ELECTRIC FORCES BETWEEN PARTICLES AT AN OIL-WATER INTERFACE IN RELATION TO PICKERING EMULSIONS

Peter A. Kralchevsky, Krassimir D. Danov, Nikolai C. Christov and Mariana P. Boneva

Laboratory of Chemical Physics and Engineering
Faculty of Chemistry, University of Sofia
Sofia 1164, Bulgaria
pk@lcpe.uni-sofia.bg

Dielectric particles (silica, glass, latex, etc.) dispersed in a nonpolar fluid (say, oil) often have surface electric charges [1]. Because of that, such particles are attracted by the oil-water interface due to the electrostatic image-force effect. The theory of this effect (originally developed for point charges) is generalized for the case of finite-size particles of a given surface charge density [2]. For typical parameter values the image-force interaction becomes significant for particles of radius $R > 30$ nm. At fixed relative particle-to-interface distance, the force increases with the cube of the particle radius. In general, this is a strong and long-range interaction. For micrometer-sized particles, the interaction energy could be of the order of 10^5 kT at close contact, and in addition, the interaction range could be about 10^5 particle radii. Especially, water drops attract charged hydrophobic particles dispersed in the oily phase, and thus favor the formation of reverse particle-stabilized (Pickering) emulsions.

Having once attached to the oil-water interface, the particles experience both tangential and normal electric forces. The tangential force is repulsive and may lead to the formation of long-range ordered two-dimensional particle arrays. In addition, the normal (electrodipping) force pushes the adsorbed particles toward the water phase and creates concavities in the oil-water interface [3]. The overlap of such two concavities gives rise to a capillary attraction between the particles [4], whose energy decays asymptotically as $1/r^4$ with the interparticle distance r. Depending on the specific system, the attractive or the repulsive force could prevail. When the attractive force is predominant, it leads to particle self-assembly into densely packed two-dimensional ordered domains. Model experiments with micrometer-sized particles are carried out and interpreted in the frame of the developed theoretical model.

References

[1] R. Aveyard, J.H. Clint, D. Nees, V.N. Paunov, Compression and structure of monolayers of charged latex particles at air/water and octane/water interfaces, *Langmuir* **16**, 1969–1979, 2000.

[2] K.D. Danov, P.A. Kralchevsky, K.P. Ananthapadmanabhan, A. Lips, Particle–interface interaction across a nonpolar medium in relation to the production of particle-stabilized emulsions, *Langmuir* **22**, 106–115, 2006.

[3] K.D. Danov, P.A. Kralchevsky, M.P. Boneva, Electrodipping force acting on solid particles at a fluid interface, *Langmuir* **20**, 6139–6151, 2004.

[4] M.G. Nikolaides, A.R. Bausch, M.F. Hsu, A.D. Dinsmore, M.P. Brenner, C. Gay, D.A. Weitz, Electric-field-induced capillary attraction between like-charged particles at liquid interfaces, *Nature* **420**, 299–301, 2002.

Keywords: particle-stabilized emulsions, electric forces