EUFOAM 2022

July 3-6, 2022 | Krakow, Poland / online

BOOK OF ABSTRACTS

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EUFOAM 2022

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Emmanuelle Rio	Importance of evaporation for bubbles and foams stability
Francesca Ravera	Nanoparticle – surfactant mixtures at liquid interfaces: properties of the interfacial layer, foams and emulsions
Simon Cox	Foams as filters: predicting particle passage through soap films
Elena Mileva	Self-assembly of antennary oligoglycines in aqueous media: fine-tuning and applications

ORAL PRESENTATIONS

Physical Chemistry of Thin Liquid Films, Foams and Emulsions

Stationary session

LIGHT-SWITCHABLE SURFACTANTS AND MIXTURES WITH POLMERS FOR CONTROL OF INTERFACES AND FOAMS

Michael Hardt (1), Christian Honnigfort (1), Dana Glikman, Marco Schnurbus (1), Björn Braunschweig (1)

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An ongoing endeavour in chemistry is to structure foams with novel properties that are inherited by their molecular building blocks and to implement (re)active elements. The use of switchable surfactants, allows us to assemble and to manipulate superstructures at interfaces with new properties. For that, precise and remote control of interfacial and bulk properties is required to change foam properties through a light stimulus.

In this contribution we will demonstrate that E/Z photo-isomerization of arylazopyrazole (AAP) surfactants can be used for this purpose. AAPs can drastically and reversibly change the interface tension and interfacial structure when the AAP surfactants are switched from the E to the Z form using green and UV light, respectively. Interfacial changes were studied with vibrational sum-frequency generation (SFG) and surface tensiometry, where we show that butyl-AAP sulfonates [Honnigfort 2020] undergo a monolayer to bilayer transition that is responsible for unprecedented changes in surface tension as well as Marangoni flows at extended air-water interfaces but also in thin liquid films and macroscopic foam. In addition, we discuss that light irradiation of complexes from poly(sodium styrene sulfonate) (PSS) and cationic AAP triethylammonium bromide [Schnurbus 2020] surfactants can cause an apparent charge reversal at the air-water interface that is also accompanied by a change in interfacial composition. These effects of the surfactant configuration on polyelectrolyte-surfactant mixtures at the interface are also a result of drastic changes in the bulk solution where both the electrophoretic mobility and the particle size change dramatically with light irradiation [Schnurbus 2022]. The joint action of interfacial as well as the bulk property changes are useful to drive the stability of aqueous foam on a global as well as a local scale.

Acknowledgements: The authors gratefully acknowledge funding from the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project-ID 433682494-SFB 1459.

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[Schnurbus 2022] Schnurbus *et al.*, Responsive Material and Interfacial Properties Through Remote Control of Polyelectrolyte-Surfactant Mixtures. ACS Appl. Mat. Int. 14 (2022), p. 4656-4667.

[Schnurbus 2020] Schnurbus *et al.*, Photo-Switchable Surfactants for Responsive Air–Water Interfaces: Azo versus Arylazopyrazole Amphiphiles" J. Phys. Chem. B, 124, 6913 (2020)

ONE-STEP GENERATION OF ALGINATE-BASED HYDROGEL FOAMS USING CO_2 SIMULTANEOUSLY FOR FOAMING AND GELATION

Imene Ben Djemaa (1,2), Stéphane Auguste (2), Leandro Jacomine (1),
Malgorzata Tarnowska (2), Wiebke Drenckhan-Andreatta (1), Sébastien Andrieux (1)
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The reliable generation of hydrogel foams remains an important challenge in a wide range of sectors including the biomedical [J. Baxter, 2020] or food [L. Ma, 2019] sectors. Using the example of alginate-calcium carbonate foams whose gelation relies on the pH-dependent solubility of the calcium carbonate, we introduce here a novel foaming method that uses CO_2 simultaneously for foaming and for acidification of the alginate solution to trigger gelation [S. Andrieux, 2019]. Diffusion and dissolution of the CO_2 from the foam bubbles into the alginate solution induces an interface-driven acidification of the pre-gelling solution (Figure 1). This allows a good matching of the foaming and gelation timescales via tuning the CO_2 content in the foaming gas, a very important criterion for an effective "liquid foam templating" [I. Ben Djemaa, 2021]. We show that using this approach, gelled foams of different relative densities can be reliably generated in a simple one-step process. We also show that interfacial rheology allows to put in evidence the interface-driven gelation. Both approaches, gas-initiated gelation and interfacial rheology for their characterization, can be transferred readily to other types of gases and formulations.

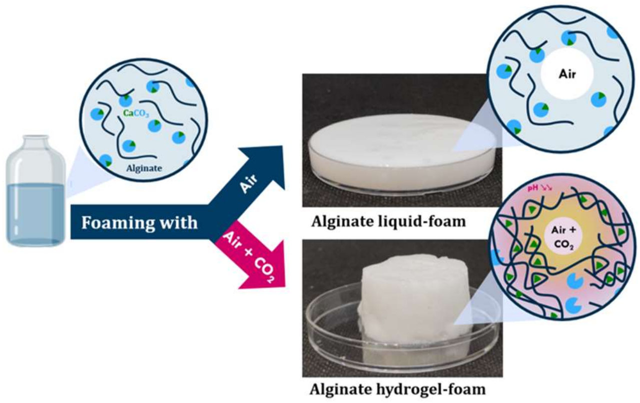

Figure 1: Illustration of our new one-step method for generating alginate-$CaCO_3$-based hydrogel foams using CO_2 for foaming and gelation. Foams with different foaming gases containing: on top, a foam with pure air remains liquid after pouring in a petri dish. On the bottom, a foam with CO_2/air= 50/50 retains the cylindrical structure of its container after being taken out.

Acknowledgements: We acknowledge discussions with Dr Laurent Apert, Dr François Schosseler, and Algaia team. We acknowledge funding from an ERC Consolidator Grant (agreement 819511 - METAFOAM), from URGO supported by CIFRE ANRT (agreement n° 2019/1150) and from the Interdisciplinary Institute HiFunMat of the University of Strasbourg, CNRS and Inserm (ANR-10-IDEX-0002 and SFRI STRAT'US ANR-20-SFRI-0012).

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J. Baxter *et al.*, J. Cardiothorac. Surg, 15, 1–8, 2020.
L. Ma *et al.*, Adv. Mater. Interfaces, 6, 1900417, 2019
S. Andrieux, W Drenckhan, FR3102364/ WO2021084200, 2019.

ELECTRONIC SURFACTANTS AT INTERFACES PROBED BY SPECTROSCOPIC ELLIPSOMETRY

Changwoo Bae(1), Samuel Albert(1), Hisham Idriss (2), Sebastien Richeter (2), Indraneel Sen (3), Sebastien Clément (2), Anne-Laure Biance (1), Oriane Bonhomme (1)

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Soap films are mostly made of water, they are then cheap, potentially biocompatible, easy to recycle materials. One tendency nowadays is to use them as sensors, their functional properties being notably set by the surfactants used to stabilize them. For example, making an opto-electronic soap film, similar to a solid organic transistor or OLED, seems then a reasonable target provided we use appropriate electronic or optoelectronic surfactants.
To that aim, the spectroscopic properties of surfactants at interfaces need to be probed and differentiated from their properties in bulk. One characterization technique of choice is to use spectrometric ellipsometry.

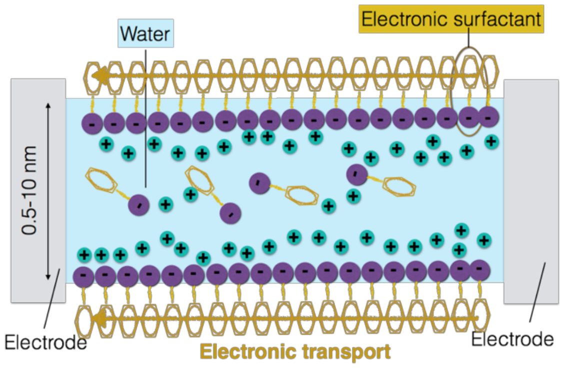

Figure 1: Schematic view of a soap film stabilized by electronic surfactants.

We will present here experimental results obtained on layers of electronic surfactants. These specifically synthesized surfactants, have a structure that allows an electronic delocalization when packed, and consequently a specific spectroscopic signature. The evolution of the optical properties of the adsorbed layer combined with the surface pressure evolution during compression allow us to discuss the organization of the adsorbed-surfactant layer properties and particularly its electronic transport ability.

Acknowledgements: This work is funded by the EU FETOPEN project PROGENY (Grant agreement ID: 899205).

INFLUENCE OF SURFACTANT CONCENTRATION ON SPONTANEOUS EMULSIFICATION KINETICS

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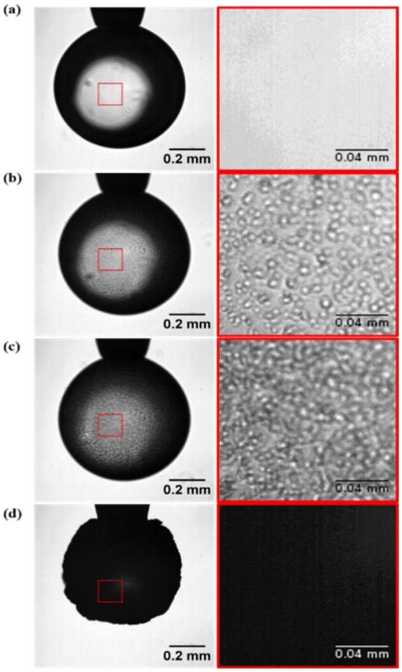
The kinetics of spontaneous emulsification is investigated on aqueous pendant drops in paraffin oil. Optical microscopy in transmission mode is used for high-spatial-resolution image recording. The influence of a lipophilic surfactant (Span 80) and two water-soluble surfactants (CTAB and SDS) is investigated. As time runs, the interface of the drops turns opaque due to the formation of microstructures associated with spontaneous emulsification. Similar surfactant mixtures have been investigated for micro and nano-emulsion stability [Zdrali, 2019]. However, to our knowledge, never for systems experiencing spontaneous emulsification.

Span 80 was used in all the experiments as spontaneous emulsification has not been observed in its absence [Schmitt, 2017]. It is demonstrated that spontaneous emulsification generates microstructures at the water paraffin oil interface. For a given composition, three specific kinetic regimes mediated by the Span 80 concentration are identified.

When modifying the drop chemical composition with CTAB (resp. SDS), spontaneous emulsification turns faster (resp. slower). This change is explained by the polarity of water molecules and the modification in water/paraffin oil zeta-potential associated with the ionic surfactants. CTAB tends in fact to reduce the zeta-potential and therefore facilitates the migration of water molecules while the SDS increases the zeta-potential. Electrostatic interaction being strengthened, water transport is hindered, producing a delay in the occurrence of spontaneous emulsification.

This work provides new experimental insights into the complexity of spontaneous emulsification when ionic and non-ionic surfactants are in competition.



Left: Pictures (1 x 1 mm^2) of a pendant drop for [Span 80] = 10 g/L at different times. (a) t = 0 s, (b) t = 1100 s and (c) t = 1400 s and (d) t = 10000 s. Right: Zoom in the selected region of interest (red square in right images).

Acknowledgements: The authors acknowledge support of CNES (‘Stabilité des Emulsions’) and ESA (‘Emulsion Dynamics and Droplet Interfaces’, Contract n. 4000128643/19/NL/PG).

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FOAM FORMATION USING SOFT POROUS MEDIA

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Foams formation with porous materials is a process of great interest to many industries, including household cleaning and enhanced oil recovery. Interaction of foams with porous media has previously been investigated both theoretically and experimentally by A, Bureiko et al [Bureiko, 2015] and N, Koursari et al [Koursari, 2019]. Foams made by compression of a soft porous media has only been investigated recently. Where the foams were made using a compression device (fig.1) with soft porous media containing surfactant solution. The soft porous media used in these investigations was sponges which matches the application which is of interest. This porous media has many uses including household, car and body cleaning. The amount and quality of foam produced by compression/decompression cycles of different sponges with surfactant solution and surfactant-polymer mixture was investigated experimentally. It was found that the maximum amount of foam is produced when the concentration of the commercial dishwashing solution is in the range of 60-80% m/m. The amount of foam produced was independent of the pore size of the media in the sponges investigated [Johnson, 2019]. This process was also explored using pure surfactant sodium dodecyl sulphate (SDS) where it was found that the amount of foam produced increased until ten times the critical micelle concentration (CMC). Any concentrations above 10 CMC produced the same mass of foam [Johnson, 2020]. For both foaming mixtures a theoretical solution was also developed which had perfect agreement with the experimental results obtained.

Figure 1: The compression device. 1- The metal plates, which can be removed and/or remodelled if required; 2- Pistons that are controlled using pressurised air; 3- Porous material to be squeezed; 4- Pressure of each piston can be controlled individually. Pressure below was constant set at 2.62bar.

Acknowledgements:
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EFFECT OF pH ON THE STABILITY OF PROTEIN FOAMS

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Proteins provide unique opportunities to tailor the properties of liquid interfaces and thereby to modulate the stability of soft colloids such as foams and emulsions. We present our recent studies on the effect of pH (in the range from pH 3 to pH 7) on the behaviour of the globular milk protein β-lactoglobulin (BLG) at liquid/gas interfaces and in thin liquid foam films as relevant to foam stability. Using several complementary surface sensitive methods, we investigated protein foams at different length scales: single interface – foam film – foam. Adsorption dynamics of BLG was studied by tensiometry, ellipsometry and neutron reflectometry (NR) [Ulaganathan, 2017a; Gochev, 2019]. Surface dilational rheometry was used to examine the viscoelastic rheological properties of BLG adsorption layers [Ulaganathan, 2017b]. The experimental results were described theoretically within the framework of a thermodynamic model [Gochev, 2021]. The charging state of the interfacial layers was probed by vibrational sum-frequency-generation (SFG) spectroscopy, showing charge reversal at the interface at bulk pH near the isoelectric point pI ≈ 5.1 of the protein [Engelhardt, 2013]. The interfacial organization of BLG was resolved on the molecular level by NR, showing formation of a heterogeneous multilayer structure near pI [Gochev, 2019]. Further, foam films were studied in order to bridge the gap between properties of single interfaces and macroscopic foam, and to discover structure-property relations in protein foams [Gochev, 2014, 2020]. The results revealed that the pH-dependencies of several key interfacial parameters are non-monotonic exhibiting an extremum around pI [Engelhardt, 2013; Ulaganathan, 2017a,b; Gochev, 2019,2021]. Intriguingly, the stabilities of foam films and foams continuously increase with increase of pH in a very good correlation [Gochev, 2020]. The conclusion is that the stability of BLG foams can be controlled in a wide range by tuning the pH of the foam-forming solution and can be predicted by investigating relevant thin liquid films. However, the important question about the lack of correlation between properties of single interfaces and film stability remains open!

Acknowledgements: the authors gratefully acknowledge the financial supports by: ERC grant agreement 638278 (B.B. and G.G.); DFG-AiF cluster project on “Protein Foams” Mi418/20-2, DFG-199448917 (B.B., R.M. and G.G.); DFG Emmy-Noether grant SCHN 1396/1 (E. Sch., E. Sco. and G.G); COST actions CM1101 and MP1106 (G.G. and R.M.).

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SURFACE PROPERTIES OF SAPONIN-CHITOSAN MIXTURES

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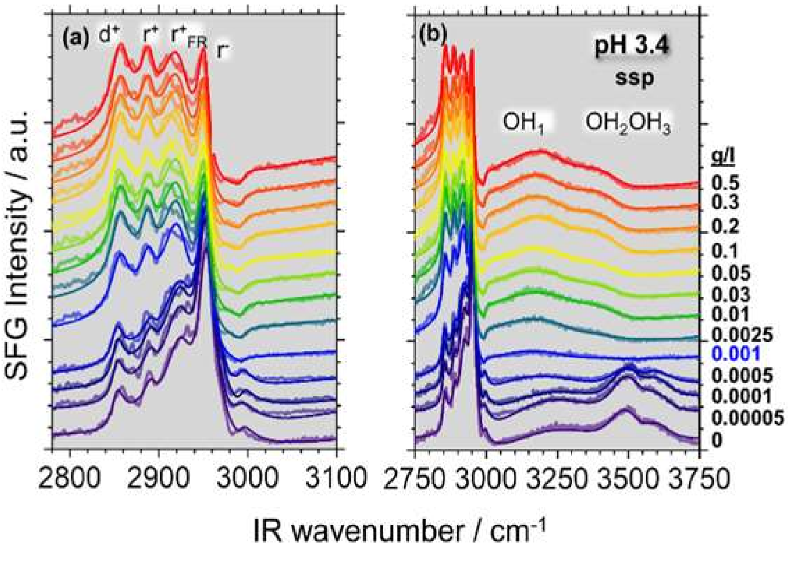
The mixtures of natural surfactants at fluid interfaces are widely used as stabilizers of emulsions and foams for many applied fields where it is important to have bio-compatible and biodegradable products, such as body-care and bio-medical fields. These natural compounds are widely used in various cosmetic, pharmaceutical and food technologies because of their efficiency as bio-active components together with their biodegradable character.

Surface properties of saponin and saponin-chitosan mixtures were analyzed as a function of their bulk mixing ratio composition using vibrational sum-frequency generation (SFG), surface tensiometry, and dilational rheology measurements.



Analyzing the SFG intensity of the O-H stretching bands from interfacial water molecules, we found that in the case of pH 3.4 for a mixture consisting of 0.1g/l saponin and 0.001g/l chitosan, the adsorption layer was electrically neutral. The effect was also confirmed for pH 2.85 in similar concentration ranges of chemicals, despite the much lower dissociation of saponin molecules under acidic conditions.

We believe that this proves the presence of chitosan in the adsorption layer, despite its complete lack of surface activity. We explain this phenomenon by electrostatic interactions between the saponin anionic surfactant and chitosan polyclinic, leading to surface-active saponin-chitosan complexes and aggregates.

This conclusion from SFG spectra is corroborated by results from tensiometry that show a significant surface tension reduction as well as significant effects on the dilational surface elasticity strictly at saponin/chitosan ratios where SFG spectra indicate zero net charge at the air-water interface. It confirm that saponin-chitosan mixtures present some remarkable properties, such as a strong amphiphilicity of the saponin and high dilational viscoelasticity.

Acknowledgements: Financial support from National Science Center of Poland research project (grant no. 2016/21/B/ST8/02107), CNR-PAN Bilateral research agreement “Biocompatible particle-stabilized foams and emulsions as carriers for healing agents”, Erasmus mobility project (MK) and POWER project no. POWR.03.02.00-00-I004/16 (ACz) is gratefully acknowledged.

Physical Chemistry of Thin Liquid Films, Foams and Emulsions

Online session

ADSORPTION PROPERTIES AND SURFACE RHEOLOGY STUDY OF PEG-8 DIMETHICONE

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The Silicone-glycol copolymers are versatile surfactants found in many industrial, household and personal care formulations. Recently, a member of this group, PEG-8 Dimethicone, (Silisurf A108) was proposed as a possible chemical aid in oil spill response operations for its excellent “herding” properties. When applied around an oil spill perimeter, this surfactant helps to significantly reduce the area of the oil slick and facilitates oil recovery, thus, limiting the negative environmental impacts. The observed ‘herding” effect is due to the surfactant-induced changes in the force balance at the tree-phase contact line (water-oil-air), and strongly depends on the dynamic adsorption properties of the surfactant and its surface dilatational rheology performance. With the present study we aimed to obtain systematic data on the adsorption properties of Silisurf A108 that would help to describe and predict its herding properties at various field scenarios.
The dynamic adsorption properties of Silisurf 108 at the air/water interface are studied in a wide concentration range (10^{-6} – 3 wt%) and at three different temperatures (10°C, 15°C and 22°C). The equilibrium surface ~~tensions~~ isotherms are obtained. The dependencies of the surface dilatational elasticity and viscosity on the surfactant concertation and the oscillation frequencies were measured after equilibrium surface tension values were reached. The obtained results present a solid experimental basis for better understanding of the mechanisms of the herder’s action and the balance of the forces at the three-phase contact region. These physicochemical characteristics are related to the herding efficiency and might serve as a guidance in the selection of suitable environmentally friendly herders for future applications.

INTERFACIAL BEHAVIOUR OF VOLATILE SURFACE ACTIVE COMPOUNDS: ADSORPTION AND EVAPORATION

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We discuss the behavior of small amphiphilic molecules which are both surface active and volatile („fragrances", such as linalool, benzyl acetate, citronellol, benzyl alcohol, geraniol). Their adsorption at the air/ water boundary, together with concomitant evaporation, is studied both experimentally, by measuring the surface tension dynamics, and theoretically. The very fast initial stage of adsorption from aqueous solution is confirmed by the maximum bubble pressure method. The increase of the surface tension due to evaporation within time scales of minutes has been interpreted by modelling, taking into account the mass fluxes and the influence of barriers.

Very good agreement is achieved between the measured surface tension vs. time, and the calculations. In a simplified version of the theory, the fits are used to determine overall „mass transfer cefficient" that characterizes the interfacial zone (values are indicated in Fig. 1). Practical relevance to the stability of fragrance-containing foams, soon after their formation, is anticipated.

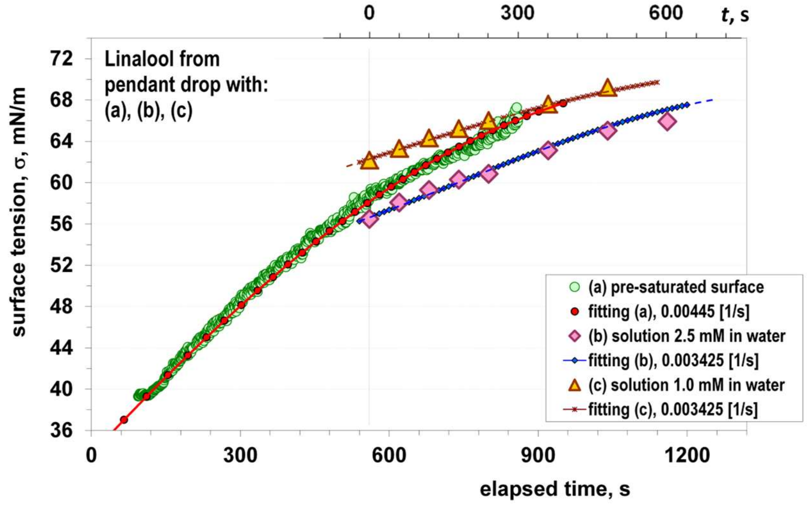

Figure 1: Measured results, together with their theoretical fits, for two types of experiments that involve evaporation from drops: (a) the A/W interface of a pendant drop is preliminarily saturated in vapors; (b), (c) the pendant drop contains an aqueous solution.

Acknowledgements: The authors are grateful for the funding support provided by: (1) the project # KP–06– Russia /3, 09. 12. 2020 with the Bulgarian Science Fund (FNI–MON), and (2) the research project № 20-53-18008, granted by the Russian Foundation for Basic Research (RFBR).

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MODELLING OF SOLUBLE SURFACTANT TRANSPORT ON AND WITHIN A FOAM FILM

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In this study, modelling of soluble surfactant transport on and within a foam film during the process of foam fractionation has been carried out. To do this, surfactant concentration is assumed to be uniform across the foam film thickness. This assumption is made due to the relative ease of diffusive transport across a thin film. Governing equations have been obtained for the velocity fields in the film and the consequent convective mass transfer of surfactants. To do this, approximate adsorption isotherms have been used to couple mass transfer equations between surface and bulk of the film, so as to derive a single equation for the evolution of the total amount of surfactant at any position along the film, regardless of how it is distributed between surface and bulk. Then, the equation for the evolution of the total amount of surfactant has been solved numerically using a spectral method. Various cases have been simulated, with flow driven primarily by Marangoni effects, in either the absence or the presence of film drainage. Then, these cases have been contrasted with one another, and with the case of an insoluble surfactant [Vitasari et al. 2013], again with and without film drainage. It was observed that solubility slows down Marangoni flow compared to the insoluble surfactant cases. This is because in the soluble cases, surfactants diffuse to the bulk while being transferred by Marangoni flow from a surfactant rich Plateau border to the centre of the film. Furthermore, a (quasi) steady-state has been discussed in which at long times an equilibrium develops between Marangoni flow and film drainage.

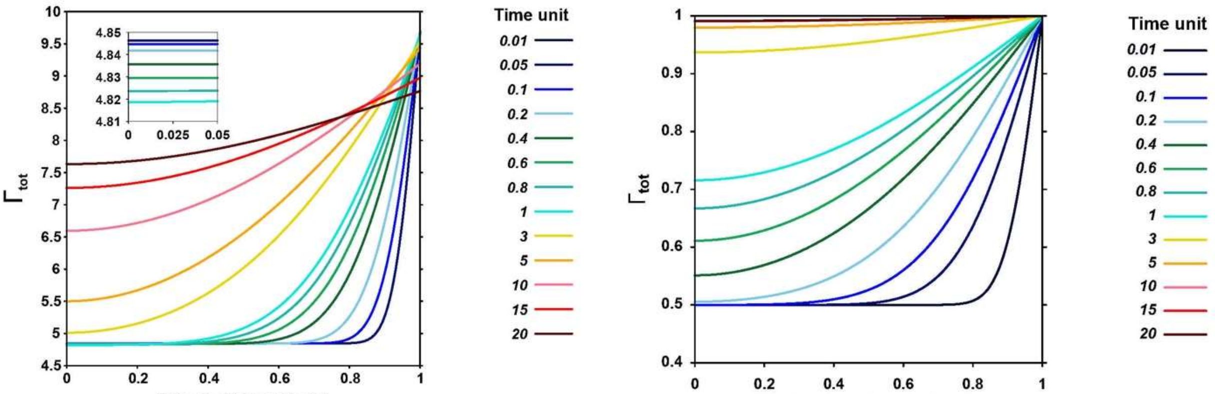

Figure A: Soluble surfactant case

Figure B: Insoluble surfactant case

Differences between the evolution of the total amount of surfactant for soluble and insoluble surfactant cases.

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LYSOZYME ADSORPTION ON MESOSTRUCTURED CELLULAR FOAMS: TEXTURAL, MORPHOLOGICAL, AND SURFACE PROPERTIES

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Protein–surface interactions are intensively investigated with regard to wide applications of biocomposite materials as well as in the field of nano-biotechnology and materials science (biomedical implants, biosensors, biochips, therapeutic nano-devices, drug delivery systems) [1].

Siliceous mesostructured cellular foams (MCFs) with various geometry structures were synthesized by using the non-ionic tri-block Pluronic copolymers (PE9400 and PE10500) as a template and trimethylbenzene (TMB) as a pore expanding agent according to a modified procedure outlined in the papers [2-4]. The MCF support due to their desirable and unique properties as well as the possibility of functionalization and changing the surface morphology (texture, roughness, porosity, geometry) during their synthesis are a very attractive group of adsorbents that can be useful as carriers of compounds showing biological activity. The physicochemical, structural, and morphological properties of the material are important in the adsorption process (speed, efficiency, and selectivity of adsorption) of biomolecules on its surface as well as protein-surface interactions (adhesion, stable interaction of adsorbent/adsorbate) [5].

The kinetics and equilibrium adsorption processes of Lysozyme from aqueous solutions at pH=7.4 on the series of MCF materials with different porosity were evaluated. The results of the study focused on a detailed analysis of structure geometry, morphology, and micro-nanostructure of the mesoporous MCF materials with different porosity before and after immobilization of biomolecules. Proper characterization of the porous structure of the protein/silica surface was determined by means of the nitrogen adsorption/desorption isotherms. The morphology and micro-nanostructure of the MCF surface with adsorbed protein layers were determined by using the atomic force microscope (AFM) and optical profilometer (OP). Moreover, the scanning electron microscope with X-ray microanalysis (SEM/EDS), transmission electron microscopy (TEM), and energy dispersive X-ray spectroscopy (EDX) was used to characterize the surface structure and the elemental composition (Si, C, O, N) of the investigated protein/mesoporous silica composites.

Acknowledgement. The authors are grateful to European Community, Seventh Framework Programme (FP7/2007–2013), Marie Curie International Research Staff Exchange Scheme (IRSES grant No 612484) for financial support of this work.

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COALESCENCE IN ETHYL LAUROYL ARGINATE - CELLULOSE NANOCRYSTALS MIXTURES; DYNAMIC THIN FILM BALANCE EXPERIMENTS

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Guanidine-based surfactant ethyl lauroyl arginate (LAE) and cellulose nanocrystals (CNC) form complexes of enhanced surface activity as compared to pure surfactant. The effect strictly depends on surfactant concentration. Dispersions of CNC and LAE were characterized for their hydrodynamic diameter and zeta potential. Both particle types were used: sulfated cellulose nanocrystals (sCNC) and carboxylated cellulose nanorystals (cCNC). sCNC which are less surface active , more readily aggregate into polydisperse aggregates. Thin film balance (TTB) experiments show that thin liquid films made from sCNC and LAE mixtures had complex morphologies and were resistant to single, 100 Pa pressure jump. For cCNC more complex aggregate morphologies were seen with the tendency to form very regular structures in the drainage period. cCNC films showed higher lifetimes as compared to sCNC up to 0.15 mM of LAE. cCNC presented unusual properties after applied step pressure change: nanoparticle interface wrinkling and folding at LAE concentration 0.15 mM or nanoparticle disintegration into islands supported by surfactant black film at 0.35 mM LAE. Pendant drop oscillations revealed that sCNC films have higher dilatational modulus and more elastic character than cCNC films.

