Mesoscopic theory for soft-matter systems

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Mesoscopic theory for soft-matter systems that combines density functional and statistical field theory is derived by a systematic coarse-graining procedure for particles interacting with spherically-symmetric potentials of arbitrary form. In the special case of weak ordering on the mesoscopic length scale the theory takes the form similar to either the Landau-Ginzburg-Wilson (LGW) or the Landau-Brazovskii (LB) field theory, depending on the form of the (effective) interaction potential between particles. Phenomenological parameters that appear in the Landau-type theories are expressed in terms of thermodynamic variables and parameters characterizing (effective) interactions.

Within the framework of this theory we obtain either separation into uniform phases (LGW case), or formation of soft crystals (LB case). In the latter case the theory predicts universal sequence of phases: disordered, bcc, hexagonal, lamellar, inverted hexagonal, inverted bcc, disordered, for increasing density of particles, well below the close-packing density. The sequence of phases agrees with experimental observations and with simulations of many self-assembling systems. In addition to the above phases, more complex phases may appear depending on the interaction potentials. For a particular form of the short-range attraction long-range repulsion potential we find the bicontinuous gyroid phase (Ia3d symmetry) that may be related to a network forming cluster of colloids in a mixture of colloids and nonadsorbing polymers.