Abstract of PhD thesis

'Dynamic control of electrostatic interactions in soft matter systems via application of external electric fields'

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Soft matter systems (e.g. liquid crystals, polymers, colloids or surface active agents) are subject of both fundamental and applied research. Soft matter systems found a great number of uses in the cosmetic industry (creams, shampoos), food and other industries (e.g. paints, polymeric materials, advanced functional materials). All living organisms are also soft matter systems, and the best example is the cell.

Despite the wide interest and practical use these systems, still little is known about the interactions of soft matter systems with externally applied electric fields, especially oscillating ones.

In my dissertation I present the results of the influence of an external oscillating electric field on the behavior of soft matter systems. The main hypothesis is related to the influence of AC electric field on the distribution of counterions near charged objects (for instance a charged colloidal particle, a charged surface of a glass slide inside an aqueous electrolyte solution). In the dissertation I identify a critical frequency of the oscillating electric field that is related to the mobility of the ions in solution and to the Debye screening length. At equilibrium the counterions screen the interactions between objects in solution (i.e., colloids, polymers) by adopting a given spatial distribution. Application of a constant electric field shifts this distribution, yet the shift takes a finite time. Via the experiments detailed below I demonstrate that application of an electric field of frequency equal or lower to the critical value partially lift the screening effect. To verify the hypothesis I conducted several experiments within a different systems:

i) A free-standing smectic film in radial electric field. AC electric field causes a charge separation at the border of the meniscus of liquid crystal film and consequently the hydrodynamic instability. The phenomenon is observed below critical frequency. Charge separation is a consequence of movement of ions in liquid crystal for distance equal or higher than Debye length.

ii) A water-in-oil emulsion subjected to AC electric field. Due to movement of ions in water droplets the interface of water/oil becomes polarized. This polarization accelerate the process of merging of the water droplets (known as electro-coalescence). In this case the process also occurs below the critical frequency and is related to Debye length in water.

iii) Phase separation of mixture of liquid crystal and polymer (project lead by mgr Natalia Ziębacz). AC electric field accelerate the separation due to movement of ions inside liquid crystal domains. The acceleration occurs for frequency lower than critical.

The results obtained in this PhD thesis are important because:

i) They fill the gap in our understanding of the interaction of external electric field and different types of the soft matter (low-frequency electric field can create a macroscopic charge separation),

ii) Experiments on the free-standing smectic films led to calculating the value of edge tension in far-from-equilibrium conditions,

iii) Experiments on water-in-oil emulsion and liquid crystal/polymer mixture proved that the mechanism is universal in its nature.