8th European Conference on Foams, Emulsions and Applications
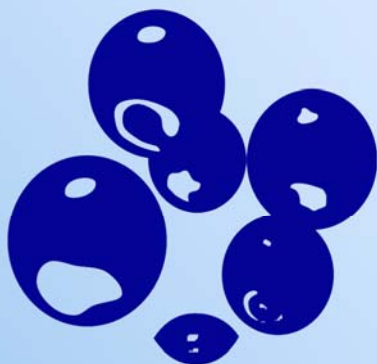

EUFOAM 2010

14-16 July 2010
Borovets, BULGARIA

BOOK OF ABSTRACTS

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<u>Contents</u>

Welcome Address

Dear Colleagues,

It is our great pleasure to welcome you at the Eufoam'2010 conference in the beautiful resort Borovets in Rila Mountain, Bulgaria (1400 m above the see level). This is the 8th conference of the Eufoam series, initiated 16 years ago by Prof. Denis Weaire, who organized the first conference on Foam Science in Renvyle, Ireland (27-29 March, 1994). The following conferences were organized in Arcachon, France (28 May – 2 June, 1996), Delft, Netherlands (4-8 June 2000), Manchester, UK (7-10 July, 2002), Marne-la-Vallée, France (5-8 July 2004), Potsdam-Golm, Germany (2-6 July 2006) and Noordwijk, Netherlands (8-10 July 2008). In all these years, the major aim of the conferences was to gather the active researchers in the area of foams and foam-related systems (cellular structures, fluid interfaces, thin films, and surfactants) and to make a link between the fundamental and applied studies in this area.

This time Eufoam'2010 is organized by the Department of Chemical Engineering, Sofia University, Bulgaria. It is our honor to host this prestigious conference for first time in Eastern and Central Europe. It was a time for such a shift in location, not only because the difficult times after the fall of Berlin wall are already in the remote past, but also because the gap between the different scientific schools on the West and in the East, which was so obvious even 10 years ago, has now almost disappeared – we are one bigger community now, despite all our diversities.

A specific feature of the Eufoam'2010 conference is its combination with two parallel events on related topics: Thematic Symposium *Colloidal Dispersions in Nanoscience* of COST Action D43 "Colloid and Interface Science for Nanotechnology"; and Training School and Final Meeting of COST Action P21 "*Physics of Droplets*" (COST is European framework for Cooperation in Science and Technology). The morning session with common plenary and invited lecturers will be followed by parallel sessions of these three events. We did everything possible to avoid the overlap of topics in the parallel sessions, thus giving to everyone the opportunity to choose the most interesting presentation for him/her. The poster sessions are also common for all participants. We believe that these combined meetings will boost the exchange and cross-fertilization of ideas between the researchers.

The conference venue is the congress center at Hotel "Samokov" in Borovets. The hotel rooms, meeting halls, restaurants, bars, relaxing facilities are all located there, which (we hope) will make you to feel very comfortable. Almost 200 participants from 25 countries (including USA, Japan, Australia, Israel, Kazachstan, and Palestine) have already registered. This large number of participants along with the respected speakers from the entire spectrum of the foam research area, give a promise for a very interesting meeting. Enjoy it!

The organizing committee

International Scientific Committee:

Michelle Adler – University Paris-Est, France

Johannes Cilliers – Imperial College, UK

Simon Cox – Aberystwyth University, UK

Thodoris Karapantsios – Aristotle University, Thessaloniki, Greece

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Eddie Pelan – Unilever, The Netherlands

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Krastanka Marinova – Sofia University, Bulgaria

Slavka Tcholakova – Sofia University, Bulgaria

Program

<u>**Tuesday, July 13th**</u>

14:00 – 20:00   *Registration*   *Registration desk in hotel Samokov*

19:00 – 21:00   *Get-together party*   *Restaurant of hotel Samokov*

<u>**Wednesday, July 14th**</u>

7:30 – 19:00   *Registration*   *Registration desk in hotel Samokov*

Opening session; Chair: D. Langevin   **Hall A (Bulgaria)**

8:30 – 8:50   <u>**P. Kralchevsky**</u> **– Opening**

8:50 – 9:30   <u>**F. Graner**</u>
Plenary lecture: Foams as model systems: of complex fluids, of grain growth, of biological tissues

9:30 – 10:00   <u>**N. Kristen**</u>**, N. Schelero,** <u>**R. von Klitzing**</u>
Invited lecture IL1: Control of foam film and wetting film stability by addition of (poly)electrolytes: electrostatics vs. ionspecifity (COST D43)

10:00 – 10:30   <u>**S. Hutzler**</u>**, M.E. Möbius, D. Weaire**
Invited lecture IL2: Foam mechanics (COST P21)

Coffee Break

Session: Foam Rheology; Chair: D. Weaire   **Hall A (Bulgaria)**

11:00 – 11:30   <u>**S. Neethling**</u>**, M. Tong**
Invited lecture IL3: Modelling foam stability: From structural simulations to continuum models

11:30 – 11:50   <u>**S.J. Cox**</u>**, A. Wyn, I.T. Davies, F. Boulogne**
O1: Topological changes in foam rheology

11:50 – 12:10   <u>**A.-L. Biance**</u>**, S. Cohen-Addad, R. Höhler**
O2: Dynamics of T1s in a 3D bubble cluster

12:10 – 12:30   **M.B. Sexton , T. Harris,** <u>**M.E. Möbius**</u>**, D. Weaire, S. Hutzler**
O3: Bubble fluctuations in simulations of sheared 2D foam

Lunch   *Restaurant of hotel Samokov*

Session: Foam Structure and Modelling; Chair: S. Cox   **Hall A (Bulgaria)**

14:30 – 15:00   <u>**M. Dennin**</u>
Invited lecture IL4: Bubble Rafts: flowing and breaking foam in two dimensions

15:00 – 15:30   <u>**M. T. Kreutzer**</u>
Invited lecture IL5: Partial Wetting in microchannel flows

15:30 – 15:50   **P. Rognon, F. Molino,** <u>**C. Gay**</u>
O4: Understanding negative and positive static dilatancy in liquid foams

Coffee Break

Parallel Session: Foam Structure and Modelling; Chair: S. Hutzler   **Hall A (Bulgaria)**

16:20 – 16:40   <u>**C. Oguey**</u>
O5: Long range topological correlations in cellular assemblies

16:40 – 17:00   <u>**M. Fátima Vaz**</u>**, S.J. Cox, P.I.C. Teixeira**
O6: Defects in bubble clusters: simulation and analytical approach

17:00 – 17:20   <u>**M. Durand**</u>
O7: Statistical mechanics of two-dimensional cellular patterns

Parallel Session: Ind. Proc. & Sustainable Development; Chair: L. Arnaudov   **Hall B (Rodina)**

16:20 – 16:40   <u>**A. Sher**</u>**, J-C. Gumy, S. Livings, C. Jimenez-Junca, K. Niranjan**
O8: Bubble mechanics of milk foams generated by steam injection and mechanical whipping

16:40 – 17:00   <u>**J. Merz**</u>**, H. Zorn, B. Burghoff, G. Schembecker**
O9: Purification of a fungal cutinase by adsorptive bubble separation: A statistical approach

17:00 – 17:20   **W. Doelling,** <u>**R. Poss**</u>**, A.-S. Dreher**
O10: System level definition for deep-bed filtration using open pore nickel and iron-based alloy metal foams

17:30 – 19:30   *Poster session & light dinner*   *Foyer of Hall A (Bulgaria)*

Thursday, July 15<u>th</u>

Session: Particles in Foams, Solid Foams; Chair: L. Ligierri   Hall A (Bulgaria)

9:00 – 9:40   **O. Velev**
Plenary lecture: Foam superstabilization and functionalization by particles with engineered structure and properties

9:40 – 10:10   **T. Horozov**
Invited lecture IL6: Solid particles in thin liquid films

