

Particles At Fluid Interfaces And Membranes Volume 10 Attachment Of Colloid Particles And Proteins To Interfaces And Formation Of Two Dimensional Arrays Studies In Interface Science

There has been much scientific interest in the behaviour of colloidal particles at liquid interfaces. From a research aspect they provide model systems for fundamental studies of condensed matter physics. From a commercial aspect they provide applications for making new materials in the cosmetics, food and paint industries. In many cases of colloidal particles at interfaces, the mechanism of particle interactions is still unknown. Particle-Stabilized Emulsions and Colloids looks at recent studies on the behaviour of particles at liquid interfaces. The book first introduces the basic concepts and principles of colloidal particles at liquid-liquid interfaces including the interactions and conformations. The book then discusses the latest advances in emulsions and bicontinuous emulsions stabilized by both solid and soft particles and finally the book covers applications in food science and oil extraction. With contributions from leading experts in these fields, this book will provide a background to academic researchers, engineers, and graduate students in chemistry, physics and materials science. The commercial aspects will also be of interest to those working in the cosmetics, food and oil industry.

Volume V is the counterpart of Volume IV and treats hydrophilic colloids and related items. Contains edited contributions on steric stabilization, depletion, polyelectrolytes, proteins at interfaces, association colloids, microemulsions, thin films, foams and emulsions. J. Lyklema is coauthor of two chapters and general editor. Other authors include: G.J. Fleer, F.A.M. Leermakers, M.A. Cohen Stuart, W. Norde, J.A.G. Buijs, J.C. Eriksson, T.Sottmann, R. Strey, D. Platikanov, D. Ekserova, V.Bergeron and P.Walstra. * This volume completes the prestigious series Fundamentals of Interface and Colloid Science. * Together with Volume IV this book provides a comprehensive introduction to colloid science. * Explains and elaborates phenomena starting from basic principles and progresses to more advanced topics

It is well known that charged colloidal particles may form an effective two dimensional suspension at a fluidic interface. Research toward the understanding of the dynamics and collective behavior of these suspended particles is at the core of engineering Pickering emulsions, which have a broad range of practical applications. In the first half of this dissertation, we will explore the single phase particle monolayer. Although microscopic images and rheological measurements have been obtained in abundance, the underlying physics behind the collective behavior of such systems is yet to be fully understood. We started by examining the attractive and repulsive potentials in this system. In the case of charged colloidal particles at a fluidic interface, capillary attraction rises from the meniscus deformation, which is predominantly due to the mismatch of dielectric constants between the aqueous phase and the non-polar phase. On the other hand, aggregation is prevented by the long range Coulombic repulsion through the non-polar phase as proposed by Aveyard and coworkers. With the basic knowledge of interaction potentials present, Monte Carlo simulation and Brownian dynamics simulation were performed, assuming pair-wise interactions with all physical constants of a system consisting of latex particles trapped at a water-decane interface. Microscopic images of such a system were recorded concurrently, serving as an internal verification of the numerical simulation. Furthermore, the pair distribution function in the radial direction and the angular order parameter, were extracted from the equilibrium configuration of the Monte Carlo simulation as well as real-time microscopic images to investigate the phase transition behaviour. The primitive simulation results agreed with the experimental observation qualitatively, showing a two-dimensional phase transition from a disordered phase to an ordered solid phase as the surface coverage of the particles increases. In the second half of the dissertation, we focus on the coalescence experiments involving a Pickering droplet. Many experiments have been performed where two particle laden interfaces have been brought into close contact in a controlled manner and various observations, including particle "bridging", have been made in an attempt to understand the stabilization mechanism of interfacial particles in a Pickering emulsion. One of the most interesting observations is the tendency for the particles on one interface to "evacuate" and those on the other interface to "aggregate" during the close approach of the surfaces. In this work, we propose to understand the mechanism of particle evacuation- aggregation via a combined experimental and theoretical approach. First, we performed real-time experiments where two particle-laden water-decane interfaces were brought into contact. Many phenomena including particle evacuation-aggregation and bridging were observed. We then developed a Brownian dynamics simulation of the evacuation-aggregation including the important relevant interparticle interactions that we presumed were important in describing the phenomena. In order to do so, we had to answer three questions. First, what are the relevant aspects of the charged particle interaction within the same interface? Second, what is the charge interaction across the two approaching interfaces? Third, what are the flow effects, including the flow between the two interfaces during approach, on the particle motion and how can we model such a flow? Toward this goal, we have incorporated both reasonable electric inter-particle interactions from available literature studies and flow interactions via a porous media model that relates the particle velocity to the local surface coverage through the effective permeability of a porous media. Thus the flow effects are captured in a mean field sense. The BD simulations were able to capture the evacuation-aggregation qualitatively and, in most instances, quantitatively. In particular the diameter of the evacuated area decreases with increasing surface coverage in both simulations and experiments, and we will describe the physical mechanisms leading to this behavior by analyzing the particle force balance in the BD simulations.

