How Fundamental Studies on Chromium Electroplating Contribute to a More Sustainable Future?

Mechanism of Cr(III)-based Oxide-Hydroxide Film Electrodeposition in an Acidic Solution

Authors

Zahra Sharifi, Saeid Behjati, Jacques H.O.J. Wijenberg, Arnoud C.A. de Vooys, Marc T.M. Koper

Abstract (poster presentation)

One of the most strategically important coating materials in today's industrial world is chromium, with applications in critical fields such as agriculture, mining, medicine, and aerospace. Unfortunately, the process of producing chromium coatings involves the use of hexavalent chromium ions, which come with significant downsides, including being hazardous to human health and the environment, challenges in waste management, and low energy efficiency. To date, researchers have not been able to find a suitable replacement for hexavalent chromium. One more sustainable alternative to hexavalent chromium is trivalent chromium, although there have been limited fundamental studies on this system. In our study, we aimed to shed light on systems based on Cr(III) ions. During our research, we discovered that one of the fundamental principles of electrodeposition from chromium baths, specifically the interpretation of cyclic voltammetry (CV) curves—which is a well-trusted interpretation among researchers and engineers—has not yet been accurately interpreted. This may be one of the reasons why research aimed at developing chromium(III)-based systems has slowed. In our study, we demonstrated that the interpretation of CV curves should be reconsidered. Using high-tech in-situ instruments like Electrochemical Quartz Crystal Microbalance (EQCM) and Electrochemical Scanning Tunneling Microscopy (EC-STM), we showed that the two cathodic peaks that appear in the CV curves during the electrodeposition process are not due to chromium reduction but are instead related to hydrogen evolution and local pH effects, which lead to the deposition of a film that later participates in chromium and chromium oxide deposition. This discovery enhances our understanding of the system and brings us closer to practically replacing Cr(VI) with Cr(III), promoting cleaner production technologies, improving recycling methods, and minimizing waste and environmental impact.