

Mechanical testing: a new approach to evaluate electrowinning performance

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The energy costs for producing electrolytic base metals, such as zinc and nickel, account for a significant part of their selling price. Therefore, industry faces a continuing pressure to improve this process efficiency. Previous works have described the effects of impurities on the energy efficiency of the electrowinning processes and on the morphology and crystal structure of the metallic product only. What has not been clearly established yet is how the morphology and texture of the electrodeposit will affect its mechanical properties and, thus, the effectiveness of the stripping and cutting stages. As the Zn and Ni deposits are bent during stripping by an applied load to the extremity of the deposit, the resulting deformation may lead to the fracture of the material and to the disruption of the stripping process, with the consequent implications in the electrowinning performance. As the Ni deposit is normally cut to be sold as small sheets or as coins, deposits with high hardness may cause a decrease in the deposit ductility, affecting both efficiency of the stripping stage and performance of the cutting machines. Then, a better understanding of the effect of contaminants on mechanical properties of metal deposits allows a more detailed assessment of product quality.

Metallic impurities and some organic compounds may contaminate the feed electrolyte solution and affect the current efficiency of the electrowinning processes and the quality of the metals deposited on the corresponding cathodes. Due to a trend of metal extraction from low-grade ores, a gradual rise of the organic concentration in the electrolytes may be expected, particularly when oxide ores (e.g., zinc silicate) are treated. In this context, our group has investigated the effects of residual organic compounds on the electrowinning of Zn (Majuste *et al.*, 2014; Majuste *et al.*, 2015) and Ni (Freire *et al.*, 2015), by an approach that combines electrochemical techniques with product analysis by microscopy and mechanical testing. The bending behavior is assessed with a customized device (Fig. 1a) and correlated to the main features of the deposit. In the case of the Ni deposits, the nanohardness of this material is also of relevance. The selected organic compounds, which are used in industrial operations, include: flocculant, flotation collectors and lubricating oil (for Zn); and extractant, diluent, flocculant, acid mist suppressant and lubricating oil (for Ni). The mechanisms by which the molecules, analyzed by Fourier transform infrared spectroscopy and gas chromatography, may affect the kinetics of metal reduction and hydrogen evolution reactions under practical conditions are evaluated. The morphology and crystallographic texture of the metal deposit, which determine its mechanical properties, are discussed based on the degree of organic adsorption on the electrode surface and interactions with water molecules and electroactive species (Majuste *et al.*, 2015).

The effect of impurities on mechanical properties of the metal deposit were evaluated after identifying the main contaminants of the Zn electrolyte, according to the corresponding effects on current efficiency (Figure 2) and, consequently, on energy consumption. Bending tests were carried out up to an angle of 50°. The measurements revealed that the organics affect the mechanical properties of the Zn deposit differently. The properties were found to be strongly correlated to the porosity of the metal deposit, grain size and preferred orientation (texture) of the Zn hexagonal platelets

(Majuste *et al.*, 2016). Highly porous deposits exhibited low ductility, which in turn caused the fracture of the sample at small bending angles (Fig. 3), impeding effective stripping.

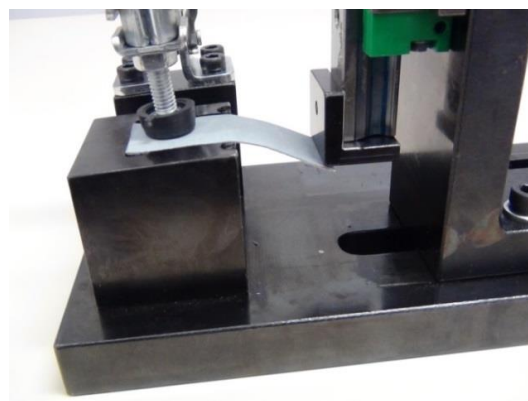


Figure 1 Photographs of the device used in the bending tests of the metal deposits.

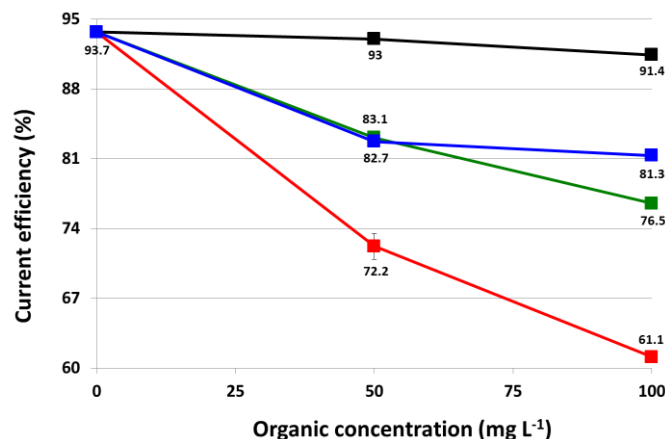


Figure 2 Effect of organics on Zn electrowinning using a continuous-flow cell with Al cathodes and Pb-0.5% Ag anodes. Conditions: 62 g.L⁻¹ Zn²⁺; 162 g.L⁻¹ H₂SO₄; 38 °C; 530 A.m⁻²; 6 h. Legend: lubricating oil (black line), collector for impurities (blue line), flocculant (green line) and collector for zinc (red line).

With regard to the effect of organic compounds on Ni electrowinning, the results indicated that only the flocculant and the acid mist suppressant exhibit relevant negative effects on current efficiency and energy consumption. At higher concentrations (50-100 mg.L⁻¹) in the sulfate solution (80 g.L⁻¹ Ni²⁺; 50 g.L⁻¹ Na⁺; pH 2.8), the effect of the suppressant also includes the cracking of the Ni deposit during the process (60 °C; 300 A.m⁻²; 6 h), which is likely related to observed reduction of grain size. Only the addition of flocculant or acid mist suppressant to the electrolyte has increased the nanohardness of the Ni deposit, which may affect the performance of the stripping and cutting stages after electrowinning.

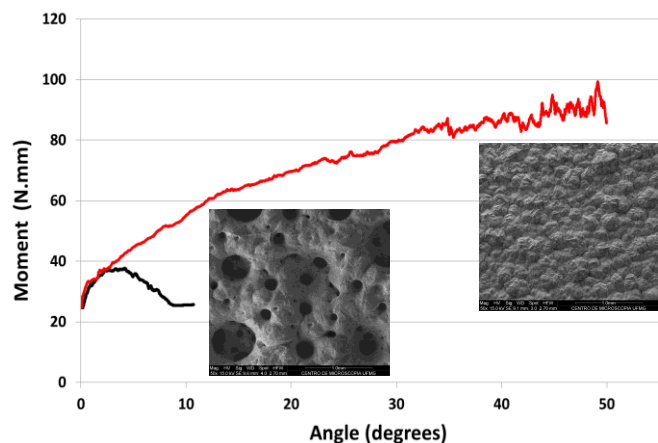


Figure 3 Moment versus angle curves for samples produced from organic-free electrolyte (red line) and solution containing 50 mg.L⁻¹ of collector for impurities (black line). Inset shows micrographs of Zn deposits.

Our approach, which provides a prediction for the behavior of different deposits during the stripping operation, allows a better assessment of the effect of organic impurities, and also metallic impurities and additives, on the quality of electrodeposits, thereby assisting industry to optimize conditions and increase productivity.

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