Colloidal Assembly at Fluid Interfaces for Advanced Materials Synthesis

Fluid Interfaces
Solid Particles at Fluid Interfaces
Liquid Marbles

Imaging Particle Motion, Interface Deformation and Capillary Forces

Particle-laden interfaces have promising potentials in many fields because the particulate nature can endow the surface with physical properties that are not readily obtained from molecular-scale surfactants. In this dissertation, we first focus on measuring capillary forces on particles at fluid interfaces in order to assess the key parameters that yield effective stabilizing particles. In experiment, the force and the displacement of a millimeter-scale particle passing through a liquid interface were recorded. We find that the peak force needed to detach a particle from an interface crowded with other particles is consistently smaller than the force at a clean interface. By ruling out other possibilities, we attribute the force reduction to the perturbation of interface shape due to the constraints imposed by free particles. Then we study the mechanics of particulate assemblies by measuring the force response under a normal indentation. We find that there exist two linear regions with different slopes. The small-slope regime starts at the beginning and persists over a range of indentations much less than capillary length. Once the system entered the higher plateau region, it has the same stiffness as a pure liquid interface. Further, from top-view images, we showed that, as long as the indenter was larger than the size of a single particle, the azimuthal compression can be relaxed through the in-plane rearrangement of particles. These features are independent of the difference in fluid mass densities, the radius of the indenter and the species of particles. Although the presence of floating particles at an interface does not change its capillary nature under a wide range of poking depth, we show that the existence of the particle raft makes the original interface tougher in terms of both the maximum force it can sustain and the largest indentation an indenter can reach. These results provide an important step toward understanding the mechanics of particulate assemblies at interfaces. Finally, we study the formation of organic 2D material in aqueous media for the purpose of potential applications in passivating objects in suspension. We optimized the conditions for the self-assembly of bola-amphiphilic molecules, and directly observed 2D sheets in optical microscope under dark-field illumination. We find that stacking is not preferred by sheets because of the likely electrostatic repulsion. Our method provides an effective way to better understand the properties of those sheets.

Anisotropic Particle Assemblies: Synthesis, Assembly, Modeling, and Applications covers the synthesis, assembly, modeling, and applications of various types of anisotropic particles. Topics such as chemical synthesis and scalable fabrication of colloidal molecules, molecular mimetic self-assembly, directed assembly under external fields, theoretical and numerical multi-scale modeling, anisotropic materials with novel interfacial properties, and the applications of these topics in renewable energy, intelligent micro-machines, and biomedical fields are discussed in depth. Contributors to this book are internationally known experts who have been actively studying each of these subfields for many years. This book is an invaluable reference for researchers and chemical engineers who are working at the intersection of physics, chemistry, chemical engineering, and materials science and engineering. It educates students, trains the next generation of researchers, and stimulates continuous development in this rapidly emerging area for new materials and innovative technologies. Provides comprehensive coverage on new developments in anisotropic particles Features chapters written by emerging and leading experts in each of the subfields Contains information that will appeal to a broad spectrum of professionals, including but not limited to chemical engineers, chemists, physicists, and materials scientists and engineers Serves as both a reference book for researchers and a textbook for graduate students

Fluid interfaces are promising candidates for confining different types of materials, e.g., polymers, surfactants, colloids, and even small molecules, to be used in designing new functional materials with reduced dimensionality. The development of such materials requires a deepening of the physicochemical bases underlying the formation of layers at fluid interfaces as well as on the characterization of their structures and properties. This is of particular importance because the constraints associated with the assembly of materials at the interface lead to the emergence of equilibrium and features of dynamics in the interfacial systems, which are far removed from those conventionally found in traditional materials. This Special Issue is devoted to studies on the fundamental and applied aspects of fluid interfaces, and attempts to provide a comprehensive perspective on the current status of the research field.

By Irina Kistner

Surface and Interfacial Forces

Soft Microgel Particles at Fluid Interfaces

Colloidal Particles at Fluid Interfaces and the Interface of Colloidal Fluids

Controlling Particle Morphologies at Fluid Interfaces

Structure and Interactions of Colloidal Particles at Fluid Interfaces

Small solid particles, confined in two-dimensions by fluid interfaces, were studied by a variety of experimental methods to understand particle motion, menisci shapes near interface-supported particles, and capillary interactions among such particles. Unwanted evaporation was circumvented by adopting non-volatile ionic liquids to create the fluid interfaces. A related application, employment of ionic liquids to float cryo-microtomed polymer sections, was also developed. The Brownian motions of nanospheres and nanorods in free-standing ionic liquid films were visualized in situ by high resolution scanning electron microscopy, which images features almost 100x smaller than possible in an optical microscope. For suspensions that are dilute and films that are thick compared to the particle diameter, the translational and rotational diffusion coefficients determined by single-particle tracking agreed with existing theoretical predictions. In thinner films, a striking and unexpected dynamical pairing of nanospheres was observed, suggesting a balance of capillary and hydrodynamic interactions. Nanospheres at high concentration displayed subdiffusive caged motion and hexagonal-lattice crystallization. Concentrated nanorods in the thin-film fluids transiently assembled into finite stacks but did not achieve high tetrahic liquid crystalline order, perhaps because of spherical impurities. A small spherical microparticles on a cylindrically curved liquid interface, to maintain constant contact angle about its wetted periphery, locally induces a quadrupolar interface deformation. Measured by optical profilometry, this deformation was compared to a recent theoretical expression, and good agreement was noted. The interface quadrupoles lead to particle capillary interactions in analogy to a 2D electrostatic quadrupoles, and as one consequence, spheres on a cylindrical interface assemble tetragonally. The assembly was monitored in the optical microscope, with particles driven to assembly as predicted, into a tetragonal lattice aligned with the underlying cylindrical axis. Lastly, ionic liquids and their mixtures with low molecular weight solvents were applied as flotation liquids for cryo-ultramicrotomy. With control of glass transition temperature and liquid viscosity, flat and ultra-thin sections were reliably floated onto transmission electron microscopy grids at cryogenic temperature. Compared to established flotation media for soft polymer systems, the required time and skill are significantly reduced, and the operator was not exposed to noxious fumes.

