

**COST Action MP1106**  
Smart and green interfaces  
- from single bubbles and drops  
to industrial, environmental and  
biomedical applications

**COST Action CM1101: Colloidal Aspects  
of Nanoscience for Innovative Processes  
and Materials**

cost



**COST Actions MP1106 & CM1101**

**Joint Training School**

**Particles at Liquid Interfaces  
– Fundamentals and Applications –**

**April 2<sup>nd</sup> – 5<sup>th</sup>, 2014**

**Bonassola (Italy)**



**Scientific Committee**

**Thodoris Karapantsios**  
*School of Chemistry - Aristotle University Thessaloniki*  
*Thessaloniki Greece*

**Libero Liggieri**  
*CNR - Institute for Energetics and Interphases*  
*Genova Italy*

**Piotr Warszynski**  
*J. Haber Institute of Catalysis and Surface Chemistry*  
*Krakow Poland*

**Chair of the School**

**Libero Liggieri**

**Local Organising Committee**

**Alessandro Benedetti**

**Francesco Mocellin (web site)**

**Eva Santini**

*CNR - Institute for Energetics and Interphases*

## PROGRAMME

### Wednesday, April 2nd

16:00 -18:00 Registration

18:00 -19:00 Libero Liggieri (CNR-Istituto per l'energetica e le Interfasi)  
Welcome, Introduction to the School Subject and Trainers  
Presentation

19:30 Welcome Party

### Thursday, April 3th

8:45 - 9:45 Ramon G. Rubio (Universidad Complutense Madrid)  
Particle-laden Fluid Interfases: Structure and Dynamics

9:45 - 10:15 Coffee Break

10:15 -11:15 Reinhard Miller (Max-Panck Inst. Kolloid und Grenzflächenforsch.)  
Adsorption Kinetics, Thermodynamics and Dilational Rheology  
of Liquid Surfactant Adsorption Layers

11:15-12:30 Poster Workshop I

12:45 Lunch

14:15-15:15 Francesca Ravera (CNR-Istituto per l'Enetgetica e le Interfasi)  
Nanoparticle-Surfactant Systems at Liquid Interfaces

15:15-16:15 Victoria Dutschk (University of Twente)  
Wettability of engineered nanoparticles

16:15-16:45 Coffee Break

16:45-17:45 Tommy Horozov (University of Hull)  
Stabilisation of Foams and Emulsions by Solid Particles

17:45-19:00 Poster Workshop II

19:45 School Dinner

### Friday, April 4th

9:00 -10:00 Urs Gozenbach (de Cavis Ltd.)

Particle-stabilized ceramic foams: formation, processing,  
characterization and commercialization

10:00 - 11:00 Tomasz Sosnowski (Warsaw University of Technology)

Inhaled drug particles and their interactions with air-liquid  
interface of the lungs

11:00 - 11:30 Coffee Breack

11:30 - 12:15 Nicoletta Palazzo (CNR - Ufficio Relazioni Europee e Internazionali)

Horizon 2020: Opportunities for Young Researchers

12:15 – 13:15 Poster Workshop III

13:30 Lunch

14:30 Visit to IENI-MARECO Laboratory

15:30 Free time

### Saturday, April 5th

8:45-9:45 Robert J. Pugh (University of Genève)

Particle Stabilized Bubbles in the Flotation Processes

9:45-10:15 Coffee Break

10:15 -11:15 Libero Liggieri (CNR-Istituto per l'Energetica e le Interfasi)

Nanoparticle Interaction with Insoluble Surfactant Layers

11:15 -11:45 STSM Opportunities & Closure

Tutorial Lecture 1

## **PARTICLE LADEN FLUID INTERFACES: STRUCTURE AND DYNAMICS**

Ramon G. Rubio

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Monolayers of particles are a promising alternative to the use of surfactants for the stabilization of fluid interfaces. In most cases the use of particles is expected to be more environmentally friendly than synthetic surfactants. Particle laden interfaces have demonstrated to stabilize emulsions and foams, which is of fundamental importance for many industries including cosmetic, pharmaceutical, food, petroleum, pulp and paper, froth flotation, and water treatment. However, this stabilizing ability may be undesirable in certain cases such as wastewater treatment, radioactive nuclear waste processing, and certain steps of oil processing. In some cases the foams used are non-water based, e.g. polymeric or metallic foams, and classical surfactants are useless. However, in these cases the foams may be stabilized by particles. The interface stabilization ability of particles depend on many factors that may be summarized in two main aspects: the structure of the monolayer formed at the interface, and the particle mobility at the monolayer. In this lecture we will focus on both issues.

