Electrodeposition of nickel composite coating from a new type of acetamide-DMSO₂-NiCl₂ ternary electrolyte

Murugan Ganapathi^a, Dimitri Soccol^a, Koen Binnemans^b
Jan Fransaer^a
Department of Metallurgy and Materials Engineering^a,
Department of Chemistry^b, KULeuven, Belgium

Metal composite coatings with nano or micron size particles have many industrial applications. Electrodeposited nickel composite coatings are used for corrosion protection, wear resistance, high temperature oxidation and to improve micro-hardness¹. It is well known that the physical and mechanical properties of the Ni composite depend on the uniformity and the amount of particles incorporated in the metal². Although Ni can be deposited from aqueous media, it is difficult to incorporate hydrophilic particle due to the hydration layer at their interface^{3,4}. Such hydrophilic particles can however be codeposited from non-aqueous electrolytes⁵.

In this study we explored a new type of ternary electrolyte (acetamide-DMSO₂-NiCl₂) for the deposition of Ni-Y₂O₃ composite coatings. Since this ternary electrolyte is new, the phase diagram and conductivity of the electrolyte were studied by DSC and impedance spectroscopy respectively. All electrochemical experiments were carried out in an Ar filled glove box with oxygen and water levels below 1 ppm. Cyclic voltammograms of a 0.6:0.4 mole fraction acetamide-DMSO₂ electrolyte with and without NiCl₂ carried out on a Pt electrode at 130 °C are shown in Fig.1. The voltammograms show that the potential window of the electrolyte is large enough to deposit Ni without decomposition of the electrolyte. Also, the Ni deposition and stripping peaks shows that the nickel deposition is quite reversible. The conductivity of the electrolyte increases with temperature due to decrease of viscosity and hence increase of the ionic mobility of the ions.

Y₂O₃ particles (average particle size 5 micron) were dried at 200 °C and added to a 0.593:0.391:0.016 acetamide-DMSO₂-NiCl₂ mixtures. The electrolyte was stirred at 300 rpm to keep the particles in suspension. Electrodeposition was carried out potentiostatically at -0.4 V vs. Ni at 130 °C. The SEM microstructure of such a deposit is shown in Fig. 2. It shows that the particles codeposited individually without agglomeration. Also particles seem to be uniformly deposited across the whole surface.

The particle content in the matrix was analyzed by EDX (Fig. 3). Results show that the Y₂O₃ concentration in the coating increased with the Y₂O₃ concentration in the plating bath and that up to 45 vol% of Y₂O₃ can be codeposited from this new ternary electrolyte which is very high compared to what can be obtained from aqueous electrolytes⁶. Hence the acetamide-DMSO₂-NiCl₂ ternary melt might be a good electrolyte for the codeposition of hydrophilic particles.

References:

1. Y.J. Xue., X. Z. Jia, Y. W. Zhou, W. Ma and J.S Li., *Surf. Coat. Technol.*, **200**, 5677 (2006).
2. F. Hu and K.C. Chan, *Appl. Surf. Sci.* **233**, 163 (2004).

Fig. 1: Cyclic voltammogram of 0.6:0.4 mole fraction acetamide-DMSO₂ with and without NiCl₂.

Fig. 2: SEM microstructure of Ni-Y₂O₃ composite deposited from a 0.593:0.391:0.016 mole fraction acetamide-DMSO₂-NiCl₂ mixture containing 80 gL⁻¹ Y₂O₃ at -0.4 V vs. Ni at 130 °C. Electrolyte was stirred at 300 rpm with a magnetic stirrer.

Fig. 3: Vol% of Y₂O₃ codeposited with Ni as a function of Y₂O₃ concentration in the plating bath.

3. L. Stappers, J. Fransaer, *J. Electrochem. Soc.*, **153**, C472 (2006).
4. L. Stappers, J. Fransaer, *J. Electrochem. Soc.*, **154**, D598 (2007).
5. J. Fransaer, E. Leunis, T. Hirato and J-P. Celis, *J. Appl. Electrochem.*, **32**, 123 (2002).
6. L. Tian and J. Xu, *Appl. Surf. Sci.*, doi:10.1016/j.apsusc.2011.03.140

Acknowledgements

The authors acknowledge the support of the Belgian Federal Science Policy Office through the IUAP project INANOMAT (contract P6/17). Also, the financial support by the K.U.Leuven (project and GOA 08/05), by the FWO-Flanders (research community "Ionic Liquids" and project G.0508.07)) and by the IWT-Flanders (SBO-project "MAPIL").