This book explores mathematics in a wide variety of applications, ranging from problems in electronics, energy and the environment, to mechanics and mechatronics. The book gathers 81 contributions submitted to the 20th European Conference on Mathematics for Industry, ECMI 2018, which was held in Budapest, Hungary in June 2018. The application areas include: Applied Physics, Biology and Medicine, Cybersecurity, Data Science, Economics, Finance and Insurance, Energy, Production Systems, Social Challenges, and Vehicles and Transportation. In turn, the mathematical technologies discussed include: Combinatorial Optimization, Cooperative Games, Delay Differential Equations, Finite Elements, Hamilton-Jacobi Equations, Impulsive Control, Information Theory and Statistics, Inverse Problems, Machine Learning, Point Processes, Reaction-Diffusion Equations, Risk Processes, Scheduling Theory, Semidefinite Programming, Stochastic Approximation, Spatial Processes, System Identification, and Wavelets. The goal of the European Consortium for Mathematics in Industry (ECMI) conference series is to promote interaction between academia and industry, leading to innovations in both fields. These events have attracted leading experts from business, science and academia, and have promoted the application of novel mathematical technologies to industry. They have also encouraged industrial sectors to share challenging problems where mathematicians can provide fresh insights and perspectives. Lastly, the ECMI conferences are one of the main forums in which significant advances in industrial mathematics are presented, bringing together prominent figures from business, science and academia to promote the use of innovative mathematics in industry.

Particles at Fluid Interfaces and MembranesAttachment of Colloid Particles and Proteins to Interfaces and Formation of Two-Dimensional ArraysElsevier

Collective Dynamics of Laterally Confined Active Particles Near Fluid-Fluid Interfaces

Colloidal Particles at Liquid Interfaces

Emulsions, Liquid Marbles, Dry Oil Powders and Oil Foams

Colloid and Interface Chemistry for Nanotechnology

Soft Colloids

Anisotropic Particle Assemblies

Bicontinuous interfacially jammed emulsion gels, now commonly termed 'bijels', are a class of soft materials, in which interpenetrating, continuous domains of two immiscible fluids are maintained in a rigid arrangement by a jammed layer of colloidal particles at their interface. Such gels have unusual material properties that promise exciting applications across diverse fields from energy materials and catalysis, to food science. This is the first book on the subject and provides the reader with a fundamental introduction. Edited by a recognised authority on bijels, the reader will learn about the bijel and its formation. Bringing together current understanding, this book aims to bring the potential application of bijels to diverse materials challenges closer to fruition. This is a must-have resource for anyone working in soft matter and applied fields.

This open access book, published in the Soft and Biological Matter series, presents an introduction to selected research topics in the broad field of flowing matter, including the dynamics of fluids with a complex internal structure -from nematic fluids to soft glasses- as well as active matter and turbulent phenomena. Flowing matter is a subject at the crossroads between physics, mathematics, chemistry, engineering, biology and earth sciences, and relies on a multidisciplinary approach to describe the emergence of the macroscopic behaviours in a system from the coordinated dynamics of its microscopic constituents. Depending on the microscopic interactions, an assembly of molecules or of mesoscopic particles can flow like a simple Newtonian fluid, deform elastically like a solid or behave in a complex manner. When the internal constituents are active, as for biological entities, one generally observes complex large-scale collective motions. Phenomenology is further complicated by the invariable tendency of fluids to display chaos at the large scales or when stirred strongly enough. This volume presents several research topics that address these phenomena encompassing the traditional micro-, meso-, and macro-scales descriptions, and contributes to our understanding of the fundamentals of flowing matter. This book is the legacy of the COST Action MP1305 "Flowing Matter".