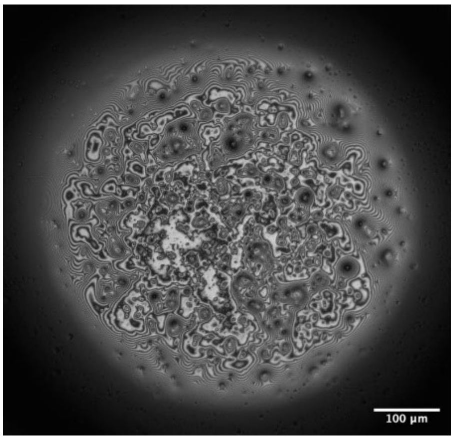

Figure 1: Film thining and regular pattern evolution in thin film balance coalescence experiment with ethyl lauroyl arginate and cellulose nanocrystals, interferometric image.

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MIXTURES OF EGG WHITE AND SAPONIN - THE DIFFERENCE BETWEEN EQUILIBRIUM AND NON-EQUILIBRIUM ADSORPTION LAYERS

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Saponin and egg white are both natural and easy-biodegradable compounds with relatively high surface activity. From the application point of view such bio-materials show a big potential in various, food, cosmetic and biomedical applications, where they can act as surfactants or emulsifiers. However, it is experimentally difficult to determine the exact surface active properties of such green surfactant mixtures due to the complex nature of their chemical structure. In the following of our previous works on the interfacial properties of adsorbed layers of egg white and also Chubak root extract as a natural source of saponin (1-2), the surface properties of the mixture of these two natural components were investigated.

The proposed contribution presents the results of adsorption studies of the mixture of saponin and egg white solutions in equilibrium and non-equilibrium conditions at the air/ water interface. The co-existence of proteins and low molecular weight surfactants (LMWS) in a solution has a profound impact on the composition of the resulting adsorbed layers. In egg white/ saponin systems (like other protein/ LMWS systems) the presence of saponin had a positive effect on the induction time of the mixture while the equilibrium surface tension did not show deviation from the equilibrium surface tension of egg white alone for a wide range of saponin concentration. This was true even at very low saponin concentrations which alone does not show measurable surface activity within 3 hours of the experiment. In addition, the surface dilational elasticity of the mixture in equilibrium conditions does not change significantly in presence of saponin at low concentrations. However, these properties are different in non-equilibrium conditions. Our experiments showed that the presence of low amounts of saponin does not affect the surface tension of the mixture meanwhile the surface dilational elasticity is decreased. These differences show that the composition of the adsorbed layer change with time and low surface active molecules are replaced by molecules with higher surface activity. The research was followed by a set of rising bubble experiments. The result showed a significant effect of saponin on the adsorption of egg white protein. Although a very low amount of saponin had a negative effect on the adsorption of egg white, amounts higher than 0.0015 g/l of saponin dramatically increased the adsorption of egg white to the air/ water interface.

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Foam Structure and Related Packing Problems

Stationary session

THE BUCKLING OF CHAINS OF HARD SPHERES AND SOFT BUBBLES

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A linear chain of hard spheres, confined in a harmonic potential, is unstable under compression and buckles. A similar behavior is observed also for chains of soft bubbles in a cylinder. However, here the deformability of the bubbles leads to some modifications. We present experimental data and theory for such chains and show that due to its simple geometry this system is particularly amenable to analytical treatment using the Morse-Witten model of bubble interaction.

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THE FOAM RISE IN A TUBE IS DRIVEN BY THE LAPLACE PRESSURE

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When an open tube of small diameter touches a liquid foam of larger bubble diameter, the bubbles spontaneously enter it one by one and in a discontinuous manner. This ascension is of interest in the related experiments of transport of foams in porous media [A. R. Kovscek 1993] or for biomedical microfluidic applications [S. L. Anna 2016]. We rationalize this observation by modelling first the dynamics of a single bubble placed manually at a tube orifice. This simpler experiment reveals that the entry is driven by Laplace pressure and the dissipation is due to the soap film friction on the wall [Bretherton 1961, Cantat 2013, Emile 2013, Raufaste 2009] and to the viscous flow of the air [Hultmark 2011]. This model is solved numerically and in a simplified form analytically. The predictions are compared to experiments.

In addition, we show that the rise of several bubbles, as occurring for foams, is well described by adding the contributions of the lamellae composing the bamboo foam, slowing down the rising dynamics.

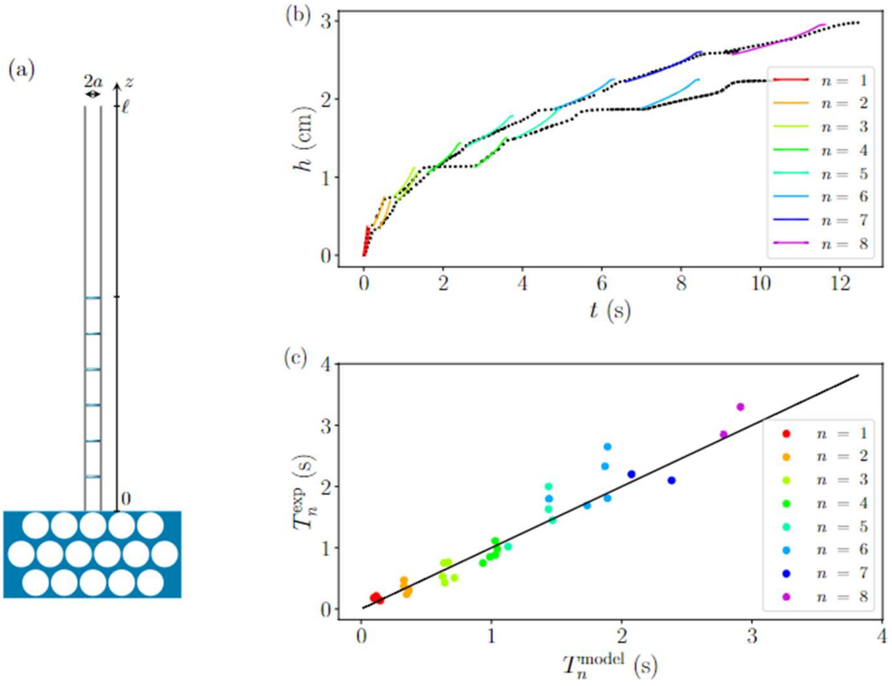

Figure 1: (a) sketch of a liquid foam rising in a capillary tube of total length l, where the inlet diameter is noted a and h the position of the first lamella. (b) The black doted lines show the time evolution of the height h for two identical experiments. The coloured lines are numerical solution of our model with n, the number of lamellae, changing every time a new bubble enters the tube. (c) The duration for one bubble to enter in the tube is T_n and depends on n. We plot

the experimental duration against the ones predicted by the model, with the black line corresponding to an equality between both.

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Coupling the shape and motion of bubbles in a CONFINED 2D flowing foam

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2D foams flows in Hele-Shaw cells with bubbles confined as a single layer have been considered as model systems to probe the rheological behavior of liquid foams. In such geometry, the frictional force between the bubbles and the confining walls greatly affects the bubbles mobility [Janiaud, 2006]. When friction occurs mainly within the surface Plateau borders [Cantat, 2013], the shape and motion of the bubbles are driven by a local equilibrium of forces acting on each soap film with three contributions: film tension, pressure force and local friction [Kern, 2004]. Most studies deal with the impact of friction on the motion of bubbles, but it is still not clear what are the main features of the bubble shape if friction can not be neglected.

To investigate this effect, we have designed a set-up that allows to produce and observe 2D foams, forced to flow through a channel of rectangular cross-section (15 cm x 1 mm), in a velocity range of 2 $\mathrm{mm.s^{-1}}$ - 2 $\mathrm{cm.s^{-1}}$.

The main result is the observation of two striking features that give rise to a "fish scale" pattern of the 2D foam flow: the bubbles are elongated in the direction of the flow and they present curved edges in preferential directions. The larger the velocity, the more pronounced this effect. We will present a model that rationalizes such observations. Modifying the bubble shape modifies the friction forces in return, which calls for a feedback on the foam mobility.

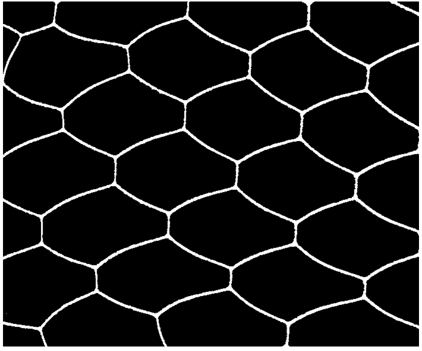

Figure
"Fish-scales" pattern inside a flowing assembly of confined bubbles. The area of the (quasi mono-disperse) bubbles in the 2D plane is around 30 mm^2. The quasi-2D foam flows from left to right.

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PERTURBING THE CATENOID: STABILITY AND MECHANICAL PROPERTIES OF NON-AXISYMMETRIC MINIMAL SURFACES

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Minimal surface problems arise naturally in many soft matter systems whose free energies are dominated by surface or interface energies. Of particular interest are the shapes, stability and mechanical stresses of minimal surfaces spanning specific geometric boundaries. The "catenoid" is the best-known example where an analytical solution is known which describes the form and stability of a minimal surface held between two parallel, concentric circular frames [Salkin, 2014]. Here we extend this problem to non- axisymmetric, parallel frame shapes of different orientations by developing a perturbation approach around the known catenoid solution. We show that the predictions of the perturbation theory are in good agreement with experiments on soap films and finite element simulations performed with Surface Evolver [Brakke, 1992]. Combining theory, experiment and simulation, we analyse in depth how the shapes, stability and mechanical properties of the minimal surfaces depend on the type and orientation of elliptical and clover-shaped frames. In the limit of perfectly aligned non-axisymmetric frames, our predictions show excellent agreement with a recent theory established by [Alimov, 2022]. Moreover, we put in evidence the intriguing capacity of minimal surfaces between non-axisymmetric frames to transmit a mechanical torque despite being completely liquid (see Fig. 1). These forces could be interesting to exploit for mechanical self-assembly of soft matter systems or as highly sensitive force captors.

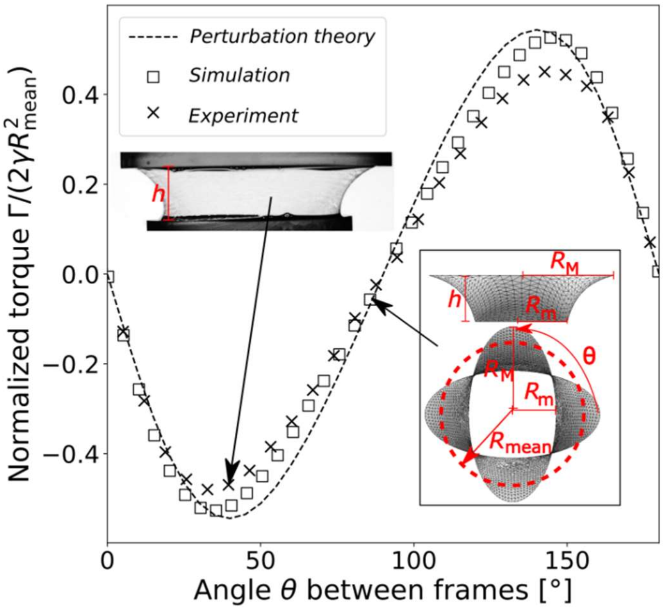

Figure 1: Normalized torque on elliptical frames

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MODELLING DRY FOAM DYNAMICS USING THE BOUNDARY INTEGRAL METHOD

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In order to understand the effects of various factors on foam rheology, a tractable foam model addressing foam dynamics is needed. The viscous froth model has been paid attention for its ability reproducing experimental observation regarding dynamic evolution of foam configuration [D Vitasari and SJ Cox, 2017P; Grassia et al, 2008; N Kern et al, 2004; SJ Cox, 2005]. However, this model has assumed the uniform distribution of pressure within a bubble, and cannot resolve the detailed foam flow field. As an alternative, a more advanced method addressing the interfacical dynamics could have been the boundary integral method (BIM). This method has been extensively studied for its applications in complex multi-phase fluid flow such as the flow of drops suspended in another fluid [C Pozrikids, 1990; FR Cunha, 2003; H Zhou, 1993; S Pålsson, 2020] as well as drops squeezing through interparticle constrictions [AZ Zinchenko, 2006]. When applying to a foam, the disjoining pressure acting on thin foam films could weaken the numerical stability in simulations and requires special treatment [IB Bazhlekov et al]. In addition, direct modelling of a realistic foam using BIM could have high computational cost due to the thin films. This burden, however, could be alleviated by adopting the dry foam assumption. In this work, we propose a novel dry foam modelling method based on BIM. The method applies in both 2D and 3D, and can be easily extended to quasi-2-D cases by adding a viscous force acting on foam lamellae. Our results show the validity of the method, which could be of high potential for future applications in more complex cases to accurately address foam dynamics.

Figure and Tables

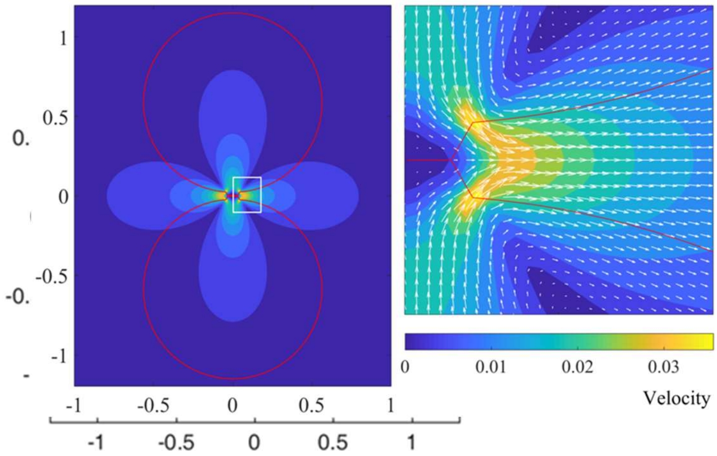

Figure 1: Relaxation processes after two bubbles contact. The intermediate configuration resulted by the quasi-2-D simulation is lagged behind due to the additional viscous force acting on foam lamellae.

Figure 2: Velocity field at the initial moment as two bubbles contact. High-velocity region occurs near the Plateau borders, due to the locally highly-curvatured lamellae.

Table 1: parameters used in the simulations.

Parameter	Description	Value
C_a	Capillary number	4.0
λ_d	Drag coefficient	150.0

Equations

In a dry foam, a point on lamella is represented by a two-fold point while the Plateau borders are represented by three-fold points. The velocity of any two-fold points on foam lamellae can be uniquely determined by an integral over the boundary of a dry foam. This boundary integral representation of velocity, in the dimensionless form, reads

$$u_j(\boldsymbol{x}_0) = u^\infty u_j^\infty(\boldsymbol{x}_0) - \frac{1}{4\pi}\int_{\Gamma_l} \left(-\frac{1}{C_a} n_i k_i - \lambda_d n_i n_k u_k(\boldsymbol{x})\right) G_{ij}\, dl \qquad (1)$$

where $\boldsymbol{u}$ is the velocity, $\boldsymbol{u}^\infty$ the velocity of exterior imposed flow, C_a the capillary number, λ_d the drag coefficient, $\boldsymbol{n}$ the unit normal vector to a lamella, $\boldsymbol{k}$ a combined vector of local curvature and local normal vector, and $\boldsymbol{G}$ the Stokeslet tensor in free space. Equation (1) reduces to an explicit expression of velocity on the boundary when is applied to dry foam flow in purely 2-D space or 3-D space. However, when applied to quasi-static foam flow between two plates, iteration method is needed as the velocity also emerges on the right-hand side of equation (1).

As the error in bubble area could accumulate during a simulation process, it is beneficial to introduce mass source into each bubble to cancel this error at each time step. Here, we consider a uniform distribution of mass source over a bubble area. The contribution of the added mass source to the velocity of boundary, i.e. $M.S.C$, is

$$M.S.C = \frac{1}{4\pi}\sum_{b=1}^{N} Q_b \int_{\Gamma_b} (x_i - x_{0i}) T_{ijk} n_k\, dl \qquad (2)$$

where Q_b is the strength of mass source in bubble b, $\boldsymbol{N}$ the number of bubbles in the dry foam, and $\boldsymbol{T}$ the stresslet tensor in free space.

We note again that equations (1) and (2) only apply to two-fold points. The position of a three-fold point, however, can be separately determined by the rule of 120-degree contact angle. This has been discussed in research on foam dynamics using the viscous froth model [N Kern, 2004], and can be used in the BIM-based modelling method for dry foam in the present work.

Acknowledgements: The authors are grateful for the sponsorship from the Resource Geophysics Academy at Imperial College London for supporting this research.

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SUM FREQUENCY GENERATION SPECTROSCOPY FOR UNDERSTANDING ARCHITECTURE OF MOLECULES AT INTERFACES

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Vibrational sum frequency generation (SFG) spectroscopy offers detailed molecular level information on the structure, ordering, and orientation of molecular groups, and the function of monolayers at various interfaces, including buried ones without noticeable contribution from the bulk phases. Of particular interest is research at the liquid-air interface, including determining the orientation of water molecules near the surface

Sum frequency generation (SFG) spectrometres are reliable nonlinear spectroscopic tools. New picosecond and femtosecond SFG spectrometres are presented. For new femtosecond SFG system realisation we created optically coupled two-channel laser system which generates narrow-band (~1.5 cm^{-1}) visible and broadband mid-IR pulses. We have achieved a high spectral resolution and a high energy of the visible channel which is limitted only by sample damage threshold.

Our picosecond and femtosecond SFG spectrometres have same property – high spectral resolution. The main features and properties of picosecond and femtosecond spectrometres are compared and discussed.

Ekspla is a laser manufacturer from Vilnius, Lithuania, designs and manufactures advanced lasers and systems. Its main competence is the ability to effectively tailor products for specific applications and requirements. The main products are pulsed femtosecond, picosecond, nanosecond lasers and tunable wavelength systems for scientific and industrial application, spectroscopy systems, and high-intensity laser systems

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Foam Structure and Related Packing Problems

Online session

TUNING THE PORE SIZE OF RIGID POLYURETHANE FOAM VIA CONTROLLED AIR BUBBLE ENTRAINMENT

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Polyurethane rigid (PUR) foams attract increasing attention as thermally insulating materials due to the urge to minimize CO_2 emission. Controlling the thermal insulation efficiency of PUR foams starts with the control of their porous morphology. In this context, the entrainment of micrometric air bubbles during the blending of the initially liquid reactive components forming the PUR foam has been shown to have a crucial impact on the final PUR foam morphology [Baumhäkel 1972, Brondi 2021]. These air bubbles serve as sites for the heterogenous nucleation and growth of foam bubbles induced by gas-releasing chemical reactions and physical blowing agent evaporation. However, detailed experimental investigation on how exactly the number of dispersed air bubbles in the liquid reactive mixture affects the final PUR foam pore size is still lacking. To fill this gap, we developed a double-syringe blending process which allows to (1) control the air bubble density in the system and to (2) strictly decouple air bubble entrainment and blending of the reactive components. This process enables us to trace back changes in the final PUR foam morphology exclusively to variations of the air bubble density in the liquid reactive mixture. Our results confirm recent findings suggesting the presence of two different bubble nucleation and growth regimes depending on the density of dispersed air bubbles [Brondi 2021] within the liquid reactive mixture. Moreover, we demonstrate an inverse proportionality between the air bubble density in the liquid reactive mixture and the final pore size of PUR foams (see Figure 1). For a single PUR foam formulation, we are therefore able to tune the mean pore size in the range of 500-1500 µm by simply controlling the initial air bubble density of the liquid reactive mixture. We think that the presented approach will not only provide an excellent model experiment to scan formulations in R&D laboratories, but it may also provide new insights on how to improve current industrial processes to push towards smaller pore sizes with identical formulations for better thermal insulation.

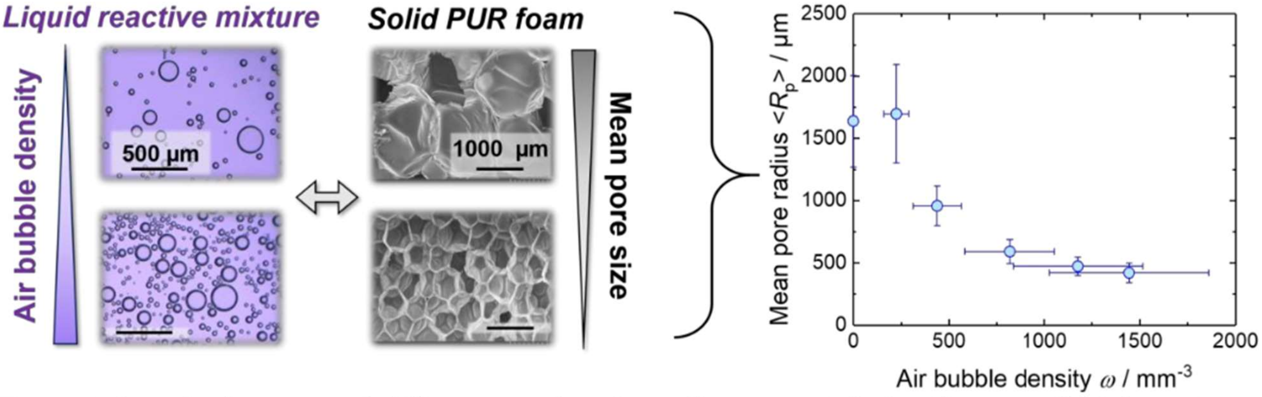

Figure 1: Interplay between air bubbles entrained mechanically in an initially liquid reactive PUR foam mixture and the pore size of the corresponding solid PUR foam.

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FOAMS AND BUBBLES IN FOODS AND CHOCOLATE

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The incorporation of bubbles in foods has created a positive market response from consumers since their first introduction over 70 years ago and has resulted in an expanding market over this period. However, although the physics and chemistry of most ingredients in commercial food products are reasonably well understood, the behaviour of bubbles and in foods are much less established and their behaviour not fully appreciated [1]. In fact, bubbles are perhaps the least studied of all food ingredients even though the aeration producing microbubbles is still one of the fastest growing unit operations in processing.

Aerated foods contain a range of air contents and many of these manufactured products, are perceived as lighter with lower calorific values but problems in manufacturing remain even today and it is generally difficult to optimize the size, the size distribution, the deviation the from spherical shapes and the stability of the bubbles during the different stages of the processing. The dispersion of the various food ingredients and the different processes involved in introducing bubbles into the melt producing well dispersed multiphase systems have been investigated by X-ray micro-computer tomographic imaging.

In aerated chocolate and the above aspects are particularly important and are discussed in some detail since it has been well established that the bubble size and size distribution can influence the texture, the mouthfeel, the crispness, the melting temperature, and the brittleness of the product [2]. Understanding the science involved in the transformation from the liquid state containing dispersed bubbles to a solid chocolate foam, stabilization of the bubbles and the control of the bubble size are highlighted.

Although CO_2 is usually used to generate bubbles in chocolate, several different gases including N_2O, Ar, N_2 have also been evaluated by Nestle and one of the research aims of several food companies to control the stability of the systems has been investigated with respect to drainage, by carrying out experiments under zero gravity conditions are also documented [3].

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NATURAL SAPONIN-BASED SURFACTANT: FOAM PROPERTIES.

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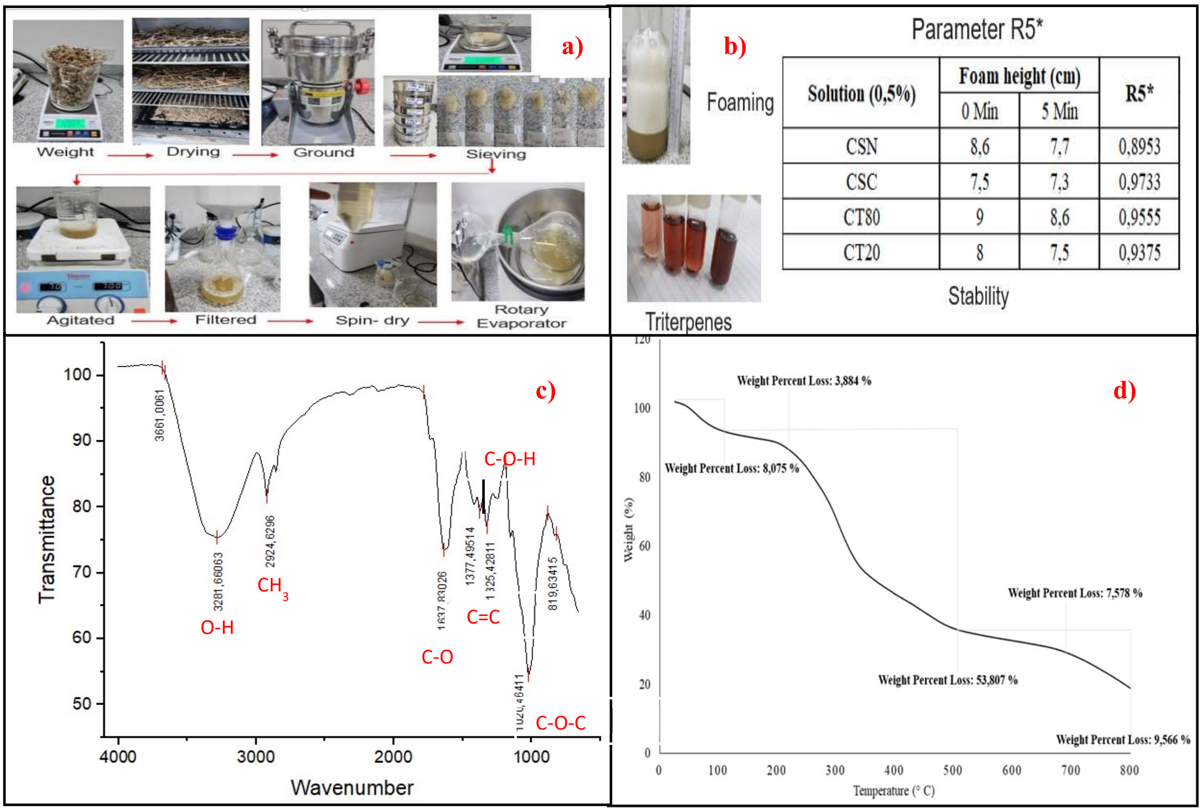
Surfactants are compounds with a wide of industrial applications. Hence, it is essential to seek novel natural sources as an alternative to synthetic ones but with similar surfactant properties [Kregiel, 2017]. Saponins are compounds, heterosides, and phytochemicals formed by various aglycones or triterpenoid steroids and one or more carbohydrates. They have high molecular weight and complex structures, giving them a variety of physical, chemical, and biological properties with numerous applications such as moisturizing, foaming, detergent, emulsifying, solubilizing, and hemolytic properties, and others; among which the ability to form foam stands out. However, various studies have established a more precise saponin definition based on its molecular structure and biosynthetic origin [Troisi, 2014].

The wet saponification was performed using the extraction method (Figure 1a). It quantified the percentage of quinoa saponins by applying the spectrophotometric method based on the construction of the calibration curve [Monje, 2006] from the saponin sample Sigma-Aldrich 47036- 50G-F (standard) as a reference profile. Liebermann-Buchard (LB) color reagent was obtained by mixing acetic anhydride and concentrated sulfuric acid (1:5). Dilutions of the commercial sample were prepared at 0.1; 0.20; 0.3; 0.4; 0.5; 0.6 and 0.7 mg/mL; 0.600 mL of each were taken, to which 1 mL of LB, was added, stirred for 20 s in a vortex, and left to stand for 37 min. The calibration curve was built (wavelength of 528 nm and 1 nm/s reading speed) and aliquot of the quinoa saponin samples was taken to be analyzed. Finally, the parameter R5* ($h_{foam\ t=5min}-h_{foam\ t=0min}$) was determined to estimate the stability of the foam.

FITR analyses were performed using Agilent Technologies Cay 630 equipment, following the KBr pillbox method, with 0.050 g of surfactant sample. The measurement parameters were: wavelength interval from 4000 to 600 cm^{-1}, resolution of 2 cm^{-1}, and eight scans. In addition, the TGA implemented the PerkinElmer STA 8000 equipment and took 10 mg of the saponin sample. The test starts from 25 °C to 800 °C, at five °C/min, using 10 mL/min nitrogen flow as carrier gas.

The presence of saponins in the quinoa wash water was confirmed by physical observation and with LB color reagent, characteristic of triterpenes. The relationship R5* parameter determined that saponin solution was 86% metastable (Figures 1b). Furthermore, different signals or asymmetric stretching vibrations and functional groups for this type of saponin were identified (Figures 1c), the alcoholic group between 3281 cm^{-1} to 2942 cm^{-1}, and the active methyl group. 2500 cm^{-1} to 1900 cm^{-1}, the presence of the C-O bond, 1377 cm^{-1} the presence of the C=C double bond, and at 1020 cm^{-1} a stretching signal C-O-C.

The TGA test showed the thermal stability of the saponins (Figures 1d), and the pronounced mass loss occurred in three regions. The most significant weight loss occurs between 200 and 400 °C, in this range, the natural surfactant has adequate thermal stability.



Solution (0,5%)	Foam height (cm)		R5*
	0 Min	5 Min	
CSN	8,6	7,7	0,8953
CSC	7,5	7,3	0,9733
CT80	9	8,6	0,9555
CT20	8	7,5	0,9375

Figure 1. Chemical characterization and properties of saponin sample.