10:10 – 10:40   **S. Stoyanov, E. Pelan, V.N. Paunov**
Invited lecture IL7: Foams stabilised by shape anisotropic particles

Coffee Break

Session: Particles in Foams, Solid Foams; Chair: J. Banhart   Hall A (Bulgaria)

11:10 – 11:40   **O. Pitois, E. Lorenceau, N. Louvet, F. Rouyer**
Invited lecture IL8: Liquid foams as soft particulate filters

11:40 – 12:00   **A. Stocco, F. Garcia-Moreno, J. Banhart, D. Langevin**
O11: Nanoparticle-stabilised aqueous foams

12:00 – 12:20   **J. Rodrigues, J. Bobroff, <u>E. Rio</u>, D. Langevin, H. Herzog, W. Drenckhan**
O12: Indestructible magnetic foams under magnetic fields

12:20 – 12:40   **S. Karakashev, O. Ozdemir, M.A. Hampton, E.D. Manev, A.V. Nguyen**
O13: Effect of particle shape on foam stability

12:40 – 13:00   **D.P. Papadopoulos, H. Omar, N. Michailidis, F. Stergioudi, <u>D. N. Tsipas</u>**
O14: Structure comparison of dolomite and titanium hydride Al metal foams

Lunch   *Restaurant of hotel Samokov*

Session: Role of interfacial properties; Chair: M. Durand   Hall A (Bulgaria)

14:30 – 15:00   **B. Selva, <u>I. Cantat</u>, M.-C. Jullien**
Invited lecture IL9: Migration of a bubble towards higher surface tension under the effect of thermocapillary stresses

15:00 – 15:30   **B. Dollet**
Invited lecture IL10: Dynamics of bubble and films: Role of interfacial rheology

15:30 – 15:50   **E. Santini, F. Ravera, M. Ferrari, L. Liggieri**
O15: Investigation on the interfacial properties of carbonaceous particles plus CTAB dispersions and on the stability of the corresponding foams and emulsions

Coffee Break

Parallel Session: Foam Rheology; Chair: M. Dennin   Hall A (Bulgaria)

16:20 – 16:40   **C. Raufaste, S.J. Cox, P. Marmottant, F. Graner**
O16: Orientational effects in the flow of liquid foams

16:40 – 17:00   **I. Irausquin, J.L. Perez-Castellanos**
O17: Finite element model for the analysis of a closed-cell metal foam under compression

17:00 – 17:20   **E. Ashoori, D. Marchesin, W.R. Rossen**
O18: The roles of dynamic foam behavior in enhanced petroleum recovery

Parallel Session: Physical Chemistry of Foams, Thin Liquid Films;   Hall B (Rodina)
     Chair: T. Horozov

16:20 – 16:40   **A-L. Fameau, B. Houinsou-Houssou, F. Cousin, F. Boue , J-P. Douliez, B. Novales**
O19: Impact of the structure of fatty acids supramolecular assemblies on the interfacial and foaming properties

16:40 – 17:00   **A. Salonen, M. In, J. Emile, A. Saint-Jalmes**
O20: Solutions of surfactant oligomers: A model system for tuning foam stability by the surfactant Structure

17:00 – 17:20   **H. Petkova, Khr. Khristov, D. Exerowa, J. Beetge, J. Venter**
O21: Molecular structure of "star-like" diethylenetriamine-based polymeric surfactants and the properties of foam films

17:30 – 19:00   ***Poster session***   *Foyer of Hall A (Bulgaria)*

20:00 – 24:00   ***Gala dinner***   *Restaurant of hotel Samokov*

Friday, July 16th

Session: Modern applications; Chair: Th. Karapantsios   Hall A (Bulgaria)

9:00 – 9:40   <u>**A. Lips**</u>
                Plenary lecture: Successes and future challenges for foam science

9:40 – 10:10   <u>**M. Edirisinghe**</u>**, E. Stride**
                Invited lecture IL11: Bubbling, foaming and capsule preparation

Session: Emulsions as bi-liquid foams; Chair: Th. Karapantsios

10:10 – 10:40   <u>**A. Colin**</u>
                Invited lecture IL12: Flow of concentrated emulsions

Coffee Break

Session: Foam Stability: Drainage, Coarsening, and Coalescence; Chair: R. Miller   Hall A (Bulgaria)

11:10 – 11:40   <u>**R. Krastev**</u>
                Invited lecture IL13: Gas permeability of single foam films

11:40 – 12:00   <u>**J. Goyon**</u>**, F. Bertrand, G. Ovarlez, O. Pitois**
                O22: Study of shear induced drainage of foamy emulsions through MRI

12:00 – 12:20   <u>**A. Delbos**</u>**, O. Pitois, E. Lorenceau, M. Vignes-Adler**
                O23: Forced foam flow through a pore

12:20 – 12:40   **B. P. Binks, P. D. I. Fletcher, M. P. Gahagan,** <u>**E. L. Sharp**</u>
                O24: Non-aqueous foams in lubricating oil systems

12:40 – 13:00   <u>**F. Garcia-Moreno**</u>**, A. Stocco, I. Manke, J. Banhart, D. Langevin**
                O25: X-ray tomography of aqueous foams

Lunch   *Restaurant of hotel Samokov*

Parallel Session: Experimental Techniques; Chair: M. Adler   Hall A (Bulgaria)

14:30 – 14:50   <u>**K. Niranjan**</u>**, C. Jimenez-Junca, J-C. Gumy, A. Sher**
                O26: Non-isothermal destabilization of steam injected milk foams: characterization and interface
                visualization

14:50 – 15:10   **R.A. Kil, Q.P. Nguyen,** <u>**W.R. Rossen**</u>
                O27: Determining trapped gas in foam in porous media from CT images

15:10 – 15:30   <u>**R.M. Guillermic**</u>**, M. Erpelding, I. Ben Salem, B. Dollet, J. Crassous, A. Saint-Jalmes**
                O28: New experimental results on foam acoustics

15:30 – 15:50   **A. Bretagne,** <u>**V. Leroy**</u>**, C. Derec, F. Elias**
                O29: Probing foams with ultrasound

Parallel Session: Physical Chemistry of Foams, Thin Liquid Films;   Hall B (Rodina)
              Chair: S. Stoyanov

14:30 – 14:50   <u>**D. Varade**</u>**, D. Carriere, W. Drenckhan, E. Rio, A. Stocco, D. Langevin**
                O30: Superstable foams made from catanionic surfactant mixtures

14:50 – 15:10   <u>**L.N. Arnaudov**</u>**, S.D. Stoyanov, S.A. Semerdzhiev, M.A. Cohen Stuart**
                O31: Highly efficient interface-assisted colloid fabrication

15:10 – 15:30   <u>**C. Stubenrauch**</u>
                O32: Mixtures of n-dodecyl-β-D-maltoside and hexaoxyethylene dodecyl ether - surface properties,
                foam films, and foams

15:30 – 15:50   <u>**T. Gambaryan-Roisman**</u>
                O33: Dynamics of free liquid films during formation of polymer foams

Coffee Break

Closing session; Chair: M. Adler   Hall A (Bulgaria)

16:20 – 16:50   <u>**L.K. Shrestha**</u>**, K. Ariga, K. Aramaki**
                Invited lecture IL14: Highly stable nonaqueous foams in glycerol-based nonionic surfactant/oil systems

16:50 – 17:10   <u>**N. Denkov**</u>
                Closing and presenting next Eufoam 2012 conference

List of Poster presentations

A - Foam Structure and Modelling

PA1:   S.J. Cox, E. Flikkema, "The minimal perimeter for N confined deformable bubbles of equal area".

PA2:   B. Embley, P. Grassia "Viscous froth simulations of sheared bubble staircases with surfactant mass transfer and Marangoni effects".

PA3:   S. Ubal, C.H. Harrison, P. Grassia, W. Korchinsky, "Simulation of mass transfer in circulating drops with applications to liquid-liquid extraction".

