BIOMIMETIC STRATEGIES FOR CHARGING, DISPERSION AND ELECTROPHORETIC DEPOSITION OF MATERIALS

Igor Zhitomirsky, Department of Materials Science and Engineering, McMaster University, Hamilton, Canada
zhitom@mcmaster.ca

Despite the impressive progress achieved in the electrophoretic deposition of materials there is a need for simple and versatile methods for the efficient dispersion, charging and deposition of colloidal nanoparticles. A critical property of a dispersant is its adsorption on the particle surface. Therefore, there is a need in the development of charged dispersing agents with strong interfacial adhesion.

A valuable bio-inspired approach emerges from the mechanism of mussel adhesion to metal and mineral surfaces in underwater environment. The strong adhesion of mussel adhesive proteins to metals and metal oxides is attributed to the chelation of catecholic amino acid, L-3,4-dihydroxyphenylalanine (DOPA) and the formation of the interfacial chemisorption complexes. The investigation of the biomimetic adhesion resulted in the development of new approach to the dispersion of inorganic nanoparticles using the organic/inorganic surface adhesion mechanisms. Cationic and anionic aromatic molecules containing catecholate, salicylate, gallate and other functional groups were investigated. Cathodic electrophoretic deposition of TiO_2, ZnO, MnO_2 and other oxides was achieved using protonated dopamine. Anionic catecholates such as 3,4-dihydroxybenzoic acid, 3,4-dihydroxyphenylacetic acid, 3,4-dihydroxyhydrocinnamic acid, caffeic acid and related organic molecules were investigated for the deposition of TiO_2, MnO_2, ZrO_2, ZnO, Fe_2O_3, NiO and other nanoparticles. Anionic gallic acid, salicylic acid and related materials were studied for deposition of various oxides. The results obtained for the phenolic molecules with different number of OH groups were analyzed and compared. The results were used for the fabrication of nanostructured oxide films by electrophoretic deposition. The influence of the lengths of the hydrocarbon chain on the electrophoretic mobility and deposition rate was investigated. It was found that organic additives can be used for efficient co-deposition of various materials. Moreover, the use of the organic dispersants for synthesis of inorganic nanoparticles by chemical precipitation methods allowed the formation of non-agglomerated nanoparticles of controlled particle size on the nanometric scale. Further progress in this technology was achieved by the use of chelating polymers and polymers, modified with catechol groups. Organic aromatic molecules, containing catechol groups were used as co-dispersants for oxides and carbon nanotubes.

Another biomimetic strategy was based on the use of commercial bile salts. It is known that bile salts solubilize various molecules in human body. It was found that bile salts containing carboxylic groups exhibit excellent film-forming properties and can be deposited electrophoretically. Various bile salts were investigated as charging, dispersing and film-forming agents for the deposition of carbon nanotubes, graphene, quantum dots, diamonds, and various neutral polymers, such as polymethylmethacrylate and polytetrafluoroethylene. Moreover, bile salts facilitated dissolution of water insoluble drugs and allowed for their deposition. Electrophoretic deposition has been utilized for deposition of different materials and advanced composites for biomedical, energy storage, catalytic and corrosion protection applications.