Particles floating on fluid-liquid interfaces are of considerable interest because of their importance in a range of physical applications and biological processes, e.g., self-- assembly of particles at fluid-fluid interfaces resulting in novel nano structured materials, stabilization of emulsions, formation of pollen and insect egg rafts, etc. The aim of this dissertation is to explore the mechanism by which particles are adsorbed at fluid-liquid interfaces. It is shown that the inertia of a particle plays an important role in its motion in the direction normal to a fluid-liquid interface, and in determining the particles adsorption trajectory and orientation in the adsorbed state. Although the importance of inertia diminishes with decreasing particle size, on an air-water interface the inertia continues to be important even when the particle size is as small as a few nanometers. This dissertation also investigates the vertical oscillations of a particle while it is being adsorbed on an interface. The fact that the particle oscillates vertically implies that its behavior is similar to that of an under-damped mass-spring-dashpot system, and that it has characteristic linear and rotational frequencies which depend on the physical properties of the fluids involved and those of the particle. The experimentally measured frequency of oscillation of a particle is in approximate agreement with the frequency calculated analytically, which is noteworthy considering that the latter depends only on the fluid and particle properties, and that there are no adjustable parameters in the analytic expression. It is shown that similarly to an under-damped system, these characteristic frequencies can be excited by an external forcing. When a particle is adsorbed on a fluid-liquid interface it induces a relatively strong transient flow in the liquid which persists for several seconds. For a spherical particle the flow is axisymmetric about the vertical passing through the particle's center. To visualize this flow, an experiment is designed based of the Particle Image Velocimetry (PIV) technique. The measurements show that the fluid directly below the particle rises up, and near the interface it moves away from the particle. The velocity near the interface is found to be about an order of magnitude larger than in the liquid below the particle.

Force and Free Energy Analyses of Cylindrical and Spherical Particles at Fluid Interfaces

Particle-Stabilized Emulsions and Colloids

Colloidal Particles at Fluid-Fluid Interfaces

Adsorption of Particles on Fluid-Liquid Interfaces

Collective Behavior of Colloidal Particles on Fluid Interface

Formation, Characterization, and Applications

The controlled generation of varying shaped particles is important for many applications: consumer goods, biomedical diagnostics, food processing, adsorbents and pharmaceuticals which can benefit from the availability of geometrically complex and chemically inhomogeneous particles. This thesis presents two approaches to spherical and non-spherical particle synthesis using macro and microfluidics. In the first approach, a droplet microfluidic technique is explored to fabricate spherical conducting polymer, polyaniline, particles with precise control over morphology and functionality. Microfluidics has recently emerged as an important alternate to the synthesis of complex particles. The conducting polymer, polyaniline, is widely used and known for its stability, high conductivity, and favorable redox properties. In this approach, monodisperse micron-sized polyaniline spherical particles were synthesized using two-phase droplet microfluidics from Aniline and Ammonium persulfate oxidative polymerization in an oil-based continuous phase. The morphology of the polymerized particles is porous in nature which can be used for encapsulation as well as controlled release applications. Encapsulation of an enzyme, glucose oxidase, was also performed using the technique to synthesize microspheres for glucose sensing. The polymer microspheres were characterized using SEM, UV-Vis and EDX to understand the relationship between their microstructure and stability. In the second approach, molten drop impact in a cooling aqueous medium to generate non-spherical particles was explored. Viscoelastic wax based materials are widely used in many applications and their performance and application depends on the particle morphology and size. The deformation of millimeter size molten wax drops as they impacted an immiscible liquid interface was investigated. Spherical molten wax drops impinged on a cooling water bath, then deformed and as a result of solidification were arrested into various shapes such as ellipsoids, mushrooms, spherulites and discs. The final morphology of the wax particles is governed by the interfacial, inertial, viscous and thermal effects, which can be studied over a range of Weber, Capillary, Reynolds and Stefan numbers. A simplified Stefan problem for a spherical drop was solved. The time required to initiate a phase transition at the interface of the molten wax and water after impact was estimated and correlated with the drop deformation history and final wax particle shape to develop a capability to predict the shape. While the microfluidic synthesis approach offers precise control over morphology and functionality, large particle throughput is a limitation. The drop impact in a liquid medium emulsion approach is limited to crosslinking or heat sensitive materials but can be extended to large scale production for industrial applications. Both approaches are simple, robust and cost effective making them viable and attractive solutions for complex particle synthesis. The choice of the approach is dependent on considerations such as particle material, size, shape, throughput and end application.

Particles at Fluid Interfaces encompasses the processes and formulations that involve the stabilisation of fluid interfaces by adsorbed particles. The prevalence of these multiphase materials underpins their use in a broad range of industries from personal care and food technology to oil and mineral processing. The stabilisation conferred by the adsorbed particles can be transient as found in froth flotation or long-lived as occurs within Pickering Emulsions. The particles can range in size from nanoparticles to millimetre-sized particles, and cover a spectrum from collapsed proteins, polymeric colloids of controlled size and shape to high dispersity mineral particles.

Particles can be adsorbed to liquid-liquid interface to minimize interfacial energy. The adsorbed particles interact in many ways. There has been a lot of theoretical predictions as well as experimental measurements of the interaction potential between particles confined at interfaces. Experimentally, we track multiple particles using optical microscope image processing of isolated pairs of particles and of more concentrated systems. Statistical methods were implemented to compute microparticle interaction forces from tracking data. The analysis of different microscopy and conventional microscopy are used to elucidate links between the microstructure and mechanical properties of a unique class of solid-stabilized emulsion formed by the bridging of fluid droplets by an interfacial particle monolayer. Remarkably, the rheological behavior is governed predominately by the solids loading and can be tailored irrespective of the droplet volume fraction. The perturbation to a cylindrical interface upon adsorption of a single spherical particle is studied first. We present an analytical model of the interfacial shape and energy upon adsorption of a single particle, and then calculate the interaction between two particles. Based on our result for a cylindrical interface, we propose a general formula for the force on a particle on a curved interface having constant mean curvature (i.e., not subject to an external forces). This study provides an important step toward understanding the interactions among interfacial particles.