PA4:   H.K. Chan, A.J. Meagher, A.M. Mughal, D. Weaire, S. Hutzler, "Spontaneous ordering of micro-bubbles in a capillary tube".

PA5:   I. Irausquin, F. Teixeira-Dias, V. Miranda, J.L. Perez-Castellanos, "Modelling of sandwich plates with aluminum foam core subjected to drop-weight impact".

PA6:   N. Kalchunkova, R. Guerra, U. Teicher, A. Nestler, "Numerical models of metal foams for the simulation of machining".

PA7:   G. Katgert, M. van Hecke, "Jammed static foam packings: Contacts, tesselations and forces".

PA8:   G. Katgert, W.C.K. Poon, "Point response in foams: correlated rearrangements".

PA9:   H. Vila-Real, M.H. Ribeiro, M. Emília Rosa, "Processing conditions and structure of sol-gel matrice".

PA10:   M. Saadatfar, A. Jones, S. Hutzler, M. Mukhrejee, G. Schroeder-Turk, F. Garcia-Moreno, J. Banhart, U. Ramamurty, D. Weaire, "Structural and finite element analysis of tomographic data for closed cell aluminium foam subject to uni-axial compression".

PA11:   S. Hutzler, J.D. Barry, S.T. Tobin, B. Bulfin, D. Weaire, "Ordered dry foams in tubes with circular, triangular and square cross-section".

B - Foam Rheology; Microfluidics of Bubbles and Drops

PB1:   N. Bennani, P. Jop, V. Mansard, A. Colin, L. Bocquet, "Droplets rearrangement rates of flowing monodispersed emulsions".

PB2:   T.S. Chan, J.H. Snoeijer, "Two-phase hydrodynamic model for air entrainment at the advancing contact line".

PB3:   S. Costa, R. Höhler, K. Krishan, S. Cohen-Addad, "Origin of fast linear relaxations in foams".

PB4:   S.A. Jones, S.J. Cox, "The flow of foam through a contraction".

PB5:   D. Dimitrova, S. Tcholakova, K.G. Marinova, N. Denkov, K.P. Ananthapadmanabhan, "Surface rheological properties of surfactant mixtures".

PB6:   K. Golemanov, S. Tcholakova, N.D. Denkov, K.P. Ananthpadmanabhan, A. Lips, "Role of surfactants in foam rheology".

C - Particles in Foams; Solid Foams

PC1:   L. Alexandrova, M. Nedyalkov, "Thin wetting film from aqueous solution of polyoxyalkylated diethylenetriamine polymeric surfactant".

PC2:   S. Faure, Q. Crouzet, D. Tiffes, G. Boutevin, C. Loubat, "New solid particles for liquid foam stabilization".

PC3:   G. Morris, S.J. Neethling, J.J. Cilliers, "Thin films stabilised by randomly packed spherical particles".

PC4:   D. Michalentzaki, E.N. Peleka, Th.D. Karapantsios, M. Kostoglou, K.A. Matis, "Experimental approach of particle – bubble interactions in a flotation system".

PC5:   F. Schüler, M. D. Gilchrist, C. Stubenrauch, "Functionally graded polystyrene foams as advanced cushioning materials".

PC6:   R. Wüstneck, J. Krägel, R. Miller, "Highly stable pickering-emulsions and the role of interfacial network formation".

D - Physical Chemistry of Foams; Thin Liquid Films

PD1:   Zh.K. Angarska, A.A. Elenskyi, G.P. Yampolskaya, K.D. Tachev, "Foam films from mixed solutions of proteins and *n*-dodecyl-β-D- maltoside".

PD2:   N. Buchavzov, D. Varade, E. Carey, J. Boos, C. Stubenrauch, "Foam films stabilized by *n*-dodecyl-β-D-maltoside, hexaethyleneglycol monododecyl ether, and their 1:1 mixture".

PD3:   R. Cohen, N. Christova, B. Tuleva, I. Terziev, I. Stoineva, "Foam film studies of a rhamnolipid biosurfactant produced from a new *Pseudomonas aeruginosa* BN10".

PD4:   R. Cohen, R. Todorov, G. Vladimirov, D. Exerowa, "Effect of rhamnolipids on pulmonary surfactant foam films".

PD5:   C. Derec, W. Drenckhan, S. Hutzler, V. Leroy, A. Möller, M. Saadatfar, C. Stubenrauch, F. Elias, "Vibration of a soap film".

PD6:   G. Gotchev, H. Petkova, Khr. Khristov, T. Kolarov, D. Exerowa, "Steric stabilization of black foam and oil-in-water emulsion films from polymeric surfactants".

PD7:   G. Gotchev, V. Pradines, V.B. Fainerman, J. Krägel, R. Miller, "Interfacial properties of mixed *β*-lactoglobulin/C_nTAB layers at the hexane/water interface".

PD8:   R.M. Guillermic, J. Emile, A. Saint-Jalmes, "Thermo-responsive interfaces, films and foams".

PD9:   D. Ivanova, Zh. Angarska, S. Karakashev, E. Manev, "Drainage of foam films stabilized by an ionic- or a non-ionic surfactant and their mixture".

PD10:   N.A. Ivanova, R.G. Rubio, V.M. Starov, V.B. Fainerman, "Equilibrium and dynamic surface properties of aqueous solutions of trisiloxane surfactants".

PD11:   A. Jamil, S. Caubet, T. Kousksou, K. El Omari, Y. Zeraouli, B. Grassl, Y. Le Guer, "Thermal properties of oil-in-water highly concentrated emulsions".

PD12:   S.I. Karakashev, R. Tsekov, R. Slavchov, E.D. Manev, "Effect of ionic strength on drainage of planar foam films".

PD13:   V. Papoti, T.D. Karapantsios, G. Doxastakis, "Comparison of foaming activity of lupin protein solutions obtained with isoelectric precipitation versus ultrafiltration".

PD14:   B. Soklev, D. Arabadzhieva, E. Mileva, "Comparative investigation aqueous solutions of C12E3, C12E4 and C12E5".

PD15:   I. Grozev, R. Todorov, E. Mileva, "Foam film drainage of aqueous solutions of glycine compounds".

PD16:   B. Rullier, M. Axelos, D. Langevin, B. Novales, "Understanding the role of protein aggregates at air/water interfaces: a multiscale approach".

PD17:   J. Delacotte, E. Rio, F. Restagno, D. Langevin, "Withdrawn films: The importance of surface rheology".

PD18:   A. Salonen, A. Knyazev, N. Von Bandel, J. Degrouard, D. Langevin, W. Drenckhan, "A novel pyrene-based surfactant: bulk, interfacial and foaming behaviour".

PD19:   V. Ulaganathan, J. Krägel, V. Pradines, R. Wüstneck, B. Bergenståhl, R. Miller, "Shear rheology of mixed ß-lactoglobulin/surfactant adsorption layers at the water/oil interface".

PD20:   G. Varas, V. Vidal, J.-C. Géminard, "Dynamics of a thin liquid film: A proxy for bubble bursting".

PD21:   P.R. Garrett, L. Ran, "The Antifoam Behaviour of Saturated Fatty-Acid Triglyceride Mixtures in Aqueous Surfactant Solutions"

E - Foam Stability: Drainage, Coarsening and Coalescence

PE1:   M. Baszczynski, P. Novák, T. Branyik, M.C. Ruzicka, J. Drahoš, "Decay of beer foam".

PE2:   I. Ben Salem, I. Cantat, B. Dollet, "Rupture criterion of a 2D foam subject to a sudden overpressure".

PE3:   A.-L. Biance, A. Delbos, O. Pitois, "The micro-macro link for liquid foam stability".

PE4:   T.B.J. Blijdenstein, P.W.N. de Groot, S.D. Stoyanov, "On foam disproportionation and surface rheology of molecular food foaming agents".

PE5:   E. Carey, C. Stubenrauch, "Tuning foam properties of a non-ionic/cationic surfactant mixture".

