

Erosion-Corrosion Resistance of Ni Composite Coatings with Embedded SiC Nanoparticles

Johny E. Henao, Franky Bedoya*, Maryory A. Gómez, Jorge A. Calderón
Centro de Investigación, Innovación y Desarrollo de Materiales- CIDEMAT. SIU - Universidad de Antioquia.
Crr 53 N° 61 – 30, Tel: 574-2196617, Medellín, Colombia
frankybedoya@gmail.com

Introduction

Coatings of Ni-SiC composites have been developed because particles embedded in Ni matrix confer high corrosion and wear resistance to the steel substrate. The amount of particles embedded in the coating increases with increasing particle concentration in the bath. Furthermore, low SiC particle size improvement the mechanical properties of the coating [1-3]. Srivastava *et al*, shown that the properties of the NiCo-SiC coatings depend on the experimental conditions and found that the better tribological properties of the coatings could be obtained using a current density of 0.8 A/dm^2 , 50 g/L of SiC and a stirring speed of 600 rpm. With this manner, they obtained Ni-SiC coatings with high microhardness values and stable friction coefficient, resulting in a lower mass loss in the wear tests [4]. Conversely Vaezi *et al*, established that with a decrease in current density or an increased content silicon carbide in the bath, increases the efficiency of the electrodeposition [5]. The incorporation of SiC nanoparticles into metal matrix produces morphologic changes into the deposit, which are responsible of microhardness increases and a better wear resistance of the composite coatings compared with pure nickel coatings [6]. Grain refining is also associate to SiC particles incorporation into the nickel matrix, which is as well linked to improvement of the corrosion resistant of the nickel coating [7]. Although there is a wealth of literature concerning the effect of the different electroplating parameters on the resulting properties of composite coatings, the effect of codeposited particles on the microstructure and the relationship between the microstructure and corrosion-erosion properties of the coatings is still object to investigation.

Experimental

The Ni and Ni-SiC coatings were obtained from a Watts solution prepared with deionized water and with the following composition p/p: 30% of $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ (Carlo Erba), 4% of $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ (Merck), 3% of H_3BO_3 (Carlo Erba). The pH of the solution was adjusted to a value of 4.6. Nanoparticles of SiC with an average diameter of 25 nm (PlasmaChem) were added to the Watts solution in concentrations of 20, 50 and 70 g/L. The temperature of the bath was maintained at 50°C . Discs of AISI 1016 steel with diameter of 14.98 mm (area = 1.762 cm^2) were used as substrate. The hydrodynamic of the system was changed according to rotating rate of the discs, been 225, 400 and 625 rpm. Coatings of pure Ni and Ni-SiC composites were obtained galvanostatically by applying a current density of -3A/dm^2 .

The corrosion-erosion resistance of the coatings was evaluated by immersion of the coated disc in a stirred solution of NaCl 0.5M with addition of silica particles of 300 microns particle size, at a concentration of 20% p/p. The solution of NaCl + SiO_2 was impulse by a Teflon-rotating-plate at a constant rotating speed of 1500 rpm. During the erosion-corrosion test, Electrochemical Impedance Spectroscopy (EIS) and potentiodynamic polarization measurements were made at different exposition times.

Results and Discussion

Pure Ni coatings have a regular morphology, constitute mainly for crystals in polyhedral form, Fig. 1(a). The incorporation of SiC nanoparticles into nickel matrix substantially modifies the coating morphology, reducing grain size and stimulating the globular aggregation, Fig. 1(b). Similar effects have been observed by others authors [8,9]. The

increases of hydrodynamic condition of the electroplating bath also cause grain refining. These results show that there are more nucleation sites for nickel electro-deposition in presence of SiC nanoparticles and as consequence smaller Ni crystals are formed.

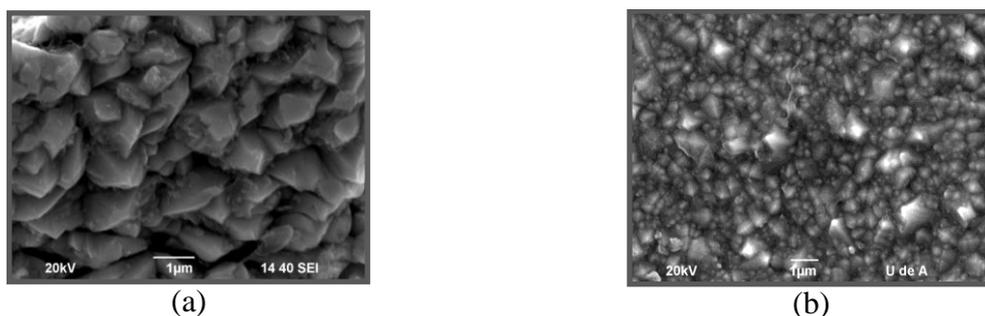


Fig. 1. SEM images of (a) pure Ni and (b) Ni-SiC coatings obtained at 400 rpm, SiC 70g/L,