Emulsion Stability and Multiphase Flow

Bicontinuous Particle-stabilized Emulsions

An Introduction to Interfaces & Colloids

Synthesis, Assembly, Modeling, and Applications

From Stabilizing Emulsions to Destabilizing Them

The Bridge to Nanoscience

A general introduction to surface and interfacial forces, perfectly combining theoretical concepts, experimental techniques and practical applications. In this completely updated edition all the chapters have been thoroughly revised and extended to cover new developments and approaches with around 15% new content. A large part of the book is devoted to surface forces between solid surfaces in liquid media, and while a basic knowledge of colloid and interface science is helpful, it is not essential since all important concepts are explained and the theoretical concepts can be understood with an intermediate knowledge of mathematics. A number of exercises with solutions and the end-of-chapter summaries of the most important equations, facts and phenomena serve as additional tools to strengthen the acquired knowledge and allow for self-study. The result is a readily accessible text that helps to foster an understanding of the intricacies of this highly relevant topic.

In the small world of micrometer to nanometer scale many natural and industrial processes include attachment of colloid particles (solid spheres, liquid droplets, gas bubbles or protein macromolecules) to fluid interfaces and their confinement in liquid films. This may lead to the appearance of lateral interactions between particles at interfaces, or between inclusions in phospholipid membranes, followed eventually by the formation of two-dimensional ordered arrays. The book is devoted to the description of such processes, their consecutive stages, and to the investigation of the underlying physico-chemical mechanisms. The first six chapters give a concise but informative introduction to the basic knowledge in surface and colloid science, which includes both traditional concepts and some recent results. Chapters 1 and 2 are devoted to the basic theory of capillarity, kinetics of surfactant adsorption, shapes of axisymmetric fluid interfaces, contact angles and line tension. Chapters 3 and 4 present a generalization of the theory of capillarity to the case, in which the variation of the interfacial (membrane) curvature contributes to the total energy of the system. The general Laplace equation is applied to determine the configurations of free and adherent biological cells. Chapters 5 and 6 are focused on the role of thin liquid films and hydrodynamic factors in the attachment of solid and fluid particles to an interface. Surface forces of various physical nature are presented and their relative importance is discussed. Hydrodynamic interactions of a colloidal particle with an interface (or another particle) are also considered. Chapters 7 to 10 are devoted to the theoretical foundation of various kinds of capillary forces. When two particles are attached to the same interface (membrane), capillary interactions appear between them. Two major kinds of capillary interactions are described: (i) capillary immersion force related to the surface wettability (Chapter 7), (ii) capillary flotation force originated from interfacial deformations due to particle weight (Chapter 8). Special attention is paid to the theory of capillary immersion forces between particles entrapped in spherical liquid films (Chapter 9). A generalization of the theory of immersion forces allows one to describe membrane-mediated interactions between protein inclusions into a lipid bilayer (Chapter 10). Chapter 11 is devoted to the theory of the capillary-bridge forces, whose importance has been recognized in phenomena like consolidation of granules and soils, wetting of powders, capillary condensation, long-range hydrophobic attraction, etc. The nucleation of capillary bridges is also examined. Chapter 12 considers solid particles, which have an irregular wetting perimeter upon attachment to a fluid interface. The undulated contact line induces interfacial deformations, which engender a special lateral capillary force between the particles. The latter contributes to the dilatational and shear elastic moduli of particulate adsorption monolayers. Chapter 13 describes how lateral capillary forces, facilitated by convective flows and some specific and non-specific interactions, can lead to the aggregation and ordering of various particles at fluid interfaces or in thin liquid films. Recent results on fabricating two-dimensional (2D) arrays from micrometer and sub-micrometer latex particles, as well as 2D crystals from proteins and protein complexes, are reviewed. Chapter 14 presents applied aspects of the particle-surface interaction in antifouling and defouling. The mechanisms of antifouling action involve as a necessary step the entering of an antifoum particle at the air-water interface. The considered mechanisms indicate the factors for control of fouling.

