Capillarity and Self-Assembly

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In this lecture, I review results and physical insights related to three fields of colloid science, to which our group and I dedicated much of our research time: (i) Lateral capillary forces between particles bound to a liquid interface; (ii) Growth of giant wormlike surfactant micelles and (iii) Oscillatory structural forces in liquid films and between colloidal particles, which combine effects of both capillarity and self-assembly.

The lateral capillary forces are due to the overlap of the deformations in the fluid interface created by each separate particle. Depending on the source of deformation, one can distinguish flotation forces (due to particle weight); immersion forces (due to particle wettability) [1,2], and forces between capillary multipoles (due to undulated contact line) [3]. Effects of particle charge and electric field will be also considered. The action of lateral capillary forces, reinforced with convective flow, leads to two-dimensional particle self-assembly, which has found applications in numerous bottom-up technologies.

Other self-assembled objects are the wormlike micelles (WLM), which determine the rheology of various products used by us in personal-care and house-hold detergency. The challenge in the theoretical description and understanding of micelle growth is related to the fact that one has to predict the so-called micelle "scission energy" with a very high accuracy. The problem was successfully solved and the micelle aggregation number was predicted without using any adjustable parameters. In the case of ionic WLM, one has to take into account the effects of counterion binding and activity coefficients [4,5].

The phenomenon stratification of foam films, which was known for decades, was interpreted as a layer-by-layer thinning of micellar (or particle) structure inside the film. It is a result of the action of oscillatory structural surface forces [6,7]. The oscillatory character of this force leads to its dualistic character – the maxima act as barriers preventing close contact and produce a stabilizing effect on colloidal dispersions. In contrast, the oscillatory minima act as potential wells and could give rise to flocculation, especially the deepest depletion minimum. A recently discovered phenomenon – vortex in evaporating foam films – reveals that particle ordering exists even in thick liquid films, containing 30–40 layers of micelles [8].

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