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PREDICTION OF CONFINED FOAM FLOWS IN COMPLEX GEOMETRIES: THE EXAMPLE OF THE NEGATIVE WAKE

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Complex fluids, and in particular foams, forced in complex flows, i. e. flows in geometries more complex that simple shear or elongational flows, display a wealth of intriguing features, like the negative wake (reversal of velocity in the wake of an obstacle displaced through a complex fluids) [Hassager, 1979]. However, such complex flows of complex fluids are utterly difficult to predict, and most studies rely on experiments or complicated numerical simulations: a simple physical picture of their main features is often lacking.

We propose a simple way to tackle these flows for arbitrary 2D foam flows confined between plates. We show that under reasonable conditions, such flows are dominated by the sliding friction, and viscoelastic stresses in the foam can be treated as corrections. We therefore use the full viscoelastoplastic model by Saramito [Saramito, 2007], which has been shown to predict complex flows with great accuracy but at the price of difficult numerical simulations [Cheddadi, 2011], in its friction-dominated limit. The velocity field is then simply the classical potential flow at leading order. The elastic stress tensor is advected by this flow, and can be computed by a very simple set of ordinary linear differential equations. These have an analytical solution if plasticity is neglected, and can be easily numerically solved when plasticity is included, with a surprisingly good agreement with experimental observations. In turn, we show how elastic stresses induce corrections on the velocity field which can also be easily calculated.

In the particular case of the flow around a circular obstacle, we show that elastic stresses do not fully relax in the wake. This requires a boundary-layer-like treatment in the wake, which yields the velocity field associated to the negative wake, for the first time, as a simple expression. We show that this novel prediction compares very well, at least qualitatively, with our experiments on foams of various liquid fraction flowing around obstacles. This new analytical method paves the way towards a much simpler understanding of the intricate coupling between elasticity and flow in viscoelastoplastic flows in general, and in foams in particular.

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SETTING OF MINERAL FOAMS: REACTION KINETICS VS SOLIDIFICATION

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Mineral foams like gypsum plasterboard, foamed concrete or artificial bone are porous materials obtained by foaming a hydraulic binder (cement, plaster, etc.), i.e. a reactive suspension (figure 1). They are sought for their lightness, their porosity or their absorbing or insulating properties. These properties are largely determined by the pore morphology, which results from the balance between aging of the fresh liquid foam, and setting, i.e. solidification following a dissolution-precipitation reaction.

To understand how the setting process is affected by the foam geometry and the foaming process, we combine Raman spectroscopy and bubble size measurements to probe at the same time the kinetics of reaction in a plaster foam, and the arrest of coarsening due to the stiffening of the liquid foam structure. We show the strong effect of the foaming process on the reaction kinetics. By using a setting retardant, we also show that the reaction timescale controls the final pore size in the solid foam.

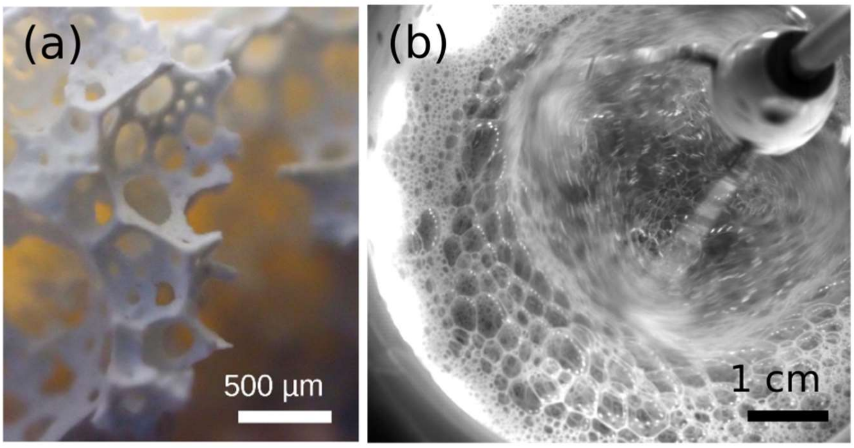

Figure 1: Plaster foam (solid material, a) obtained by foaming a liquid plaster suspension (b).

Foam and Aerogels Stability: Drainage, Coarsening, Coalescence / Film Rupture

Stationary session

Impact of evaporation on foam films and bubbles stability

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The stability of soapy objects such as films, bubbles and foams has been studied widely because of the numerous applications concerning food industry, climate prediction or artistic utilization of giant bubbles.

It has been demonstrated that their stability is primarily affected by the thinning dynamics of the thin soap films. The drainage dynamics, which is the capillary or gravity driven flow in the liquid film has been widely investigated [1]. However, more recently, researchers also became interested in the influence of evaporation on this thinning dynamics [2,3].

In this presentation, I will show that, to describe bubble stability, evaporation must be taken into account as soon as the films are thin enough [4]. We will see that the bubble lifetime can be predicted by taking into account both the drainage and the evaporation to describe the thinning dynamics [2] and that this is all the more important concerning the stability of giant soap films. I will also esquisse some hypothesis concerning the influence of physical-chemistry on the film thinning.

Figure 1: Soapy objects whose stability is affected by evaporation: foam, Giant soap film and surface bubble.

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AQUEOUS FOAM COARSENING STUDIES IN THE INTERNATIONAL SPACE STATION

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When bubble coalescence and drainage are negligible, the microstructure of aqueous foams coarsens with time due to gas diffusion among bubbles driven by capillary pressure. At long times, statistically self-similar growth sets in where the bubble size distribution scaled by the average radius becomes independent of foam age and this radius grows asymptotically with age following a power law. Its exponent has been studied and explained in dilute bubble dispersions and dry foams containing very little liquid. However, the cross over between these regimes and its relation with the jamming transition where spherical bubbles touch their neighbours remains to be clarified.

To fill this gap, we have investigated foam coarsening in the International Space Station where gravity induced drainage is avoided. Foams with a wide range of controlled liquid fractions were observed at their surfaces using a camera and, in the bulk, using multiple light scattering (Born et al., 2021). We find good agreement with previous experiments and theories in dry foams and the expected coarsening exponent in dilute bubble dispersions. We also analyse the shape of the bubble size distributions, providing evidence for a statistically self-similar growth regime at long times. The size distributions feature an unexpected contribution of small bubbles. At liquid fractions close to the jamming transition we observe a sharp crossover where growth exponents and bubble size distributions change in the statistically self-similar regime. The coarsening rates agree with theories at liquid fractions below 25%, they are much larger closer to jamming.

These new features remain to be explained and numerical simulations are currently being undertaken.

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SURPRISE BEYOND COARSENING: FLUOROCARBON VAPOURS REDUCE COALESCENCE IN FOAMS

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For decades, traces of fluorocarbon (FC) vapours have been added to the gas phase of foams to improve their long-term stability by suppressing the gas exchange between bubbles via an osmotic effect. In doing so, it has generally been assumed that the FC had no other effect on foam stability. However, we show here that FC (perfluorohexane in our case) also has a pronounced effect on coalescence in foams, i.e. on the stability of foam films against rupture [Steck 2021]. Working with surfactants that make highly unstable foams (see Figure 1), we show that coalescence is dramatically reduced and that this is a general phenomenon for a wide range of surfactants (ionic and non-ionic surfactants, siloxane surfactants, lipids, etc.). We confirm this observation with life time measurements of individual foam films generated in a thin film pressure balance and a vertical film pulling device. Similar observations were made with emulsions, when working with Ostwald ripening (coarsening) inhibitors [Schmitt 2004]. We complement our investigations with surface tension measurements of the foaming solution in the presence of FC at different partial pressures. These measurements show a clear synergy between the fluorocarbon and the surfactant which can be explained by (a) the formation of mixed layers of both species at the gas/water interface at low fluorocarbon concentrations and (b) the formation of a macroscopic fluorocarbon film if the gas phase is saturated with fluorocarbon vapor [Fainerman 2017]. Similar phenomena have been put in evidence for alkane vapours [Binks 1996]. How exactly the mixed FC/surfactant layer leads to a reduction in coalescence remains to be elucidated.

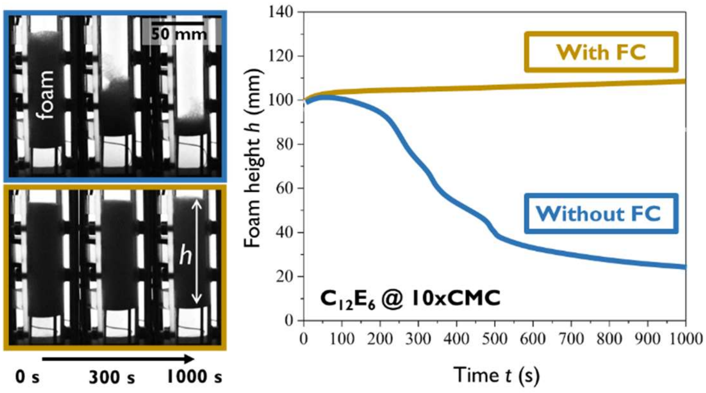

Figure 1: Evidence of increased foam stability in the presence of fluorocarbon vapours at short time scales via reduction of coalescence. (left) Photographs showing temporal evolution of foams, (right) foam height vs time.

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WHEN NEUTRONS DIVE INTO FOAM: SCATTERING AND REFLECTIVITY TO FOLLOW AGING OF FOAMS

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Liquid foams are non-equilibrium multi-scale soft structures. Moreover, the foamability of a surfactant solution as well as the metastability of the foam are still difficult to predict. In order to better understand the physico-chemical factors that affect the aging of foams at different length scales, a new columnar device was developed. It enables the simultaneous data collection from a small-angle neutron scattering (SANS) diffractometer, from an optical camera and an electrical conductivity meter. In order to evaluate the potentiality of this device, a foam from a mixture of the nonionic alkylether BrijO10 surfactant and of the sodium dodecyl sulfate (SDS) anionic surfactant was generated in D2O and analyzed as a function of time.
The volume of the foam, its liquid fraction and the radius of the foam bubbles as a function of time (obtained by image analysis and conductivity processing) are macroscopic information, necessary for foam lifetime characterization but not sufficient. SANS analysis is known to provide useful information at the nano-scale, on the structure of the inter-bubble film or the surfactant self-assemblies trapped within the foam [Axelos, 2003][Mikhailovskaya, 2017][Hohenschutz, 2021]. However, to extract this information over a large structural range and in order to be able to compare the various structural features (the specific surface area, the liquid fraction, the film thickness) determined from different techniques, we have for the first time performed a quantitative analysis - in absolute scale - of the scattering data.
The analysis of nano- and macroscopic information obtained simultaneously enabled us to better understand the correlation between the mechanisms of drainage, ripening and coalescence involved at the different scales in the aging of the foam.

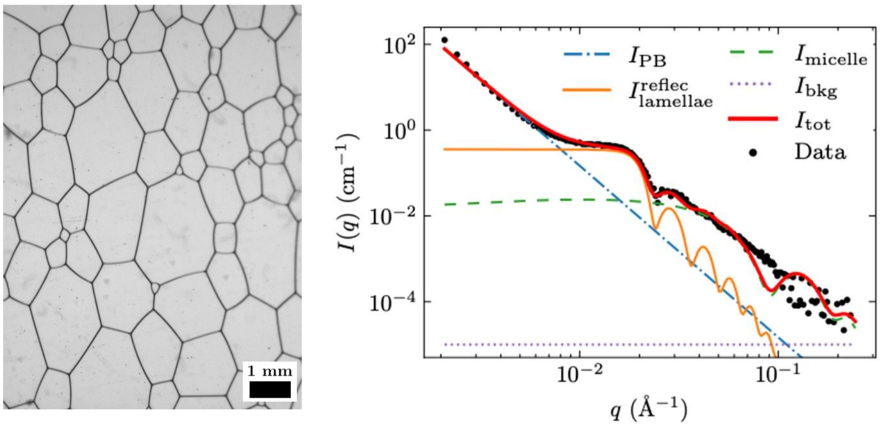

Figure 1: Left - Picture of a foam obtained for a 65 min aging time (free drainage mode). Right - Various contributions of the total scattering simulation (red curve) to adjust SANS data from a foam as photographed in left picture : I_{PB} *from Plateau Borders,* $I_{micelle}$ *from micelles present within the foam,* $I_{lamellae}^{reflec}$ *from lamellae.*

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FOAMABILITY OF POLYVINYL ALCOHOL SOLUTIONS AND EFFICIENCY OF ANTIFOAM AGENTS

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In recent studies [1,2] it was shown that the foamability of solutions of conventional surfactants with hydrocarbon chain-length from 12 to 16 C-atoms depends primarily on: (1) the dynamic surface coverage of the bubbles by surfactant molecules and (2) the charge of the surfactant head-group. Two master curves, one for the nonionic and another one for the ionic surfactants, were found to describe the experimental data for the various systems, studied under different experimental conditions.

In the current study we investigate the foamability of a series of polyvinyl alcohols (PVAs) with different molecular mass and degree of hydrolysis, in four different foaming tests, and compare the obtained results with those for one ionic surfactant (sodium lauryl ether sulfate, SLES) and one nonionic surfactant (Brij 35). The efficiency of one silicone-based antifoam compound and its emulsion on the respective foams was also determined.

The foaming experiments performed in the absence of antifoam showed that the rate of PVA adsorption on the air-water interface depends on the degree of PVA hydrolysis – higher degree of hydrolysis leads to higher hydrophilicity of the polymer molecule and to related lower adsorption. As a consequence, the foamability of PVA solutions with higher degree of hydrolysis is lower, the foams formed are much less stable, and the antifoam compound and emulsion destroy these foams very efficiently. The experimental data for the PVA solutions fall on the master curve for the other nonionic surfactants, showing for first time that the approach developed for regular surfactants in Refs. [1,2] can be used also for describing the foamability of polymeric solutions.

The efficiency of the antifoam compound is much higher for foams generated in the fast foaming methods (e.g. in the Bartsch test), as compared to the foams formed in slow foaming method (bubbling test), thus showing that the critical parameter for the antifoam performance is the surfactant area-per-molecule in the dynamic adsorption layer during foam generation. Good correlation between the antifoam efficiency and the surfactant area-per-molecule is found, as in the previous study [3].

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MEASUREMENT OF LIQUID FRACTION OF FOAM BY CONDUCTIVE WIRE-MESH SENSOR

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The liquid fraction Φ of foam is an important quantity in engineering process control and essential to interpret foam rheology. Currently available methods are either complex laboratory-based techniques or cannot provide spatial resolution. Therefore, in this work we performed in-situ measurements of the liquid fraction based on foam's electrical conductivity [Feitosa, 2005] by employing conductive wire-mesh sensor (WMS) [Prasser, 1998]. Two arrays of wires are placed inside the foam (figure 1a) and at each crossing point the local liquid fraction is determined. This approach offers 2D measurement of liquid fraction distribution (figure 1b) with very high frame rate, up to 10k fps. The measurements were validated by simultaneous measurement of liquid fraction by neutron radiography (NR) [Heitkam, 2018].

A systematic dependency between WMS readings and the liquid fraction from NR is found (figure 1c). However, WMS overestimates the liquid fraction systematically, which could be an effect of the liquid bridge formation between the wires.

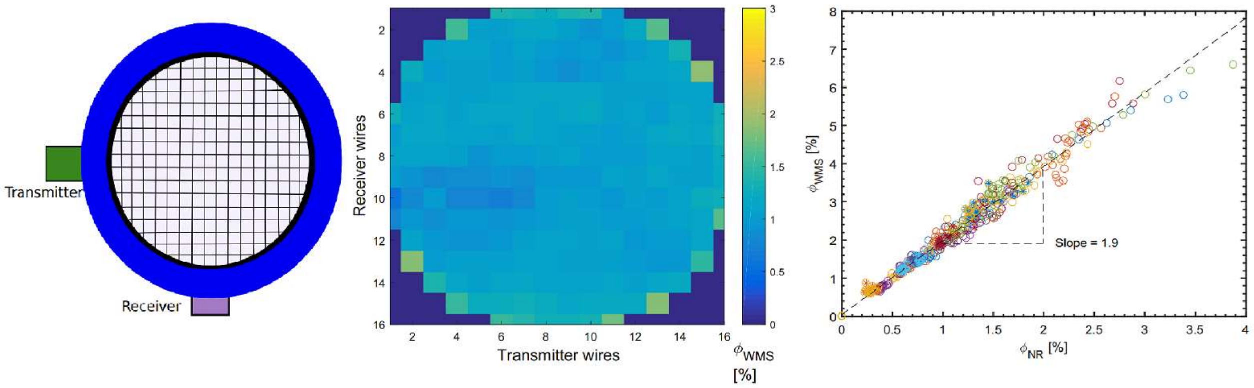

Figure 1: (a) Schematic of a wire-mesh sensor; (b) 2D distribution of liquid fraction Φ measured by WMS; (c) parity plot of liquid fraction measured by WMS and neutron radiography where different colours in the circle symbol indicate different measurement runs.

Acknowledgements: The financial support by the Deutsche Forschungsgemeinschaft (HE 7529/3-1) is gratefully acknowledged. This work is based on experiments performed at the Swiss spallation neutron source SINQ, Paul Scherrer Institute, Villigen, Switzerland.

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DYNAMICS OF TWO-DIMENSIONAL LIQUID BRIDGES

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We have simulated the motion of a single vertical, two-dimensional liquid bridge spanning the gap between two flat, horizontal solid substrates of given wettabilities, using a multicomponent pseudopotential lattice Boltzmann method. For this simple geometry, the Young–Laplace equation can be solved (quasi-)analytically to yield the equilibrium bridge shape under gravity, which provides a check on the validity of the numerical method. In steady-state conditions, we calculate the drag force exerted by the moving bridge on the confining substrates as a function of its velocity, for different contact angles and Bond numbers. We also study how the bridge deforms as it moves, as parametrized by the changes in the advancing and receding contact angles at the substrates relative to their equilibrium values. Finally, starting from a bridge within the range of contact angles and Bond numbers in which it can exist at equilibrium, we investigate how fast it must move in order to break up.

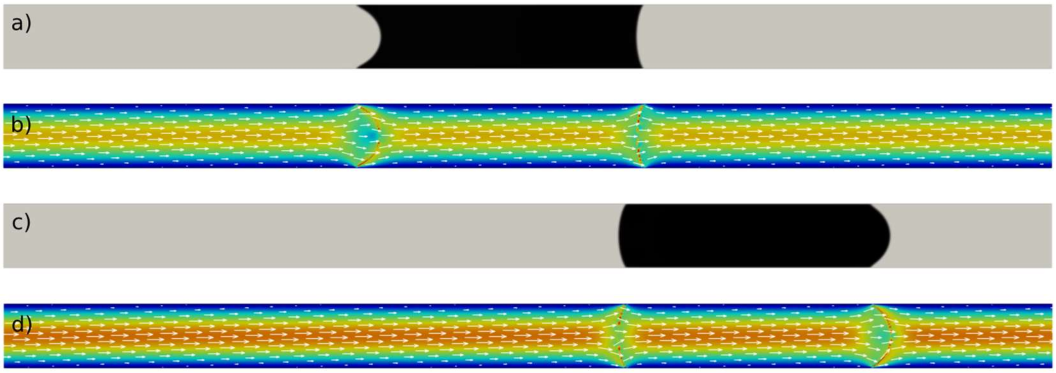

Figure 1. Example of two liquid bridges moving due to an external force between (a) two hydrophilic substrates, and (c) two hydrophobic substrates. Panels (b) and (d) show the velocity fields corresponding to panels (a) and (c) respectively, where the colours denote the velocity magnitude (red for fast and blue for slow) and the arrows indicate its direction.

Acknowledgements: We acknowledge financial support from the Portuguese Foundation for Science and Technology (FCT) under the contracts: EXPL/FIS-MAC/0406/2021, PTDC/FIS-MAC/5689/2020, UIDB/00618/2020 and UIDP/00618/2020.

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Foam and Aerogels Stability: Drainage, Coarsening, Coalescence / Film Rupture

Online session

LIQUID PINCH-OFF FROM A FOAMY DROPLET IN A HELE-SHAW CELL

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Placing some foam on a vertical surface is a ubiquitous situation in our daily life; we put some amount of foam on our faces during shaving, or on a vertical wall to clean it. In such a situation, sometimes foams lose their solution from the bottom. To address when it happens, we carried out a model experiment. We confined some amount of foam in a Hele-Shaw cell and observed how the foam behaves under the gravity. Sometimes the solution aggregating at the bottom of the foamy droplet pinches off ("pinch-off" mode) but sometimes it does not happen ("No Pinch-off" mode) as shown in Fig. 1. We predicted that the liquid hanging from the bottom of the foamy droplet pinches off if the weight of the hanging liquid is greater than the capillary force, i.e.,

$$m_\ell > 2D\gamma/(g\sin\alpha) = m_\ell^*. \qquad (1)$$

Here, m_ℓ is the mass of hanging liquid, D is the cell thickness, γ is the surface tension of the solution, g is gravitational acceleration, and α is the tilting angle of the cell, respectively. We fabricated a morphology phase diagram and confirmed that our experimental results are explained well by the prediction as shown in Fig. 2 [Tani, 2022].

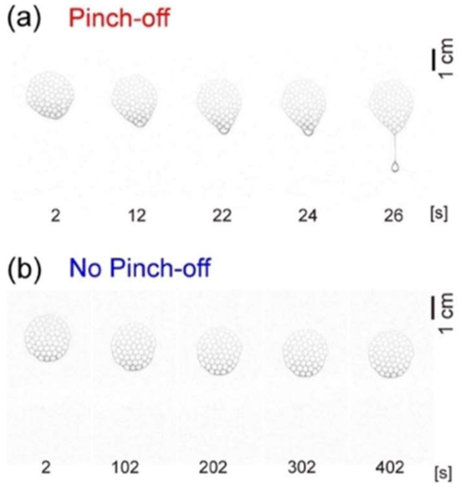

Figure 1: series of pictures observed in our experiments: (a)"pinch-off (P)" and (b)"no pinch-off (NP)" modes.

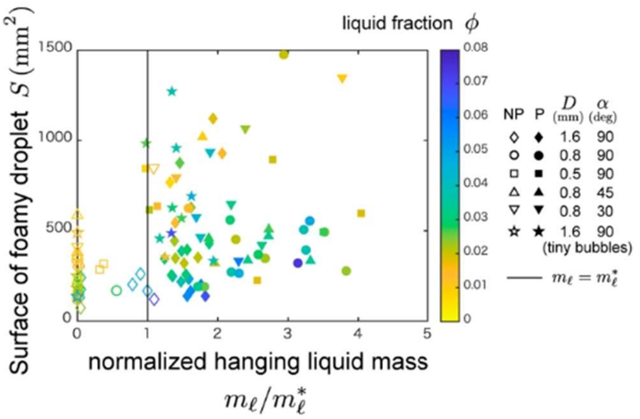

Figure 2: morphology phase diagram where the observed patterns are mapped as the functions of surface area of the foamy droplet S and the normalized mass m_ℓ/m_ℓ^* of the liquid hanging from the bottom of the foamy droplet.

Acknowledgements: This work was partially supported by JSPS KAKENHI (20K14431,17H02945 and 20H01874).

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DYNAMICS OF STRUCTURAL RELAXATION NEAR A DRY-WET TRANSITION IN A TWO-DIMENSIONAL FOAM

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Liquid foams can take three states depending on the liquid fraction ϕ; these are called dry, wet and bubbly foams, from low to high ϕ. Bubbly foams consist of spherical bubbles, but do not have an elastic modulus under small shear. The transition point from wet to bubbly is consistent with the jamming transition point ϕ_J (~ 0.16 in two-dimensional foams). The wet foams near ϕ_J have physical properties similar to frictionless soft particles such as emulsions and colloidal suspensions, and many studies have reported that static properties show the critical behavior near ϕ_J [G. Katgert, 2010][A. Boromand, 2019]. However, dynamical properties of the wet foams are poorly understood. Recently, we experimentally investigated the dynamics of the structural relaxation of bubbles in the two-dimensional wet foams by injecting a constant amount of liquid into the foams. The slight increase in ϕ as a perturbation induces a rearrangement of bubbles. We found that the correlation length and relaxation time associated with the rearrangement event increase as ϕ increases. Furthermore, it was found that its collective rearrangement depends on the size distribution of the bubbles [N. Yanagisawa, 2021].

In this study, we experimentally clarify the dynamics of the structural relaxation of bubbles near the dry-wet transition. As a result, we observe the sequential bubble rearrangement, and find that this characteristic relaxation behavior is related to the degree of anisotropy of the bubble shapes [N. Yanagisawa].

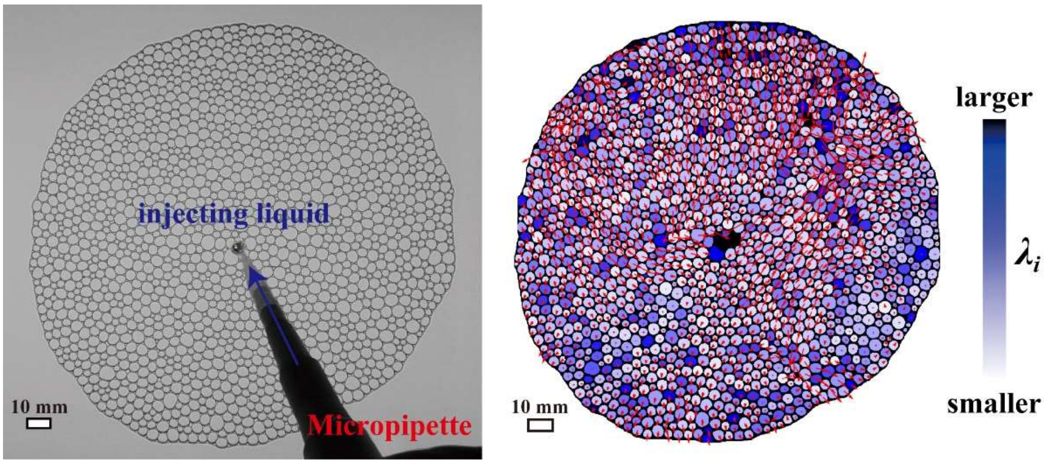

Figure 1: (left) Snapshot of foam in our experiment. (right) Overlapped image of spatial distribution of displacement vectors and an anisotropy parameter for bubbles. Vectors are shown five times larger than their actual lengths for visibility. λ_i is the anisotropy parameter for bubble i.

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A WINDING PATH TO SUPERSTABLE LIQUID FOAMS STABILISED BY POLYELECTROLYTE MULTILAYERS

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Despite intensive research on "superstable" foams with solid-like interfaces, many questions remain open concerning their morphology. Our objective is therefore to modify the mechanical properties of bubble surfaces in a controlled manner in order to systematically investigate their influence on the stability and self-organization of bubbles in a foam. We focus our study on two aspects: (1) creating interfaces with controlled mechanical properties, and (2) large-scale generation of bubbles stabilized by these interfaces. For (1), we deposit successive polyelectrolytes multilayers (PEM) of alternating charge (NaPSS- and PAH+) on the surface of air bubbles [Trégouët 2018]. To characterize the viscoelastic properties of the created "Polymeric skin" as a function of the environmental conditions and number of PEMs, we use oscillatory pressure elastometry in a rising bubble configuration (Figure 1a) [Ginot 2021]. For (2), we are developing a millifluidic system to continuously generate air bubbles travelling through solutions containing the polyelectrolytes of alternating charges (Figure 1b). For this purpose, several communicating millifluidic chips are stacked to allow bubbles to successively travel in the different polyelectrolyte solutions at timescales sufficient for polymer adsorption (Figure 1c) [Dubas,1999]. We optimize the flow conditions to avoid flow instabilities and ensure a limited liquid phase mixing by fluorimetry. Finally, we provide a first analysis of the long-term stability of foams composed of PEM-coated bubbles, showing that these foams are stable over at least six months after PEM adsorption.

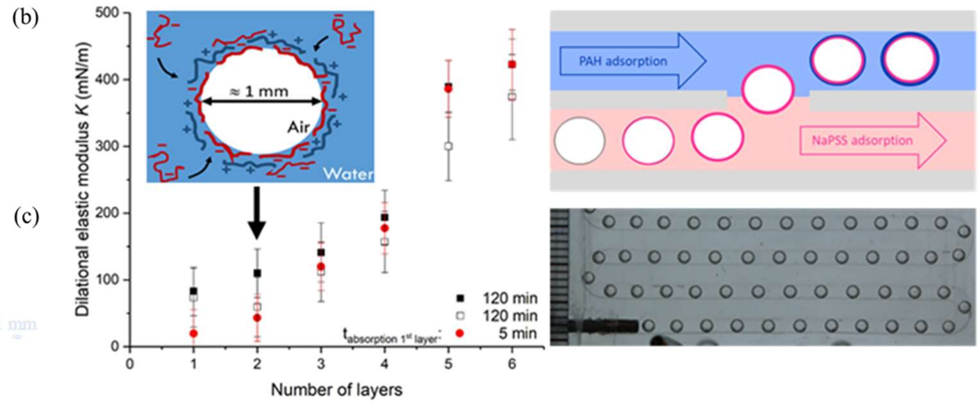

Figure 1: (a): Dilational elastic modulus K as a function of the number of polyelectrolyte multilayers (PEMs) obtained from pressure elastometry. Insert: Scheme of a bubble covered with a polyelectrolyte bilayer.
(b) Illustration of bubbles changing channel and hence polyelectrolyte solution.
(c) Continuous bubble generation in the millifluidic chip.