The *structure of monolayers* is governed by the interactions between them, which depend on their chemical nature, their size, the roughness of their surface, and the nature of the fluids adjacent to the interface. When the particles are micron sized, it is possible to visualize them by optical microscopy, thus the structure can be directly extracted and analyzed in real space. The phase diagram of monodisperse particle monolayers shows fluid phases (gas-like and liquid-like), a hexatic phase and a hexagonal solid phase. The situation is more complex in the case of polydisperse particles where binary crystals or glassy structures can be obtained depending on concentration, size disparity and particle interactions. The surface particle-density range for which fluid-like structures are observed increases as the particle size is decreased. High stabilization abilities usually correspond to high particle densities. [1,2]

Some destabilization mechanisms of emulsions and foams (coalescence, ripening, draining) are strongly dependent on the *mobility of particles* attached to the interfaces. In highly diluted monolayers particles describe a typical Brownian trajectory (diffusive motion), from which the diffusion coefficient can be easily obtained. [3] However, the interaction between particles is usually long-ranged which makes the motion subdiffusive. In this case some viscoelastic models, e.g. Jeffrey's model, have to be used to obtain the diffusion coefficient. This is possible still for monolayers in fluid-like states. In the case of concentrated monolayers the particle motion is usually restricted to

oscillations around the equilibrium position. These concentrated states are the ones most frequently found in practical applications, where armored droplets or bubbles are present.

It is known that *interfacial rheology* is strongly related to the stabilizing ability of surfactants, including polymers and proteins. Tracking the trajectories of particles embedded in a surfactant monolayers allows one to obtain the shear viscosity.[4,5] In the case of interfacial rheology the results obtained are still under debate, though the method offers the possibility to be applied to very small systems, similar to droplets (emulsions) or Plateau films (foams).

### **Further readings**

1. “Colloidal particles at liquid interfaces”, B.P. Binks, T.S. Horozov Eds., Cambridge University Press, Cambridge, 2006.
2. L.J. Bonales et al. Langmuir 27 (2011) 3391
3. E.L. Cussler, “Diffusion”, 2<sup>nd</sup> Ed. Cambridge Univ. Press, Cambridge 1997
4. T.A. Waigh, Rep. Prog. Phys. 68 (2005) 685
5. A. Maestro et al. Soft Matter 7 (2011) 7761

Tutorial Lecture 2

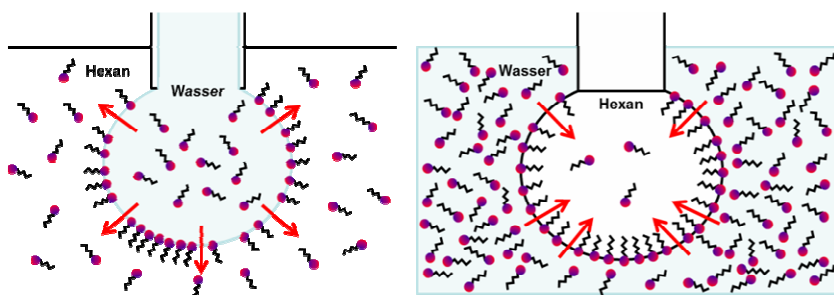
**ADSORPTION KINETICS, THERMODYNAMICS AND  
DILATIONAL RHEOLOGY OF LIQUID SURFACTANT  
ADSORPTION LAYERS**