Figure 2 shows XRD diffractogram of pure Ni and Ni-SiC coatings. Pure Ni coating exhibit the most intense peaks at 2θ angles of 44° , 52° and 77° . These peaks are attributed to crystal planes (111), (200) and (220). However, other crystal orientations appear due to the incorporation of SiC nanoparticles into the coating. An intensification of the diffraction peak at (200) plane and additional signals corresponding to crystal planes (222), (400) were observed in Ni-SiC coatings. The change in the Ni crystallization mode due to SiC particles incorporation is consequence of the variations in the atomic packing of the Ni and produces more compact structures of the deposit. GDOES analysis of a Ni-SiC coating shows that the coating consists essentially of Ni with 1.1% Si near of the surface. The amount of Si into the coating increases until a concentration of 1.7% close to the substrate.

Figure 3 shows potentiodynamic polarization of pure Ni and Ni-SiC coatings carried out during erosion-corrosion test. The corrosion potential of the coated samples shifts to more positive potentials according to the increment of the SiC content in the coating. Similar effect was observed when hydrodynamic condition during the electroplating was increased. Furthermore, lowest corrosion current was obtained during the erosion-corrosion test for the coating samples obtained at high rotation rate of the working electrode and high SiC content in the electroplating bath.

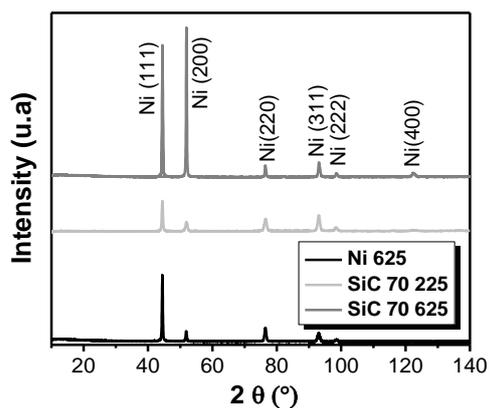


Fig. 2. XRD patterns of Ni and Ni-SiC coatings, SiC 70 g/L

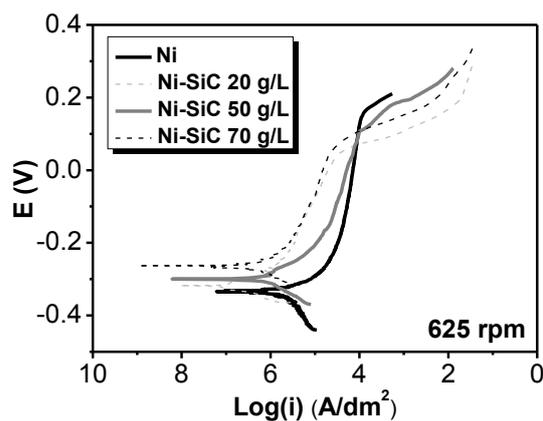


Fig. 3. Polarization curves of pure Ni and Ni-SiC coatings during erosion- corrosion tests.

Figure 4 shows impedance diagrams of Ni and Ni-SiC coatings carried out at different exposition times in corrosion-erosion test. Impedance diagrams of pure Ni coatings exhibit one capacitive loop at high frequencies and an inductive loop at low frequencies, Fig 4(a). The inductive loop indicates an active dissolution of metal during the test. On the other hand, impedance diagrams of the Ni-SiC composite coatings exhibit only one flattened loop and higher impedance than Ni coating. Both Ni and Ni-SiC coatings show reduction of impedance

values during the erosion-corrosion test, however the reduction is more severe in pure Ni coatings. These results confirm that Ni-SiC coatings are more resistant to erosion-corrosion phenomena. The incorporation of SiC nanoparticles into the Ni matrix improves the hardness and anticorrosion properties of the Ni coating, this as a result of induced changes in the microstructure and more compact atomic packing in the electroplating of the Ni matrix.