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THE TEMPERATURE OF SOAP FILMS

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The stability of soap bubbles and films has implications in many unsuspected areas. The aerosols created during the bubble bursting are involved in the exchange of liquid between the ocean and the atmosphere, but also in air pollution, for example above swimming pools, in toxins aerosolization as well as in the expel of flavors on top of carbonated drinks. Induced aerosolization is also relevant in glass industry, where they are at the origin of major defects or in geological physics such as gas exsolution in magmatic chambers.

The lifetime of the bubbles and films, stabilized by surface active molecules, is essentially determined by the thinning rate. This thinnign rate is fixed both by the liquid flow in the film, the so-called capillary or gravity drainage, and by evaporation. If soap film drainage has been widely studied, it is only very recently that advances on the influence of evaporation on thinning have been obtained [Li2012,Poulain2018,Champougny2018]. These recent results have demonstrated the significance of evaporation, which becomes prevalent for films of a few hundred nanometers or less.

Obviously, the evaporation rate directly contributes to the film thinning [Poulain2018,Miguet2020], but it also impacts the soap film lifetime through various mechanisms, for which the relative importance is not yet fully quantified. To the best of our knowledge the existence of a global cooling due to evaporation of foam films has been overlooked.

In this presentation, I will show the significance of evaporation-induced cooling. To do so, we measured and modeled the temperature variation of an evaporating soap film for different ambient humidity values and glycerol concentrations (Figure 1 left).

Experimentally, we observed that the temperature first decreases and then increases until the ambient temperature is reached again. We report that the magnitude of the cooling effect depends on both the relative humidity and the initial glycerol concentration, decreasing the values of these two parameters leading to stronger effects. This cooling effect is explained by the soap film evaporation through the latent heat of vaporization. As shown in the right part of figure 1, we modeled satisfactorily the maximum cooling effect by considering a heat balance constituted of the latent heat of vaporization, the thermal conductivity from the surrounding atmosphere to the film, and the radiative flux. The cooling can reach -8°C in our conditions.

We expect that the cooling effect can be significant, especially regarding the questions raised by the community on surfactant crystallization, film drainage, marginal regeneration, and film lifetime.

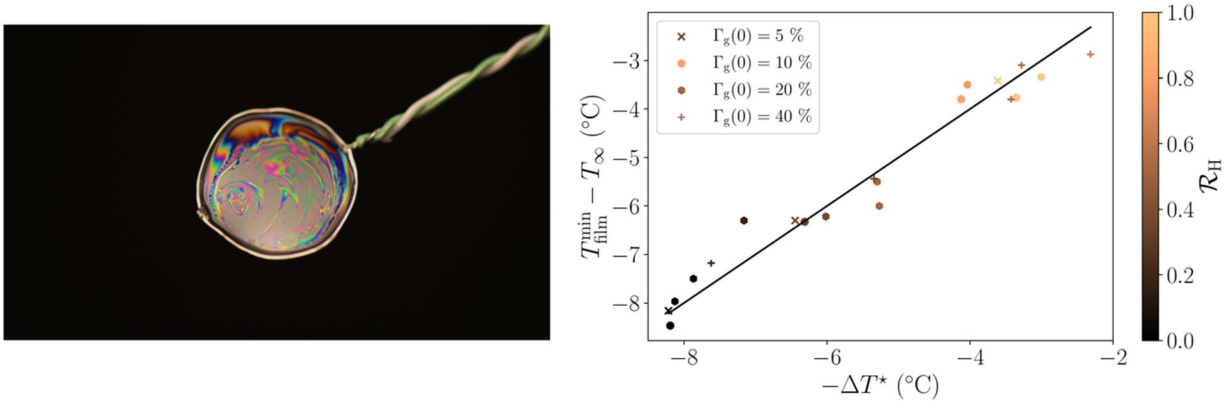

Figure 1: (left) Photograph of a soap film hanging on a frame constituted of a thermocouple probe. The radius of the soap film is 6 mm. (right) Maximum cooling effect as a function of theoretical prediction. The relative humidity is encoded by color and the initial glycerol concentration by the symbols. The solid line represents equality between the two axis.

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DETERMINATION OF FOAM STABILITY THROUGH ELECTRICAL MEASUREMENTS IN LIQUID BRIDGES

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Foams can be found in many products such as foods, cosmetics, fire extinguishers, etc. Moreover, they are part of various processes (flotation, oil extraction, wine production). There are cases where the presence of foam in a product or in a process is desirable and its stability adds value to them. However, there are also cases where the presence of stable foam is detrimental. In the present work, the creation of an air-bubble inside a liquid bridge, during the reduction of the volume of the bridge, allows the formation of a thin liquid film**.** The application of electrical measurements at the bridge (and as a consequence at the film), allows the determination of the film stability against rupture and thus of the foam resistance to coalescence.

Experiments took place with liquid bridges created by several solutions of surfactants (e.g. SDS, BaC 50, Ethylan 1008) at different concentrations but also of various mixtures of them, in the presence and in the absence of NaCl, under stable ambient conditions (i.e. temperature and moisture), and for various liquid drainage rates (e.g 10 and 20μl/h). These experiments showed that the highest the concentration of the surfactant, the highest the strength against thinning of the thin liquid film interface so the longest the time until its rupture, thus the stability of the corresponding foam would be also the highest.

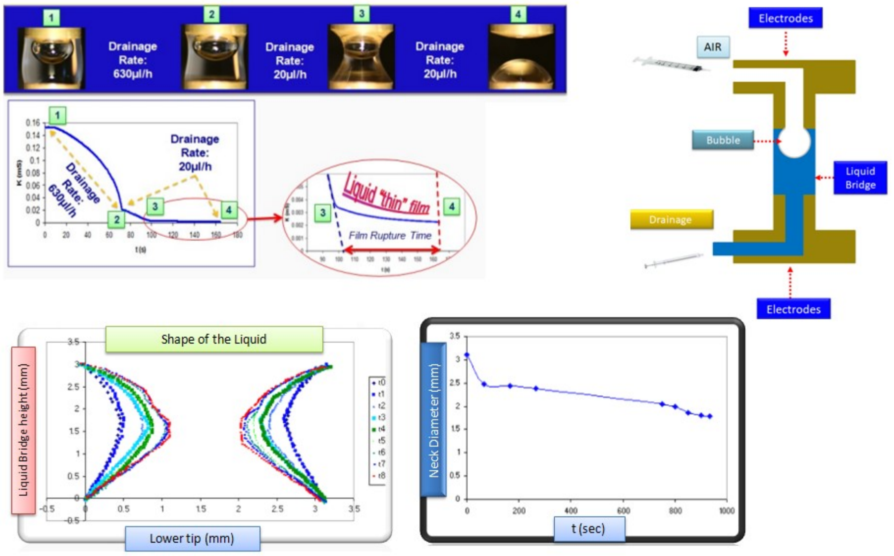

Figure 1: Electrical measurements in liquid bridges for the determination of liquid film stability

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MICROSCOPIC ORIGINS OF DISSIPATION IN SHEARED 2D FOAMS: INSIGHTS FROM SIMULATIONS.

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Foam mechanical properties (rheology) are modified by (i) the foam structure, such as its liquid fraction, the bubble size or the packing properties and, (ii) the nature of the surfactants used to stabilize the foam.
By running level-set simulations of a sheared 2D bubble assembly [1], we investigate this second point. In particular, we identify the different origins of microscopic dissipation, and we quantify them as a function of the physical properties of the surfactant molecules (diffusion coefficient, ability to adsorb at interfaces…). Finally, our results are compared with an analytical derivation of these thermodynamical effects [2] in the case of a single film submitted to small deformations, an extension of the situation investigated by Lucassen 50 years ago [3]. Whereas this simple model captures well most of our simulation results, discrepancies due to the complex geometry of a liquid foam will be discussed.

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Particles / Aggregates or Fibers in Foams, Aerogels or Thin Liquid Films

Stationary session

NANOPARTICLE – SURFACTANT MIXTURES AT LIQUID INTERFACES: PROPERTIES OF THE INTERFACIAL LAYER, FOAMS AND EMULSIONS

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Composite nanoparticle – surfactant layers at liquid interfaces have been widely investigated during last decades being of great interest in many applied fields spanning from the stabilisation of emulsions and foams to the development of innovative nano-structured materials, such as nano-capsules or functionalized porous materials. These layers may be obtained exploiting the spontaneous adsorption and self-assembly of amphiphilic NP-surfactant complexes at the surface of composite dispersions. The type and amount of surfactant associated to nanoparticles determine the capability of complexes to segregate at the liquid interfaces and to modify the mechanical and structural properties of the layers [Liggieri 2011]. We present here recent results where composite layers are investigated both at water-air and liquid-liquid interfaces with the aim of deepen the mechanisms of formation and surface re-organization in relation to their mechanical and viscoelastic dynamic properties. The adsorption properties of the complexes at liquid interfaces are investigated via interfacial tension and dilational rheology measurements. Emulsions and foams stabilized by the same surfactant-NP systems have been also investigated and their behaviour interpreted on the basis of the interfacial properties characterization.

Results obtained for binary nanoparticle dispersions, specifically TiO_2 - SiO_2, associated to a short chain cationic surfactant, in relation to their efficiency as foam stabilizers, are also presented which allowed us to understand the role of the dispersion composition in setting up the selective adsorption to the water-air interface which determines the structure of the mixed interfacial layers [Llamas 2010].These results are important in view of the application to the development of new functionalized porous materials. To this regard, recent results are presented on the production of solid foams adopting techniques which utilizes particle stabilized foams to obtain porous materials with particular morphological and functional features such as, for example, TiO_2 based photocatalytic filters for air purification [Zabiegaj 2017, Cristofolini 2022].

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Cristofolini et al. submitted to Colloids and Surfaces A, 2022

RHEOLOGY OF A PARTICLE-LADEN SOAP FILM

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Research in line with the pioneer work of Pickering succeeded recently to produce new objects which can be described as gas pockets in air and are named gas marbles. They are made of gas surrounded by a layer of grains constrained by thin liquid film in gas environment [Timounay 2017]. The rheology of such particle laden soap has still to be understood and is promised to be different of the one of granular raft as cohesion between grains are strengthen by confinement of liquid between two liquid/air interfaces. We investigate experimentally the behaviour of particle laden soap film constituted of slightly polydisperse polystyrene spheres trapped in a single film made of a tetradecyl trimethyl ammonium bromide (TTAB) and glycerol aqueous mixture of the same density as the particles. The particles being of a diameter (~ Ø 80 µm) greater than the typical film thickness they cross both interfaces and the surface tension gives rise to attractive interactions between the particles. To study the strain-stress relation of particle laden film, it is stretched in the rheometer cell and sheared at imposed velocity, measuring the stress. The strain-stress results are compared with local shear rate measured through image correlation. We show that, at dense particle volume fraction, the granular film exhibits a complex visco-plastic behaviour which is largely influenced by interfacial parameters such as surface tension and surface viscosity of the carrying fluid. To account for the non-local rheology of the particle laden soap film, we confront the particle velocity fields to kinetic theory extended to dense granular media [Losert 2000].

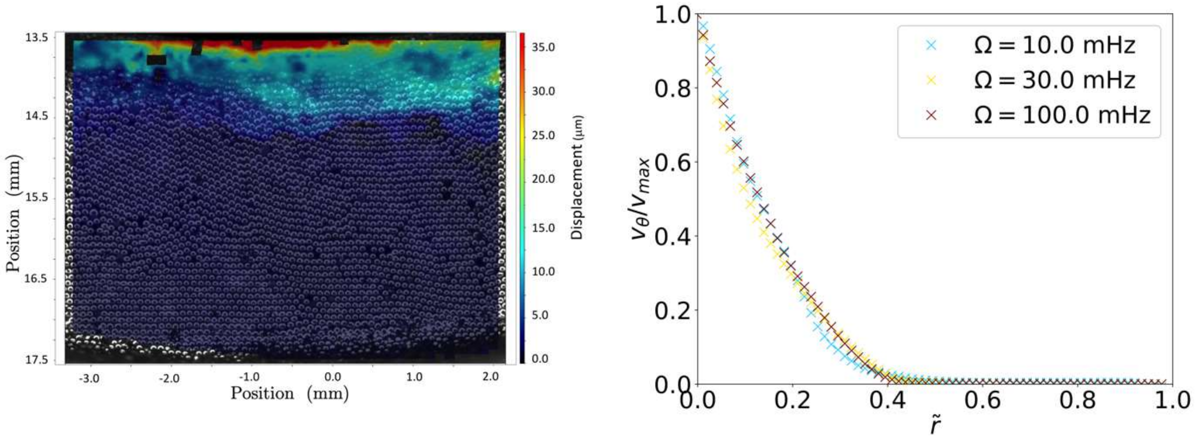

Figure 1: Left : Image of a portion of a granular film in the rheometer cell for an axis rotation of 10 mHz. The colour maps codes the displacement fields during $\delta t = 5\ 10^{-2}$ *s. Right : Velocity profiles along a radius of the rheometer cell for different rotation speed.*

Acknowledgements: This work has received support from the CNRS and ANR-19-CE30-0009

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DEFORMATION OF THIN ELASTIC RIBBONS IN QUASI-2D FOAM COLUMNS

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Liquid foams usually exhibit well-defined structural features governed, in the low-density limit, by Plateau's laws. Confining bubbles into tubes to form foam columns leads to periodically ordered foam structures which are controlled by the ratio of tube width to bubble diameter [Pittet, 1995]. Such foam columns are particularly well-suited to investigate quantitatively their interaction with deformable objects. It was shown that the competition between elasticity and capillarity allows to assemble, orient or spontaneously bend slender elastic structures [Roman, 2010].

We consider a model experiment, consisting of the so-called "staircase" structure formed in a square section tube where bubbles of equal volume are rearranged in a staggered pattern [Hutzler, 2009]. This quasi-2D structure has central soap films connected with 120° angles, in which we introduce elastic ribbons of different bending rigidities. We focus on the elasto-capillary interactions between the ribbons and the periodically ordered foam to find out which parameters lead to the deformation of the ribbon (capillarity dominated) or to the deformation of the foam (rigidity dominated). Using X-ray micro-tomography, we quantify the equilibrium shapes of the quasi-2D foam/ribbon systems. We provide a detailed analysis of the ribbon profile, that compares well with our theoretical predictions in the whole range of bending rigidities. Finally, we discuss proof-of-concept experiments showing that such setup can be used as a method to mold materials with characteristic shapes and curves imprinted by the foam structure [Jouanlanne, 2022].

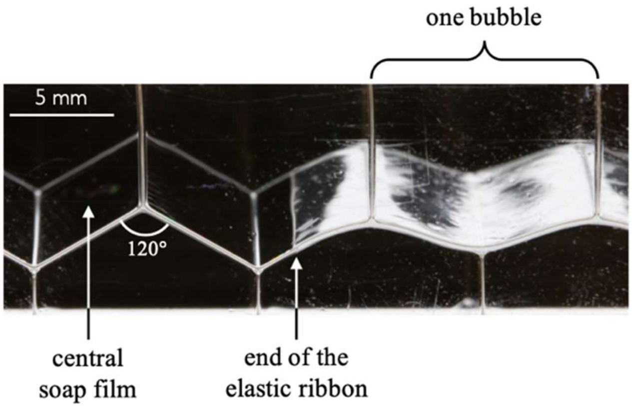

Figure 1: Equilibrium shapes of a quasi-2D foam/ribbon system: column of bubbles periodically ordered into a staircase structure, with (right) and without (left) a thin elastic ribbon inserted into the structure.

Acknowledgements: We thank all colleagues from MIM, TSP, MCUBE, PECMAT teams for the fruitful discussions and the access to equipment at ICS. We also acknowledge funding from the Interdisciplinary Institute HiFunMat and the ERC Consolidator Grant (agreement 819511 – METAFOAM).

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INFLUENCE OF THE LIQUID PRESSURE ON GRANULAR FILM OPENING

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Gas marbles are new materials made of gas encapsulated by a granular film composed of a dense layer of particles constrained by a thin liquid film. This object can resist to an inner pressure 10 times higher than the Laplace pressure of a classical soap bubble [Timounay, PRL, 2017]. Investigating the behavior of granular films to triggered opening, Timounay *et al.* have revealed a transition to jamming at particle surface fraction $\phi_s \approx 0.84$ where film opening is inhibited by particles bridging the two interfaces [Timounay, Soft Matter, 2017]. Beyond the surface fraction influence, the exceptional mechanical strength has been attributed to the cohesion between the grains due to capillary forces. However, this cohesion was not controlled in previous experiments. Thus, we have developed a dedicated device to tune capillary forces by controlling the pressure in the liquid of the granular film. Indeed, lowering the liquid pressure curves the liquid/air interfaces around the particles (Figs. 1.d - e) and increases the cohesion forces. For a given high particle surface fraction ($\phi_s \approx 0.9$), the influence of capillary cohesion on the film resistance was investigated from the retraction dynamics consecutive to a hole creation. Experiments led for different particle sizes and various liquid pressure (cohesion forces) revealed three different ruptures: total (liquid-like behavior), intermittent and partial opening (solid-like behavior). The values 0, 0.5 and 1 are respectively assigned to these openings (top-views in Figs. 1.b - c). In Fig. 1.a, averages on 5 experiments reveal a progressive transition as a function of liquid pressure between the different opening dynamics. We evidence that larger is the liquid depression, more likely the opening of the granular film is inhibited. Moreover, larger is the particle size, lower is the pressure of transition from liquid-like to solid-like behavior of the granular film.

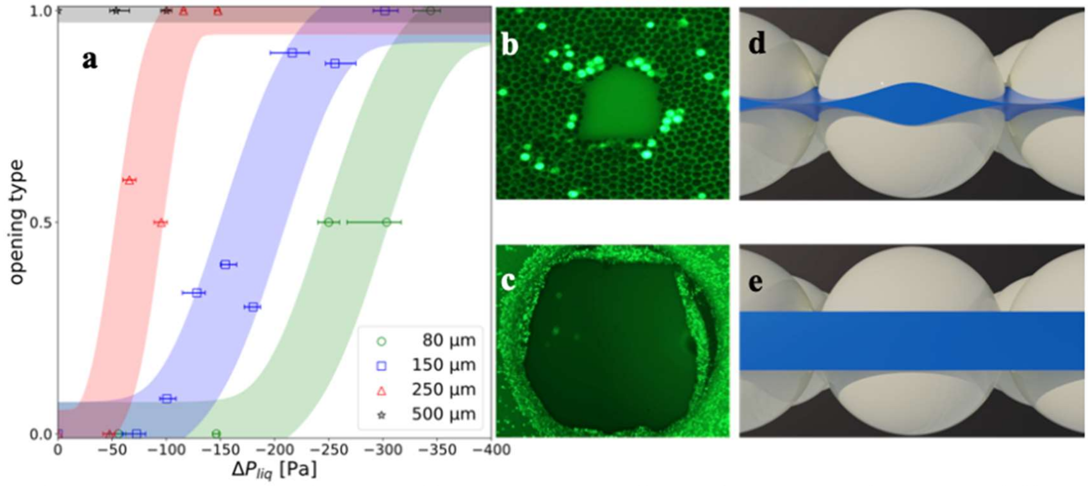

Figure 1: (a) Retraction type as a function of liquid pressure and particle sizes. Final top-view of (b) partial and (c) total film opening. Surface Evolver simulations of a granular film at (d) high and (e) zero liquid depression.

Acknowledgements: This work has received support from the CNRS and ANR, with the reference ANR-19-CE30-0009.

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WHY IS X-RAY TOMOGRAPHIC MICROSCOPY A USEFUL TOOL IN FOAM CHARACTERISATION?

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One of the common characteristics of materials is that their function and properties are encoded in their microstructure. It is therefore evident that visualising and quantifying the microstructure often significantly contribute to understanding and in turn improving material properties. This approach is especially relevant for complex materials such as foams are. A large part of the structure visualisation challenges can be tackled with traditional methods such as visible light microscopy or more advanced electron microscopy. In certain cases when a true volumetric visualisation is required both these techniques quickly hit their limits and X-ray imaging takes over, Fig 1. As apparent from Fig 1, there is a spatio-temporal domain only accessible with X-ray tomographic microscopy. This domain is very relevant for the majority of foam-like materials.

Through selected scientific cases I would like to highlight the current trends in X-ray tomographic imaging of liquid and solid foams with a specific emphasis on dynamic visualisation of the foam microstructure in various scenarios such as the nucleation of polyurethane foam [Perez-Tamarit 2019] or flow of a liquid foam [Raufaste2015]]

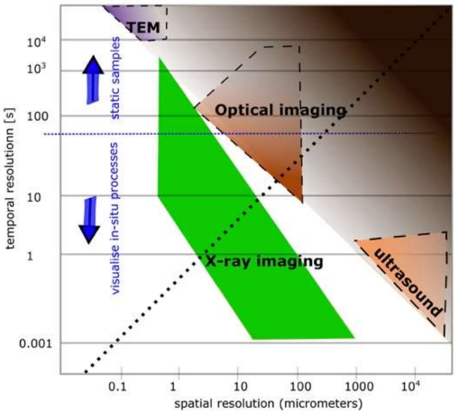

Figure 1: Typical working domains of imaging techniques applied to visualise the 3D structure of foam samples. The upper right corner is covered by various techniques, while the lower left corner is where the ultimate imaging technique would perform.

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STRUCTURE AND STABILITY OF FOAM AT HIGH PRESSURE

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The application of aqueous foam in various applications, especially in the energy sector is becoming an increasingly popular topic. Use of foam compared to pure liquid phases brings several advantages, e.g. in gas flooding processes, such as minimisation of gravity override and viscous fingering. This in turn leads to improved yield and efficiency in the recovery of crude oil. Bubble structure and stability are critical factors in the effective use of foam in EOR. As such, much attention has been paid to improving foam stability through various methods, e.g. addition of nanoparticles. However, due to technical limitations, there is a lack in systematic investigation, especially of bubble structures and fundamental mechanisms of foam film stability.

To date, relatively little work has been done to study foams at reservoir conditions even though temperature and pressure are known to play a significant role in foam behaviour. In this summary we present recent work [Amro, 2019] using a novel, commercial foam analysis system (see *Figure 1*) for systematic, simultaneous and time resolved measurement of foam height and bubble structure. Measurements were recorded during and after foam generation, allowing for comparison of both foamability and foam stability. Despite being initially similar, foams generated with N_2 and CO_2 show markedly different decay behaviour and react differently to changes in pressure. At pressures up to 15 Mpa, N_2 foam is increasingly stable, whereas the stability of CO_2 foam decreases with pressure. This is explained by the higher solubility of CO_2 in the film phase, which in turn increases disproportionation via Ostwald ripening. Interestingly, a significantly increased stability is observed in case of CO2-foams beyond the critical pressure which indicates a strong change in the governing properties and mechanisms that requires further investigation.

Figure 1: KRÜSS High Pressure Foam Analyser - HPFA

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Particles / Aggregates or Fibers in Foams, Aerogels or Thin Liquid Films

online session

EVERLASTING BUBBLES?

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Soap bubbles are by essence fragile and ephemeral. Depending on their composition and environment, bubble bursting can be triggered by gravity-induced drainage and/or the evaporation of the liquid and/or the presence of nuclei. They can also shrink due to the diffusion of the inner gas in the outside atmosphere induced by Laplace overpressure.

Through a very simple process, we produce bubbles made of a composite liquid film able to neutralize all these effects and keep their integrity for more than 1 year in a standard atmosphere. The liquid film contains plastic micro-particles that prevent drainage and a water/glycerol mixture that suppress evaporation (thanks to hygroscopic properties of glycerol). The unique properties of this composite film are rationalized with a nonlinear model and used to design complex objects.

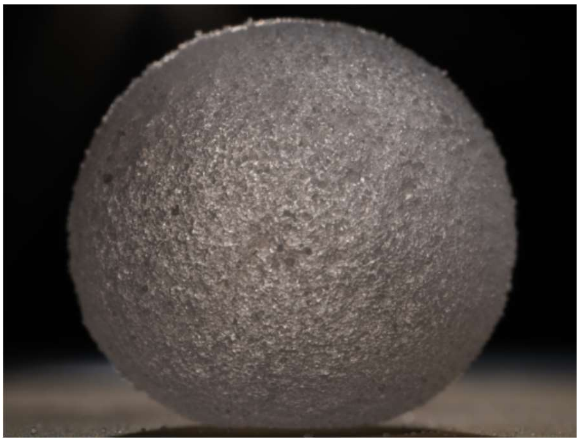

Figure 1: Water/glycerol gas marble perfectly intact in a standard atmosphere after ~9 months (285 days). This bubble kept its integrity for more than 1 year (465 days)

Acknowledgements: We would like to thank Pr. F. Zoueshtiagh for useful discussions and technical assistance. This work was partly supported by ISITE-ULNE (ERC Generator program), Institut Universitaire de France and Renatech network.

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NON-AQUEOUS FOAMS STABILIZED BY FATTY ACID CRYSTALLINE PARTICLES

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Liquid foams are complex colloidal systems based on gas bubbles dispersed in a liquid continuous phase (Fameau and Saint-Jalmes 2017).Two different categories of liquid foams exist: aqueous or non-aqueous. In contrary to aqueous foams, which have been extensively studied, non-aqueous foams represent a new promising emerging field (Fameau and Saint-Jalmes 2017). Two types of non-aqueous foams are gaining interest: oil foams based on vegetable oil (oleofoams) and alcohol-based foams (Fameau et al. 2021; Fameau and Saint-Jalmes 2020). Oleofoams are a promising option to develop new food products combining both a reduced fat content and new appealing textures and sensorial properties. Alcohol-based foams are gaining interest nowadays since the global pandemic due to COVID-19 and the frequent use of alcohol-based hand sanitizers as recommended by the World Health Organization. The main difference between aqueous and non-aqueous foams comes from the relatively large difference in the surface tension of the solvents (Fameau and Saint-Jalmes 2017). For non-aqueous systems, the low surface tension makes the adsorption of hydrocarbon-based surfactants energetically unfavourable. One way to produce and stabilize non-aqueous foams is to use surfactant crystalline particles, which can adsorb at the air-liquid surface (Fameau and Binks 2021) (Fig. 1).

In this talk, we will present how natural fatty acids crystalline particles can lead to the production and stabilization of both oleofoams and alcohol-based foams (Fameau et al. 2021; Callau et al. 2020). The formation and stabilization mechanisms of these two types of non-aqueous foams are the same and based on the adsorption of fatty acid crystalline particles at the air-liquid surface, which reduce the bare surface area by their presence rather than lowering the surface tension. The key parameter for fatty acid crystals to adsorb at the air-non-aqueous liquid surface is to exhibit a suitable three-phase contact angle below 90°. These foams are ultrastable due to the dense layer of adsorbed crystals at bubble surfaces that considerably reduce both disproportionation and coalescence.

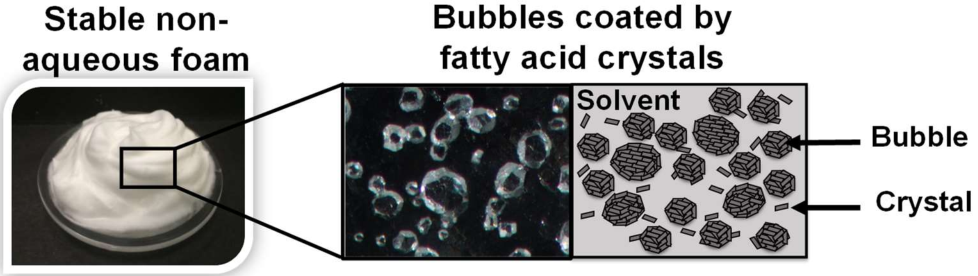

Figure 1: Illustration of non-aqueous foam stabilized by the presence of fatty acid crystals both in bulk and at the interface as observed by polarized light microscopy

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NANOEMULSION TEMPLATE METHOD FOR PREPARING POLYMERIC NANOCARRIERS

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Cardiovascular diseases, respiratory diseases, cancers, and neurodegenerative disorders are steadily on the top of worldwide leading causes of death. Nowadays, the issue is even superior due to the soaring mortality rates correlated with concerns of a rapidly aging of our population. Modern medicine is therefore facing up considerable challenges.

One of the main limitations in treating such complex diseases is the ineffective delivery of therapeutic agents (drugs) to the site of their actions. Most commercially available drugs, often having a high treatment efficacy, are poorly water-soluble or even in-soluble substances, making them challenging to deliver efficiently. Their poor bioavailability in biological fluids, toxicity, low therapeutic concentration, non-targeted delivery, and undesirable side effects result in the conventional treatment's low therapeutic effectiveness.

Therefore, we developed novel methodologies for preparing polymeric nanocarriers of hydrophobic active substances based on stable nanoemulsion [Szczęch, 2020; Szczepanowicz, 2010]. The nanoemulsion droplets were prepared using the spontaneous emulsification method assisted by the Quzo effect. Formed nanodroplets were stabilized by docusate sodium salt (AOT)/poly-L-lysine (PLL) interfacial complexes. Utilizing the nanoemulsion as a template allows for the preparation of two types of nanocarriers, liquid core and polymeric core nanocarriers. The following polymers, i.e., poly(caprolactone) (PCL), poly(lactic acid) PLA, or poly(lactide-co-glycolide) (PLGA)), and hydrophobic active agents (e.g., paclitaxel, cyclosporine, carnosic acid) were used for the preparation.

All polymeric-based nanocarriers were characterized by size (hydrodynamic diameter), size distribution, zeta potential, and imaged by cryoSEM.

Acknowledgments: This research was funded in part by the National Science Centre of Poland - grant GRIEG 2019/34/H/ST5/00578 and by the statutory research fund of ICSC PAS.