Reinhard Miller

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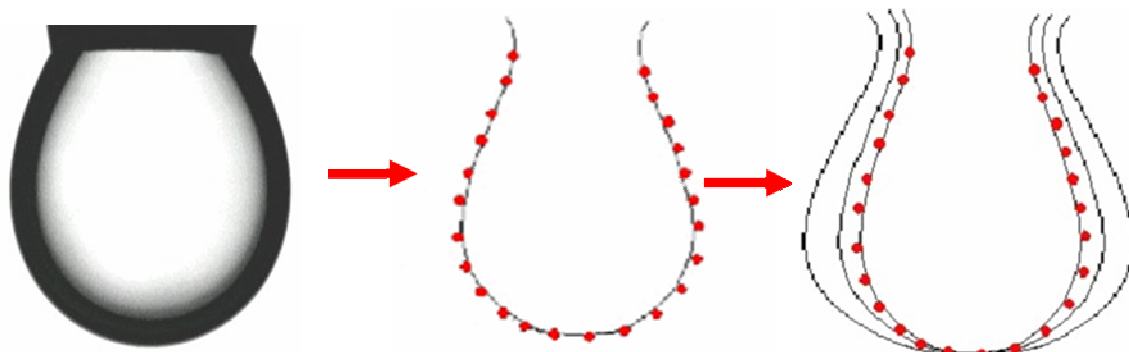
Surfactants are amphiphilic molecules which self-assemble at liquid interfaces. Due to this adsorption, one of the main quantities, the surface tension  $\gamma$  of the liquid interface is reduced. This property is essential for quite a number of technological processes, such as foaming or emulsification. In such processes large interfaces are created. The work  $W$  to be done to create a new surface of area  $A$  is  $W=A \times \gamma$ . Therefore, any reduction of the surface or interfacial tension, respectively, leads to a smaller demand of energy for the production of foams or emulsions.



Ionic surfactants are essentially soluble in water and adsorb at water/air or water/oil interfaces. In contrast, non-ionic surfactants are soluble in both

phases, in water and in oil. Thus, these molecules do not only adsorb at the interface but also transfer across the interface and are distributed between the two liquid phases according to the partitioning coefficient.

The easiest measurable quantity is the surface (or interfacial) tension  $\gamma$ . There are quite a number of techniques for measuring  $\gamma$ . The drop profile analysis tensiometry (PAT) is



presently the most frequently used. The principle of this method is to determine the coordinates of the profile of a drop (or bubble) and compare it with profiles calculated by the Gauss Laplace Equation (GLE). The only fitting parameter in the GLE is the surface tension so that the best fit of the experimental by the calculated profile corresponds to the respective value of  $\gamma$ .

Besides the PAT, also other tensiometry methods will be presented and discussed in detail, such as maximum bubble pressure (MPT) and capillary pressure tensiometry (CPT). Although much less reliable, classical methods like ring and plate tensiometry are still used in practice due to the existence of industrial norms.

When changes of the interfacial area of a drop or bubble are generated, the surface tension is changing in a respective way. Such experiments give access to the dilational rheology of liquid interfaces. Oscillating drops and bubbles are the corresponding methods to yield the interfacial dilational elasticity and viscosity. The two methods PAT and CPT complement each other and provide rheological data in a rather broad frequency range.

### **Further readings**

1. R. Miller and L. Liggieri (Eds.), *Interfacial Rheology*, Vol. 1, Progress in Colloid and Interface Science, Brill Publ., Leiden, 2009, ISBN 978 90 04 17586 0
2. R. Miller and L. Liggieri (Eds.), *Bubble and Drop Interfaces*, Vol. 2, Progress in Colloid and Interface Science, Brill Publ., Leiden, 2011, ISBN 978 90 04 17495 5
3. P. Kralchevsky, R. Miller and F. Ravera (Eds.), *Colloid Chemistry in Nanotechnology*, in "Progress in Colloid Interface Science", Vol. 4, CRC Press, 2013, ISBN 978 14 66 56905 8.



Tutorial Lecture 3

## **NANOPARTICLE – SURFACTANT SYSTEMS AT LIQUID INTERFACES**

Francesca Ravera

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Investigating the interfacial properties of particle-surfactant composite systems is increasingly relevant in many technological fields where multiphase systems subjected to dynamic conditions are involved and in foam and emulsion technology where particles are widely employed to effectively control bubble/drop coalescence and film stability.

The different physico-chemical aspects dealing with the interaction between nano-sized particles (NP) and surfactant adsorbed layers at liquid interfaces are analyzed and discussed as well as the conditions for the surface segregations and the possible effects on the interfacial properties of the system.

