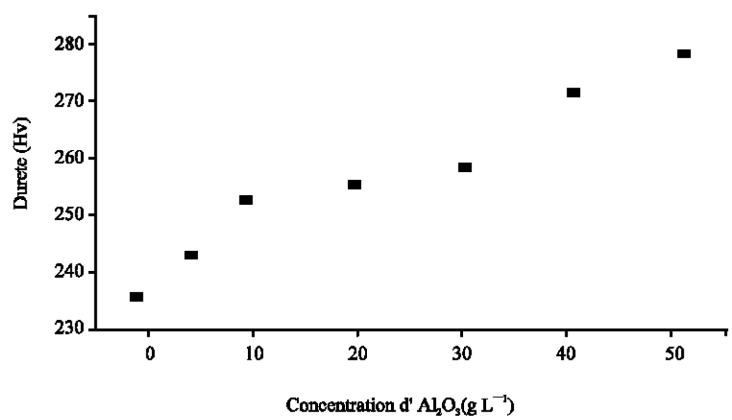

Fig. 2: Microhardness of films as function of l_2O_3 concentration

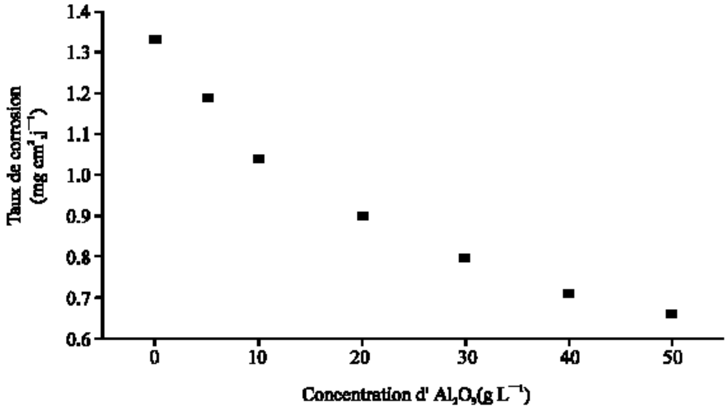

Fig. 3: Corrosion rate as function of Al_2O_3 concentration

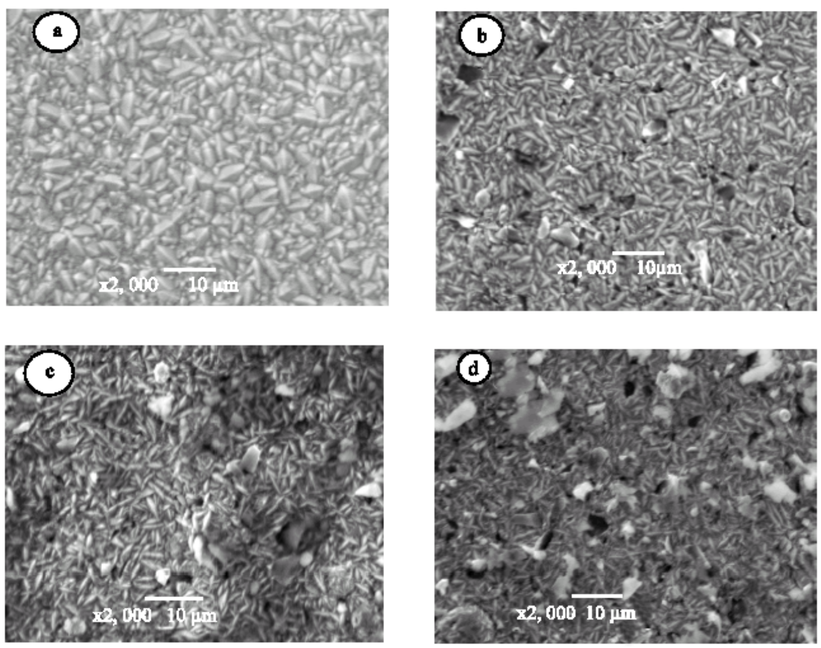

Fig. 4: Morphology of electrolytic coatings : (a) pure nickel, (b) nickel with 10 g L^{-1} Al_2O_3, (c) nickel with 20 g L^{-1} Al_2O_3 and (d) nickel with 50 g L^{-1} Al_2O_3

CONCLUSION

Elaboration of nickel coatings and (Ni- Al_2O_3) composite films by electrolytic way on stainless steel was effectuated with success. We found that the adhesion of films is very good thanks to the thermal shock test. The determination of thickness of different films electrodeposited shows that it increases with addition of solid particles. The tests of corrosion realized on our coatings develop the decrease of corrosion rate with increasing Al_2O_3 concentration.

The microhardness of films increase with addition of solid particles in the metallic matrix. This is probably due to the heterogeneity of coatings and it occur a good mechanical properties to them. Pure Nickel morphology shows an homogeneous and compact metallic structure. The codeposited coatings present in the optimum conditions a high degree of codeposition and all the substrate is covered by Al_2O_3 particles.

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