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Wet Foams, Foam Rheology, Interfacial Rheology, Dynamics of Surfactant-Laden Interfaces

stationary session

FOAMS AS FILTERS: PREDICTING PARTICLE PASSAGE THROUGH SOAP FILMS

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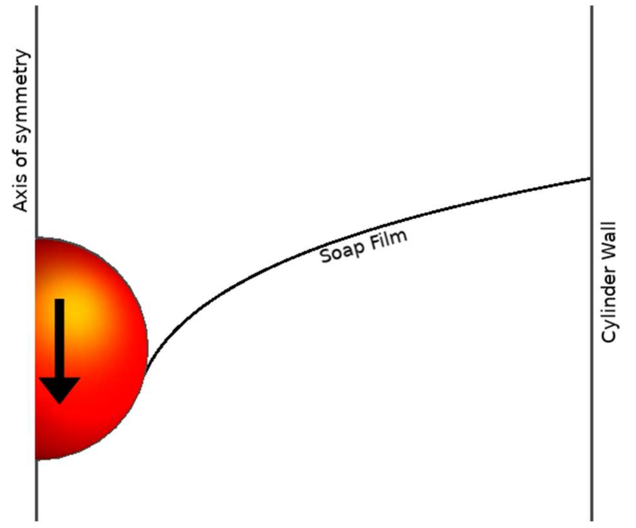
Soap films can behave as “inverted” filters, trapping *small* particles and those with low kinetic energy. Foams, consisting of many soap films, are also used in the suppression of explosions, dissipating the energy of fast-moving objects.

When a solid particle impinges on a soap film it first deforms the film into a catenoid-like shape. It is then possible to determine the retarding force that the film exerts on the particle. As the particle moves through the film, a point is reached at which the film becomes unstable, in a manner familiar to anyone who has formed a soap film catenoid between two rings and pulled them apart. We will explain the details of this instability in the case of a spherical particle falling through a bamboo foam, and the bounds on particle weight and size that ensure that it can be trapped by the foam. As well as particle shape, we will explain the role of the contact angle at which the soap film meets the particle on the formation of satellite bubbles.



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COMBINING OPTICAL AND X-RAY MEASUREMENTS OF AN OVERFLOWING LIQUID FOAM

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Froth flow is of central importance for mineral processing by froth flotation. In flotation plants, the recovery of solid mineral particles [Neethling, 2002] and liquid from the overflowing froth [Stevenson, 2003] is monitored by optical observation and, therefore, limited to the froth's free surface. The laboratory-scale experiment in this work investigates the flow behaviour of an aqueous foam at a horizontal overflow (Fig. 1) in combined optical and X-ray radiographic measurements. Simultaneously, the foam's liquid fraction was determined by measuring the electrical conductivity between electrode pairs. The optical measurements, performed both through a transparent wall and at the free surface of the overflowing foam, captured light reflexions on the foam bubbles, which were analysed by adapting particle image velocimetry algorithms. While the opacity of the foam limits optical measurements to the surface-near bubbles, our approach of X-ray particle tracking velocimetry (X-PTV) [Lappan, 2020] sheds light on the three-dimensional foam flow. The customised tracer particles used in this work consisted of a 3D-printed tetrahedral polymer structure with a total of four small metal beads at its corners (Fig. 1). Owing to their shape and the light-weight material composite, the tracers adhered to the bubble-scale foam structure and were carried by the foam. X-ray radiography visualises the motion paths of each tracer's metal beads, representing the local streamlines of the foam flow. Further, the X-ray radiographs map the foam's liquid fraction distribution, thus extending the local measurement of the liquid fraction by means of the electrode pairs. X-PTV reveals comparatively high flow velocities of the three-dimensional foam flow, in particular near the overflow, whereas the optical measurements are subjected to wall or surface effects, yielding lower flow velocities. However, X-PTV with customised foam flow tracers comes to its limit in unstable foams at high liquid fraction and high flow velocity.

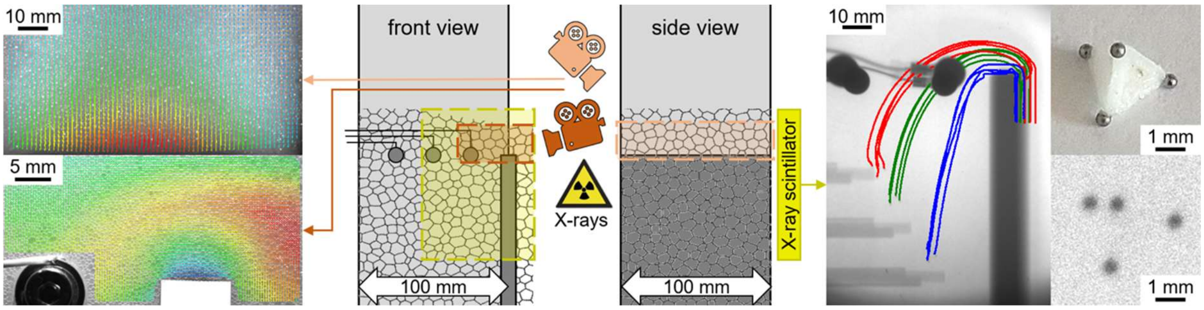

Fig. 1: Overflowing liquid foam is imaged in a laboratory experiment by means of optical and X-ray radiographic measurements employing customised tracer particles. Local flow velocities are determined using adapted PIV and X-PTV algorithms. Near the overflow, the foam's liquid fraction is monitored by means of electrode pairs.

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3D LIQUID FOAM FLOW IN AN HOURGLASS-LIKE CONSTRICTION

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It is very challenging to capture the structure evolution of 3D flowing liquid foam, such as the bubble deformation and plastic rearrangements. Lately, X-ray tomographic microscopy appeared as one of the useful probes to visualise the deformation and displacement fields of bubbles flowing around an obstacle [Raufaste, 2015]. Our current focus is to describe foam flow through a 3D hourglass-like constriction. Monodisperse bubbles, 150 and 400 µm in diameter, were produced by a microfluidic setup, and displaced through the constriction. High-resolution tomograms were recorded every 0.2 s for 10 s. Each acquired 3D image covered a volume of 5.9 × 5.9 × 5.3 mm^3 with a voxel size of 2.92 µm. We developed a 3D quantification toolbox to reconstruct the individual bubbles geometry, and to extract their displacements and deformations. We compare velocity fields acquired in experiments to simple models and we show the interplay between the bubble deformations and the macroscopic flow. As an outlook we will present our preliminary observations of a recent experiment, in which liquid foams were subjected to a rheometric flow in a plate-plate rheometer and simultaneously 3D imaged.

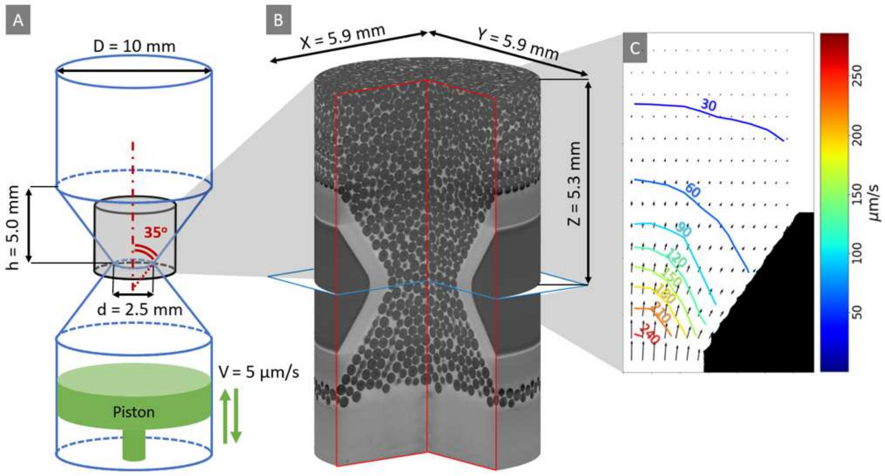

Figure 1: (A) diagram of the hourglass-like constriction with the piston in green and the acquired field of view in grey. (B) two stacked 3D images (above and below the horizontal blue plan), with a vertical red cut showing the bubbles inside the constriction. (C) Example of extracted time and space averaged flow field with iso-velocity contours.

Acknowledgements: Zdenek Matej, Edward Andò, Christian Matthias Schlepütz, Stephen Hall

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MEASUREMENT OF ANISOTROPIC DRAINAGE IN LIQUID FOAM USING NEUTRON RADIOGRAPHY

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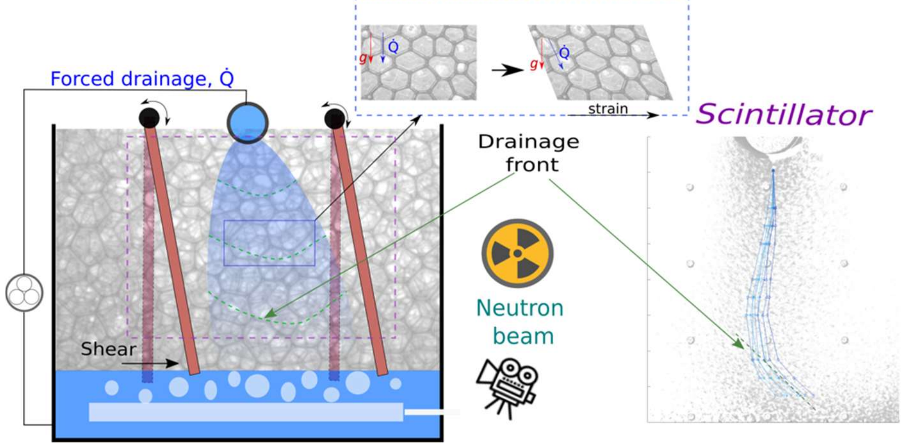
Transport of liquid through foam is governed by the mutual effects of capillary, gravitational, and inertia forces. This process defines the distribution of liquid in foam and is essential for industrial applications, e.g. production of polymeric or metal foams, and flotation. Neethling (2006) has shown that sheared foam could not be considered as an isotropic material, and also predicted that a vertical drainage flow in sheared foam is deflected horizontally, leading to inhomogeneous liquid distributions.



(a) *(b)*

Figure 1: A schematic representation of a forced drainage flow between sheared plates (a) and set of assessed positions of a drainage front (b) by means of neutron radiography

We present the first experimental validation of anisotropic drainage in liquid foam. A pseudo-2D foam sample was created between two parallel plates in a Hele-Shaw style cell (Figure 1, a). Two internal walls were rotated to control the shear on the foam structure. A forced drainage flow was employed by adding liquid to the top of the foam. (Figure 1). The deflection of the vertical drainage flow is quantified by neutron radiography. We tracked the displacement of the liquid front with shearing by following the peak of the liquid content in horizontal slices of the foam (figure 1, b). By varying the bubble size and the drainage flow rate, we observed a sustained trend of increasing anisotropy of a foam drainage while it was subjected to an increasing strain magnitude.

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IMPACT OF THE AIR POLLUTANTS ON THE LUNG SURFACTANT: INTERFACIAL STUDY

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Nanoparticles (NPs) are widely used in different industries for various applications, however, there is always a severe inhalation risk of those mixed and ubiquitous nanoscale particles for human beings. Health concerns have been raised [1] because these nanosized pollutants have high chances to be permanently deposited in the deeper sections of the lungs, e.g., the alveolar region, where the alveoli sacs are covered by a layer of liquid called the lung surfactant. The influences of the inhaled mixture of NPS are dependent on their interactions with the lung surfactant -the first the first barrier which they face before getting exhaled, or being accumulated in the alveoli, or entering the blood circulation. As following inhalation NPs penetrate deep into the lung and from there can readily migrate into the blood stream. Increasing incidences of strokes, Alzheimer's, respiratory and cardiovascular diseases and, finally, cancer.
These interactions are affected by the physicochemical properties of the NPs and their concentration. For the mixed nanoparticles, the outcomes are influenced not only by the physicochemical properties of each type of NPs, but also by the interparticle interactions with other nanoparticles of different nature.

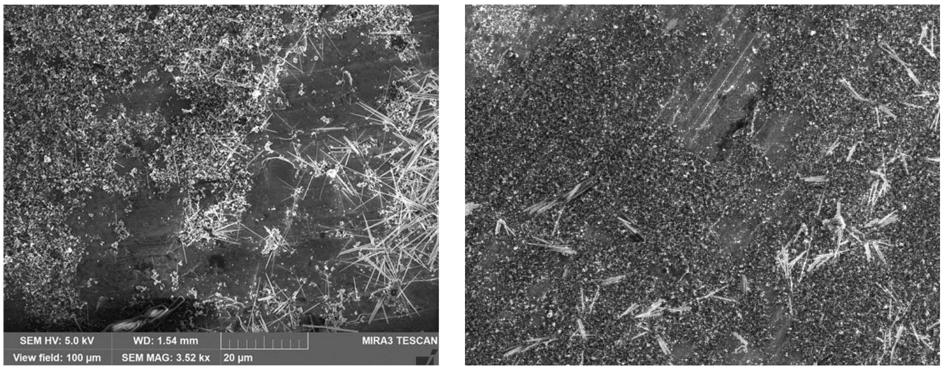

Figure 1. SEM of a) Anatase+Rutile+CNT premixed with DPPC, b) Anatase+Rutile+CNT mixed with DPPC afterwards. Scale bar of 20um.

In this study, the effect of the mixture of Carbon Nanotubes (CNTs) and Titanium Dioxide (TiO2) nanoparticles (Anatase and Rutile) on the interfacial behaviour of the monolayers of Dipalmitoyl phosphatidylcholine (DPPC), as the main constituents of the lung surfactant, was investigated. Three different mixing methods were utilised to simulate possible real-life scenarios of nanoparticle mixtures to reach the lung surfactant. To mimic the alveoli sacks the Profile Analysis Tensiometry (PAT) in a pendant drop mode at 37°C was used and the interfacial tension of these mixtures with the same concentration of 0.01 wt% were measured.

This study shows that just a different mixing procedures significantly affect the nature of particle-particle interactions (Fig.1) but also nanoparticles-surfactant relation when in DPPC[2]. Indicating the harmful impact of Nano-materials on the lung monolayer domain and consequently a human wellbeing, driven by the size, shape, configuration and exposure. The outcome of this study could not only provide a guidance for the usages of nanoparticles in pulmonary drug delivery, but also help revise the Health and Safety regulations of the NPs applications.

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INTERPLAY BETWEEN BULK AGGREGATES, SURFACE PROPERTIES AND FOAM STABILITY OF NONIONIC SURFACTANTS

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In our previous study [Mustan, 2021] we showed that foams formed from two oil-soluble nonionic surfactants (Span 60 and Brij 72) can remain stable for more than 10 days at room temperature at high sugar concentration. The major aim of the current study is to reveal the interrelation between the surfactant structure and foam stability by investigating 6 polyoxyethelene alkyl ethers and 12 fatty acid esters with a wide variety of hydrophobic chain lengths (C12; C16; C18 and C18:1) and hydrophilic head-groups (sorbitol, glycerol, sucrose). Foams stable for more than 100 days at room temperature are obtained when sucrose palmitate or stearate (P1670 or S1670) are used as surfactants. This exceptional foam stability is related to the gelation of the aqueous phase and to the formation of solid adsorption layer with zero surface tension upon compression, thus preventing water drainage and decelerating the bubble Ostwald ripening. The foam stability decreases with (i) increasing the number of EO groups in polyoxyethylene alkyl ethers and in fatty acid sorbitan esters; (ii) decreasing the number of C-atoms in the surfactant tail for all studied surfactants; (iii) addition of double bond in the surfactant tail. The lower foam stability in all three cases is related to the worse packing of the surfactant molecules within the adsorption layer, leading to faster Ostwald ripening and subsequent bubble coalescence. The diesters present as admixture in the fatty acid esters play an important role in the foam stabilization by further compacting the adsorption layers and lowering the rate of Ostwald ripening. These conclusions can be used as a predictive tool for surfactant selection in the development of food or pharmaceutical foam concentrates that can be diluted before final use.

Acknowledgements: This work was partially supported by Unilever R&D Colworth, UK and by the Bulgarian Ministry of Education and Science under the National Research Programme “Healthy Foods for a Strong Bio-Economy and Quality of Life” approved by DCM # 577/17.08.2018.

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SYNERGY IN AQUEOUS SYSTEMS OF BIO-SURFACTANTS: SAPONIN/PECTIN MIXTURES

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Foams based on bio-surfactant aqueous systems are widely applied in cosmetics, food and pharmaceutical industries, and in medicine. Their experimental characterization is a complicated matter, and requires an appropriate model application. Thin liquid films are basic elements of the foams, and therefore, are suitable models for the investigation of their stability. Saponins are natural bio-surfactants with specific chemical structure and various biological activities. They exhibit antiallergic, anti-inflammatory, antiviral, antibacterial activity, reduce the cholesterol and fatty acids absorption, and are used as adjuvants in vaccines preparation etc., and are preferred stabilizers of industrial foams. Apple pectins are often used as natural stabilizers of foams and emulsions in food industry.

The present work explores the performance of aqueous solutions of Quillaja saponins and their mixtures with Apple pectins. The aim is to clarify the behaviour of the newly composed mixed formulations, with tunable structure and properties, so as to favour the formation of stable biodegradable foams. The investigations are focused on the adsorption-layer characteristics (dynamic surface tension and surface rheology), as well as on the drainage and stability of thin foam films (drainage kinetics, film thickness, disjoining pressure isotherm, critical pressure of rupture). The methodology involves several research instrumentations: profile analysis tensiometer (PAT-1), microinterferometric method of Scheludko-Exerowa and the TLF Pressure balance technique.

The obtained results presume the formation of hydrogel structures in the solution bulk and are indicative for the presence of synergetic interactions between the two major compounds of the aqueous formulation. The data might be interpreted as experimental evidences for structural reorganizations, both in the solution bulk and at the interfaces. The studied systems will be further implemented for optimization and fine-tuning the properties of the proposed mixtures, based on Quillaja saponins and Apple pectins, in view of future industrial, pharmaceutical and biomedical applications.

Acknowledgements: The support by the European Regional Development Fund within the Operational Programme Science and Education for Smart Growth", Project CoE "National Center for Mechatronics and Clean Technologies", No. BG05M2OP001–1.001-0008 is gratefully acknowledged

Wet Foams, Foam Rheology, Interfacial Rheology, Dynamics of Surfactant-Laden Interfaces

online session

VELOCITY DEPENDENCE OF SPREADING BEHAVIOURS OF FOAM ON A SUBSTRATE

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Spreading of a foam is commonly observed in daily life, for example when shaving, washing, and so on. Nonetheless, dynamics and mechanism of the foam spreading have been unclear yet. Classically, spreading of a liquid to a film has been investigated for a long time [Taylor, 1960]. The thickness of the viscous fluid coated a plate is well explained by the Landau-Levich-Derjaguin (LLD) model [de Gennes, 2004]. Furthermore, the liquid spreading on a plate with an elastic sheet has been described by an extended LLD law [Seiwert, 2013]. Meanwhile, foam is different from a liquid droplet since foam has elasticity. It is known that foam bubbles near a substrate have three types of behaviour depending on the roughness of the surface [Marchand, 2020]. But the deformation dynamics and structural changes when they are spreaded from a three-dimensional structure to a two-dimensional one have yet to be revealed. Here we investigated the spreading dynamics of the foam on a substrate.
We investigated the behaviour of the foam when the foam is spreaded with a constant velocity by an acrylic plate. It was found that there are three types of behaviour depending on the moving velocity of the acrylic plate and the gap between the plate and the substrate, which is different from the Landau-Levich-Derjaguin model. Therefore, we investigate the dynamics of each behaviour in detail.

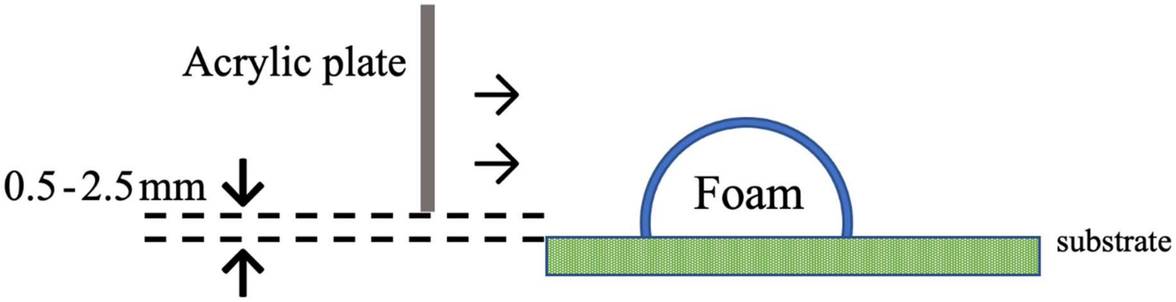

Figure 1: Schematic diagram of the experimental setup of the foam spreading. The velocity of the moving acrylic plate was varied from 2.5 to 45 mm/s, and the height of the acrylic plate from the substrate was changed from 0.5 to 2.5 mm.

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SURFACTANT TRANSPORT BETWEEN FOAM FILMS AROUND MENSCI WITHIN A FIVE-FILM FOAM

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A model originally developed by Bussoniere and Cantat [2021] is considered for film-to-film surfactant transport around a meniscus within a foam. It is supposed that the surfactant transport rate is dependent upon film-to-film tension difference. The model is applied to consider the case of a so called five-film device which has been studied experimentally by Bussoniere and Cantat, [2021]. In this particular device, motors are used to compress two peripheral films on one side of a central film and to stretch another two peripheral films located on the central film's other side. The amounts of compression or stretch that are imposed on the peripheral films can be large, and in addition, compression or stretch can be imposed at high velocities (with velocity here being measured relative to a characteristic velocity that is associated with physicochemical properties of the foam films themselves). In the present contribution, the model is therefore applied to this high compression/high stretch and/or high velocity scenario. The actual strain that results on elements within each film might however differ from the imposed strain. Knowing this actual strain and knowing also the instantaneous film length, it is possible to determine the amount of surfactant currently on each film (and thereby also the amount of surfactant that has transferred either from films or onto them). Very distinct surfactant transport behaviour is predicted for the stretched film compared to the compressed one. In particular when a film is stretched by a sufficient amount at sufficiently high enough velocity, the surfactant flux onto it is predicted to become extremely ``plastic", being permitted to increase significantly.

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CO_2 FOAM BEHAVIOUR IN CARBONATE ROCK: EFFECT OF SURFACTANT TYPE AND CONCENTRATION

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An understanding of the dynamics of CO_2 foams flowing through a reservoir rock is useful for many sub-surface applications, including both enhanced oil recovery (EOR) and CO_2 storage (for CCS). A series of experiments have been carried out to investigate the impacts of surfactant type and concentration on the behaviour of super-critical CO_2 foams flowing through a high-permeability Indiana Limestone. The stability of the two selected surfactants, a betaine and a sultaine, was tested at 60°C for over 4 months. Both surfactants were found to be stable over the period of the test.

Foam-flood tests were carried out with the super-critical CO_2 to determine the basic foaming behaviour of the two surfactants. The concentration response of the betaine (0.01wt% - 0.5wt%) and sultaine (0.05wt% - 0.5wt%) was also investigated. For both surfactants, reducing the surfactant concentration resulted in a reduction of the transition foam quality, f_g*, and the maximum apparent foam viscosity. However, the betaine showed better foaming behaviour at a concentration close to the critical micelle concentration. A comparison between the behaviour of these surfactants with CO_2 foams and N_2 foams, where dissolution of the gas into the surfactant solution is expected and not-expected respectively, is also presented.

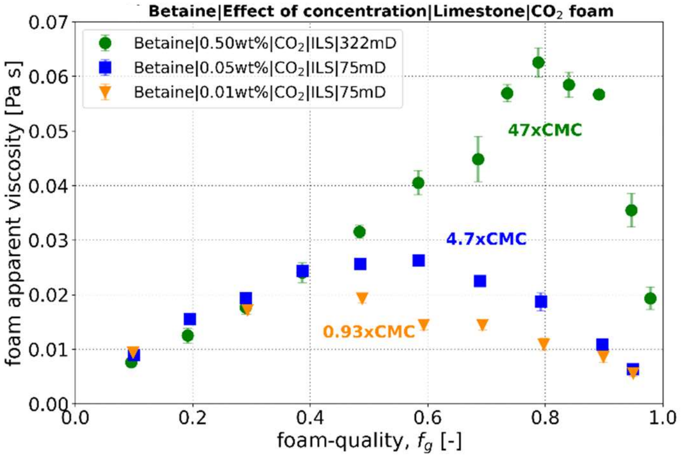

Figure 1: Variation in foam apparent viscosity with variation in surfactant concentration, for the betaine. The permeability of the limestone core for each test is indicated in the key, and the curves are also labelled with the concentrations in terms of the CMC.

Acknowledgements: We acknowledge the support of Shell Global Solutions International B.V. for this work.

FOAM FRONT PROPAGATION IN FLOW REVERSAL

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The pressure-driven growth model [Shan and Rossen, 2004] is used to capture the propagating foam front in the foam improved oil recovery process, in the case when at a certain time t^*, the net driving pressure Pdriv is decreased below the hydrostatic pressure Phyd at depth, leading to a change in the flow direction [Eneotu and Grassia, 2020] (see Figure 1). Flow reversal at depth would take place if the pressure field downstream of the front is increased by external factors, such as new gas injection wells away from the original one, or if injection pressure is suddenly reduced, or indeed if the gas injection well is shut in. In both forward and reverse flow, the foam front is idealized as the finely-textured region where the mobility of foamed gas drops by orders of magnitude relative to a pure gas or pure liquid mobility. Via fractional flow theory it has been established that the mobility of the reversed flow front might differ from that of the forward flow front [Eneotu and Grassia, 2020]. Therefore, the reversed foam front trajectory does not necessarily have to be the same as in the forward flow case. Distinct formulations of the pressure-driven growth model are then required to compute the foam front for forward and reverse flows, respectively.

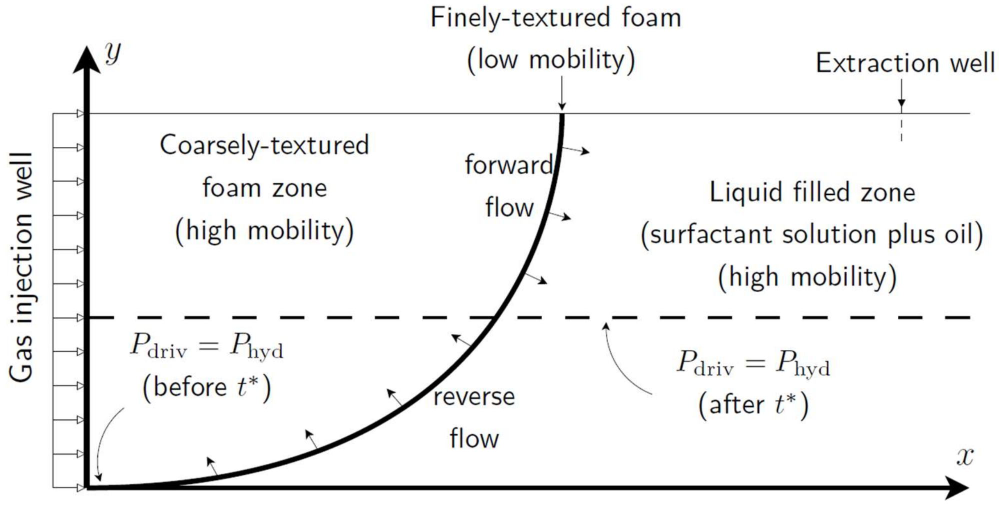

Figure 1: Foam front propagation across a vertical domain y and a horizontal domain x. At time t*, the front starts backtracking at the depth where $P_{\mathrm{driv}} = P_{\mathrm{hyd}}$ (after t*).

Acknowledgements: EPSRC grant no. EP/V002937/1.

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INNOVATIVE FOAM-BASED CLEANING CONCEPTS FOR HISTORICAL OBJECTS

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The historical surfaces of artistic and cultural objects can be regarded as the 'faces' of these pieces of art. The surfaces are often soiled as a result of long-term exposure to environmental influences. Their cleaning represents important challenges as each surface requires a tailor-made cleaning method to remove dirt without damaging the art piece. Recent research shows that foamed detergents can clean far more efficiently than non-foamed ones. Not only do they reduce the amount of detergents by up to 90%, but they also generate additional physical cleaning mechanisms which await to be understood and exploited. In particular, the processes acting at the contact zone between the aqueous foam and the non-aqueous "dirt" must be clarified. In a collaboration with the "Bavarian Administration of State-Owned Palaces, Gardens and Lakes", the University of Cologne, the Institut Charles Sadron in Strasbourg and the University of Stuttgart, we work on understanding the different mechanisms involved in foam-based cleaning, and to exploit this understanding to develop innovative cleaning methods [Schad, 2021], [Schad, 2022]. Our current understanding of and progress on the subject will be presented, including the surprising observation that unstable foams clean better than stable foams: **Less is More!!!**

Figure 1: Cleaning historical objects with foam.

Acknowledgements: We thank our cooperation partners Dr. Dirk Blunk, Universität zu Köln, and Dr. Heinrich Piening, Bayerische Verwaltung der staatlichen Schlösser, Gärten und Seen, Schloss Nymphenburg, with whom we work together on this project. We acknowledge funding from *The German Federal Environmental Foundation* (Deutsche Bundesstiftung Umwelt, DBU, AZ 34788/01-45) and an ERC consolidator grant (agreement 819511 - METAFOAM).

