FUNDAMENTAL ASPECTS OF SOLVENT-SOLUTE INTERACTIONS IN ELECTRODEPOSITION AND ELECTROPHORETIC DEPOSITION

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The application of metal, ceramic and composite coatings by electrodeposition and electrophoretic deposition (EPD) onto a substrate is vital for technologies such as electronics, optics, sensors, automotive, and aerospace. The technology at commercial level is almost wholly based on concentrated aqueous solutions of metal salts with a variety of additives and conditioners that produce the required functional and aesthetic properties of the coatings.

All electrodeposition media are composed of ionic and molecular components. These can be solvents, particles, metal-containing species, and additives such as brighteners, conductivity and viscosity modifiers. The relative interactions between these species are controlled by the charge density on the ions and the dipole moment/polarizability of the molecular species in the form of coordinative bonds, electrostatic attraction/repulsion or van der Waals bonds. Each of these species also interacts with the charged substrate in the double layer at the electrode-solution interface. Each of the interactions can determine important properties for electroplating. The interactions between the metal salts in solution with a neutral additive or with anionic species can determine metal redox potentials and metal solubility. The interactions of the metal or particle in solution with the substrate can determine deposition overpotential and current efficiency. The interactions between the substrate with the anions, cations and additives can determine deposit morphology. And the interactions between cations and anions can determine solvent viscosity and conductivity.
This review outlines the interactions in aqueous, organic and ionic liquids that are responsible for the advantageous properties of each solvent in electrodeposition and EPD. The potential windows for electrodeposition, the solubility of metal salts, the conductivity and viscosity of electrolytes are associated with the greenness chemistry and the economics of the process, the control of deposit morphology, the deposition of architectures at the nanoscale and the deposition of water-sensitive metals such as aluminum.
To better understand the interactions between the key elements of an electrodeposition or EPD bath; the applications of electrochemical techniques, such as the voltammetry, is highlighted.