PE6:   N. Louvet, E. Lorenceau, F. Rouyer, O. Pitois, "Foam permeability: a reappraisal of Lemlich's assumptions".

PE7:   A. Meagher, D. Weaire, S. Hutzler, "Evolution of a monodisperse crystalline microfoam containing a component of insoluble gas".

PE8:   T. Mönch, S. Odenbach, "Gas injection in high temperature metal melts".

PE9:   P. Novak, M. Baszczynski, T. Branyik, M. Ruzicka, J. Drahos, "Foam stability: effect of physico-chemical properties of beer".

PE10:   L. Saulnier, E. Rio, W. Drenckhan, D. Langevin, "Liquid foams aging".

PE11:   S.T. Tobin, A. Meagher, B. Bulfin, M.E. Möbius, D. Weaire, S. Hutzler, "An interactive study of the lifetime distribution of soap films".

PE12:   M. Tong, K. Cole, S. Neethling, "An integrated numerical model for predicting the evolution of the bubble size distribution in 2D foam".

PE13:   T. Trittel, Th. John, A. Eremin, R. Stannarius, "Thermotropic liquid crystal foams".

PE14:   R. Verdejo, F.J. Tapiador, M.M. Bernal, N. Bitinis, M.A. Lopez-Manchado, "Fluid dynamics of evolving foams".

PE15:   R. Petkova, S. Tcholakova, D. Sidzhakova, N.D. Denkov "Role of polymer-surfactant interaction for foam formation and stability"

PE16:   N. Alexandrov, K.G. Marinova, C. Bilke-Krause, K.D. Danov, "Effect of the EO-groups and counterions on the surface dilatational rheology, foamability and foam stability".

PE17:   R. Stanimirova, K.G. Marinova, N. Alexandrov, T. Schörck, T. Winkler, C. Bilke-Krause, "Impact of the SLES structure (number of EO-groups) and the additives on the surface rheology and foam drainage".

G - Experimental Techniques

PG1:   E. Kolodziejczyk, S. Garcia, C. Appolonia-Nouzille, C. Curschellas, J.-M. Jung, M. Leser, C. Gehin-Delval, "Foam bubble size characterization: comparison between different techniques".

PG2:   R. Mokso, U. Kaydok, F. Marone, M. Stampanoni, "Ultra-fast X-ray tomography as a tool to study foams behaviour in 3 dimensions".

PG3:   P. Bárczy, J. Szőke, B.M. Somosvári, P. Szirovicza, T. Bárczy, "FOCUS: Foam evolution and stability in microgravity".

PG4:   N. Michailidis, F Stergioudi, H. Omar, D. Papadopoulos, D.N. Tsipas, "Experimental and FEM Analysis of the Material Response of Porous Metals Imposed to Mechanical Loading".

H - Industrial Processes and Sustainable Development

PH1:   I. Högberg, F. Andersson, A. Almesåker, M. Norgren, E. Hedenström, H. Edlund, "Novel surface active chelating agents with potential applications in sustainable industrial processes".

PH2:   M. Ferrari, F. Ravera, E. De Angelis, F. Suggi Liverani, L. Navarini, "Interfacial Properties of Green Coffee Oils".

PH3:   A. Turbin, G. Della Valle, J.L. Doublier, D. Marion, B. Novales, "Foaming and rheological properties of the soluble phase of wheat flour dough".

Plenary lecture PL1

Foams as model systems:
of complex fluids, of grain growth, of biological tissues

F. Graner

CNRS & Institut Curie, Paris, France
francois.graner@curie.fr

Foams are a model to understand complex materials which behave both like solids and liquids. First, if it undergoes a small deformation, a foam reverts to its initial shape (elastic behaviour). Second, after a large deformation it can be sculpted (plastic behaviour). Third, at large deformation rate, it flows like a liquid (viscous behaviour). This triple behaviour can be experimentally investigated in a channel where the foam flows around obstacles of various shapes. Simulations and theory linked the detailed description at the level of the bubble with the global level where the foam behaves like a continuous material. The constitutive equation led to successfully tested predictions of the foam flow under shear (« Couette » flow) [1] and around a circular obstacle (« Stokes » flow) [2].

The coarsening of dry foams is a model for that of concentrated emulsions, or of grains in a polycrystal. In 2D, the individual growth rate of a bubble has been known since von Neumann. It determines the collective behaviour of bubbles, that is, the evolution of bubble size and shape distributions. After a transient, the foam reaches a self-similar growth regime where the average bubble size grows in time, while all dimensionless quantities (such as the distribution of number of faces) remain constant. In 3D, the individual growth rate of a bubble has been known since Mullins, but its effect on the global distributions was much more difficult to study. Large and long 3D simulations [3] and experiments [4] have evidenced the 3D self-similar growth regime.

Biological cells have almost no common points with bubbles. However, they too tile the space without gaps nor overlap, so that they too undergo « T1 » rearrangements. Thus some tools and approaches developed to study a foam apply to cell packing [5] and dynamics [6]. We explore the limits of this analogy. We now try to apply it even to the development of living tissues in the fruit fly Drosophila.

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Plenary lecture **PL2**

Foam superstabilization and functionalization by particles with engineered structure and properties

Orlin D. Velev

Department of Chemical and Biomolecular Engineering
North Carolina State University, Raleigh, NC 27695, USA
Email: odvelev@unity.ncsu.edu

We will discuss how particles with anisotropic shape and controlled properties can be synthesized and used in the formation of Pickering foams and emulsions with new functionality. We have designed processes for the large-scale formation of rod-like polymer particles. These rod-like particles act as "superstabilizers" of foams and emulsions by forming rigid intertwined adsorption shells around the bubbles or droplets. The superstabilization effect is made possible by rod entanglement, formation of hairy shells, and sustaining of thick water films. Similar long-term stabilization was achieved with irregular particles from hydrophobically modified cellulose (HMC), formed by a water-only pH-jump precipitation process. Such particles can also be used to enrich the Pickering foams and emulsions with additional features such as colour, specific rheological response, stability against drying, controlled destabilization and controlled release of components. We will discuss how the addition of pH-sensitive dyes during the process of formation of HMC particles leads to co-precipitation and strong adsorption of the dyes on the cellulose particle surfaces. These strongly coloured HMC particles act not only as strong stabilizers of the foams, but also allow their intense and selective coloration without any colouring of the solution medium. The results illustrate how particle stabilizers can be used to make dispersion systems of unusual properties.

Plenary lecture **PL3**

Successes and future challenges for foam science

A Lips

Unilever Discover Port Sunlight Laboratory
Bebington, Wirral UK, CH 64 6SQ

Foams continue to fascinate scientists from many disciplines with rich challenges for deep understanding, and connecting with a wide spectrum of industrial problems and opportunities. From an industrial perspective, the challenges are many fold, across a continuum of making and controlling aerated structures, for stability and dynamics, with holistic tuning for specific applications. Air can serve the role of '*soft filler',* as e.g. in ice-cream, or of ensuring desired lubricity, e.g. in the *'just right'* lather generated during personal washing.

Interfacial design, for creation, lifetime and interaction of bubbles, is an underlying generic need, as is the manipulation of foam mechanics and rheology in terms of bubble size and dynamic interfacial behaviour.

In recent years, there has been significant progress in theory and experimental validation of foam rheology, including slip, with definitive insight on the role of interfacial elastic behaviour. How foams can undergo *'jamming',* under the influence of attractive thin film forces, has also been clarified. Many of the new scientific ideas and techniques have proven valuable for technologies, as will be discussed.

Growing emphasis has also been on *bubble longevity* in fluid foams. We will discuss an approach based on insoluble monolayers, keeping micron sized bubbles stable on the order of years. In these systems, shrinkage arrest appears to be conferred by polygonal nano structuring of the insoluble monolayer at the interface of initially slightly shrunk bubbles. This arrested state of the interface implies the virtual absence of subsequent relaxation processes with an effective surface tension tensor close to zero. The detailed molecular understanding of this is not fully elucidated. Indeed it remains a general challenge to develop techniques and models to characterize and understand the exceptional metastability implicit in the surface structures of long lived bubbles in fluid foams, be they particulate, polymeric or surfactant in nature.