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FOAM BASED ON ALKYL POLYGLYCOSIDES FOR CLEANING PIPES CONTAMINATED WITH *Bacillus subtillis* SPORES

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One of the main daily basis obligations for the food industries is the cleaning process involving the consumption of a huge amount of water, energy and chemicals known to have a significant impact on the environment. In order to optimize these cleaning practices and to make food industries more sustainable, it is therefore necessary to use innovative cleaning processes. In this aim, it has been recently demonstrated that foam flow can be used to efficiently remove spores and biofilms in agri-food industries (Dallagi, 2022). However, these foams were produced by using Sodium Dodecyl Sulfate (SDS), a petroleum-based surfactant whose production has a high environmental footprint. Other surfactants, such as alkyl polyglycosides, which are biodegradable surfactants, and could be also suitable for this use (Drakontis, 2020). Our aim is to study the decontamination effect of foams based on alky polyglucosides of different alkyl chains in order to both decrease further the environmental footprint of the foam cleaning process in food industries and to better understand the decontamination process of the foams.

In the first step, we studied the use of wet foam flow formulated with alkyl polyglycosides of different alkyl chains to clean stainless steel surfaces contaminated with *Bacillus subtillis* spores. We demonstrated that the foams formulated with alkyl polyglycosides have similar cleaning effect than those formulated withe SDS (Fig.1). We also demonstrated that for the conditions used, no significant difference in cleaning was observed between alkyl polyglycosides of different chain lengths. In the second step, we characterized the foams produced in terms of drainage, bubble size, and amount of liquid. We demonstrated that the foams formulated with alkyl polyglycosides of different alkyl chain sizes and the foam formulated with SDS have similar physico-chemical properties. Finally, we calculated the life cycle assessment of the cleaning processes carried out with alkyl polyglycosides, and we compared it to the one carried out with SDS. We demonstrated that the environmental footprint decreased when foams were formulated with alkyl polyglycosides in comparison to foams based on SDS. Our results show that alkyl polyglycosides are suitable option to replace SDS in foam formulations in order to used foam flow for cleaning and decontamination in food industries and to decrease the environmental footprint.

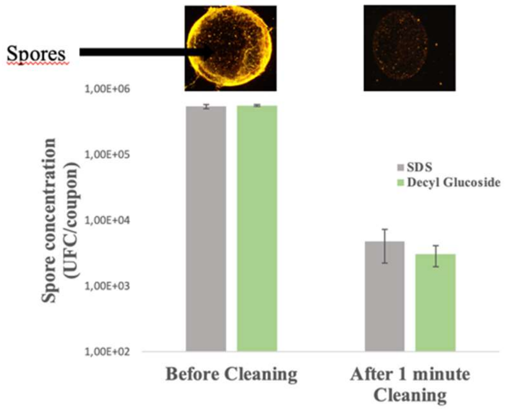

Figure 1: Cleaning effect of foams with SDS and Decyl glucoside to remove drops of Bacillus subtillis *spores.*

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Industrial Applications of Foams, Emulsions and Thin Liquid Films

Novel Materials or Biomaterials in Dispersed Systems (Foams, Aerogels, Emulsions or Thin Liquid Film)

stationary session

SELF-ASSEMBLY OF ANTENNARY OLIGOGLYCINES IN AQUEOUS MEDIA: FINE-TUNING AND APPLICATIONS

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Key ideas and recent investigations are presented about the structure and the specific performance of synthetic antennary oligopeptides in fluid media. The newly acquired knowledge regarding the fine-tuning options for the onset, stability and properties of the obtained supramolecular aggregates (tectomers) in aqueous solution formulations, is discussed in details. The emerging application prospects regarding the design of biomimetic and biocompatible materials, and super-regular coatings are identified, and commented in view of the novel concept of nanoarchitectonics.

Acknowledgements: The study is funded by Bulgarian National Fund for Scientific Research through Project “Design and Characterization of Soft Nanostructured Materials Based on Antennary Oligoglycines”, Grant Number КП-06-Н39/5. The support by the European Regional Development Fund within the Operational Programme Science and Education for Smart Growth", Project CoE "National Center for Mechatronics and Clean Technologies", No. BG05M2OP001–1.001-0008 is also gratefully acknowledged.

REMOVAL OF IMPURITIES FROM PROTEIN FOAM IN FOAM FRACTIONATION PROCESS BY WASH WATER ADDITION

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This work investigates a simple and efficient method to remove the impurities from a protein foam through washing the foam in a foam fractionation process (figure 1). The entrained substances are directed downward by wash water to the drain outlet together with the liquid. However, due to the irreversible protein adsorption at air interface, the already adsorbed protein molecules do not desorb upon wash water addition and are transferred to the foam outlet. Here, we performed experiments on bovine serum albumin (BSA), as a model protein and NaCl salt, as a model of soluble impurities. The experiments were conducted in a glass foam fractionation cell, where the liquid level was kept constant. The wash water was added on the foam top with different flow rates and BSA and NaCl concentrations were measured at the outlets for further analysis. The influence of initial bubble size and the wash water rate on the purification efficiency were investigated. The results revealed that the wash water displaces the entrained liquid in the foam and reduces the salt content at the foam outlet. The process shows higher salt removal for higher wash water rates as well as for foams with larger bubble sizes, where up to 93% of the salt was removed from the main solution in a steady state process. The washing efficiency is also enhanced at lower air flow rates, yielding longer dwelling times. However, the foam stability becomes an important issue at longer dwelling times, since the increased foam collapse significantly reduces the foam flow to the outlet.

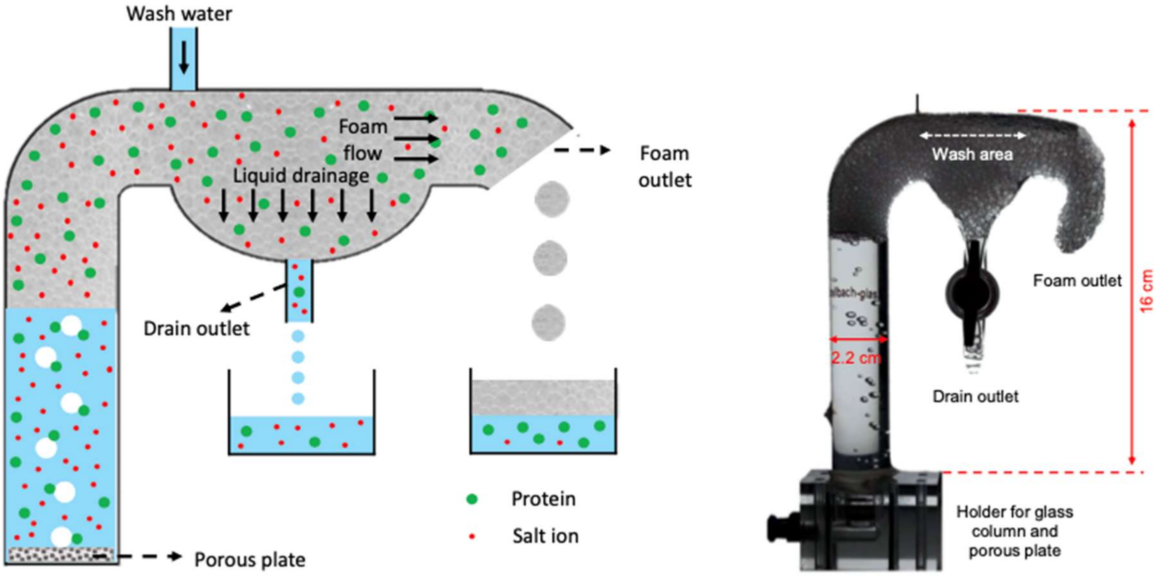

Figure 1: Left) Schematic of the wash water – assisted foam fractionation for salt removal from protein foam, and right) a picture of the foam fractionation cell

ELECTRONIC SURFACTANTS FOR USE IN SOAP FILM BASED SENSORS AND DEVICES

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Conjugated oligomers and polymers are powerful advanced functional materials used in modern organic opto-electronic devices [Tour, J. M., 2000]. A particular area of interest is supramolecular electronics having nanoscale structural features formed from the self-assembly of molecular components [Ellinger, S., 2007]. In this context, the self- assembly of π-conjugated oligomers and polymers [Fernández, G., 2008] at gas-water interfaces and in soap films has never been explored, despite its unique architecture, i.e. nanometrically confined water sandwiched between two functional interfaces.

In this context, we propose here to synthetize conjugated oligomers/polymers-based electronic surfactants to serve two complementary functions. I. As surfactants they can mechanically stabilize a new class of electronic soap films. II. As electronic molecules self-assembled at the gas-water interface, they can form a conducting/semiconducting optoelectronic monolayer to be exploited as functional architecture in advanced organic sensors and devices.

More specifically, the presentation will focus on the synthesis and characterization (physicochemical and ecotoxicological) of oligo/polythiophenes-based surfactants which possess conjugated structures coupled with interesting electronic properties [van Rijn, P., 2011]. Their surface activity (Langmuir trough characterizations), optical, and optoelectronic properties, in bulk and at interfaces, will also be presented. In addition their ecofriendly properties were tested on bacterial biological models by bacterial growth inhibition ecotoxicological assays.

This work is funded by the EU FETOPEN project PROGENY (Grant agreement ID: 899205), targeting in exploiting unique properties of soap films as advanced functional materials, to be used in fundamentally new type of biomimetic devices and sensors categorized as Proto-Opto-Electro-Mechanical Systems (POEMS).

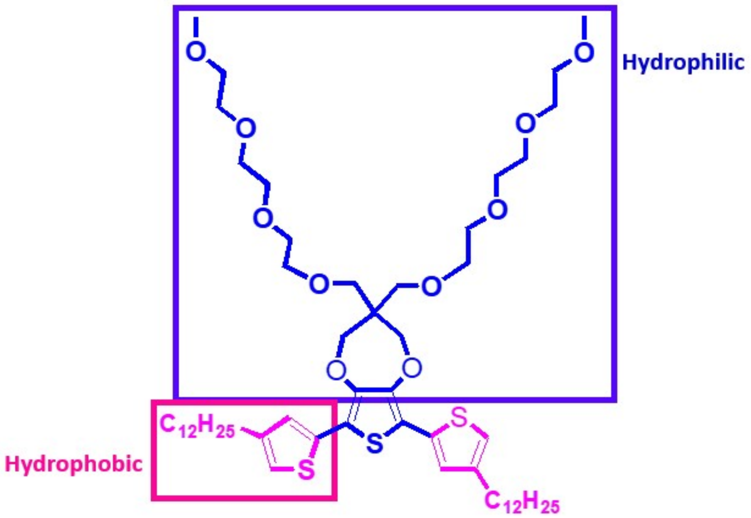

Figure 1: The structure of one of the synthesized electronic surfactants.

Acknowledgements: This work is funded by the EU FETOPEN project PROGENY (Grant agreement ID: 899205).

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EMULSIONS STABILIZED BY CLAY PARTICLES AS TEMPLATES FOR FUNCTIONAL HYDROGELS

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Lipid-based liquid crystalline phase dispersed in water are used in preparation of versatile delivery systems for various active substances [Lancelot, 2014]. Such emulsions with ordered internal structure composed of hydrophilic and lipophilic regions makes it possible to encapsulate both water- or oil-soluble active substances for their transport through aqueous media. For instance, *L2* phase prepared from a mixture of dodecane and phytantriol in the presence of water consists of inverse micelles with an aqueous core dispersed in the oil medium (Figure 1). Stabilisation of such self-assembled droplets with nanoparticles provides long term stability of emulsions, and moreover, it permits to functionalize the surface of the droplets for specific applications [Muller, 2013]. We use Laponite clay nanoparticles as droplet stabilizers that allows us to apply the method proposed by Haraguchi for preparation of reinforced hydrogels [Haraguchi, 2002]. Laponite plays a role of physical cross-linkers during polymerization of polyacrylamide and leads to enhanced mechanical properties of the resulted hydrogels. In our case the emulsion droplets act as multifunctional stabilizers improving even better the mechanical resistance of such hybrid materials. We correlate the mechanical properties with the structure by studying the multi-scale organization of the materials with electron microscopy, X-ray Scattering and Small Angle Neutron Scattering (SANS).

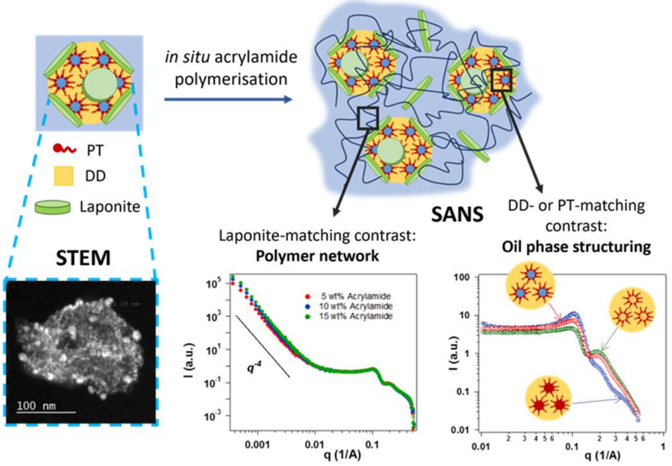

Figure 2: (Left) Sketch of the L2 phase emulsion droplet stabilized by Laponite and composed of inversed micelles of phytantriol (PT) with an aqueous core (shown with blue colour) dispersed in dodecane (DD) and its image obtained with scanning transmission electron microscopy (STEM); (right) sketch of the hydrogel/emulsion hybrid material and its SANS spectra at various matching contrasts.

Acknowledgements: AM acknowledges financial support from LABEX MMCD.

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LONG-LIFE MICRO-BALLOONS: MICRO-BUBBLE ENCAPSULATION BY ELECTROSTATIC TEMPLATING WITH IONIC SURFACTANTS

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Micro-bubbles display unique properties allowing the design of original functional fluids, relevant for many industrial processes and products. However, their disproportionation and coalescence limit severely their use. While encapsulating bubbles with hydrophobic colloids is commonly used to lessen such destabilizing aging effects, the interfacial interactions before particle attachment to the bubble surface remains poorly understood and difficult to control. We propose here a robust micro-bubble encapsulation process, that goes beyond the so-called Pickering technique, using electrostatics as a driving force to guide either particles or polymerizable precursors (metasilicate anions) to the bubble surface. Taking advantage of attractive interactions between surfactant-laden charged bubbles and oppositely charged self-assembling species, our method produces micro-balloons with diverse protective shells that remain stable for years. Considering heterogeneous electrostatic double-layer interactions, we can quantitatively predict critical particle surface potentials, required for complete encapsulation. Furthermore, the particle-based shells can be disintegrated with a pH adjustment, allowing for a controlled release of encapsulated payloads, while the glassy continuous silicate capsules are chemically resistant to pH changes. Finally, our process which can be equally applied to liquid droplets easily scales up for industrial developments.

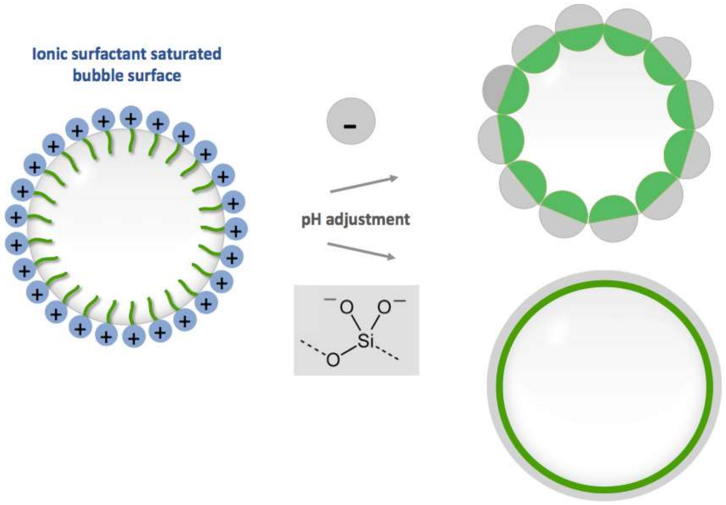

Figure 1: Schematic representation of micro-bubble encapsulation by electrostatic templating with ionic surfactants. Surfactant saturated micro-bubbles are mixed with oppositely charged particles or polymer precursors (metasilicate) to produce various protective shells around the bubbles.

A JANUS SOAP FILM DESIGNED TO FUNCTION AS AN ARTIFICIAL LEAF

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Dissymmetric architectures are one of the most general principles encoded by nature: cell membranes show a dissymmetric transmembrane distribution of phospholipids (1), which may lead to *e.g.* transmembrane electric potential gradients and different propensity for interaction with substances on the opposite interfaces. They also show an inside-outside dissymmetry of membrane-bound proteins, which is quite apparent in the function of photosynthetic and respiratory membranes where it leads to creation of the transmembrane proton gradients used to synthesize ATP. Our concept design for *a soap film based artificial leaf* (See Fig. 1 below) requires a milestone achievement for effective artificial photosynthesis- water oxidation and CO_2 reduction photo catalysis should occur on opposite functionally dissymmetric soap film surfaces.

In this talk, we present, to the best of our knowledge, the first proof of functional dissymmetry in soap films thus creating a *self-assembled Janus membrane*, by employing amphiphilic fluorescent organic molecular probes as dopants. Apart from inspiring applications in the field of electronics and optoelectronics, this proof-of-concept has particular relevance if soap films are to be utilized as platforms for artificial photosynthesis (*artificial leaves*) akin to thylakoid membranes in plants.

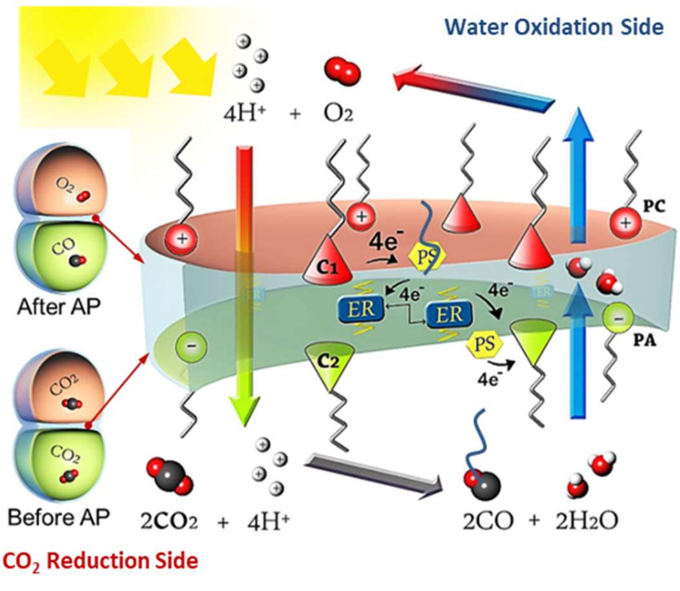

Fig 1. Concept design for a dissymmetric soap film based single Artificial Leaf, created at the junction of an internally doped soap bubble pair. C1 and C2 represent surfactant class supramolecular catalysts for water oxidation and CO_2 reduction, respectively.

Acknowledgment: This work is funded by the EU FETOPEN project SoFiA (Grant agreement ID: 828838). https://cordis.europa.eu/project/id/828838

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Industrial Applications of Foams, Emulsions and Thin Liquid Films

Novel Materials or Biomaterials in Dispersed Systems (Foams, Aerogels, Emulsions or Thin Liquid Film)

online session

BACTERIA CELL INTERFACIAL PROPERTIES INFLUENCING SURFACTANTS ADSORBED LAYERS AND FOAMABILITY

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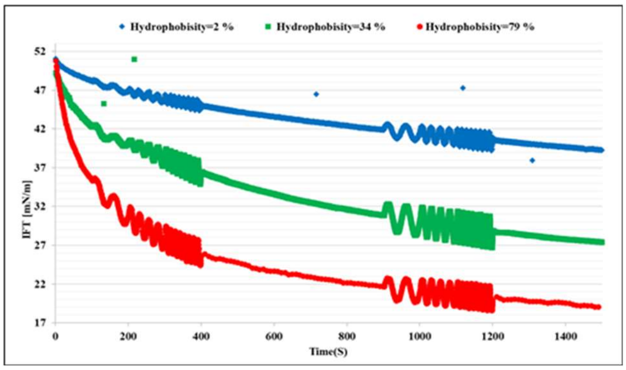
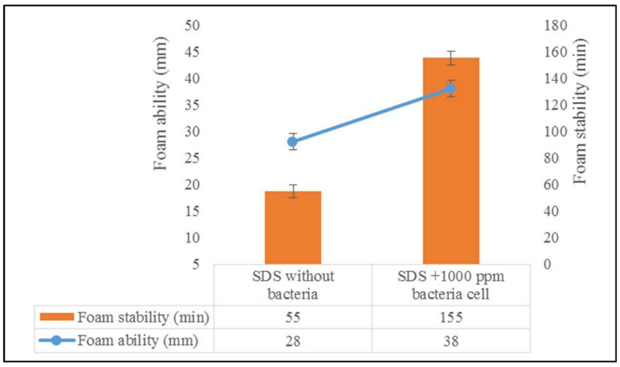
For many multiphase systems such as food industries, biotechnology and petrochemical processes, bacterial cells play important role directly or via their produced biosurfactants. The interfacial properties of such biosurfactants are studied in several works, however, there are only a few references available describing the direct impacts of microorganisms on interfacial properties. In the present work, the interfacial properties of three bacteria *MJ02* (Bacillus Subtilis type), *MJ03* (Pseudomonas Aeruginosa type), and *RAG1* (Acinetobacter Calcoaceticus type) with the hydrophobicity factors 2, 34, and 79%, respectively, were studied, along with their impact on foam formation and stability. A relationship between the adsorption dynamics and interfacial tension (IFT) reduction with the hydrophobicity of the bacteria cells were observed. The cells with highest hydrophobicity (79%) exhibit a very fast dynamics of adsorption and lead to relatively large interfacial elasticity values at short adsorption time. The maximum elasticity values (at the studied frequencies) were observed for bacteria cells with the intermediate hydrophobicity factor (34%), however, at longer adsorption times.

Suspensions of the bacteria cells MJ03 show a relatively fast dynamics of adsorption, however still slower than classical surfactants such as CTAB and SDS. The addition of bacteria cells (MJ03) to surfactant solutions (cationic CTAB, anionic SDS and non-ionic C_{12}DMPO) were studied and the following results were observed. I- For CTAB, due to an opposite net charge to MJ03, and formation of large bacteria-surfactant complexes, the dynamics of surface tension slows slightly down, while the surface elasticity increases significantly. II- For SDS a more complex behavior is observed, i.e. a significant increase in the dynamics of adsorption and decreasing elasticity values at small amounts of MJ03 are observed, which can tend to a different trend at higher cell concentrations. III- Adding bacteria cells to C_{12}DMPO solutions, leads to smaller effects due to weaker interactions. Foam formation experiments with the surfactant solutions show a significant increase in foamability and foam stability for the case II, i.e. the addition of bacteria cells to SDS solutions), while both foamability and foam stability decrease for case I (addition of bacteria cells to CTAB. The impact of adding bacteria cells on the foam produced of C_{12}DMPO solutions (case III), is almost negligible. Such foam formation mechanism and characterization results can be well interpretated via the analysis of the mentioned interfacial properties.





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REVIEW-THE IMPACT OF COFFEE MAKING PROCESSES AND PARAMETERS ON THE CHARACTERISTICS OF COFFEE FOAM

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Coffee has become a very important part of our daily lives and has been appreciated for the unique sensory properties. The foamy layer, called crema that is present on top of an espresso coffee, is an important and intrinsic part that is responsible for influencing these properties. Coffee foam, unlike the foam of alcoholic beverages like beer and champagne, has long been considered from an artistic viewpoint and has only been scientifically studied in the past two decades. This paper reviews the literature reported in this area during this time frame. Roasting, grinding, brewing processes and their corresponding parameters like degree of roasting, grind size, physicochemical properties of brewing water have been scientifically studied to relate them with the characteristics of the coffee foam. Future direction of the study is also discussed.

POSTER PRESENTATIONS

P1_1

ADSORPTION KINETICS OF GLOBULAR PROTEINS AT AIR/WATER INTERFACE: A NEW THEORETICAL APPROACH

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Adsorption of proteins at soft (liquid/fluid) interfaces, as relevant to the stability of thin liquid films and macroscopic foams and emulsions, is a large and well-established domain of the colloid and interface science, and its history is longer than a century. An enormous body of experimental data is available in the literature, obtained by many surface-sensitive methods and concerning various animal or plant proteins – adsorption dynamics, surface rheology, structure and other aspects of the behavior of proteins at soft interfaces have been intensively investigated. On the other hand, the development of theoretical tools for describing protein adsorption is difficult, because of the complicated interfacial behavior of proteins as compared for example to low-molecular-weight surfactants. It is now well established that the formation and the evolution of a protein adsorption layer at a soft interface proceeds through several major steps: induction time, followed by a relatively steep increase of the surface pressure Π, and a final relaxation phase of slight residual surface pressure increase. It is believed that such behavior is a result from the interplay of diffusion-controlled adsorption from the bulk phase and time- and surface pressure- dependent conformational changes of the adsorbed protein molecules at the interface.

In this study we develop a previously proposed concept [Won *et al.*, 2017] for theoretical treating of experimental data on the dynamic surface pressure $\Pi(t)$ for globular proteins adsorbing at the surface of an air bubble in solution. This concept involves Fick's diffusion transport and, respectively, the temporal change of the adsorbed amount $\Gamma(t)$. Estimation of the latter requires a protein adsorption model to relate Π and Γ. For this purpose, we use the model proposed by [Fainerman *et al.*, 2003] in its contemporary version [Gochev *et al.*, 2021]. The tackled idea is that the adsorption activity coefficient b_1 in the adsorption isotherm $b_1c \sim \Gamma$ is assumed to change during the process of adsorption, i.e., it is time-dependent $b(t)$ and increases with the time of adsorption up to its value b_1, which characterizes the equilibrium adsorption isotherm. The variable adsorption activity coefficient reflects the conformational changes and structure formation by the protein molecules. We present results for bovine serum albumin solutions in pure water and show that the concept of time-dependent adsorption coefficient $b(t)$ provides very satisfactory results.

Acknowledgements: This work was funded in part by Polish National Science Centre project (No. 2020/38/E/ST8/00173), and the ICCCW NASU project III-5-22-26.

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P1_2

STABILITY OF THIN LIQUID FILM IN BUBBLE-SOLID ADHESION

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Interactions between a gas bubble and a solid particle are a key aspect of many industrial processes. Froth flotation is one of the examples in which bubble–particle attachment plays a vital role. The flotation process is used for the selective separation of particles dispersed in a liquid using air bubbles, based on the difference in surface wettability of the separated materials. One of the key steps in the flotation process is the attachment of the gas bubble to the surface of the solid by forming a three-phase contact (TPC) at the gas-liquid-solid interface. Effective TPC formation depends on the stability of the thin liquid film formed between the colliding bubble determined by the action of electrostatic and hydrophobic forces. The contribution of hydrophobic forces increases with increasing hydrophobicity of the solid surface. Despite numerous works that have been published on this topic, the phenomena underlying this process are still not fully understood.
This work is focused on an experimental study of kinetics and mechanism of the TPC formation by the bubble colliding with a model flat surface with different degrees of wettability and zeta potential values. Mechanism of three-phase contact formation and phenomena occurring during collisions of the bubble with a solid surface (monitored using a high-speed camera) were studied. The drainage time of a thin liquid film was determined along with TPC formation time, TPC line expansion velocity and diameter and bubble dynamic contact angles were measured.
It was observed that the formation of TPC occurs when the surface of the solid has a sufficient degree of hydrophobicity (expressed by the contact angle) and also depends on the differences between the zeta potential of the bubble and solid. In the case when both surfaces possess a negative charge, the limiting value of the contact angle is about 35°, while for oppositely charged surfaces its value decreases to about 31°. It was confirmed that the bubble adhesion velocity and effectiveness (measured by the diameter of the created TPC) increase with increasing surface hydrophobicity. Based on the obtained results, the mechanism of bubble-solid adhesion in relation to the hydrophobicity and zeta potential of the solid surface was discussed.

Acknowledgements: This work was financed by the National Science Centre Research Grant No. 2019/33/N/ST8/03026.

P1_3

DYNAMIC ADSORPTION LAYER AND FOAM FILM STABILITY PROBED BY DYNAMIC FLUID-FILM INTERFEROMETRY

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Motion-induced dynamic adsorption layer of surfactants at the surface of a rising bubble is a widely accepted phenomenon. Although its existence and formation kinetics has been theoretically postulated and confirmed in many experimental attempts, the investigation primarily remains qualitative in nature. In this paper we present the results that, to the best of our knowledge, can provide a first quantitative proof of the presence and influence of the dynamic adsorption layer on colliding bubble interface mobility. The drainage dynamics of a single foam film formed by a colliding bubble at the surface of n-octanol solutions in a liquid column was measured. We performed this study for a total of five different surfactant concentrations and two different release depths in the liquid column (short: 1 cm and long: 40 cm), before the foam film was formed at the interface. The time evolution of thickness and morphology of the single film formed by a freely rising bubble, having different surfactant distribution of the adsorption layer at its surface, was determined using Dynamic Fluid-Film Interferometry (DFI) technique. Variations in drainage dynamics of a single foam film were used to quantitatively probe the state of the adsorption layer at the bubble surface, showing differences in its interface mobility depending on both the bulk concentration and the release depth. It was found that in a certain n-octanol concentration range, the drainage of the foam film was initially spectacularly faster. This is expected only when the dynamic adsorption layer at the bubble interface has a fully developed architect-ture. Moreover, significant influence of ambient humidity on observed trends was discussed.