In fact, depending on their hydrophobic-philic properties, or wettability, NP can transfer into the adsorption layers and change significantly their surface thermodynamics, structure and dynamic characteristics. In other cases especially with insoluble layers, or surfactants soluble in the second phase, NP can be captured by the adsorbed surfactant layers.

The transfer/accumulation of particles into the liquid interfaces mainly affects the interfacial tension and the dilational rheology, and also the surfactant-particle aggregation processes leading to phase transitions and eventual formation of interfacial viscoelastic networks. The study of dilational rheology, especially for composite systems, has been proven to be one of the most effective tool to obtain qualitative and quantitative information about the structural features and the kinetic processes in interfacial layers. To exploit the potentialities of this kind of investigation it is important, from one side, to rely on appropriate experimental techniques to access the interfacial properties of mixed NP-surfactant systems and, on the other side, to use theoretical models allowing the extraction of information on the features of the interfacial layers to be optimized.

Some significant experimental studies are reported dealing with different NP-surfactant systems which provide different scenarios. These are for examples dispersion where the wettability of the NP are varied by the surfactant adsorption of them, or NP interacting with surfactants at the liquid-liquid interfaces and producing viscoelastic interfacial network, phase transition within insoluble monolayer modified by the presence of incorporated NP.

**Further readings:**

1. R. Miller, L. Liggieri (eds), *Interfacial Rheology*, Brill, 2009.
2. P. Kralchevsky, R. Miller and F. Ravera (eds), *Colloid and Interface Chemistry for Nanotechnology*, in PCIS, Vol. 4, Taylor & Francis, 2013
3. TN Hunter, RJ Pugh, GV Franks, GJ Jameson, *The Role of Particles in Stabilising Foams and Emulsions*, *Advances in Colloid and Surface Sci.*, 137 (2008), 57-81.
4. F. Ravera, E. Santini, G. Loglio, M. Ferrari, Liggieri, *J. of Phys. Chem. B*, 110 (2006) 19543
5. F. Ravera, M. Ferrari a, L. Liggieri , G. Loglio, E. Santini, A. Zanobini, *Colloids & Surfaces A*, 323 (2008) 99

Tutorial Lecture 4

## STABILISATION OF FOAMS AND EMULSIONS BY SOLID PARTICLES

Tommy S. Horozov

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It is known that small solid particles can act as foam and emulsion stabilisers even in the absence of surfactants. Often the particle-stabilised foams and emulsions have exceptional stability that cannot be achieved by the most powerful surfactants alone.

This talk will focus on the role of particle wettability in their behaviour at isolated liquid interfaces, in thin liquid films, foams and emulsions. The topics covered will also include particle attachment to air-water and oil-water interfaces, particle monolayers and mechanisms of emulsion and foam stabilisation. Methods for measuring particle contact angles at liquid interfaces, as well as foams and emulsions from particle-surfactant mixtures will also be discussed.

### Further readings

1. “*Colloidal Particles at Liquid Interfaces*”, B. P. Binks and T. S. Horozov, eds., Cambridge University Press, Cambridge, 2006.
2. R. Aveyard, B. P. Binks, J. H. Clint, “Emulsions stabilized solely by solid colloidal particles”, *Adv. Colloid Interface Sci.*, 2003, 100–102, 503–546.
3. T. S. Horozov, “Foams and Foam Films Stabilized by Solid Particles”, *Curr. Opin. Colloid Interface Sci.*, 2008, 13, 134–140.
4. T N. Hunter, R. J. Pugh, G. V. Franks, G. J. Jameson, “The role of particles in stabilising foams and emulsions”, *Adv. Colloid Interface Sci.*, 2008, 137, 57–81.
5. F. Leal-Calderon, V. Schmitt, “Solid-stabilized emulsions”, *Curr. Opin. Colloid Interface Sci.*, 2008, 13, 217–227.

Tutorial Lecture 5

## WETTABILITY OF ENGINEERED NANOPARTICLES

Victoria Dutschk

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The lecture on wettability of engineered nanoparticles contains general information on nanomaterial classes and application of nanoparticles starting with a brief introduction into nanotechnology and some advanced technologies based on. Since nanoobjects and the corresponding nanosystems have been under consideration in colloid and interface science for many decades, the focus is put on nanomaterials as a part of colloids in the length scale of approximately 1–100 nanometer range.

