Experimental and Theoretical Studies of the Colloidal Stability of Nanoparticles – a General Interpretation Based on Stability Maps

Claudia Eisermann, Doris Segets, and Wolfgang Peukert

Institute of Particle Technology, Friedrich-Alexander-University Erlangen-Nuremberg, Cauerstr. 4, 91058 Erlangen, Germany, W.Peukert@lfg.uni-erlangen.de

This contribution addresses the understanding of the stabilization of nanoparticles in suspension. Specifically, we study ZnO quantum dots in ethanol for which the influence of particle size, reactant ratio as well as surface coverage on colloidal stability in dependence of the purification progress was investigated. The results revealed that not only the well-known \( \zeta \)-potential determines the colloidal stability but also the surface coverage of acetate groups bound to the particle surface. The acetate groups act as molecular spacers between the nanoparticles and prevent agglomeration. DLVO calculations for quantum dots based on the theory of Derjaguin, Landau, Verwey and Overbeek using a core-shell model did lead to interaction energies < 1 kT even for stable systems, i.e. generally accepted rules for colloidal stability break down. We find that the stability is better understood in terms of dimensionless numbers which represent attractive forces \( F_A \) as well as electrostatic repulsion \( R \), steric effects (G), transport properties (Schmidt number Sc) and particle concentration (C). Evaluating the colloidal stability in dependence of time by means of UV-Vis absorption measurements a stability map for ZnO quantum dots is derived.

From this map it became clear that the dimensionless steric contribution to colloidal stability scales with a stability parameter including dimensionless repulsion and attraction as well as particle concentration and diffusivity of the particles according to a power law with an exponent of -0.5. Finally, we show that our approach is valid for other stabilizing molecules like cationic dendrons and is generally applicable for a wide range of other material systems and particle sizes (e.g. Au, Si, ZrO\(_2\) nanoparticles with particle diameters between 20 and 200 nm) within the limitations of vanishing van der Waals forces in refractive index matched situations, vanishing \( \zeta \)-potential and systems without a stabilizing shell around the particle surface.