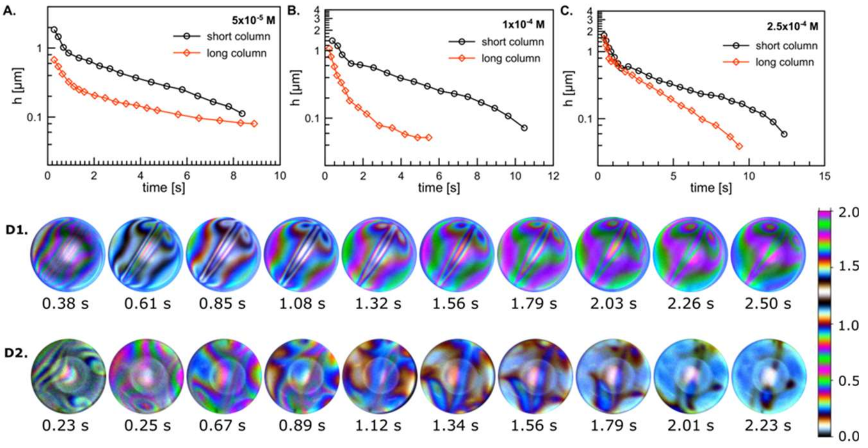

Fig. 1. Time evolution of average thickness of a single foam film formed in short (1 cm) and long (40 cm) columns at free surface of n-octanol solutions of concentrations (A) 5×10^{-5} mol/dm^3, (B) 1×10^{-4} mol/dm^3 and (C) 2.5×10^{-4} mol/dm^3 determined using DFI method. Below (Figs. D) sequence of experimentally acquired DFI images illustrating initial stage of foam film drainage in short column (D1) and long column (D2) for n-octanol concentration of 1×10^{-4} mol/dm^3. Values of time from the moment of the bubble collision and liquid film formation are given below each image. Column scale represents thickness in microns.

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P1_4

ROLE OF SURFACE RHEOLOGICAL PROPERTIES FOR DYNAMICS OF FILM THINNNING

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The dynamics of drainage of thin liquid films is of crucial importance for the properties and stability of the bulk foams. For this reason, the properties of the thin liquid films (TLFs) have been studied extensively in the literature. In the current study, we investigate the mode of drainage for thin liquid films formed from the range of different saponins, having different surface rheological properties, which were characterized by Golemanov et al. 2013, 2014 and Pagureva et al. 2016. The major aim of the current study is to clarify how the rheological properties of the adsorption layers affect the dynamics of film thinning.

Asymmetric regime of drainage is observed in films formed from saponin solutions having low dilatational and negligible shear elasticities (Figure 1B), whereas the saponins with high dilatational elasticity exhibit symmetric regime of drainage (Figure 1A). The time of film thinning depends significantly on the elasticity of the adsorption layers. The drainage time increases significantly for systems with symmetric regime of drainage. The fastest thinning is observed for films, formed from saponins with low dilatational elasticity and zero shear elasticity.

This study is of scientific and practical interests. On one hand it addresses the more fundamental question about the factors which determine the behavior of thin liquid films. On the other hand, it is important with regard to the application of saponins as foam stabilizers in commercial products.

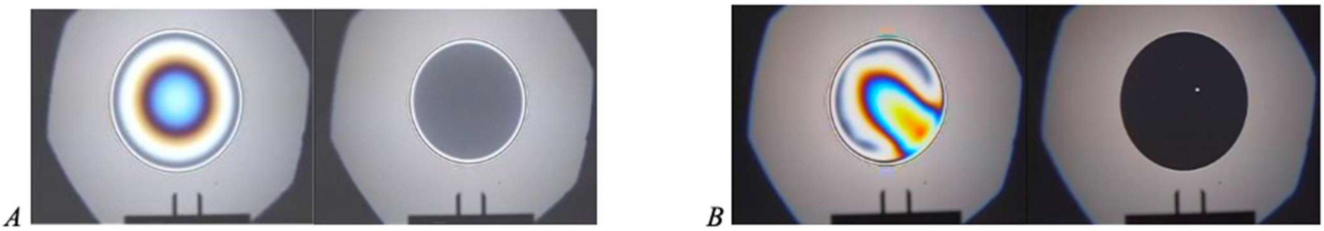

Figure 1: Consecutive stages in the process of thinning of foam films, stabilized by saponin solutions – A. Symmetric and B. Asymmetric regime of drainage.

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P2_1

A PHASE-FIELD MODEL TO SIMULATE FOAMS FLOWING IN AN OBSTRUCTED CHANNEL

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Numerical simulations are a valid alternative for the investigation of flowing foams in two- and three-dimensional domains. Large advances in this field have for instance been achieved with the Surface Evolver [Brakke, 1992; Cox, 2006], which discretizes the air-liquid interfaces of the foam with a triangle mesh. A numerical model derived from the phase field theory is here suggested to simulate flowing foams with gas concentration (ε) ranging from 40 to 99%. Phase-field models constitute a class of efficient computational methods that allows one to investigate three-dimensional multiphase flows [Kim, 2012]. Each bubble with index i is here associated with an identification function $\phi_i(\boldsymbol{x},t)$, where $\boldsymbol{x}$ is the spatial coordinate vector and t the time. As one moves from the bubble inner region to the outer region, ϕ_i undergoes a smooth but rapid transition from unity to zero over an interfacial width ξ [Borcia, 2017]. To compute the foam transport, each identification function is updating in time and space by solving the advection equation

$$\frac{\partial\phi_i}{\partial t} + \boldsymbol{u}\cdot\nabla\phi_i = -\frac{1}{\tau}\left(f_b + f_r - \xi^2\nabla^2\phi_i\right) \qquad (1)$$

where $\boldsymbol{u}(\boldsymbol{x},t)$ is a vector velocity field, τ a response time associated with the foam dynamics and $f_b(\phi_i)$, respectively, $f_r(\phi_i,\phi_{j\neq i})$ bulk and repulsive terms [Lavarotti, 2021]. As application, a periodic channel with height H and length L = 1.7 H is chosen. The two-dimensional flow is obstructed by two semi-disks with radii R = 0.2 H. The present simulation is our attempt to reproduce the quasi-two-dimensional experimental system in [Dollet, 2007], where a horizontal mono-layer bed of bubbles is confined between either a column of water and an upper plate or between two plates.

The channel is filled with N = 96 bubbles exhibiting a specific size distribution and a pre-defined gas fraction (ε). Figure 1 illustrates the channel schematics along with the foam bubbles being transported from left to right. Each “sharp” bubble interface, shown in blue in the Figure, is defined by the isoline ϕ_i = 0.5. At very low gas fraction (ε = 0.44), the bubbles tend to remain in the channel core. With increasing gas fraction, the foam expands vertically to gradually fill the stagnant lower and upper cavity zones between the obstacles. At gas fraction $\varepsilon \approx 0.7$, the stagnant zone persists only downstream of the obstacles, in-line with previous observations. At high gas fractions (ε = 0.99), many of the viscoelastic foam properties, such as irreversible topological rearrangements known as T1-events, could be reproduced. Especially near the obstacle, the higher frequency of T1-occurrence was found to match the previously reported kinetics of two-dimensional foam flowing around a cylindrical obstacle [Dollet, 2007].

On the one hand, the present model is capable of treating interacting bubbles subject to large deformations and, on the other hand, the movement of individual bubbles carried away in regions of low gas fraction. The method was here applied to mono- and poly-disperse foam flowing in an obstructed channel at gas fractions below, near and above the jamming point. The next step will be to include the coupling with a Navier-Stokes solver. Future work will also include an extension to three-dimensional simulations. This can be easily achieved with the phase-field model, because in contrast to other methods, e.g. Volume-of-Fluid methods, the transport equation for the scalar identification functions do not differ substantially between two and three dimensions.

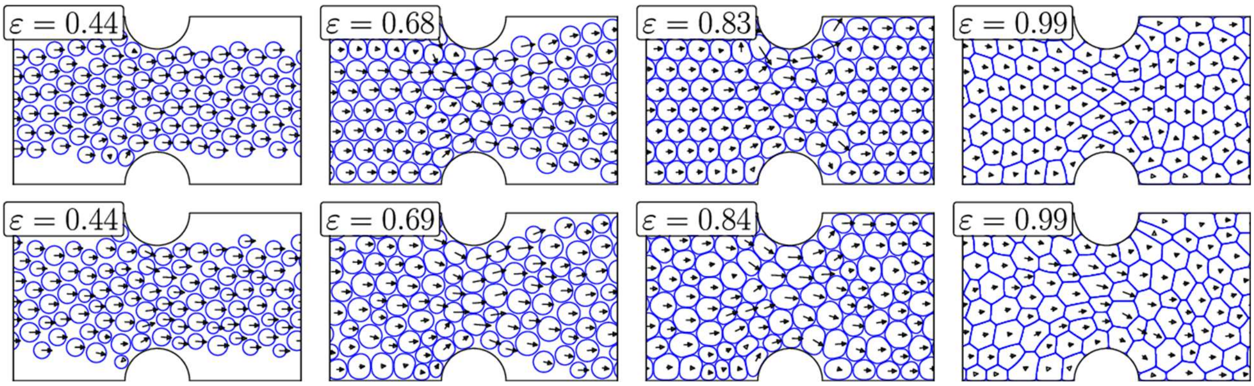

Figure 1: Instantaneous foam states arbitrarily taken from the dynamic simulations. The black arrows located at the bubbles' centres represent the velocity vectors. The upper and lower rows illustrate the mono- and poly-disperse foams, respectively. ε is the gas fraction.

Acknowledgements: S.H. acknowledges the financial support of the Deutsche Forschungsgemeinschaft (HE 7529/3-1).

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P2_2_ONLINE

THE NONLINEAR BEHAVIOUR OF CONFINED CHAINS OF HARD SPHERES AND SOFT BUBBLES UNDER COMPRESSION AND TILT.

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Linear chains of soft or hard spheres, confined by a transverse harmonic potential, buckle under compression and arrange in the form of modulated zig-zag patterns [2-3]. Our experiments support recent computational and theoretical work [1-3]. In the case of chains of spheres that are slightly tilted, they also highlight the role of friction in allowing unstable configurations in their absence [4]. Due to its simplicity, our experimental set-up should also be of interest in the context of teaching about instability and symmetry breaking at the school or undergraduate level. Furthermore, despite differences in the interaction forces, the structures found are reminiscent of those of confined ions, which interact via Coulomb forces [5].

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P3_1_ONLINE

SQUEEZE FILM FLOW OF VISCOPLASTIC BINGHAM FLUID BETWEEN NON-PARALLEL PLATES

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Squeeze film flow of a viscoplastic Bingham fluid between non-parallel plates has been analysed. It is assumed that the force applied to the plates is known, therefore, their velocity must be found, and the film thickness decreases then as time proceeds. Moreover, for non-parallel plates, the position along the plates at which flow reverses direction is found as part of the solution. In the Newtonian limit, the thickness of the gap between the plates in the parallel system never quite reaches zero at any finite time [G. Covey, 1981], while for the non-parallel case a finite time can be obtained when the plates touch one another at a point. In squeeze flow of a viscoplastic Bingham fluid between parallel and non-parallel plates, under a fixed applied force, a final steady film thickness can sometimes be reached. This final thickness turns out to be sensitive not just to the plate tilt angle but also to the so called Oldroyd number which is defined as the ratio between yield stress and imposed stress. Nevertheless for squeeze film flow of Bingham viscoplastic fluid between non-parallel plates, the results show that other cases exist in which the lubrication force cannot always balance the applied force, leading to the plates approaching and touching at the narrowest end of the gap. Moreover torques that develop within the system have been analysed.

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P3_2_ONLINE

A NUMERICAL MODEL FOR COARSENING IN WET FOAMS WITH A REALISTIC BUBBLE-SCALE STRUCTURE

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Over time, gas diffusion through the liquid in a foam results in the growth of large bubbles at the cost of smaller ones. This is the process of coarsening, which is driven by the higher gas pressure in small bubbles. It reduces the foam's yield stress, and may decrease its effectiveness in applications such as fire suppression. However, coarsening is not well understood for foams of moderate liquid fraction. How can one account for gas diffusion through the Plateau borders, and how does this influence the variation in bubble volume? Experiments with wet foams encounter difficulties due to liquid drainage, while existing theoretical predictions are limited for foams wet enough not to obey Plateau's laws.

Current simulations of wet-foam coarsening typically use idealised approaches, such as the Durian bubble model or the Potts model. These are suited to large numbers of bubbles, but do not realistically capture the bubble-scale structure. Furthermore, they have not yet reproduced existing experimental results regarding the scaling of the bubble volumes during coarsening. Another approach, suited to simulations of smaller systems, is that of [Kähärä, 2014] who discretise all liquid-gas interfaces. This allows realistic bubble shapes, while the resolution of both interfaces of the thin films allows bubble rearrangements to occur without careful mesh adjustments. The approach has thus far been applied to rheology in two dimensions.

We present a quasi-static adaptation of the model by [Kähärä, 2014] intended for coarsening, which is implemented in the Surface Evolver [Brakke, 1992]. We add a qualitatively realistic form for the disjoining pressure, with attractive and repulsive components, which allows the contact angle between the thin films and Plateau borders to be set. The foam structure is obtained by minimising its total energy via conjugate gradient iterations.

To implement coarsening, we follow [Schimming, 2017] in using an approximate local solution of the diffusion equation to obtain the gas flow rate through interface elements, and thus through both the thin liquid films and Plateau borders. Together with validation of our structural model, we present simulation results regarding the coarsening of ordered, two-dimensional foams with a single defect, for a range of liquid fractions. Our model is also applicable to disordered foams, and we expect it to extend straightforwardly to three-dimensional problems.

Acknowledgements: Funded by ESA REFOAM MAP contract 4000129502.

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P3_3

STUDY OF A PINCH IN THE VICINITY OF A MENISCUS IN A THIN LIQUID FILM

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In a thin liquid film connected to a meniscus, the meniscus creates a capillary suction that generates a thinner zone where the meniscus connects to the film. This thin zone called "pinch" is the origin of the phenomenon of marginal regeneration (see Fig.1 (a)) observed in the 1960s by Mysels in soap films [K.J. Mysels *et al.*, 1959]. It has been shown recently [J. Miguet *et al.*, 2021] that marginal regeneration is of major importance to describe the thinning of films over time. This thinning is in turn essential to predicting the lifetime of films therefore their stability.

We study the pinch dynamics in a horizontal film of silicone oil deposited on a solid surface by spin-coating. The meniscus is created by depositing a capillary tube on the film. We measure the thickness of the film in the region of the pinch, perpendicular to the capillary, using a hyperspectral camera. We obtain thickness profiles (cf. Fig.1 (b)) at different times, which can then be compared with the theoretical model of the dynamics of this pinch established by Aradian [A. Aradian, 2001].

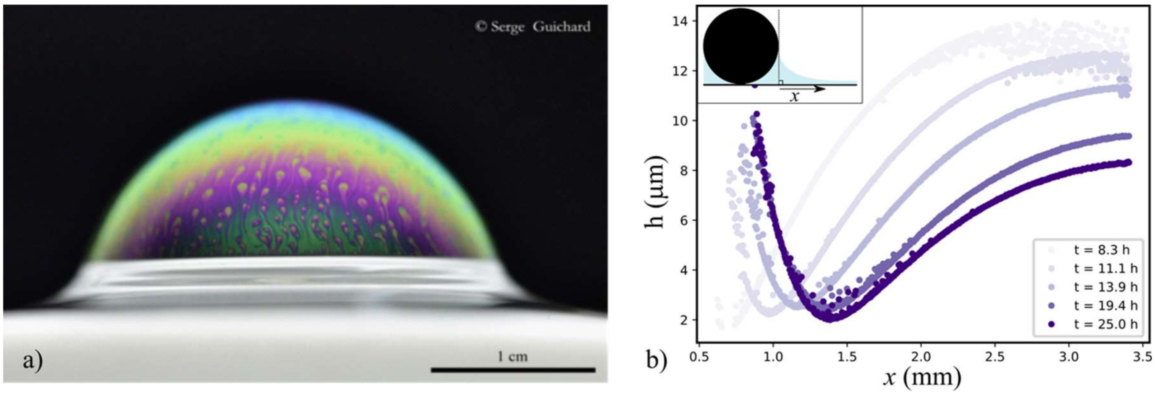

Figure 1: (a) Photograph of a surface bubble illustrating marginal regeneration: thin circular patches rise while the rest of the thicker film falls [J. Miguet et al.*, 2021]. (b) Thickness profiles, in the pinch zone, of a silicone oil film of initial thickness 10 micrometers, the meniscus being created by an 80-micrometer diameter capillary. We can see that the thickness starts by decreasing rapidly, this is the meniscus, then reaches a minimum – the pinch – then relaxes to the initial thickness of the film.*

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P3_4

MEASUREMENT AND SIMULATION OF FOAM DRAINAGE IN TWO DIMENSIONS USING NEUTRON RADIOGRAPHY

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The liquid fraction is a key parameter of foam influencing many of its properties. Foam drainage change dynamically the liquid fraction distribution in a foam. It is therefore of general interest to understand it in its principle behaviour. Liquid drainage is typically described by the unsteady, three-dimensional drainage equation [Verbist, 1996]. However, apart from optical observation in a Hele-Shaw cell [Hutzler, 2005], unsteady and multi-dimensional measurement of liquid fraction distribution is scarcely approached. Here, two-dimensional foam drainage experiments and simulations were carried out to validate the horizontal terms of foam drainage equation and to show its limitations. Using neutron radiography [Heitkam, 2018], we measured the two-dimensional liquid fraction distribution in steady, dynamic and periodic drainage experiments. This allowed the multi-dimensional drainage equation to be validated dynamically and in steady-state. In particular, the damping character of the foam drainage was quantified as a function of different frequencies and amplitudes. This yields guidelines for forced-drainage experiments with peristaltic pumps.

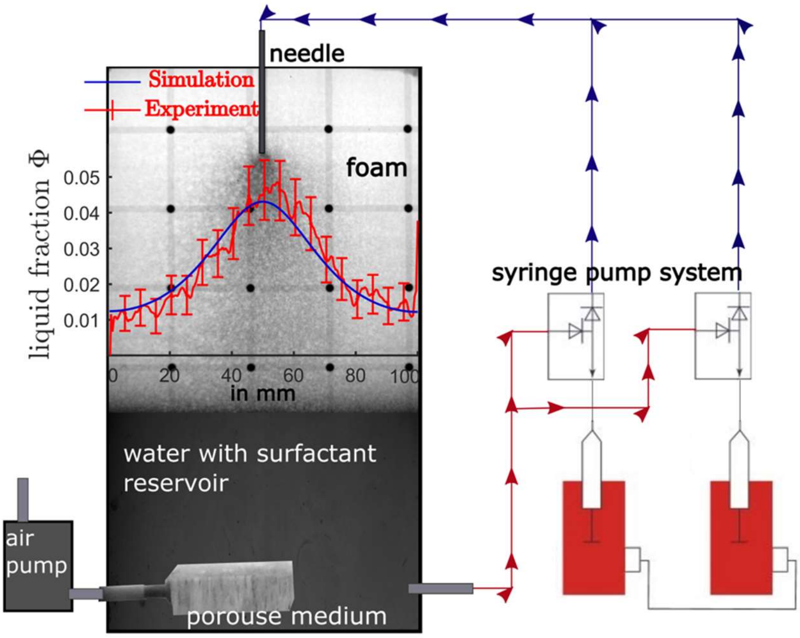

Figure 1: Foam drainage setup with a comparison between a simulated and measured horizontal liquid fraction profile in red

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P4_1

PLATFORM DEVICE FOR THE ELECTRICAL CHARACTERIZATION OF SOAP FILMS

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Designer soap films may be utilized as functional, soft materials in new types of biomimetic devices and sensors (proto-opto-electro-mechanical systems - POEMS) that offer added functionalities and good environmental compatibility. However, to use soap films in such a way, further research into their properties is necessary. A key to studying those characteristics is an R&D platform that permits maintaining stable soap films over prolonged periods. The setup has to provide control over the film thickness. Moreover, the device needs access points and tools to characterize the film properties individually and concurrently. Such properties may include electronic and ionic transport as well as optical, gas diffusion and acoustic attributes.

We have designed and built such an R&D platform to hold liquid films with a diameter of 5 mm. The Ø 60 mm frame is made from anodized aluminum. It contains internal channels to feed liquid into the sides of the film or draw liquid out of it via a microfluidic pump allowing controlling the thickness and stability of the film. It is planned to determine the film thickness with interference measurements. The frame has another channel to couple an optical fiber into the liquid for optical experiments. To permit transport measurement on the surfactant layer on the film surface, four gold leads are connect to the film's sidewalls. Conducting PEDOT electrodes will be grown from those leads through the liquid to the film surface. The growth of such polymer electrodes has been performed successfully.

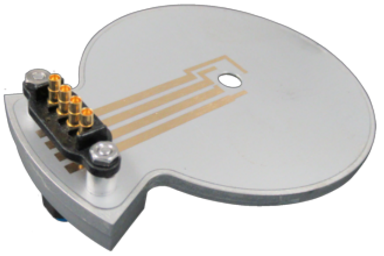

Figure 1: Fabricated frame of R&D device

The frame is enclosed by a chamber with gas ports that permit controlling the atmospheric environment on either side of the film to perform gas diffusion experiments. Both chamber sides exhibit quartz glass windows which can be replaced with various investigative tools such as a

CCD, a microscope objective or acoustic devices. The setup also allows for the integration of additional microfluidic devices that may be used to manipulate the film and its composition.

Figure 2: Fabricated chamber of R&D device

Acknowledgements: This work is funded by the EU FETOPEN project PROGENY (Grant agreement ID: 899205), aiming at the utilization of unique properties of soap films as advanced functional materials to be used in fundamentally new types of devices and sensors labeled Proto-Opto-Electro-Mechanical Systems (POEMS).

P4_2

EFFECT OF PARTICLE HYDROPHOBICITY ON FOAMABILITY AND FOAM STABILITY

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Particulates are present in a number of recognised industrial foaming processes such as mineral particle froth flotation, de-inking flotation, and food processing. To produce foam, surfactants can be added to the system to provide high foaming and foam stability. Solid particles of suitable size and hydrophobicity can also be used. Progress in the development of particle-stabilised foaming systems was mainly due to the fact that particles can have a number of economic and environmental benefits over common surfactants. Most studies have concentrated on stabilising foams with moderately to strongly hydrophobic particles. However, hydrophilic particles can also perform as foam stabilisers through stratification mechanism.

Surface wettability can be characterised by the value of the contact angle formed between a liquid droplet placed on a solid surface at the solid-liquid-gas interface and is an important aspect in many processes used in industry. One method of altering the hydrophobicity of a solid surface is silanisation. Another method to render surface wettability is to convert some of the silanol surface groups to alkoxy groups by an esterification process. This method leads to the covalent attachment of alcohol molecules to the surface and results in highly stable and homogeneous hydrophobic surfaces, which gives it an important advantage over silanisation.

In the present study, the effect of the presence of solid particles with different wettability on the foaming properties and stability of foam formed from the tripropylene glycol n-butyl ether (TPnB) solution was investigated. Soda-lime glass beads of size 70-110 µm were used as a model solid, which wettability was altered by esterification with n-alcohols (C_3-C_{10}). TPnB was used as a foaming agent at a constant concentration, which ensured the production of a foam that is neither too abundant nor too stable over time. The foam was generated in a cylindrical glass column filled with the test solution by introducing air through a sintered glass disc located at the bottom. During measurements, images of the foam were recorded using a digital camera and then processed to obtain foam height over time and foam half-life.

It was observed that the foam was significantly higher when unmodified or partially hydrophobic beads were present compared to sole TPnB solution. For strongly hydrophobic particles, the foam was also higher than for the frother solution itself, but also lower than for slightly hydrophobic particles. The unmodified glass beads gave even moderate foam compared to air-bubbled water (without frother).

However, the stability of the foam after the termination of the air flow, expressed as the half-life of the foam, was quite short both without and with addition of particles, regardless of their hydrophobicity and concentration.

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P5_1

FOAMABILITY AND FOAM STABILITY OF LICORICE ROOT EXTRACT: DYNAMIC SURFACE PROPERTIES EFFECTS

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The root extract of Licorice (*Glycyrrhiza glabra*) is rich in saponins. So it can be considered a great source of natural surfactant. The Licorice root has been used traditionally for decades for foaming agents in the food industry. It is well determined that the dynamic surface properties at liquid interfaces affect the foamability and stability of colloidal systems [Santini, 2019]. This research focuses on dynamic surface properties of Licorice Root Extract (LRE) solutions and their effects on foam behavior. In this study, the dynamic surface tension and surface dilational viscoelasticity, at the air-water interface were measured by using pendant drop tensiometry [Berry, 2015]. The transient surface tension was measured over 6000 seconds, then, drop sinusoidal oscillations with 10% volume amplitude were started to measure the surface dilation parameters. For foamability examinations, the air was injected through a porous disc at the bottom of a graduated column containing 20 ml of solution. The foam stability was determined by measuring the height of foam as a function of time and the half-life of foam was considered as the output. Figure 1 shows the foam properties along with the surface properties results for LRE at different concentrations. As the LRE concentration increases, the surface tension decreases, which is expected due to the free available surfactant molecules in the solution and adsorption at the drop surface. The surface tension reduction continues up to the CMC value of LRE. Moreover, with increasing LRE concentration before the CMC, a sharp increase in foamability is observed. For LRE concentration above the CMC, the foamability reaches a constant value. These two results show well a significant relationship between surface tension reduction and foamability. Also, Figure 1 indicates maximum foam half-life values can be obtained for high surface elasticities, which illustrates the significant role of the elastic part in foam stability due to the dynamic adsorbed layers. Therefore, the results demonstrate a good correlation between changes in surface elasticity and the stability of LRE foams.

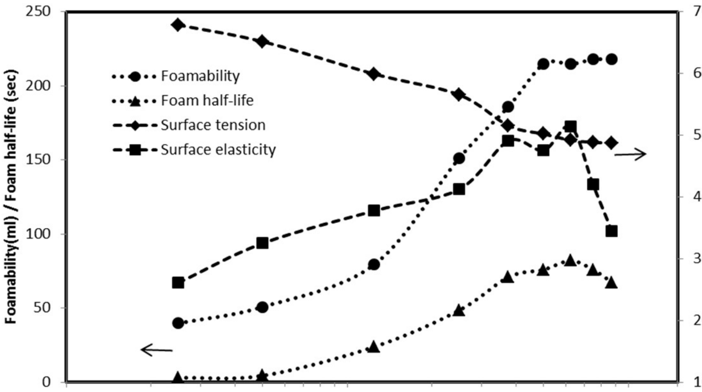

Figure 1: Foamability, foam half-life, surface tension and surface elasticity (0.01Hz) vs. LRE concentration.

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P5_2

SURFACE ACTIVITY OF HYDROPHOBICALLY DECORATED CHITOSAN

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Chitosan (deacetylated chitin, poly (D-glucosamine)) as a natural, biodegradable cationic polymer has been hydrophobically modified to obtain a new class of compounds combining the properties of hydrophilic polyelectrolytes with the ability to the hydrophobic association. The hydrophobically decorated polyelectrolytes can find a wide range of applications as functionalized building blocks for speciality materials with tuneable features [Szczęsna et al., 2022]. The modification reactions were carried out using *n*-octanoic, *n*-dodecanoic and *n*-hexadecenoic acid linked via amide or ester bonds. The degree of grafting was selected at 30 per cent. To increase the solubility, we dissolved the hydrophobically decorated chitosan in 1% of acetic acid pH = 2.85 or acetate buffer = 5. Our research showed that surface activity, behavior in solution and stability of emulsions prepared with these amphiphilic macromolecules significantly depend on the length of the hydrocarbon chain and the type of linker. Figure 1 presents the difference in surface activity of newly synthesized compounds

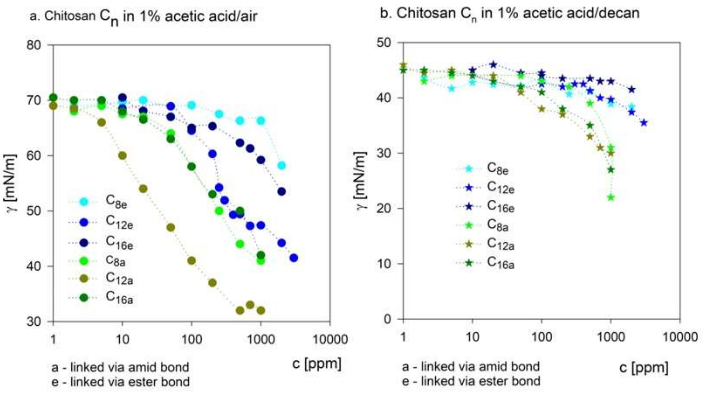

Figure 1:Dependence of equilibrium surface tension on concentration and type of linker for hydrophobically decorated chitosan: a. at interface 1% acetic acid/air b. at interface 1% acetic acid/decane

Acknowledgements: This work has been supported by the National Science Center Poland OPUS programme (2017/25/B/ST4/02450) as well as by a statutory activity subsidy from the Polish Ministry of Science and Higher Education for the Faculty of Chemistry of Wrocław University of Science and Technology and the Jerzy Haber Institute of Catalysis and Surface Chemistry, Polish Academy of Sciences

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P6_1

A MACHINE LEARNING APPROACH TO SEGMENT IMAGES OF FOAM AT A TRANSPARENT WALL

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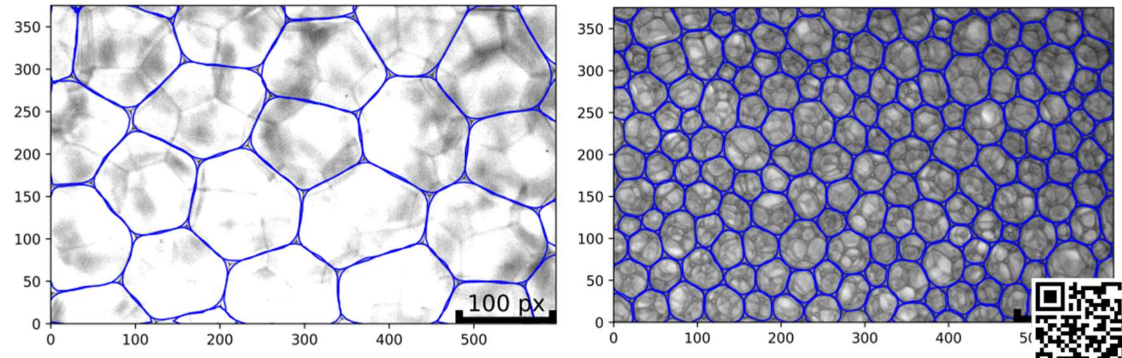
The bubble size distribution is a crucial parameter influecing the mechanical behaviour of aqueous foams. However, resulting from the opaque nature of foam, the possibilities of determining the size of individual bubbles are strongly limited. When foam is in contact with a transparent wall, bubble sizes can be estimated by measuring the visible area of the surface bubbles [Wang, 2009]. In this work an approach based on machine learning is proposed to segment images of such surface bubbles. An available model, designed for the analysis of cell images [Schmidt, 2018], was trained on images of foam with varying bubble size, polydispersity and liquid fraction. Finally, the trained model was validated on images with known bubble size distribution, where a good agreement for different bubble sizes- and shapes could be found [Knüpfer, 2022]. The trained model weights are provided for further usage.