IL1

Control of foam film and wetting film stability by addition of (poly)electrolytes: electrostatics vs. ionspecifity

Nora Kristen, Natascha Schelero, Regine v. Klitzing

Stranski-Laboratorium, Institut für Chemie, TU Berlin, Str. d. 17.Juni 124, D-10623 Berlin, Secr. TC 9, fax: +49 30 31426602, klitzing@mailbox.tu-berlin.de

The (de)stability and functionality of thin liquid films plays an important role in processes and technical applications like foaming, emulsification and flotation. Within this work the stability of single films is tuned by the addition of different electrolytes and polyelectrolytes. The films are either free-standing (*foam films*) or supported by a solid substrate (*wetting films*) and they are formed from aqueous surfactant solutions. The interactions between film surfaces are determined in a thin film pressure balance (TFPB). By this method equilibrium measurements of a disjoining pressure isotherm (disjoining pressure vs. film thickness) are determined. The disjoining pressure is a quantitative measure for the interactions between the two opposing film interfaces, including repulsive electrostatic, attractive van der Waals and steric contributions [1].

Usually the addition of low molecular salt like NaCl leads to a thinning of the aqueous film due to screening of the electrostatic interactions. But not only the ionic strength, also the type of added ion has a pronounced effect on the film thickness and stability. For instance a "simple" water wetting film becomes thicker and more stable by adding NaI instead of NaF at a fixed ionic strength [2]. It is explained by a stronger adsorption of I^- ions at the film surface in comparison to F^- ions due to differences in the hydration shell. Similar trends are observed for foam films and wetting films formed from surfactant solutions. Surprisingly, also an SDS film is thicker and more stable after addition of NaI instead of NaF, which means that negatively precharged surfaces can be even more negatively charged by the addition of chaotropc (water breaking) anions.

The addition of polyelectrolytes leads to another effect beside electrostatic screening and ionspecificity: Complexation between the surfactant and the polyelectrolyte at the film surfaces becomes important. For instance, with a cationic surfactant like C_nTAB a film with positively charged surfaces is formed. After addition of polyanions, the surface charge is assumed to be reversed. In both cases, a (thick) Common Black Film (mainly stabilized by electrostatic forces) is formed due to the electrostatic repulsion of the two interfaces [3]. But what happens at the isoelectric point where the surface charge is zero? Is a (thin) Newton Black Film (mainly stabilized by steric forces) formed or does the film break? Results on the stability of films with different polyelectrolyte concentrations are presented. In order to distinguish between hydrophobic and hydrophilic interactions polyelectrolytes of different hydrophobicity are studied. The effect of polymers on surface charge is compared to the influence of their monomers.

An overview on the effect of low molecular electrolytes and polyelectrolytes with respect to electrostatics and ion specifity will be given.

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IL2

Foam mechanics

S. Hutzler, M.E. Möbius and D. Weaire

Foams and Complex Systems, School of Physics, Trinity College Dublin, Dublin 2, Ireland
stefan.hutzler@tcd.ie

Foams offer a number of intriguing problems (and solutions) related to the mechanics of "matter with granularity" [1] and may be a better tested than systems of hard grains for which they have been intensively debated. How do static properties such as shear modulus or yield stress vary with packing density as a rigidity loss is approached? How does foam flow? Can it be described as a Herschel-Bulkely fluid and what is the exponent of the strain-rate dependence of stress? Under what conditions does shear localize in two-dimensional foams? Is nonlocality of its dynamics key to its understanding? What can a continuum description offer and what are its limits [2]? This presentation will address the above questions and try to offer answers, definitive or speculative.

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IL3

Modelling foam stability: From structural
simulations to continuum models

Stephen Neethling and Mingming Tong

Department of Earth Science and Engineering, Imperial College London, London, UK
E-mail: s.neethling@imperial.ac.uk

Foam stability and the evolution of the bubble size distribution within the foam are key factors in many foam processes. Foam stability is also one of the areas of foam behaviour that is least well understood. This is especially true of foams in which the main factor in the stability is film failure and the resultant bubble coalescence and surface bursting. The reason why foam stability is hard to predict is that it is the result of a complex interaction between various factors, including liquid drainage, foam structure and film stability.

We will be attempting to use models for the stability of individual films to predict the macroscopic foam stability, as well as the evolution of the bubble size distribution within the foam (both spatially and temporally). Ideally structural simulations of the foam should be carried out, where the failure of individual films can be modelled and the evolution of the structure predicted. Some simulations of this type will be demonstrated, where Surface Evolver is used to model the collapse of a foam due to coalescence and bursting. The problem with these types of simulations, is that for 3D foams they are limited to a maximum of a couple of thousand bubbles, which is many orders of magnitude fewer than would be encountered in most industrial or even laboratory systems. In order to overcome this problem, a continuum approximation is required.

As coalescence and bubble growth depends not only on the average bubble size, but on the bubble size distribution as well, a population balance model will be used for predicting for the bubble size evolution. The population balance model requires a number of geometric and topological foam properties, including the number of faces per bubble and the size of the films between the bubbles. In particular, the relationship between the size of the film separating bubbles and the size of the bubbles to which it is attached will be shown. The reason why this is an important parameter is because the rate at which a film drains, and thus its average lifetime, is strongly dependent on its size. These relationships are obtained by carrying out 3D Surface Evolver simulations of random foams over a wide range of poly-dispersities.

The population balance model, together with the required geometric models are then coupled with liquid drainage and film stability models in order to predict the growth and breakdown of foams, together with the evolution of the internal bubble size distribution. These predictions are then compared to laboratory foam stability experiments.

O1

Topological changes in foam rheology

S.J. Cox[1], A. Wyn[1], I.T. Davies[1], F. Boulogne[1,2]

[1]*Institute of Mathematics and Physics, Aberystwyth University, Aberystwyth, UK*
[2]*Bâtiment 470 - Faculté des Sciences d'Orsay, 91405 Orsay Cedex, France*
Email: foams@aber.ac.uk

When a foam flows, it does so through a series of neighbour switching T1 topological changes. These are a local manifestation of a macroscopic plastic response. We present quasi-static bubble-scale simulations using the Surface Evolver that probe the details of the T1s and their effect on the resulting flow.

In particular, we show that (i) in simple shear there are preferred orientations for T1s, and our data suggests that there are two distinct mechanisms driving their occurrence; (ii) the bunching of films behind a sedimenting non-circular obstacle leads to a non-zero torque, an elastic effect that is modulated by the plasticity; (iii) in the same way, the drag on an obstacle embedded in a foam flow is controlled by the T1s at its trailing edge, and therefore the liquid content of the foam, and the lift on an obstacle is determined by its asymmetry.

O2

Dynamics of T1s in a 3D bubble cluster

A.-L. Biance[1], S. Cohen-Addad[2], R. Höhler[2]

[1]*LPMCN, Université de Lyon et CNRS, Lyon, France*
[2]*LPMDI, Université Paris-Est, Marne-La Vallée, France*
Email: anne-laure.biance@lpmcn.univ-lyon1.fr

We study experimentally the dynamics of strain induced T1 neighbour switching in clusters of 3D bubbles. To determine the physico-chemical processes that set the time scale of such rearrangements, foaming solutions of a wide range of well characterized bulk and interfacial rheological properties are used. At low strain rates, the time scale is set by a balance between surface tension and surface viscous forces and we present a simple physical model that explains these findings, on the basis of previous experimental and theoretical work with 2D foams [2]. At higher strain rates, rearrangement dynamics are driven by the applied strain. In a wider context, our study of T1s in bubble clusters provides insight into the structural relaxations that accompany the flow of 3D foams.