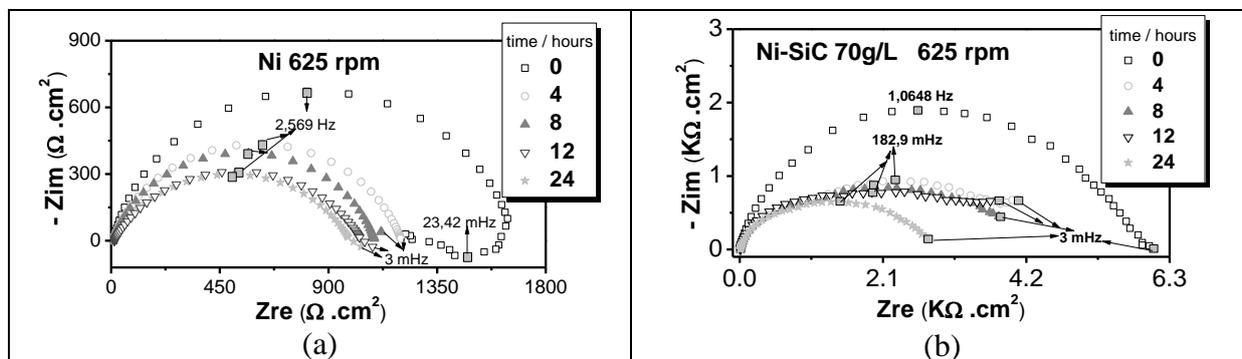


Fig. 4. Nyquist plots of electrochemical impedance of pure Ni and Ni-SiC composite coatings during the erosion-corrosion tests. (a) Ni coating, (b) Ni-SiC composite coating.

Conclusions

The incorporation of SiC nanoparticles and the increases of hydrodynamic condition in the electroplating process cause grain refining of the Ni deposit. Additionally, the inclusion of SiC into Ni coating during electroplating cause changes in the Ni crystallization. The change in the Ni crystallization mode due to SiC particles incorporation is consequence of the variations in the atomic packing of the Ni and produces more compact structures of the deposit. As a result of that, better resistance to erosion-corrosion is obtained in the Ni-SiC composite coating compared to pure Ni coating.

Acknowledgements

The authors wish to thank the University of Antioquia for the support received for this project.

References

- [1] I. R. Aslanyan, J. P. Bonino, and J. P. Celis, "Effect of reinforcing submicron SiC particles on the wear of electrolytic NiP coatings: Part 1. Uni-directional sliding," *Surface and Coatings Technology*, vol. 200, pp. 2909-2916, 2006.
- [2] I. R. Aslanyan, J. P. Bonino, and J. P. Celis, "Effect of reinforcing submicron SiC particles on the wear of electrolytic NiP coatings: Part 2: Bi-directional sliding," *Surface and Coatings Technology*, vol. 201, pp. 581-589, 2006.
- [3] X.-t. Yuan, D.-b. Sun, H.-y. Yu, and Y. Wang, "Effect of nano-SiC particles on the corrosion resistance of NiP-SiC composite coatings," *International Journal of Minerals, Metallurgy and Materials*, vol. 16, pp. 444-451, 2009.
- [4] M. Srivastava, V. K. W. Grips, and K. S. Rajam, "Electrochemical deposition and tribological behaviour of Ni and Ni-Co metal matrix composites with SiC nano-particles," *Applied Surface Science*, vol. 253, pp. 3814-3824, 2007.
- [5] M. R. Vaezi, S. K. Sadrnezhad, and L. Nikzad, "Electrodeposition of Ni-SiC nano-composite coatings and evaluation of wear and corrosion resistance and electroplating characteristics," *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, vol. 315, pp. 176-182, 2008.
- [6] L. Benea, P. L. Bonora, A. Borello, and S. Martelli, "Wear corrosion properties of nano-structured SiC-nickel composite coatings obtained by electroplating," *Wear*, vol. 249, pp. 995-1003, 2002.
- [7] A. Sohrabi, A. Dolati, M. Ghorbani, A. Monfared, and P. Stroeve, "Nanomechanical properties of functionally graded composite coatings: Electrodeposited nickel dispersions containing silicon micro- and nanoparticles," *Materials Chemistry and Physics*, vol. 121, pp. 497-505, 2010.
- [8] L. Benea, F. Wenger, P. Ponthiaux, and J. P. Celis, "Tribocorrosion behaviour of Ni-SiC nano-structured composite coatings obtained by electrodeposition," *Wear*, vol. 266, pp. 398-405, 2009.
- [9] M. Lekka and N. Kouloumbi, "Corrosion and wear resistant electrodeposited composite coatings," *Electrochimica Acta*, vol. 50, pp. 4551-4556, 2005.