This work uses silica nanoparticles to stabilize oil-in-water and water-in-water emulsions. These emulsions are called Pickering emulsions and have potential use for enhanced oil recovery. There are two challenges with using nanoparticles for subsurface applications which are the high salinities and elevated temperatures of reservoir brines. These conditions are problematic because nanoparticles without surface modification are unstable, because of nanoparticle charge screening, which leads to particle agglomeration. Additionally, much of the current research on particle stabilized emulsions focuses on using nanoparticles modified with hydrophobic molecules or surfactants with the sole intent of getting particles to the oil/water interface. Because of this, many of these particles are not applicable for subsurface applications due to their lack of stability in brine. To address these challenges, I functionalize silica nanoparticles with different concentrations of a hydrophilic silane called (3-glycidyloxypropyl)trimethoxysilane (glymo) and stabilize Pickering emulsions with these particles. Glymo was selected as a nanoparticle surface modifier because of its ability to sterically stabilize particles in brine. I characterized the static stability of different Pickering emulsion formulations by using a centrifuge and by calculating the emulsion demulsification pressure. I correlate a critical demulsification pressure to emulsions that show little change in emulsion drop size while flowing, which I define as dynamically stable. The critical demulsification pressure is applied to several untested Pickering emulsion formulations to verify its applicability as an emulsion pre-screening tool. I perform a rheological characterization on emulsions stabilized with low and high surface coverage glymo-coated particles to establish relationships between nanoparticle bridging and the extent of glymo surface modification with different ionic strength brines. I use cryo-scanning electron microscopy to visually assess the bridging behavior of these different Pickering emulsions. I use fumed silica particles, with different wettabilities, and assess their ability to destabilize a model Pickering emulsion. I determine there is a strong correlation between the wettability of a fumed silica particle and its ability to destabilize a model emulsion. This work is relevant because most of the current research on Pickering emulsions focuses primarily on how to tune the properties of colloidal particles to generate stable emulsions with less overall emphasis on methods to destabilize them. Lastly, an aqueous, two phase system is stabilized with 6 nm and 50 nm silica particles modified with 2-(methoxy(polyethyleneoxy)6-3-propyl)trimethoxysilane (PEG-silane). Stabilization of the water/water interface results in emulsions that have relatively good stability to shear. Water-in-water emulsions do not contain any oil which is often considered a major limitation of Pickering emulsions for EOR, therefore these emulsions are potential candidates for enhanced oil recovery

Formation and Applications

Attachment of Colloid Particles and Proteins to Interfaces and Formation of Two-Dimensional Arrays

Measured Capillary Forces on Spheres at Liquid Interfaces and the Mechanics of Interfacial Particulate Assemblies

Fundamentals of Interface and Colloid Science

Particles at Fluid Interfaces and Membranes

Directed Assembly of Complex Shaped Particles at Fluid Interfaces

Colloid and interface science dealt with nanoscale objects for nearly a century before the term nanotechnology was coined. An interdisciplinary field, it bridges the macroscopic world and the small world of atoms and molecules. Colloid and Interface Chemistry for Nanotechnology is a collection of manuscripts reflecting the activities of research to

Certain small solid particles are surface-active at fluid interfaces and thus are able to stabilize materials previously considered impossible to stabilize in their absence. Liquid marbles, particle-coated non-sticking liquid droplets, represent one of these materials. Preparation of liquid marbles was described only about 15 years ago and they are now widely studied by many research groups and numerous applications of liquid marbles have been advanced. The book is written for postgraduates and researchers working on the area who are training to become chemists, soft matter physicists, materials scientists, and engineers.

Planar fluid interfaces -- Interfaces of moderate curvature : theory of capillarity -- Surface bending moment and curvature elastic moduli -- General curved interfaces and biomembranes -- Liquid films and interactions between particle and surface -- Particles at interfaces : deformations and hydrodynamic interactions -- Lateral capillary forces between partially immersed bodies -- Lateral capillary forces between floating particles -- Capillary forces between particles bound to a spherical interface -- Mechanics of lipid membranes and interaction between inclusions -- Capillary bridges and capillary-bridge forces -- Capillary forces between particles of irregular contact line -- Two-dimensional crystallization of particulates and proteins -- Effect of oil drops and particulates on the stability of foams.

Performance as Interfacial Stabilizers

Surfactants

Particles Confined by Fluid Interfaces

Free Energy and Force Analyses of Heterogeneous Cylindrical Particles at Fluid Interfaces

Capillary Interactions Among Microparticles and Nanoparticles at Fluid Interfaces

Bijels

Colloidal particles can stabilize a fluid interface. This phenomenon, first observed over a century ago, enables a robust "bottom-up" approach for synthesis of functional materials with well-defined microstructure using colloids with tunable chemistry and geometry as building blocks. Familiar examples are particle-stabilized emulsions and foams, which are utilized in several industries including personal products, foods, and pharmaceuticals. In this dissertation, the assembly of particles at fluid interfaces is investigated with two underlying intentions: to develop new insight into how the 3-D morphology of particle-stabilized interfaces can influence the rheological properties of soft materials. For materials synthesis, colloidal particles with specific wetting properties arrest spinodal decomposition of a partially miscible fluid pair. The resultant non-equilibrium microstructure, known as a bijel, is then used as a general platform to synthesize a novel family of bicontinuous macroporous, hierarchically porous, and composite materials with tunable chemistry and morphology. Applications for these materials are numerous and related to the same interface (membrane), capillary interactions appear between them. Two major kinds of capillary interactions are described: (i) capillary immersion force related to the surface wettability (Chapter 7), (ii) capillary flotation force originated from interfacial deformations due to particle weight (Chapter 8). Special attention is paid to the theory of capillary immersion forces between particles entrapped in spherical liquid films (Chapter 9). A generalization of the theory of immersion forces allows one to describe membrane-mediated interactions between protein inclusions into a lipid bilayer (Chapter 10). Chapter 11 is devoted to the theory of the capillary-bridge forces, whose importance has been recognized in phenomena like consolidation of granules and soils, wetting of powders, capillary condensation, long-range hydrophobic attraction, etc. The nucleation of capillary bridges is also examined. Chapter 12 considers solid particles, which have an irregular wetting perimeter upon attachment to a fluid interface. The undulated contact line induces interfacial deformations, which engender a special lateral capillary force between the particles. The latter contributes to the dilatational and shear elastic moduli of particulate adsorption monolayers. Chapter 13 describes how lateral capillary forces, facilitated by convective flows and some specific and non-specific interactions, can lead to the aggregation and ordering of various particles at fluid interfaces or in thin liquid films. Recent results on fabricating two-dimensional (2D) arrays from micrometer and sub-micrometer latex particles, as well as 2D crystals from proteins and protein complexes, are reviewed. Chapter 14 presents applied aspects of the particle-surface interaction in antifouling and defouling. The mechanisms of antifouling action involve as a necessary step the entering of an antifoum particle at the air-water interface. The considered mechanisms indicate the factors for control of fouling.