Among other physico-chemical characteristics, wettability of nanoparticles is an important issue for a wide range of applications. The main part of the lecture will give an overview of wetting, including wetting on rough surfaces. The contact angle is an excellent measure describing the wettability of particles and their affinity to interact with liquids. Wettability of porous media such as powders can be characterised by spontaneous capillary penetration of a liquid into pores spaces. Two experimental techniques are most commonly employed. The first one, height-time technique, measuring the height to which the liquid front advances in porous solids during the capillary rise process. The second one, is a weight-time technique, studying the increase in the weight of porous solids caused by the progression of the liquid inside their pores. The complex geometry of particle pore spaces creates numerous combinations of interfaces, capillaries, and wedges in which a liquid is retained, and results in a variety of air-liquid and solid-liquid configurations, making the interpretation of the results extremely difficult. In both cases, the experimental results were described by means of Washburn's equation. A conceptually new methodology to get more information about wetting properties of nanoparticles using the Wilhelmy plate method together with modern optical techniques for surface roughness analysis will be presented.

The literature on this topic is vast. Therefore, the aim of the lecture is to provide added value in terms of simplified explanations of complex wetting concepts.

### **Further readings**

1. Everett DH: *Manual of symbols and terminology for physicochemical quantities and units. Appendix II: Definitions, Terminology and Symbols in Colloid and Surface Chemistry, Part 1*, Pure and Applied Chemistry 31 (1972) 605.

2. Fernández-García M, Martínez-Arias A, Hanson JC, Rodríguez JA, *Nanostructured oxides in chemistry: Characterization and properties*, Chem Rev 104 (2004) 4063-4104.
3. *Towards predicting nano-biointeractions*, International Council on Nanotechnology, 4 (2008) 1-79.
4. *Nanoscience: Colloidal and interfacial aspects*, Surfactant Science Series 147 (Ed. Victor Starov), Taylor and Francis, UK, pp. 1-1216.
5. Dutschk V, Marmur A: *The contact angle as analytical tool, Chapter 12 in: Colloid and Interface Chemistry for Nanotechnology*, Progress in Colloid and Interface Series (Eds. P Kralchevsky, R. Miller, F. Ravera), pp. 255-270, 2013.

Tutorial Lecture 6

**PARTICLE-STABILIZED CERAMIC FOAMS:  
FORMATION, PROCESSING, CHARACTERIZATION AND  
COMMERCIALIZATION**

Dr. Urs. T. Gonzenbach

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More than a hundred years ago, Ramsden and Pickering discovered the ability of fine particles to stabilize oil-water interfaces. Interestingly, little work appeared afterwards and it was only recently that the principles of particle stabilization were applied to the formation of liquid ceramic foams. Such foams are technically important soft matter and crucial as intermediates for the production of porous ceramics. However, their thermodynamically unstable nature is a critical issue that can be drastically improved using particles as foam stabilizers. For efficient foam stabilization, particle wettability needs to be tailored to promote particle attachment to the liquid-gas interface of freshly introduced gas bubbles, but also to avoid strong particle agglomeration in the bulk.

Our invention of in-situ particle hydrophobization is a powerful method to deliberately tailor wettability of colloidal particles of all kind via adsorption of short-chain amphiphilic molecules in order to enable the formation of stable wet foams.

This presentation takes you on a journey from the early discovery of emulsion stabilization with fine particles to the long road to commercialization in the area of particle-stabilized ceramic foams. It gives an overview of our activities in this emerging field and describes our method in detail, focusing on parameters controlling foam formation, processing of wet foams into porous ceramics and their outstanding mechanical, thermal, electrical and microstructural properties. Last but not least, some insights are given regarding the commercialization and application of this highly interesting material class.



Examples of porous alumina (density  $0.36\text{g/cm}^3$ , left), porous gypsum panel (density  $0.25\text{g/cm}^3$ , middle) and a complex-shaped tube insulator also made from porous gypsum (right).

