TYPE Editorial
PUBLISHED 26 March 2024
DOI 10.3389/fphy.2024.1388370

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OPEN ACCESS

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RECEIVED 19 February 2024
ACCEPTED 11 March 2024
PUBLISHED 26 March 2024

CITATION
Castañeda-Priego R, Pica Ciamarra M, Corezzi S, Ghosh SK and Liu Y (2024), Editorial: Reviews in soft matter physics.
Front. Phys. 12:1388370.
doi: 10.3389/fphy.2024.1388370

Editorial: Reviews in soft matter physics

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KEYWORDS

soft matter, physics, review, colloid, interface, carbon black, membrane, neutron scattering

Editorial on the Research Topic
Reviews in soft matter physics

Soft matter covers a wide range of materials important for our everyday life, such as paints, shampoos, biological systems, therapeutic materials, batteries, and food. Often, soft materials are very complicated with a hierarchical structure covering the length scale for many orders of magnitude. The structural complexity makes it challenging to understand the structure-property relationships for soft matter materials. This Research Topic, Reviews in Soft Matter Physics, includes timely reviews of a few interesting research fields: the effect of the surface roughness on colloids at fluid interfaces by Rahman et al., the effect of the particle shape on the phase behavior of 2D colloidal systems by Wang et al., the rheology of carbon black suspension by Richards et al., phospholipid membranes influenced by molecular and nanoscopic additives by Kumargage et al., and the use of neutron spin echo tools to study soft materials by Luo et al. These reviews provide experts' opinions of the current status and challenges in these fields.

Colloidal particles are omnipresent at immiscible fluid interfaces. Rahman et al. highlight the significance of colloidal particles, specifically those with surface roughness, in various natural and human-made substances. These particles play a crucial role in diverse applications. Conventional studies focus on smooth spherical colloidal particles, and pay very little attention to heterogeneous surface topography. Recent research emphasizes the significant impact of particle surface roughness on material properties, highlighting increased interest in rough particle suspensions and interfaces. Surface roughness induces attractive capillary interactions among isotropic spherical particles, leading to 2D aggregation at fluid interfaces. Conversely, for shape-anisotropic particles, it masks the interaction, fostering well-dispersed monolayers. Tailoring particle surface roughness introduces distinctive and adjustable behaviors across diverse materials. The review covers rough particles' "life cycle" at interfaces, exploring single-particle adsorption, interparticle interactions, assembly, rheology, and desorption, and investigates the connection between these behaviors and their applications, such as Pickering emulsions and foams to develop 2D materials. It emphasizes the recent emerging interest in particle surface roughness as a tunable design parameter for influencing interfacial pinning, capillary interactions, assembly, and the mechanics of particulate monolayers, which offers insights into various naturally occurring phenomena such as bacterial movement or the migration of microplastics.

Most investigations on the thermodynamics, structure and transport properties of colloidal dispersions focused on spherical particles for which the interparticle interaction only depends on the relative distance between the particles. When the spherical symmetry is broken and the interaction potential depends on the orientation of the particles, colloidal dispersions exhibit a richer and more intriguing phenomenology. Wang et al. summarized their recent experimental contributions on suspensions of ellipsoidal and rod-shaped particles in a two-dimensional geometry. When in equilibrium, these particles form a nematic phase at high density, while when quenched, they are trapped in a disordered solid state. Intriguingly, this transition occurs in two steps, the freezing of rotational motion occurring before that of the translational one. Elongated particle's tendency to arrest in a disordered structure is further highlighted by mixing them with a monolayer of spheres. In this instance, a small density of elongated particles is enough to destroy the 2D crystal of spheres. Furthermore, they also provided some perspectives and challenges that pointed out the relevance of the particle shape on the colloidal self-assembly and stability.

Carbon black is commonly used in fuel cell electrodes, batteries, and conductive inks. Many applications need to suspend carbon black into a liquid. Understanding the rheological response is a key to successful applications. However, carbon black suspensions have complicated rheological behavior. Richards et al. reviewed the recent research efforts to link rheological behavior of carbon black suspensions with their microscopic structures. The authors discussed in detail the hierarchical structures of carbon black suspensions and the microstructure changes at a weak flow regime and a strong flow regime. They also showed the effect of Mason number in predicting the microstructure properties of complex carbon black suspensions. These discussions are useful to further optimize the processing methods of manufacturing this important type of systems.

Lipid membranes play a crucial role in living cells, where they simultaneously serve as a protective barrier and communication channel between cells and their environment. This biological multifunctionality has also inspired the design of synthetic lipid membranes for many practical applications. Whether biological or synthetic, lipid membranes typically host molecular or nanoscopic additives that modulate the properties relevant to their biological function or artificial performance. The review by Kumarage et al. focuses on phospholipid membranes and discusses how their structural, thermodynamic, elastic, and dynamic properties are affected by different classes of additives, in an effort to explore the interdependence between partitioning of additives into phospholipid membranes and resultant physical membrane properties. It also points to the potential to elucidate the evolutionary optimization of biological membranes and to accelerate the development of artificial lipid membranes with functions tuned for applicative purposes.

Neutron scattering is a commonly used technique to study soft matter materials. The review by Luo et al. discusses two types of neutron instruments, spin-echo small angle neutron scattering (SESANS) and neutron spin echo (NSE), and how these instruments can be used to study different types of materials. SESANS can probe the structures of materials by measuring the spatial correlation function instead of the scattering patterns in the reciprocal space. And NSE probes the dynamics of materials by measuring intermediate scattering functions. The basic principles of both SESANS and NSE are presented with the applications of these two instruments to study a wide range of materials, such as colloidal systems, concentrated protein solutions, protein internal domain motions, lipid membranes, microemulsions.

The soft matter materials are directly related with everyday life of our society. However, our comprehension of the fundamental physics of these materials is still limited. The reviews presented in this Research Topic are just a small collection of a broad range of active research fields in soft matter physics. They clearly provide a glimpse of the opportunities and challenges in these vibrant research fields to our community. Nevertheless, more experimental, theoretical and computational research efforts are certainly needed to deepen our understanding and expand our knowledge in soft matter physics.

Author contributions

RC-P: Writing–original draft, Writing–review and editing. MP: Writing–original draft, Writing–review and editing. SC: Writing–original draft, Writing–review and editing. SG: Writing–original draft, Writing–review and editing. YL: Writing–original draft, Writing–review and editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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