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Particles at Fluid Interfaces and Membranes

Directed Assembly of Complex Shaped Particles at Fluid Interfaces

Colloid and interface science dealt with nanoscale objects for nearly a century before the term nanotechnology was coined. An interdisciplinary field, it bridges the macroscopic world and the small world of atoms and molecules. Colloid and Interface Chemistry for Nanotechnology is a collection of manuscripts reflecting the activities of research to

Certain small solid particles are surface-active at fluid interfaces and thus are able to stabilize materials previously considered impossible to stabilize in their absence. Liquid marbles, particle-coated non-sticking liquid droplets, represent one of these materials. Preparation of liquid marbles was described only about 15 years ago and they are now widely studied by many research groups and numerous applications of liquid marbles have been advanced. The book is written for postgraduates and researchers working on the area who are training to become chemists, soft matter physicists, materials scientists, and engineers.

Planar fluid interfaces -- Interfaces of moderate curvature : theory of capillarity -- Surface bending moment and curvature elastic moduli -- General curved interfaces and biomembranes -- Liquid films and interactions between particle and surface -- Particles at interfaces : deformations and hydrodynamic interactions -- Lateral capillary forces between partially immersed bodies -- Lateral capillary forces between floating particles -- Capillary forces between particles bound to a spherical interface -- Mechanics of lipid membranes and interaction between inclusions -- Capillary bridges and capillary-bridge forces -- Capillary forces between particles of irregular contact line -- Two-dimensional crystallization of particulates and proteins -- Effect of oil drops and particulates on the stability of foams.

Performance as Interfacial Stabilizers

Surfactants

Particles Confined by Fluid Interfaces

Free Energy and Force Analyses of Heterogeneous Cylindrical Particles at Fluid Interfaces

Capillary Interactions Among Microparticles and Nanoparticles at Fluid Interfaces

Bijels

Colloidal particles can stabilize a fluid interface. This phenomenon, first observed over a century ago, enables a robust "bottom-up" approach for synthesis of functional materials with well-defined microstructure using colloids with tunable chemistry and geometry as building blocks. Familiar examples are particle-stabilized emulsions and foams, which are utilized in several industries including personal products, foods, and pharmaceuticals. In this dissertation, the assembly of particles at fluid interfaces is investigated with two underlying intentions: to develop new insight into how the 3-D morphology of particle-stabilized interfaces can influence the rheological properties of soft materials. For materials synthesis, colloidal particles with specific wetting properties arrest spinodal decomposition of a partially miscible fluid pair. The resultant non-equilibrium microstructure, known as a bijel, is then used as a general platform to synthesize a novel family of bicontinuous macroporous, hierarchically porous, and composite materials with tunable chemistry and morphology. Applications for these materials are numerous and related to the same interface (membrane), capillary interactions appear between them. Two major kinds of capillary interactions are described: (i) capillary immersion force related to the surface wettability (Chapter 7), (ii) capillary flotation force originated from interfacial deformations due to particle weight (Chapter 8). Special attention is paid to the theory of capillary immersion forces between particles entrapped in spherical liquid films (Chapter 9). A generalization of the theory of immersion forces allows one to describe membrane-mediated interactions between protein inclusions into a lipid bilayer (Chapter 10). Chapter 11 is devoted to the theory of the capillary-bridge forces, whose importance has been recognized in phenomena like consolidation of granules and soils, wetting of powders, capillary condensation, long-range hydrophobic attraction, etc. The nucleation of capillary bridges is also examined. Chapter 12 considers solid particles, which have an irregular wetting perimeter upon attachment to a fluid interface. The undulated contact line induces interfacial deformations, which engender a special lateral capillary force between the particles. The latter contributes to the dilatational and shear elastic moduli of particulate adsorption monolayers. Chapter 13 describes how lateral capillary forces, facilitated by convective flows and some specific and non-specific interactions, can lead to the aggregation and ordering of various particles at fluid interfaces or in thin liquid films. Recent results on fabricating two-dimensional (2D) arrays from micrometer and sub-micrometer latex particles, as well as 2D crystals from proteins and protein complexes, are reviewed. Chapter 14 presents applied aspects of the particle-surface interaction in antifouling and defouling. The mechanisms of antifouling action involve as a necessary step the entering of an antifoum particle at the air-water interface. The considered mechanisms indicate the factors for control of fouling.