**Further readings:**

1. A. R. Studart, U. T. Gonzenbach, E. Tervoort, and L. J. Gauckler, "*Processing routes to macroporous ceramics - a review*", Journal of the American Ceramic Society, 89 [6] 1771-1789 (2006).
2. U. T. Gonzenbach, A. R. Studart, E. Tervoort, and L. J. Gauckler, "*Ultrastable particle-stabilized foams*", Angewandte Chemie-International Edition, 45 [21] 3526-3530 (2006).
3. U. T. Gonzenbach, A. R. Studart, E. Tervoort, and L. J. Gauckler, "*Stabilization of foams with inorganic colloidal particles*", Langmuir, 22 [26] 10983-10988 (2006).
4. U. T. Gonzenbach, A. R. Studart, E. Tervoort, and L. J. Gauckler, "*Macroporous ceramics from particle-stabilized foams*", Journal of the American Ceramic Society, 90 [1] 16-22 (2007).
5. B. P. Binks, "*Particles as surfactants - similarities and differences.*" Current Opinion in Colloid & Interface Science, 7, 21-41 (2002).

Tutorial Lecture 7

## INHALED DRUG PARTICLES AND THEIR INTERACTIONS WITH AIR-LIQUID INTERFACE OF THE LUNGS

Prof. Tomasz R. Sosnowski

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Aerosols formed by micro- and nanoparticles easily penetrate the respiratory system allowing inhaled particles to land on the liquid-covered surface of the lungs. Therefore inhalation can be conveniently used as a method of drug delivery in the treatment of respiratory diseases but also in the systemic therapy taking an advantage of a large surface area of the air/blood barrier which enables the effective drug transport to the circulation. It is often overlooked that deposition of aerosol particles on the lung surface initiates a cascade of physicochemical events which may affect the fate of inhaled material in the organism but it can also modify the innate properties of lung fluids. These processes should be carefully evaluated to fully understand the action of inhaled drugs.

This lecture provides an outlook on several important issues related to drug delivery by inhalation, i.e.:

- generation methods for medicinal micro- and nanoparticle aerosols,
- aerodynamic particle transport within the respiratory system,
- mechanisms of particles interactions with the interface of lung fluids (lung surfactant and bronchial mucus).

Examples of in vitro experiments which confirm the importance of interfacial processes are presented and discussed.

### **Further readings**

1. Sosnowski T.R (2014). *Nanosized and nanostructured particles in pulmonary drug delivery*. J. Nanosci. Nanotechnol. – accepted
2. Gradon L., Sosnowski T.R. (2014). *Formation of particles for dry powder inhalers*. Adv. Powder Technol. <http://dx.doi.org/10.1016/j.apr.2013.09.012>
3. Odziomek M., Sosnowski T.R., Gradoń L. (2012). *Conception, preparation and properties of functional carrier particles for pulmonary drug delivery*. Int J. Pharmaceutics 433, 51-59.



4. Sosnowski T.R., Koliński M., Gradoń L. (2012). *Alteration of surface properties of dipalmitoyl phosphatidylcholine by benzo[a]pyrene: a model of pulmonary effects of diesel exhaust inhalation*. J. Biomed. Nanotechnol. 8, 818-825.
5. Gac, J., Sosnowski, T.R., Gradoń, L. (2008). *Turbulent flow energy for aerosolization of powder particles*. J. Aerosol Sci. 39, 113-126.
6. Sosnowski, T.R., Moskal, A., Gradoń, L. (2007). *Mechanisms of aerosol particle deposition in the oro-pharynx under non-steady airflow*. Ann. Occup. Hyg. 51, 19-25

Tutorial Lecture 8

## **PARTICLE STABILIZED BUBBLES IN THE FLOTATION PROCESSES**

Robert. J. Pugh

*Visiting Prof, Dept. of Chemistry, University of Geneva, Switzerland.  
bobbpugh42@gmail.com*

Froth flotation was originally established as an industrial process in the early 20 Century, to separate mineral particles. Over the past 100 years it has been gradually developed, enabling it to spread, to a wide range of further applications. Essentially, the process involves the attachment of finely divided partially hydrophobic particles to air bubbles, to produce three phase froths on the surface of the flotation cells with the hydrophilic particles remaining dispersed in the aqueous. In this way, particles are separated, based on their differences in surface wettability. In addition, the particles control the stability of the foam or froth. Although the flotation process consists of several major elementary sub-processes, one of the most critical involves the interaction of the more valuable, suspended particles (copper, silver, gold) with a chemical reagent (a flotation collector) in order to make the surface sufficient hydrophobic and become targets of the bubbles generated in the cell. The less valuable (gangue) particles (Silica) remain hydrophilic and do not interact with the collector reagents. Both the fundamentals and practical aspects of froth flotation in the area of mineral processing have been well established but the process has been modified and advanced and has been applied in many other diverse application such as the treatment and utilization of wastewater, the removal of ink from paper (de-inking), recycling of plastic separation of crude oil from tar sand and the separation of biological materials.