Trained model weights available at:

Figure 1: Images from the surface of foams with varying bubble size and liquid fraction in contact with a wall. The blue outlines were detected using the proposed method.

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P6_2

FOAM-BASED CLEANING OF HISTORICAL SURFACES

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The historical surfaces of artistic and cultural assets are often soiled as a result of long-term exposure to environmental influences. Cleaning these objects is a great challenge as each surface requires a tailor-made cleaning method to remove dirt without damaging the artwork. Our goal is to develop new, innovative foam-based cleaning methods. We were able to reveal that foams have great potential as suitable cleaning agents for several reasons. Firstly, the amount of detergent can be reduced by up to 90%. Secondly, foams allow covering hard-to-access surface shapes and last but not least they generate additional physical cleaning mechanisms, namely imbibition and wiping [Schad, 2021]. These mechanisms can be optimized when working with foams with the “right instability”: the foams need to be sufficiently stable to maintain imbibition, while they need to be sufficiently unstable to ensure an optimal “bubble-wipe” [Schad, 2021]. The combination of imbibition and wiping is so efficient that it is sufficient to simply let the foam sit on the surface for a while before removing it by vacuuming. No additional mechanical action is needed: Less is More! [Schad, 2021] Having shown this fundamental principle on model surfaces, we are now testing our cleaning foams on real historical objects that are difficult to clean. Our goal is to clean the historic carriages of kings and emperors of past centuries in the “Marstallmuseum” in Nymphenburg Palace in cooperation with the "Bavarian Administration of State-Owned Palaces, Gardens and Lakes". First cleaning tests with foams on historical, gold-plated surfaces showed a successful cleaning result (Figure 1). Using foams for cleaning, one can also clean rough and vertical surfaces without additional mechanics.

Figure 1: Historic wooden carved and gold-plated shell on the drawbar of the Renaissance sleigh of King Ludwig II of Bavaria (left) before cleaning, (centre) during cleaning with foam and (right) after cleaning. Photo: Tamara Schad, Bavarian Palace Administration

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P7_1_ONLINE

DESIGNING AND MODELING PORE SIZE AND STRUCTURAL PROPERTIES OF MESOCELLULAR SILICA FOAMS FOR ENZYME ADSORPTION

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In the present work, the synthesis of mesoporous MCF silica supports with tunable porosity and pore size for protein adsorption, as well as characterization of their structural properties, are presented. MCF materials with various structure properties were synthesized using the non-ionic triblock copolymers Pluronic PE9400 and PE10500 as templates and trimethylbenzene (TMB) as organic cosolvent acting as pore expanding agent [1,2].

The adsorption processes of selected proteins (BSA, OVA) from phosphate buffered saline solutions at pH=7.4 on the series of MCF materials with different porosity are investigated. The equilibrium adsorption isotherms and kinetic dependences (concentration vs. time profiles) for the adsorption processes of biomolecules were determined by applying a UV–Vis spectrophotometer [3]. The dependences between pore diameter and kinetic rate were analyzed. It was found that the adsorption process of proteins on porous silica adsorbents is slow and limited by the diffusion of molecules into the internal adsorbent porous structure and is strongly dependent on the pore size of MCF material.

The textural properties of the prepared MC support with tunable porous structure before and after protein adsorption were determined from the nitrogen sorption isotherms. The basic porous structure parameters of studied silica adsorbents: the BET specific surface area (S_{BET}), the micropore area (S_{mic}), the external surface area (S_{ext}), the total pore volume (V_t), the micropore volume (V_{mic}), the average pore diameter (D_{av}), the average hydraulic pore diameter (D_{hy}) were calculated. Additionally, diffuse reflectance spectroscopy (UV-Vis DRS) was applied to study the structure of prepared protein/silica composites. The analysis with UV-Vis DRS spectroscopy showed the existence of protein molecules on the MCF surface (well-known absorbance maxima for BSA and OVA by ~280 nm and 229 nm, respectively).

The electrochemical character and surface charge density of the MCF supports covered by protein molecules were determined by using potentiometric titration. It was found that the electrochemical character of pure silica surface is significantly different than for the silica surface with adsorbed protein molecules. Native MCF adsorbents have a point of zero charges, pHPZC, near 4.3, however, as a result of protein adsorption, their surfaces become amphiphilic, with pH_{PZC} near 6.5.

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P7_2_ONLINE

HSA/NANOSILICA BIOCOMPOSITE: STRUCTURAL, TEXTURAL AND MORPHOLOGICAL PROPERTIES

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Nanoscale silicas and biocomposites based on nanosilica particles and protein molecules are new promising materials for biomedical/pharmaceutical applications (eg. enterosorbents and vulnerosorbents). In this work, we prepared new nanosilica supports with unique morphological and textural properties by geometric modification (GM) of initial fumed silica A-300 (nanosilica, Chuiko Institute of Surface Chemistry of NAS of Ukraine) in a specially selected atmosphere using a ball mill [1,2]. The effectiveness of Human Serum Albumin (HSA) adsorption from aqueous solutions at pH=7.4 on the initial fumed silica A300 (NS) surface and GM-treated at various times i.e.1,4,7 hours was investigated.

The geometrical and textural properties of a biocomposite based on fumed nanoscale silica and HSA molecules were characterized using the nitrogen adsorption/desorption isotherms. The micro-nanostructure and morphology of the initial nanoscale silica particles and GM-treated nanosilica before and after albumin layer adsorption was determined by using atomic force microscopy (AFM). Additionally, the scanning electron microscopy (SEM) with the X-ray microanalysis (TEM/EDX) were used to study the topographic properties and elemental composition of the nanosilica surface and GM-nanosilica covered by the adsorbed HSA molecules.

Acknowledgements
The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme FP7/2007-2013/under REA grant agreement no. PIRSES-GA-2013-612484.

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P7_3_ONLINE

STUDY OF THE INTERACTIONS BETWEEN O_2 NANOBUBBLES AND THE PULMONARY SURFACTANT

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An aqueous dispersion of oxygen nanobubbles (ADON) is a unique gas-liquid colloidal system and may be attractive as a new concept in treating the respiratory diseases by inhalation [Odziomek et al., 2022]. Before a potential application of ADON as an aerosol drug carrier with the additional function of oxygen supplementation, the screening of ADON interactions with physiological fluids of the lungs is needed. The aim of this work is to investigate the influence of ADON and selected inhalation drugs on the surface properties of the pulmonary surfactant model (MPS). The characteristics of the air-liquid interface were studied under simulated dynamic conditions of the respiratory cycle using the oscillating droplet tensiometer (Sinterface) and Infasurf (ONY Biotech) as MPS. Dynamic properties of the interface were described by rheological parameters.

The results indicate that the surface viscosity of MPS at the air-liquid interface of ADON (in water or physiological saline) does not change much compared to the systems without nanobubbles, while the surface elasticity is decreased (Fig.1). It suggests a potential reduction of the range of surface tension variability during breathing-like oscillation of the interface, although the surface tension hysteresis, known as the essential indicator of the proper function of the surfactant, remains preserved. This allows us to conclude that ADON is relatively safe for the pulmonary surfactant, so it can be considered as an alternative carrier for inhalation drugs.

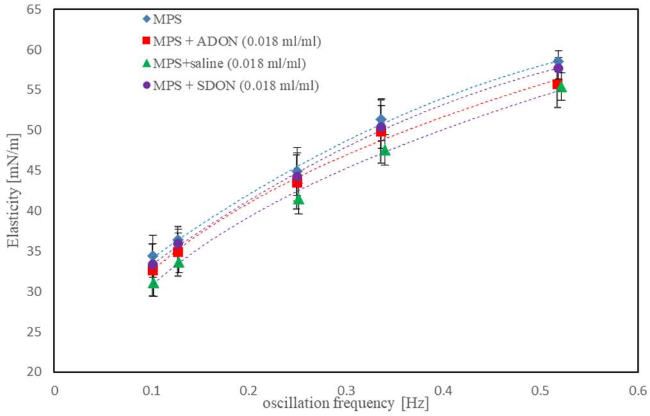

Figure 1: Dilatational elasticity of the air-water interface for MPS and ADON.

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P7_4_ONLINE

POLYURETHANE FOAMS: BIOLOGICAL ACTIVITY AND ENVIRONMENTAL FRIENDLINESS

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The ever-increasing interest in polyurethane foams (PUF) in scientific and applied aspects should be associated, first of all, with the peculiarities of their structure - the polyblock structure of polyurethanes, which predetermines unlimited possibilities for regulating their structure, physical and, hence, practical properties.

Polymers characterized by biological activity at the level of micro- and macroorganisms are the subject of our research.

Biologically active polyurethane foams - a range of polyurethane foam materials has been developed with immobilized biologically active (metal)organic and natural compounds (BAC) as macrochain extenders and/or end-group and PUF, containing BAC, not associated with a polymer carrier, having:

- bactericidal and complex bactericidal / fungicidal activity of prolonged action against pathogenic microbes *S. aureus, E. coli, Klebsiella pn., Pseudomonas aeruginosa, Proteus mirabilis, Pr. vulgaris; Aspergillus oryzae, Penicillium brevcom pactum*, which can also inhibit the growth of microorganisms on the surface of foam and are resistant to biotic factors;
- self-adhesive properties;
- controlled local anesthetic action;
- non toxic effect.

For use in veterinary medicine, two-component biocompatible, bactericidal / fungistatic / fungicidal polyurethane foams of prolonged action have been developed, which are formed directly on the surface of the surgical suture of an animal (cattle) in 5-6 minutes. Toxicological studies of polyurethane foam in relation to human erythrocytes showed the absence of hemolysis zones of erythrocytes, both in the process of forming polyurethane foam and in the process of "aging" (after 14 days).

Eco-friendly polyurethane foams are based on natural oils (canola, palm, soybean, linseed) and (exo)polysaccharides (starch, carboxymethylcellulose, xanthan) as an alternative to synthetic raw materials. By regulating the content of renewable compounds (up to 66-68% wt.), an increase in the strength characteristics of polyurethane foam up to 50% was achieved compared to the matrix. Water absorption increases by 40-50 times. PUF is an order of magnitude more stable in acidic and alkaline mediums. Weight loss after 10 months of incubation in the soil due to the synergistic effect of renewable compounds (oils/polysaccharides) exceeds the values of the matrix up to 200 times.

Morphology of polyurethane foams. The image of the cell structure of the PUF sample, obtained by optical microspectroscopy, was processed by computer analysis, and the statistical parameters of the cells were determined. All elastic PUF are fine-meshed foam. Cells with a size of 0,02 mm^2 make up 1/3 of the total number, the rest are cells with an area of 0,02-0,05 mm^2. The distribution of cells is close to normal. Most of the investigated PUF cells have a form factor from 0,4 to 0,6.

The developed PUF-materials are aimed at maximum assistance to the sustainability of various spheres of human activity.

P7_5

EFFECT OF POLYDISPERSITY OF NICKEL-SILVER CORE-SHELL NANOPARTICLES ON THE PROPERTIES OF METALLIC FILMS

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In the last years, the properties of metallic films such as structure, conductivity, and flexibility have been extensively studied according to the application of conductive materials for the fabrication of printed electronic circuits and devices. It was noticed that most conductive films are based on metal nanoparticles (NPs) [Liu, 2015]. Although monodisperse NPs have better stability against the aggregation process than polydisperse ones, some specific requirements have to be addressed and several specific challenges should be overcome for obtaining nanoparticles with monodisperse size distribution. Moreover, considering the geometric aspects of films, more tight packing of NPs can be obtained while using polydisperse nanoparticles (voids between large NPs are filled with small NPs), and hence higher conductivity can be achieved.

In the present research, we focused on the effect of polydispersity of Ni-Ag NPs on the structure and properties of conductive films obtained by thermal sintering. The conductivity of metallic films formed based on monodisperse Ni-Ag NPs was compared with polydisperse ones, formed by mixing NPs with different average sizes (model polydisperse system). In all cases, the optimal conditions for the formation of conductive patterns (weight ratio of NPs for polydisperse composition, the concentration of the wetting agent, sintering temperature, and duration) were determined. It was found that metallic films containing 100, 220, and 420 nm Ni-Ag NPs with a mass ratio of 1:1.5:0.5, respectively, are characterized by the lowest resistivity, 10.9 μΩ·cm, after their thermal post-coating sintering at 300°C for 30 min that is only 1.6 higher than that of bulk nickel [Pajor-Świerzy, 2021].

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P7_6

THE INFLUENCE OF COUNTERIONS ON PROPERTIES OF PDADMAC/PSS THIN FILMS

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To obtain thin films of novel functions one has to fabricate well-defined nanostructures of controlled architecture. Polyelectrolyte multilayer films (PEMs) are among the most promising systems in the field of material science, intensively developed and broadly examined with constantly increasing interest. However, the formation mechanism of polyelectrolyte multilayers in the presence of **the Hofmeister series of counterions is not entirely clear.**

The main goal of the presented studies was to examine the influence of monovalent counterions on the structural and surface properties of PEMs. The polyelectrolyte films were constructed from poly(diallyldimethylammonium)chloride (PDADMAC) and polysodium 4-styrenesulfonate (PSS). The following counterions were used: NH_4^+, Cs^+, Rb^+, K^+, Na^+, Li^+ to prepare polyelectrolyte solutions. The formation of PEMs in the presence of selected electrolytes with particular emphasis on the kinetics and efficiency of the deposition process was investigated by quartz crystal microbalance with dissipation (QCM-D). Additionally, the surface topography of studied PEMs was investigated by atomic force microscopy (AFM). Further, their physical and chemical properties were completed with electrochemical studies of PEMs' permeability. Our results proved that mass adsorbed, roughness, morphology and permeability towards selected electrochemical probes depended on the type of the countercation used for film deposition. Fig. 1 shows the dependence of $(PDADMAC/PSS)_5$ mass on the type of countercations.

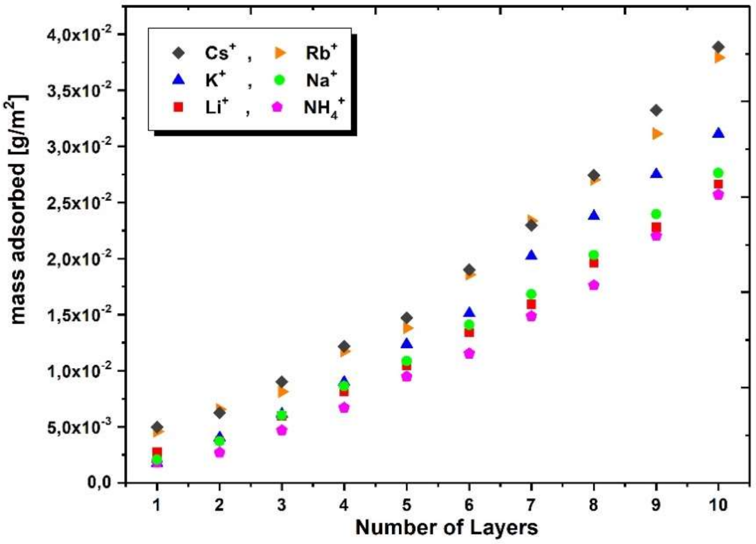

Figure 3: Dependence of mass of PDADMAC/PSS film formed in the presence of various countercations on the number of polyelectrolyte layers.

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P7_7

HYBRID FOAMED CONCRETE AS A NOVEL POROUS MATERIAL FOR DOMESTIC PASSIVE HEATING.

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Environmental pollution and energy crisis are one of the biggest problems the world is facing due to industrialisation, rapid population and living standards growth. Just in the UK, heat represents almost half of the use of energy, as around 80% of domestic heat is supplied by natural gas. Under current trends towards environmental pollution, waste and the Ordinary Portland Cement's production (in >5 billion tons annually, as concrete, due to its inherent strength and durability properties, is the second most used substance on Earth after water, thus responsible for more than 7% of the CO2 global emissions), are one of the most significant in impacting (negatively) the global climate and human wellbeing.

To reduce the building thermal energy consumption (reducing the space heating and cooling energy) and increase energy saving for civil buildings while in service. Thus, the work presented here is focused on the design and fabrication of the novel hybrid freestanding concrete (Fig.1.) based on the foam scaffolding, to be applied as a light thermal insulation material [1], with unique tailored structural properties. The study included the systematic research on the single interface (bubble) by Profile Analysis Tensiometer (PAT), the stability measurements of the 3D foam dopped with Portland Cement, followed by an appropriately design gel casting protocol [2], in order to achieve a low-costs, high-porosity, fire- resistance material.

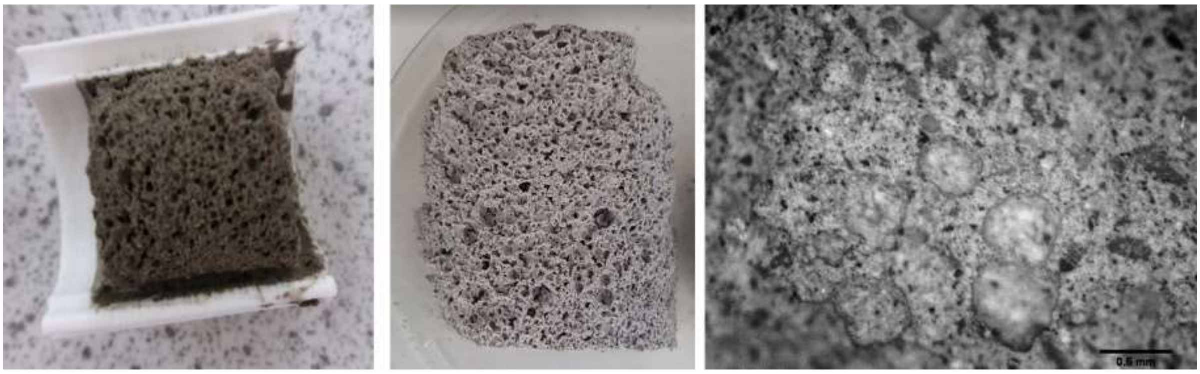

Figure 1: Freestanding foamed concrete samples.

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P7_8_ONLINE

STRUCTURAL AND FUNCTIONAL MODIFICATION OF WPI USING VACUUM COLD PLASMA

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In this study, we evaluated the impact of cold plasma on the functional properties of WPI. Whey Protein Isolate powder was treated with cold plasma, applying three different gases, atmospheric (1), argon-atmosphere combination (2), and sulphur hexafluoride (SF6) (3). The process was accomplished under controlled conditions (Frequency and time). The physicochemical and interfacial properties of the treated powder were evaluated using different analysis techniques. Results showed a significant difference in the surface tension, zeta potential, particle size, and the fluorescence intensity (Table 1) of the plasma-treated samples and the non-treated WPI sample. Meanwhile, the adsorbed layer thickness and the surface dilational elasticity of WPI (Fig 1) increased with the cold plasma treatment. A decrease in sulphur content and an increase in detected carbonyl group in the plasma-treated samples represents oxidation reactions utilizing cold plasma that may change the surface properties of the protein. However, the FTIR spectrum did not show a significant difference in the functional group of samples.

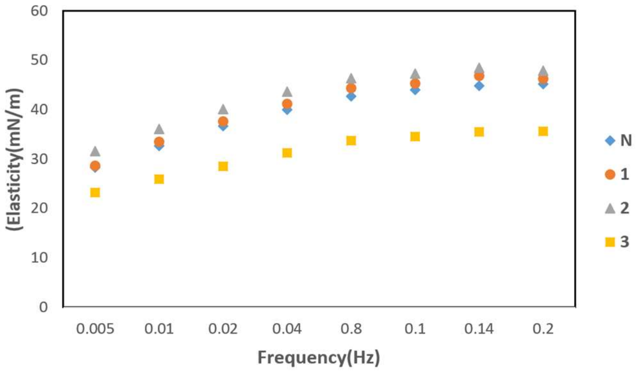

***Figure 1**: Frequency sweep for WPI powder (0.1% ~ 10^{-3} g/ml) measured by Pendant Drop Tensiometer*

Sample	Intensity	ʎ$_{max}$ (nm)
Non-treated (n)	264.56±0.31^{a}	334
Atmosphere gas (1)	218.95±0.1^{b}	334
Atmosphere gas+ Argon gas (2)	310.65±0.30^{c}	334
SF6 gas (3)	214.54±0.38^{b}	334

***Table 1:** Fluorescence emission maxima (ʎ$_{max}$) and their intensity (I) of whey protein isolate at 0.05 wt. % concentrations. Values for intensity are given as means ± standard deviation*

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P7_9

FOAMABILITY OF PURE C_NTAB SOLUTIONS AND THEIR MIXTURE WITH N-OCTANOL

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It is well known that mixtures of various flotation reagents show often a synergetic effect, i.e. their overall effectiveness is greater than expected from their individual characteristics. This synergetic effect can affect significantly recovery and selectivity of a flotation separation process, and can also be related to foamability and foam stability.

The paper presents a systematic investigation on the influence of length of hydrophobic chain of four cationic surfactants: n-alkyltrimethylammonium bromides (C_nTAB, n=8, 12, 16, 18) mixed with n-octanol (C8, used as a non-ionic additive) on foamability of their pure and mixed solutions.

The foam height of one-component solutions and binary mixtures were characterized as a function of the surfactant concentration and the number of carbons (n) in the alkyl chain of C_nTAB. The experimental results of foamability measurements in one-component and mixed solutions revealed the synergistic effect, causing a significant enhancement in the foam height. As was shown in the Fig. 1, in the presence of n-octanol, the height of foam increased remarkably for all C_nTAB solutions studied. In addition a simple method of assessment of concentration ranges of synergistic effect was proposed, based on one-component solutions surface tension and foam heights values. The analysis allow for determination of so-called critical synergistic concentration (CSC) determined from the equation:

$$d\sigma_{eq} = \sigma_{water} - \sigma_{(c)} \qquad (1)$$

where σ_{water} and $\sigma_{(c)}$ are the equilibrium surface tensions of water and surfactant solution of a given concentration respective-ly. The CSC values are, shown in Fig. 1 as a vertical lines.

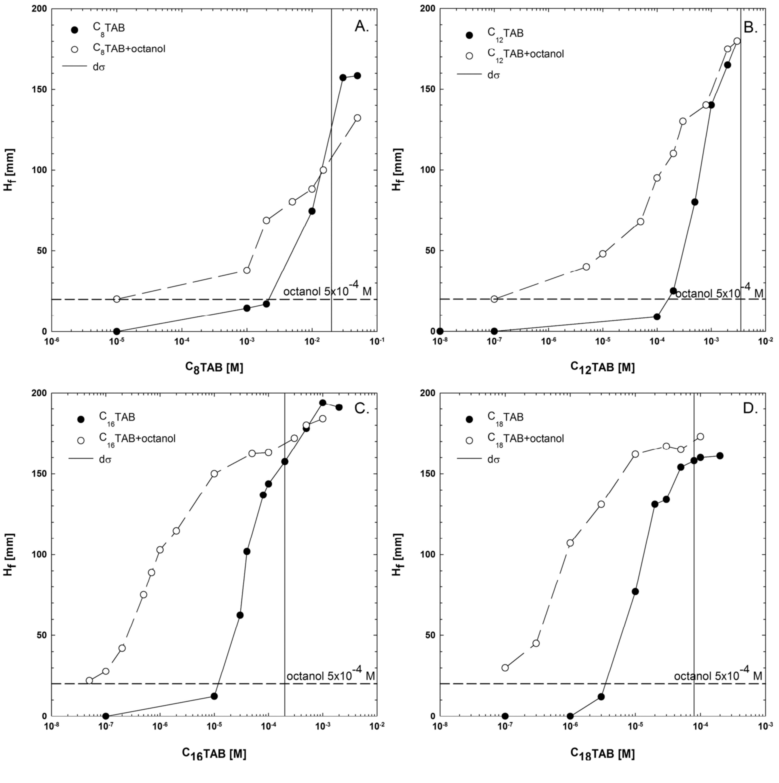

Figure 1: Height of foam after the foaming time is equal to 20 s for (A) C_8TAB, (B) $C_{12}TAB$, (C) $C_{16}TAB$, and (D) $C_{18}TAB$ solutions of various concentrations and their mixtures with 5×10^{-4} M n-octanol. The height of foam for pure $5 \times 10{-}4$ M n-octanol solution is marked in the figure as a horizontal dashed line (CSCs are marked by vertical solid lines)

SYNERGISTIC EFFECTS IN SOLUTIONS OF AMINOACID SURFACTANTS MIXED WITH N-OCTANOL

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Two-phase systems, which are stabilized by adsorption layers of surface-active substances, are the subject of intensive scientific interest and have various important industrial applications. Examples of such systems vary from foams, emulsions, surfactant solutions to sophisticated microemulsions, foamed emulsions, biological cells or even liposomes. A parameter that describes the functional properties of such systems, is surface activity which can be evaluated through surface tension measurements. Such studies can provide some basic information on dynamics of adsorption layer formation, its structure and interactions between adsorbed molecules. Surface tension variations can be also used as a convenient parameter in determination of concentration range of synergistic effects occurring in surfactants blends. In this paper such synergistic effects have been monitored for mixed solutions of aminoacid surfactants (AASs), and non-ionic n-octanol[a]. A surface tension measurements based on analysis of shape of a submerged bubble has been implemented to study the state of adsorption layer at liquid/gas interface in AASs/n-octanol mixtures of different concentrations. It was demonstrated that the mixtures, in particular AASs concentration range, is characterized by surface activity higher (black points in Fig. 1A), than that expected from simple summation of contributions from each of the mixture's individual components (blue points in Fig. 1A). This effect was strongly dependent on the structure of the AASs hydrophilic "head". The observed result was further validated by molecular dynamics simulation, which revealed that observed trends can be explained by the surface aggregation process. This has been further confirmed through dynamic light scattering (DLS) experiments.

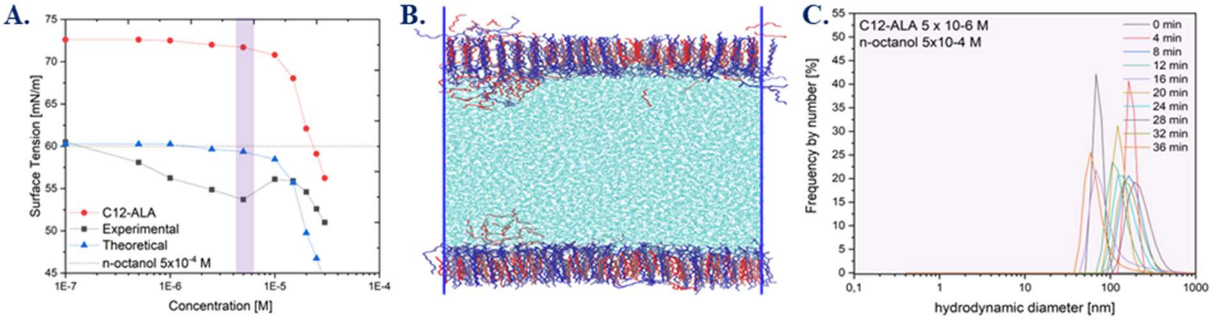

Fig. 1. (A) Example of surface tension values for C12-ALA / n-octanol systems: red points indicate surface activity for pure aqueous solutions of C12-ALA, blue points show theoretical surface tension values obtained by simple summation of surface tension variations of each of the mixture's components, black points demonstrate the experimentally observed values. (B). Snapshot of simulation box, illustrating formation of surfactants aggregation at liquid/gas interface (C12-ALA / n-octanol system). (C). Dynamic light scattering analysis for C12-ALA / n-octanol system, indicated formation of aggregates (for C12-ALA concentration marked in Fig. A).

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