This work uses silica nanoparticles to stabilize oil-in-water and water-in-water emulsions. These emulsions are called Pickering emulsions and have potential use for enhanced oil recovery. There are two challenges with using nanoparticles for subsurface applications which are the high salinities and elevated temperatures of reservoir brines. These conditions are problematic because nanoparticles without surface modification are unstable, because of nanoparticle charge screening, which leads to particle agglomeration. Additionally, much of the current research on particle stabilized emulsions focuses on using nanoparticles modified with hydrophobic molecules or surfactants with the sole intent of getting particles to the oil/water interface. Because of this, many of these particles are not applicable for subsurface applications due to their lack of stability in brine. To address these challenges, I functionalize silica nanoparticles with different concentrations of a hydrophilic silane called (3-glycidyloxypropyl)trimethoxysilane (glymo) and stabilize Pickering emulsions with these particles. Glymo was selected as a nanoparticle surface modifier because of its ability to sterically stabilize particles in brine. I characterized the static stability of different Pickering emulsion formulations by using a centrifuge and by calculating the emulsion demulsification pressure. I correlate a critical demulsification pressure to emulsions that show little change in emulsion drop size while flowing, which I define as dynamically stable. The critical demulsification pressure is applied to several untested Pickering emulsion formulations to verify its applicability as an emulsion pre-screening tool. I perform a rheological characterization on emulsions stabilized with low and high surface coverage glymo-coated particles to establish relationships between nanoparticle bridging and the extent of glymo surface modification with different ionic strength brines. I use cryo-scanning electron microscopy to visually assess the bridging behavior of these different Pickering emulsions. I use fumed silica particles, with different wettabilities, and assess their ability to destabilize a model Pickering emulsion. I determine there is a strong correlation between the wettability of a fumed silica particle and its ability to destabilize a model emulsion. This work is relevant because most of the current research on Pickering emulsions focuses primarily on how to tune the properties of colloidal particles to generate stable emulsions with less overall emphasis on methods to destabilize them. Lastly, an aqueous, two phase system is stabilized with 6 nm and 50 nm silica particles modified with 2-(methoxy(polyethyleneoxy)6-3-propyl)trimethoxysilane (PEG-silane). Stabilization of the water/water interface results in emulsions that have relatively good stability to shear. Water-in-water emulsions do not contain any oil which is often considered a major limitation of Pickering emulsions for EOR, therefore these

Modelling Colloidal Particles Adsorbed at Fluid-fluid Interfaces

Interaction, Micromechanics, and Applications of Colloidal Particles at Fluid Interfaces

Directed assembly of complex shaped particles at fluid interfaces.

Surfactants... today you have probably eaten some, or rubbed others on your body. Plants, animals (including you) and microorganisms make them, and many everyday products (e.g. detergents, cosmetics, foodstuffs) contain them. Surfactant molecules have one part which is soluble in water and another which is not. This gives surfactant molecules two valuable properties: 1) they adsorb at surfaces (e.g. of an oil droplet in water), and 2) they stick together (aggregate) in water. The aggregates (micelles) are able to dissolve materials not soluble in water alone, and adsorb surfactant layers, at the surfaces of particles or (say) oil droplets in water, stop the particles or drops sticking together. This is why stable emulsions such as milk do not separate into layers. This book treats the basic physical chemistry and physics underlying the behaviour of surfactant systems. In this book, you will first learn about some background material including hydrophobic hydration, interfacial tension and capillarity (Section I). Discussion of surfactant adsorption at liquid/liquid and solid/liquid interfaces is given in Section II, and includes thermodynamics of adsorption, dynamic and rheological aspects of liquid interfaces and the direct characterisation of surfactant monolayers. In Section III, a description is given of surfactant aggregation to give micelles, lyotropic liquid crystals, microemulsions and Winsor systems. There follows a discussion of surface forces and the way they confer stability on lyophobic colloids and thin liquid films (Section IV). Various dispersions stabilised by adsorbed surfactant or polymer (including solid in liquid dispersions, emulsions and foams) are considered in Section V. The wetting of solids and liquids is explored in Section VI. Like surfactants, small solid particles can adsorb at liquid/liquid interfaces, form monolayers and stabilise emulsions and foams. Such behaviour is covered in Section VII. It is assumed the reader has a knowledge of undergraduate physical chemistry, particularly chemical thermodynamics, and of simple physics. Mathematics (elementary algebra and calculus) is kept at a level consistent with the straightforward derivation of many of the equations presented.

Progress in Industrial Mathematics at ECMI 2018

Self-organization of Magnetic Particles at Fluid Interfaces

Macro- and Micro- Approaches

Colloidal Particles at Fluid Interfaces

Flowing Matter

Core-shell Particles at Fluid Interfaces