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O3

Bubble fluctuations in simulations of sheared 2D foam

M.B. Sexton , T. Harris, <u>M.E. Möbius</u>, D. Weaire, S. Hutzler

Foams and Complex Systems, School of Physics, Trinity College Dublin, Dublin 2, Ireland
mobiusm@tcd.ie

The bubble dynamics of sheared, disordered foams are highly heterogeneous. Due to the continuous shear-induced rearrangements, the bubbles start to move diffusively with respect to the mean flow. Intuitively, one would expect the diffusion to scale linearly with the shear rate. However, it was found in experiments that the diffusion constant scales non-linearly with the shear rate [1]. In order to better understand the origin of this non-trivial scaling, we perform simulations of a linearly sheared two dimensional wet foam using the soft disc model. We discuss to what extent the simulations agree with the experimental data.

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IL4

Bubble Rafts: flowing and breaking foam in two dimensions

M. Dennin

Department of Physics and Astronomy, University of California, Irvine, Irivne, USA
Email: mdennin@uci.edu

Bubble rafts have long been of interest as a model two-dimensional system for the study of complex fluids. Consisting of a single layer of gas-bubbles on an aqueous substrate, bubble rafts allow for excellent control over bubble size, size distribution, bubble solution composition, and for the tracking and characterizing of each bubble in the system. Additionally, bubble rafts have been used in a wide-range of flow geometries and with varied methods of confinement. These features of bubble rafts have provided insight in a range of issues related to the visco-elastic nature of foams and other complex fluids. In this talk, we will present results from two different experimental configurations: oscillatory planar shear and uniaxial extension. Both of these experiments provide insight into fundamental transitions between fluid-like and solid-like regimes. For the oscillatory shear, as the amplitude of oscillation is increased, the system makes a transition from a regime in which no T1 events (neighbour switching events) to one in which T1 events are present. We will report on the differences in the frequency dependence of the response of the system in these two regimes. For the uniaxial extension, at low speeds, the system exhibits pinch-off behaviour that is consistent with a fluid-like response. As the speed of extension is increased, the system exhibits classic fracture behaviour. We will report on this transition, with a focus on comparing behaviour in ordered and disordered bubble rafts.

IL5

Partial Wetting in microchannel flows

M. T. Kreutzer

TU Delft, The Netherlands

O4

Understanding negative and positive static dilatancy in liquid foams

P. Rognon[1], F. Molino[2], C. Gay[1]

[1]*Matière et Systèmes Complexes, Université Paris DiderotParis 7, CNRS, UMR 7057,*
Bâtiment Condorcet, Case courrier 7056, F75205 PARIS cedex 13, France
[2]*Department, Department of Endocrinology, Institute of Functional Genomics,*
CNRS, UMR 5203, INSERM U661, Universities of Montpellier 1 and 2,
141 rue de la Cardonille, F34094 MONTPELLIER cedex 05, France
Email: cyprien.gay@univ-paris-diderot.fr

Dilatancy, known in granular materials since the works of Reynolds [1,2], has been observed in liquid foams: a continuous deformation rate tends to raise their liquid contents (dynamic dilatancy). Weaire and Hutzler provided a thermodynamical analysis of static dilatancy [3] and derived its magnitude based on empirical and numerical estimates of the shear modulus dependence on liquid fraction. In particular, they predicted negative dilatancy for very dry foams. We show that dilatancy actually reflects two phenomena, for which we present geometrical interpretations both in 2D and in 3D. The first one contributes positively to dilatancy and is related to the increase of the total Plateau border lengths upon foam deformation. The second one, which is related to the shear modulus, has a negative contribution and becomes dominant in the limit of truly 2D foams (without upper or lower interfaces)which has been studied by Weaire and Hutzler.

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O5

Long range topological correlations in cellular assemblies

C. Oguey

LPTM, University of Cergy-Pontoise, France
Email: oguey@ptm.u-cergy.fr

Many cellular systems have similar characteristics despite their great variety of material realisations: solid or liquid foams, metallic grains, biological tissues, etc. Therefore, it seems adequate to retain only a minimal number of features, essentially geometry, space filling and disorder.

This talk will briefly review the results known so far on the topology of 2D foams. The local observable is the bubble's number of sides n or the topological charge $q = 6 - n$. In 2D, this charge averages to zero. The pair correlation $g(j, q_1, q_2)$ is proportional to the joint probability of occurrence of two cells of charges q_1, q_2 at topological distance j. For nearest neighbours, $j = 1$, this correlation enters the Aboav-Weaire law, satisfied by many systems with exceptions (Poisson-Voronoi partitions).

At larger distance j, the main investigations were done by Rivier *et al.* [1], Fortes-Pina [2], Szeto *et al.* [3], Oguey *et al.* [4]. The main methods we use are maximum entropy and a recurrence equation obeyed by the mean number of cells at distance j around a central one of charge q.

On one hand, the very general fact that correlations tend to zero at large distance (asymptotic independence of events) implies *sum rules* for the correlation coefficients. Those sum rules can be interpreted as the vanishing of the lowest total charge moments induced by conditioning on a central charge q, in a way analogous to electrostatic screening. Polynomial bounds on the layer populations and a generalisation of Aboav-Weaire law to arbitrary distance j follow from these sum rules.

On the other hand, taking the sum rules into account in the asymptotics of the pair correlation implies that g-1 cannot decay too rapidly. Typically, in two dimensions, it behaves as $1 / j^4$ at large j. I'll comment on the rigidity related to this rather slow decay and on eventual verifications of this prediction.

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O6

Defects in bubble clusters: simulation and analytical approach

<u>M. Fátima Vaz</u>[1], S. J. Cox[2] and P.I.C. Teixeira[3,4]

[1]*Instituto de Engenharia de Mecânica and Departamento de Engenharia de Materiais, IST, UTL, Avenida Rovisco Pais, P-1049-001 Lisboa, Portugal*
[2] *Institute of Mathematics and Physics, Aberystwyth University, Aberystwyth SY23 3BZ, UK*
[3] *Instituto Superior de Engenharia de Lisboa, Rua Conselheiro Emídio Navarro 1, P-1950-062 Lisboa, Portugal*
[4]*Centro de Física Teórica e Computacional da Universidade de Lisboa, Avenida Professor Gama Pinto 2, P-1649-003 Lisboa, Portugal*
Email: fatima.vaz@ist.utl.pt

Topological defects play an important role in foam deformation. This work describes simulations of 2D finite aqueous foam clusters containing topological defects either isolated (disclinations and dislocations) or in pairs. Surface Evolver simulations were performed on large finite clusters of bubbles. These allow us to evaluate the effect of the topology of the defects, and the distance between defects, on the energy and pressure of foam clusters of different sizes.

The presence of one defect, in particular a disclination, clearly affects the energy and the pressure of the cluster. The energy of a disclination cluster deviates from the energy of a defect-free cluster if the number of sides of the central cell is different from six, and decreases as the number of shells increases. Both the energy and the pressure of a cluster with a central cell with six sides match very well with those found for a 5/7 dislocation cluster. In fact, the average pressure in each shell is the same in the two cases. Many processes, such as plastic deformation, deal with the interactions between defects. Our simulations of pairs of defects reveal how the presence of one defect is 'felt' by the other defect as a function of their separation.

Analytic approaches have been developed, in the context of solids or of liquid crystals, for the same cases as studied here. For most of them defects in foams follow the predicted trends known for a continuous medium. For example, the energy of two disclinations with opposite strengths a distance d apart appears to be proportional to ln d. Nonetheless, a perfect match between analytical results and simulations is not to be expected, as the assumptions under which the former were derived are not always satisfied in the systems considered here. Clusters with central cells with five and seven sides are examples of this: because these disclinations have the same strength (in absolute value), one would expect that they would have the same energy, yet the two clusters have different boundaries, and it is clear that the energy of a cluster is strongly dependent on boundary shape. The defect shape and cluster shape should be included in future work.

