Properties of Charged Particles in Non-polar Fluids

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This talk will discuss recent results that explore the properties and behavior of charge on colloidal particles suspended in non-aqueous fluids. Such charges can lead to a long-range repulsive interaction, which can drive new phases in the colloidal particles, and can help stabilize the particles against aggregation.

Surfactant Self-Assembly at Interfaces, Induced by Polyions

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The formation of surfactant multilayer structures, induced by polyions or multivalent counterions, at interfaces will be described and discussed. Although surfactant self-assembly at interfaces has been reported in concentrated surfactant systems, lung surfactants, and in polyelectrolyte/surfactant mixtures, it has been less commonly observed in relatively dilute surfactant systems. The ability of multivalent counterions, such as Ca^{2+} or Al^{3+}, to induce multilayer formation at interfaces in a range of anionic surfactants and anionic/nonionic surfactant mixtures has been explored. The role of counterion type, the anionic surfactant architecture, the nature of the nonionic cosurfactant, and the surfactant and counterion concentrations will be described. The surfactant surface multilayer structures exhibit extreme and persistent wetting properties on hydrophobic surfaces; and offer great potential for applications requiring soft lubrication, enhanced adsorption and efficient delivery/retention of a range of benefit agents to interfaces and surfaces. The parameters explored illustrate how these surface properties can be manipulated and controlled.

Charged Rod-like Colloids in Electric Fields: Field-induced Phases, Dynamical States and Non-equilibrium Critical Phenomena

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Biomolecular Interactions at the Lipid-Aqueous Interface

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Studies of biomolecular interaction with lipid bilayers supported by a surface as well as in dispersions have been helpful in order to reveal the nature and driving force for such interactions at biological membrane surfaces. Lipid bilayer studies are also helpful in understanding interactions of relevance for applications like emulsification, antimicrobial substances as well as drug delivery. The state of the lipid can affect the biomolecular interaction, as will be illustrated with recent result for nucleic acids and peptides. The integrity and state of the lipid layer in itself can also be affected. Biological membranes do not only occur as bilayer structures, but bilayers have also been shown to, depending on the lipid composition, curve into intriguing 3D structures. The biological implications of such transitions are not fully understood, but have the potential to be utilized in a range of life science applications. However, this requires the development of well-defined model system, which can be obtained by adsorption of liquid crystalline nanoparticles, forming lipid layers on nanostructured surfaces as well as by phase transition within the interfacial layer, invoked by lipolytic activity. Some examples of our recent results regarding the transition of 2D lipid interface into 3D layer structure as well as the reverse process will be discussed.

Particle-Cell Assemblies: Cyborg Cells, Cellosomes and Colloid Antibodies

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Living cells interfaced with a range of polyelectrolytes, magnetic and noble metal nanoparticles, hard mineral shells and other complex nanomaterials can perform functions often completely different from their original specialisation. Such ‘‘cyborg cells’’ are already finding a range of novel applications in areas like whole cell biosensors, bioelectronics, tissue engineering, cell implant protection and bioanalytical chemistry. In the first part of my lecture, I will outline the recent developments of my research group on functionalization of cells with polymers and nanoparticles and will discuss several applications of this technology for toxicity microscreening and testing of environmental exposure. Another remarkable application of polyelectrolyte-functionalized cells resulted in the fabrication of spherical, rod-like and rhombohedra-like 3D hollow clusters of viable cells, also termed cellosomes. Polyelectrolyte-coated cells are able to self-assemble on air microbubbles and inorganic microcrystals, forming a monolayer-like cellular membrane produced upon dissolution of the sacrificial core. The resulting cellosome structures are viable for at least several weeks, strongly resemble several natural colonial microorganisms, and have potential applications in bio-printing and tissue engineering.
In the second part of this lecture I will discuss a new class of engineered colloids which can recognise the shape and size of targeted microbial cells and selectively bind to their surfaces. These imprinted colloid particles, which we called “colloid antibodies”, were recently fabricated by partial fragmentation of silica shells obtained by templating the targeted microbial cells. We demonstrated the shape and size recognition between such colloidal imprints and matching microbial cells. High percentage of binding events of colloidal imprints with matching target cells was achieved. We explored the binding of colloidal imprints to target microbial cells in a binary mixture of cells of different shape and size, which also resulted in high binding selectivity. We probed the role of the electrostatic interactions between the target cells and their colloid imprints by pre-coating both of them with polyelectrolytes. Shape-selective binding occurred predominantly in the case of opposite surface charges of the colloid cell imprint and the targeted cells. The cell shape recognition mechanism is based on the amplification of the surface interaction between the target cell and its colloidal imprint due to the increased contact area in case of shape and size match. Such colloidal cell imprints can be additionally functionalized with surface groups which can enhance their binding efficiency to the microbial cells, deliver a drug payload directly to their surface and/or allow them to be manipulated using external fields. We produced such “colloid antibodies” with photothermal mechanism for shape-selective killing of matching cells. This was achieved by the subsequent deposition of: (i) gold nanoparticles and (ii) silica shell over yeast cells, which were chosen as model pathogens. We demonstrated that fragments of these composite gold nanoparticle/silica shells act as “colloid antibodies” and can bind to cells of matching shape and deliver gold nanoparticles directly onto their surface. After irradiation with a laser, the localized heating around the gold nanoparticles killed the microbial cells of matching shape. We confirmed the cell shape-specific killing by photothermal colloid antibodies in a mixture of two microbial cultures of different cell shape and size. This approach opens a number of avenues for building powerful selective biocides based on combinations of colloid antibodies and other cell killing strategies which can be applied in new selective antimicrobial therapies.

Directional Growth and Assembly of Plasmonic Colloids

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The assembly of nanoparticle building blocks is a pre-requisite for the amplification of the properties of the components and/or the generation of new features unique to the ensemble. Usually, nanoparticles employed for these assemblies are spherical and lack a geometrical preference toward directional self-assembly, thus limiting their potential applications. In contrast, controlled self-assembly of non-spherical nanoparticles, such as gold nanorods, enables these arrays to form defined 1D, 2D or 3D structures with a vector dependence of the desired properties. We show in this communication several examples where the morphology of gold nanoparticles can be modulated by means of colloid chemistry methods, and in turn exploited to direct the assembly of such nanoparticles into a variety of nanostructures with interesting properties.

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