Non-linear DC Electrophoresis in High Electric Field Conditions

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Abstract

Very recently, the synthesis and experimental study of a new class of highly charged polymer particles has been described, which spontaneously charge in non-aqueous low-polarity solvents [1,2]. These suspensions are an example of what is known as salt-free systems. The study of suspensions of charged colloidal particles in a salt-free medium is nowadays increasing [3]. The term salt-free does not mean that there are not ions present in the suspension because those ions coming from the charging process of the colloidal particles, which are known as "added counterions", will always dissolve into the supporting medium. This fact implies that the electric double layers that surround the colloidal particles in non-aqueous suspensions are constituted by one single ionic species.
For those systems, there is a non-linear singular relationship between the surface potential and the surface charge density. While for low surface charge density this relation is roughly linear, above a critical value of the surface charge density, the surface potential increases very slowly. This phenomenon is related to the counterion condensation effect, i.e., the generation of a compact layer of counterions that develops very close to the particles surface, and can considerably affect the macroscopical physical behavior, such as the electrokinetics, the rheology, etc., of these suspensions. Striking non-linear effects in the presence of high electric fields, as the unbinding of counterions from the condensation regions, have been observed in electrophoresis experiments [1,2].
In this work we have performed some initial calculations with the finite element method using COMSOL Multiphysics® for solving the full time-dependent non-linear governing equations inside a unit Wigner-Seitz cell. In the model, we have strong bidirectional couplings between Electrostatic, Laminar Flow and Transport of Dilute Species interfaces. In the theoretical study of the electrophoretic mobility against the applied electric field, we have successfully reproduced the numerical results of the standard linear perturbation model in the limit of low applied electric fields and test its range of validity. From this starting point we have explored the electrophoretic behavior as the electric field is increased.

References

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Figures used in the abstract

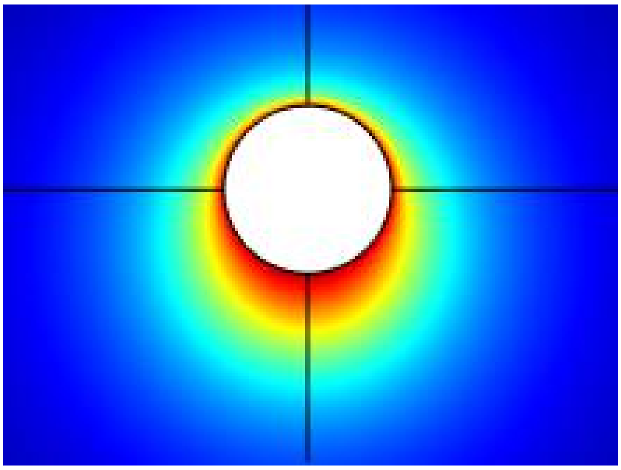

Figure 1: Ionic distribution deformation under application of the external electric field.