### **Further readings**

1. R.J. Pugh, *The Physics and Chemistry of Frothers, Froth Flotation, A Century of Innovation*, Soc. of Mining, Extraction and Metallurgy Publication, Denver, USA. 2007
  2. V. Nguyen and H.J. Schulze, *Colloidal Science of Flotation*, Marcel Decker, New York, 2004
  3. S. Lu, R.J.Pugh, and E.Forsberg, *Interfacial Separation of Particles*, Studies in Interface Science Series, vol. 20, Elsevier Publications, Amsterdam, 2005
  4. K. Theander R.J. Pugh, *Surface Chemical Aspects of Flotation Deinking*, Colloids and Surfaces, A, Physicochemical and Eng Aspects, 240, (1-3) 111-130. 2004
- [Huiting Shent](#), [R.J. Pugh](#), [E. Forsberg](#), *A Review of Plastics Waste Recycling and the Flotation of Plastics*. Resources Conservation and Recycling, vol 25 (2), 85-108, feb 1999,

Tutorial Lecture 9

## NANOPARTICLE INTERACTION WITH INSOLUBLE SURFACTANT LAYERS

Libero Liggieri

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Insoluble surfactant layers at the liquid interface are important systems in relation to several technological applications and natural phenomena. In fact these systems may show interesting self-assembling behaviours which can be utilised for different technological applications (membranes, materials, etc.). In addition, insoluble layers of phospholipids have been utilised as excellent models for the investigation of some of the physicochemical properties of cell membranes and of the Lung Surfactants.

The availability of nanometric particle that can be incorporated in the above interfacial layers opens interesting possibilities for the development of new applications or for the assesment of the impact of nanoparticles on biological systems.

In this lecture, we will first recall the basic physicochemical concepts related to the insoluble surfactant layers and the classical experimental tools utilised for their investigation. Then we will summarise recent studies aimed at elucidating the interaction of nanoparticles with the insoluble surfactant layers and the consequent effects of their structure and their physico-chemical properties.

Examples will be reported about the interaction of NPs with phospholipids monolayers, showing how these investigations can be utilised to obtain information about the potential adverse effects on biologically relevant systems.

### **Further readings:**

1. E. Guzman, et al. [\*Mixed DPPC-cholesterol Langmuir monolayers in presence of hydrophilic silica nanoparticles\*](#). *Colloids and Surfaces B: Biointerfaces* 105 (2013) 284-293.
2. B. Binks. *Colloidal particles at liquid interfaces*. *Phys. Chem. Chem. Phys.*, 9 (2007) 6298-6299
3. G.W. Feigenson. *Phase diagrams and lipid domains in multicomponent lipid bilayer mixture*. *Biochimica et Biophysica Acta* 1788 (2009) 47-52.
4. E. Guzman et al., *Effect of Hydrophilic and Hydrophobic Nanoparticles on the Surface Pressure Response of DPPC monolayers*. *J. Phys. Chem. C* 115 (2011), 21715-21722

Tutorial Lecture 10

## **HORIZON 2020: OPPORTUNITIES FOR YOUNG RESEARCHERS**

Nicoletta Palazzo

*Responsabile U.O. Genova CNR-D.G. Ufficio Relazioni Europee e Internazionali  
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The presentation will give a general overview of Horizon2020, the EU Framework Programme for Research and Innovation that will run in the period 2014-2020, and then focus in particular on the specific actions to support the training and mobility of researchers (Marie Skłodowska-Curie Actions) and the ERC grants to support excellent researchers at the career stage at which they are starting or consolidating their own independent research team or programme (European Research Council-ERC Grants)