O7

Statistical mechanics of two-dimensional cellular patterns

M. Durand

Laboratoire MSC, Université Paris-Diderot, Paris, France
Email: marc.durand@univ-paris-diderot.fr

Foams and related physical systems (like emulsions, biological tissues, or polycrystals) serve as a paradigm for a wide range of physical phenomena and mathematical problems. Such cellular patterns are partitions of the plane without gaps or overlaps, so their structures obey certain physical, geometrical, and topological constraints. These constraints set the mean number of sides per cell to 6 in a two-dimensional foam. However, much less is known on the probability for a cell (of given size) to have n sides. Recent experiments [1] have shown that the width of the distribution of sides per cell in a foam under oscillatory shear reaches a stationary value after a few cycles. Moreover, this stationary value seems to be strongly correlated to the width of the distribution of bubble sizes within the foam.

These results suggest that a foam under "macroscopic agitation" can be adequately described using the ideas and formalism of statistical thermodynamics. I will show that, as for other athermal systems, the energy is not pertinent to describe the macroscopic state of a foam. Instead, a more appropriate state variable is introduced: the total cell curvature. The probability distribution of the number of sides for a cell of given area is derived from this formalism. This expression allows to correlate the distribution of sides ("topological disorder") to the distribution of sizes ("geometrical disorder") in cellular systems. The bubble size-shape correlations deduced from the theory are investigated, and compared with experimental data. The function of state which is minimized for a finite cluster of cells at equilibrium is also derived.

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O8

Bubble mechanics of milk foams generated by steam injection and mechanical whipping

A. Sher[1], J-C. Gumy[2], S. Livings[3], C. Jimenez-Junca[4], K. Niranjan[4]

[1]Nestlé PTC Marysville, OH, USA
[2]Nestlé PTC Orbe, Switzerland
[3]Nestle Research Center, Vers-chez-lec-Blanc, Switzerland
[4]Department of Food Biosciences, University of Reading, Reading, UK
Email: Alexander.Sher@rdoh.nestle.com

An increasingly preferred form of coffee consumption is with the addition of frothed/foamed milk. Cappuccino type beverages are valued for the foam quality and result in higher coffee beverage consumption. Use of fresh (pasteurized) milk for frothing/foaming is perceived by consumers to have added value and quality. The demand for single-cup, steam froth or mechanically whipped foam of liquid milk for in-home or out-of-home applications is on the rise.

Though the main appeal of such beverages lies in their foamed top, there is a lack of understanding of parameters that drives foam quality. Foaming is a complex process and highly dependent on the foaming system as well as on the method of foam generation. Moreover, the coexistence of various surface-active compounds, including antifoaming agents, in milk based foamed beverages makes milk foam an even more challenging system to understand.

The present study aims to understand the effect of milk intrinsic properties and foam generation parameters on foams generated by two main methods - mechanical whipping and steam injection. The main differences between milk foams generated by these two methods will be shown and the underlying mechanisms of foam generation and stabilization will be discussed.

The presentation will also include experimental data and related discussion on protein foams. It will focus on the effect of injection time on milk froth stability, stiffness and protein assembly at the bubble interface, as well as on the effect of shear stress on foam quality generated by mechanical agitation at various shearing conditions. Further, the effect of environmental parameters such as temperature and pH on characteristics of foams generated by steam injection and mechanical whipping will be compared.

O9

Purification of a fungal cutinase by adsorptive bubble separation: a statistical approach

<u>J. Merz</u>[1], H. Zorn[2], B. Burghoff[1], G. Schembecker[1]

[1]*Plant and Process Design, Technical University Dortmund, Dortmund, Germany*
[2]*Institute of Food Chemistry and Food Biotechnology, Justus Liebig University, Giessen, Germany*
Email: juliane.merz@bci.tu-dortmund.de

To satisfy the steadily increasing industrial demand for microbial enzymes, cost-effective methods are required to concentrate and selectively purify the target enzymes from complex culture broths. Foam fractionation, a procedure known in principle but new in application, is regarded as a gentle, economical, and ecological compatible method for the separation and/or concentration of proteins, including active enzymes [1]. Foam fractionation belongs to the adsorptive bubble separation techniques. The physical basis of separation is the preferential adsorption of surface-active substances at the gas-liquid interface, which is generated by aerating the feed solution with air, noble gas, or nitrogen. Potential applications of this method lie in the early stages of down stream processing, where the separation and concentration of a dilute protein from a large volume of crude starting material is required.

To date, only a small number of enzymes have been concentrated by adsorptive bubble separation. While most studies showed the "proof of principle" [1] with model solutions, enzyme purification directly from fermentation processes has rarely been addressed.

In this study, foam fractionation was used to purify an extracellular cutinase from submerged cultures of the basidiomycete Coprinopsis cinerea. In screening experiments, approx. 80% of active enzyme was recovered with an 11 fold concentration within 15 minutes, involving only a single foam fractionation step [2]. Compared to traditional purification strategies [3] the main advantage of this method, beside time and cost saving, is the almost complete preservation of enzymatic activity.

Various physiochemical parameters, such as pH and gas flow rate, as well as apparatus design parameters like the configuration of the column, affect the efficiency of the foam fractionation process. The influence of these parameters and their interactions were analysed using a design of experiments. Thus, the foaming process could be optimised systematically.

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O10

System level definition for deep-bed filtration using open pore nickel and iron-based alloy metal foams

W. Doelling[1], R. Poss[2], A.-S. Dreher[3]

[1]*General Manager, Alantum Europe GmbH, Sauerlach, Germany*
[2]*Material Development, Alantum Europe GmbH, Sauerlach, Germany*
[3]*Material Development, Alantum Europe GmbH, Sauerlach, Germany*
Email: rposs@alantum.com

Iron and nickel-based alloy metal foams offer a substrate that opens up entirely new possibilities for the manufacturing of diesel particulate filters (DPF), especially for commercial and off-road vehicles. The good ductility and high flexibility of the 100% open-pore material allows the DPF design to be determined freely. Different porosities make it possible to define the level of deep-bed filtration in the system. Simple canning without filter beds and integrated DOC/DPF properties also provide economic benefits.

High temperature and corrosion resistance are among the basic requirements of an effective substrate for diesel particulate filters. During this process, metal foams are coated and thermally treated with a high-alloy metal powder that is tailored to the particular application and design. Fusion takes place, contributing to an extreme enlargement of the specific surface of the light metal foam and resulting in a good filter effect. At the same time, the temperature resistance of the thermal conductive alloy foam increases up to 1,000 °C with peaks of up to 1,200 °C. The composition of the alloy can be modified and customized within a broad range thanks to the production process which also enables various properties of the alloy foam to be adapted to meet specific customer requirements. Additionally, a catalytically active coating can be applied either completely or only to zones or layers.

In contrast with current market standard substrates, the homogenous alloy foam remains flexible, ductile and can be cut at any length, allowing it to be rolled, stacked, bent, and shaped. Even very complex structures can be manufactured. A further benefit is the simple canning that only requires a connection to the external housing. As the system is able to operate without a filter bed, it is possible to manufacture closed coupled DPF systems more cost effectively.

The particle deposition rate can be set to meet efficiency requirements in a range between 50 and 80%, depending on the number of foam layers and their pore sizes. Compared with partial flow filters, there are no blow-off effects. As the alloy foam is made solely from metal and does not contain any environmentally harmful substances, it is easy to recycle.

