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“Outstanding Young Researchers” Special Issue
Editorial Overview

A glance into the future of colloid and interface science: What outstanding young researchers tell us.

Nicholas Abbott and Marie Pierre Krafft

Colloids and interfaces are ubiquitous in our lives and environment, from living cells to fuel cells, from food to medicine, from cosmetics to large tonnage industrial products. In the recent years, colloidal systems have played an increasing role in emerging strategies in medicine and energy by furthering innovative frontline materials (functional nanoparticles, graphene oxide, ionic liquids, etc.) and exquisitely engineered interfaces. Structural complexity, often inspired from naturally-occurring systems, allows augmented functionality. The outstanding young authors of this Special Issue have captured such advancements reached through new conceptual and experimental tools, innovative materials, deeper understanding of interfaces many of which are involved in strategic applications, and the exploration of novel purposes. Our knowledge of colloidal systems engages more and more dynamic or dissipative systems rather than thermodynamic ones in a continuously expanding scope of applications.

In this Issue, on the more fundamental side, Liu and Xi explore the phase behavior, structures and dynamics of colloidal systems having both short-range attraction and long-range repulsion. The competition between the two features results in phase separation, leading to the formation of intermediate-range order structures and engenders new phases in both equilibrium and nonequilibrium phase diagrams. More realistic than the usual hard sphere - or sticky hard sphere - interaction-based models, these systems should, in particular, help understand the behavior of proteins in concentrated solutions. In addition, Jiang discusses key differences that underlie assemblies formed by either lipids or proteins, and then presents some intriguing recent results on the self-assembly of cyclodextrin complexes and the emerging field of “lattice self-assembly”.

Understanding the mechanisms that govern complex and emergent behaviors is an everlasting challenge. Using experimental rheology, along with modeling and simulations, Germann analyzes localized velocity bands produced by strong shearing deformation in solutions of polymers. Shear banding is a ubiquitous phenomenon in many soft materials. Taking advantage of the improved spatial and temporal resolution allowed by single-molecule fluorescence, Niu and Wang examine the translational diffusion and adsorption/desorption kinetics of polymers at a solid/liquid interface.

Graphene oxide, the water-dispersible complement of graphene has tremendous potential in water-borne hybrid materials, coatings, membranes and adsorbents.

However, whether its behavior is most accurately described as particle-like or surfactant-like remains is still questioned. Tabor et al. examine the recent developments in our understanding of the bulk and interfacial colloidal properties of graphene oxide in the context of its chemistry and system thermodynamics, and provide insight on this critical question.

Several reviews in this edition focus on interfaces that are critical to new applications. In particular, some interfaces are subjected to large amplitude deformations at a high strain rate during processing or uses. Garbin examines the dynamics of particle-laden interfaces when submitted to extreme deformations. Such interfaces are present in numerous advanced materials, including bijels, dry water, foams and medical microbubbles used in ultrasound contrast diagnosis. Trybala reports on recent studies of drainage and imbibition of foams on porous substrates, emphasizing the distinction between free foam drainage and drainage of foam supported on porous substrates using both experiment and theory. Applications of foams to the cosmetics and pharmaceutical industry are described. Loget discusses the hot topic of solar energy conversion using silicon-based light absorbing interfaces coupled with low-cost transition metal nanocatalysts. The main interfacial architectures employed are reviewed and the emerging strategies used to efficiently oxidize water under solar illumination are discussed. Ionic liquids have promising applications in lubrication and energy storage. Radiom describes the ionic liquid-solid interface under space confinement. Camargo et al. analyze the current status of plasmonic nanocatalysis, a novel frontier in catalysis that enables the use of light in the visible or near-infrared regions as a sustainable energy input to drive molecular transformations using controlled nanostructures based on plasmonic and catalytic metal model systems.

A series of perspectives are also presented on recent studies relevant to conventional and particle-stabilized emulsions. Davies et al. describe progress in the development of Pickering emulsions stabilized by organic or inorganic particles for biomedical applications based on both probing their design for passive diffusion-based release as well as stimuli-responsive delivery. Maestro reports on spontaneous adsorption of ligand-coated nanoparticles at fluid interfaces, with a focus on the effect of ligands on interfacial structure (characterized by using neutron scattering methods) and interfacial rheological properties. Salentining discusses the equilibrium and dynamic colloidal properties of food emulsion droplets during digestion and their implications for designing nature-inspired functional personalized food colloidal materials. Maldonado-Valderrama presents her opinion on the latest developments in analytical methods and measurements of the digestion of interfacial lipid layers that determine the fate of emulsions during oral, gastric and duodenal physiological processes.

Advances in colloidal systems for use in medicine are highlighted in a number of articles published in this edition. Rosenholm reports on the formation and characterization of nanoparticles of diamond, with an emphasis on the photoluminescent properties and potential for use in biomedical imaging. Merkel provides an insightful perspective on the challenges of developing colloidal systems that permit the delivery of nucleic acids for gene therapy. The promise of polymeric

nanogels is highlighted along with unresolved challenges. Finally, Howell describes recent advances involving liquid-infused surfaces, and their potential utility in enabling new levels of control over the movement of droplets on surfaces in the context of point-of-need diagnostics. The topics addressed in the article include approaches to active control of droplet movements.

In addition, several articles focus on descriptions of recent efforts to understand complex biological processes through development of simple laboratory models. For examples, Perry presents a fascinating view of recent research involving the phase separation of polymers, driven by the growing appreciation of the role of membraneless organelles within biological cells. Parallels between observations of phase separation in synthetic and living systems are discussed. Guzman describes more efforts to develop models of surfactant-decorated interfaces present in the lung, and the use of these models to assess the toxicity of inhaled particles. Sarkar describes the slippery topic of biotribology of the mouth, where a remarkable diversity of surfaces (from hard enamel to soft tissue and foods) slide against each other in the presence of complex endogenous biolubricants. Opportunities for new materials technologies are discussed.

Overall, this edition will convey to the reader that complexity and functionality have become major keywords in the field, and that the area is rich in compelling fundamental and applied challenges. Most importantly, the quality and sharp insight offered by the young and talented authors of this edition tell us that the future of our field is very bright indeed. We hope this edition will serve to introduce these young and promising researchers to our community.