Solid-fluid interfacial properties of model ferrofluids

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Ferrofluids are colloidal suspensions of ferromagnetic particles dispersed in a solvent. Experimental studies of the interfacial behavior of these fluids have recently attracted considerable attention [1]. Some theoretical analyses of the wall induced alignment of dipolar particles have also been published [2,3] but most of them are based on integral equation theories [2] and less sophisticated density-functional theories [3]. In the present work we extend our modified mean-field (MMF) density-function theory [4] to the study of inhomogeneous dipolar fluid and fluid mixtures.

Microscopic model

The interaction of magnetic dipoles is modeled by the Stockmayer potential, which is the sum of the isotropic Lennard-Jones and the anisotropic dipole-dipole interactions.

MMF density-functional theory

Our analysis is based on the following grand canonical variational functional:

$$\Omega[\rho(z),\alpha(z,\vartheta)]/A = \int_0^\infty dz \{ f_{HS}(\rho(z)) + k_B T \rho(z)$$
$$\times \int d\omega \alpha(z,\omega) \ln[4\pi\alpha(z,\omega)] \}$$
$$-\int_0^\infty dz \int d\omega \rho(z)\alpha(z,\omega)(\mu - V_{ext}(z,\omega))$$
$$+(1/2)\int_0^\infty dz \int_0^\infty dz' \int d\omega \int d\omega' \Phi_{eff}(z,z',\omega,\omega')$$
$$\times \rho(z)\alpha(z,\omega)\rho(z')\alpha(z',\omega')$$

where A, T and μ denote the area of the solid-fluid interface, its temperature and the chemical potential, respectively, $\rho(z)$

is the number density and $\alpha(z,\omega)$ is the orientational distribution function, f_{HS} is the free energy density of hard-sphere system, V_{ext} is the external potential and Φ_{eff} is the analytically calculated effective potential. The equilibrium profiles minimize Ω. For the functional we use the fundamental measure theory originally proposed by Rosenfeld [5]. The magnetization of the inhomogeneous system is obtained from the orientation distribution function.

Results

The density and magnetization profiles of magnetic particles are determined at different temperatures and chemical potentials. The temperature and dipole-strength dependence of the excess adsorption is discussed. Applying an external magnetic field the magnetostriction coefficient of ferrofluids is calculated both in the bulk and the spatially inhomogeneous phases.

References

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