IL6

Solid particles in thin liquid films

T.S. Horozov

Department of Chemistry, University of Hull, Hull, United Kingdom
t.s.horozov@hull.ac.uk

Solid colloidal particles can spontaneously attach to air-water or oil-water interfaces and act as an effective stabiliser of foams and emulsions. The thinning and stability of the liquid films separating the bubbles or droplets are crucial for the overall stability of foams and emulsions. They are strongly affected by the presence of particles in the films. To understand better the role of solid particles in such systems we investigate the behaviour of micrometer and submicrometer solid particles in free standing liquid films by the so-called Film Calliper Method. The films are observed in monochromatic reflected light and the thickness profile of the film meniscus is reconstructed from the interference pattern (Fig. 1). It is used to determine the three-phase contact angle of bridging particles (simultaneously attached to both film surfaces) in real time without the need of sophisticated equipment or complex calculations. The applicability of the method for measuring the particle contact angle at air-water and oil-water interfaces in the absence or presence of surfactants is demonstrated. The obtained results are linked to the stability and properties of particle-stabilised foams and emulsions.
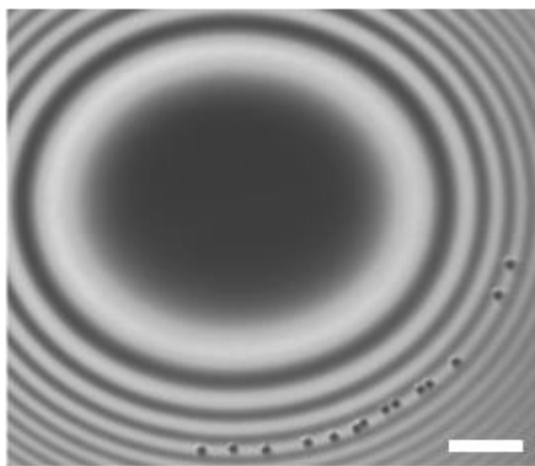
Figure 1. An aqueous foam film with bridging latex particles observed in monochromatic reflected light. The scale bar is 25 μm.

IL7

Foam stabilisation using shape-anisotropic materials

Simeon. D. Stoyanov[1], Eddie Pelan[1] and Vesselin N. Paunov[2]

[1] *Unilever Research Vlaardingen, Olivier van Noortlaan 120, 3133 AT Vlaardingen, The Netherlands*
[2] *Surfactant & Colloid Group, Department of Chemistry, University of Hull, Hull, HU6 7RX, United Kingdom*
Email: simeon.stoyanov@unilever.com

The long term stability of aerated products, stabilised by proteins, surfactants or fat, is mainly limited by the disproportionation process. This problem can be partly avoided by gelling the continuous phase, but it could lead to undesired textural changes. The real solution will be to structure (gel) the bubble surface, making it very elastic and impossible to shrink/expand. This lead to re-awakened broad interested in the study of solid particles as emulsifiers of dispersed systems [1]. The advantage of particle stabilisation is that it is almost impossible to displace an adsorbed particle once adsorbed to an interface, which gives particle stabilised foams excellent stability, especially with respect to disproportionation. Recently Alargova et. al. [2] have demonstrated that epoxy rods can be used to for stabilisation of emulsions and foams. Important factor for good foam stabilisation is rod contact angle at air/water interface, which needs to be close to 90°. However the epoxy resins have limited applicability and be able to fully utilise this approach one needs to find alternative materials for making fibers. There are numerous examples of rod- and fibre-like structures in food systems, such as microcrystalline cellulose (MCC) and natural plant fibres, which however are hydrophilic and have no affinity to adsorb at air/water interface. To overcome this limitation one needs to modify the surfaces of these fibers to achieve desired surface activity. Here we will illustrate our approach by using rigid $CaCO_3$ rods (diameter of $1.0\mu m$, length of $25\mu m$) permanently modified by fatty acids [3]. Dispersions of such rods have very good foamability and stability for several months. Foams show a bi-modal bubble size distribution, mediated by the interplay between rigid rod length and bubble curvature. Alternatively one can prepare fibers from (natural) polymers or waxes [4,5], which have the right wetting properties. We will illustrate this approach by showing fibers made from ethyl cellulose or shellac wax, which in addition to their foam stabilization capacity can have some additional functionality [6].

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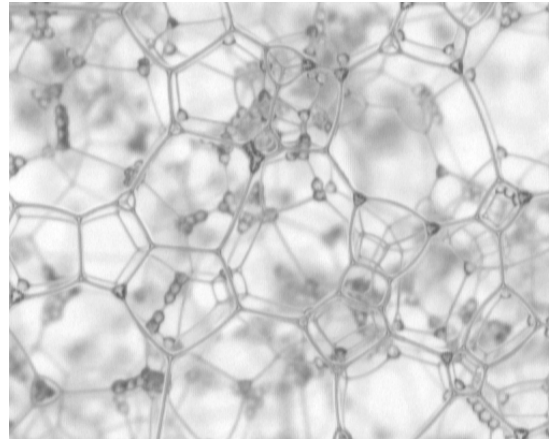[6] A. L. Campbell, S. D. Stoyanov and V. N. Paunov, *ChemPhysChem*, **10**, 2599 (2009).

IL8

Liquid foams as soft particulate filters

O. Pitois, E. Lorenceau, N. Louvet, F. Rouyer

Laboratoire de Physique des Matériaux Divisés et des Interfaces, Université Paris-Est
77454 Marne la Vallée Cedex 2, France
Email: olivier.pitois@univ-mlv.fr

Understanding the drainage behaviour of liquid foams made with suspensions of non-brownian solid particles or droplets is a challenging issue. Among others, it has been shown that the average velocity of the particles is smaller than the velocity of the suspending liquid, resulting in a global increase of particles fraction in the draining suspension [1]. Although the consequences of such a concentration effect are considerable, e.g. the brutal arrest of drainage, the physical underlying mechanisms remain unclear. Traffic jam and trapping effects are often put forward [2-4], suggesting that, to this regard, liquid foams behave as solid filters. Through experiments and numerical simulations, we investigate the motions and the capture of solid hydrophilic spheres incorporated into the liquid phase of a foam. We report results showing that, in the context of filtering, liquid foams have indeniable advantages with respect to their solid counterpart. Finally, we stress that filtering properties of liquid foams could be exploited and we suggest several dedicated applications.

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O11

Nanoparticle-stabilised aqueous foams

A. Stocco[1], F. Garcia-Moreno[2,3], J. Banhart[2,3], D. Langevin[1]

[1] Laboratoire de Physique des Solides, University of Paris-Sud, Orsay, France
[2] Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany
[3] Technische Universität Berlin, Germany
*antonio.stocco@mpikg.mpg.de*

Fumed Silica nanoparticles, (Wacker Chemie, Germany) characterized by an intermediate hydrophobicity, were used to stabilise aqueous foams without the addition of any other components. Oil-water dispersions stabilized by these particles are known as "Pickering emulsions"; here, air in water dispersions can be regarded as "Pickering foams". Extraordinary properties (stability, structure and dynamics) are often found when the liquid interfaces are stabilised by solid particles instead of using standard surfactants.

Here, some results regarding the air-water interfacial properties and stabilization mechanisms in aqueous foams are presented.

At the water surface, an ellipsometric model to evaluate the contact angle θ and the surface coverage ϕ of nanoparticles with different hydrophobic character is proposed [1]. Moreover, surface tension γ, surface elasticity E measurements and Brewster angle microscopy were carried out in order to elucidate the absorption kinetics and the interfacial structure respectively.

Foam dynamics was followed by diffusing wave spectroscopy for foams at different particle concentrations c and liquid fractions ε. Detailed information on the bubble and particle arrengements were obtained by x-ray tomography.

We intend to discuss the role of θ, ϕ, γ, E, c, ε on foam structure and stability in the framework of the Gibbs stability criterion $E > \gamma/2$ (for stable foam against coarsening) [2].
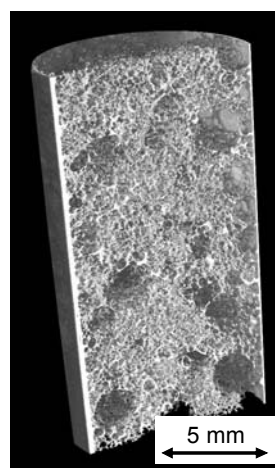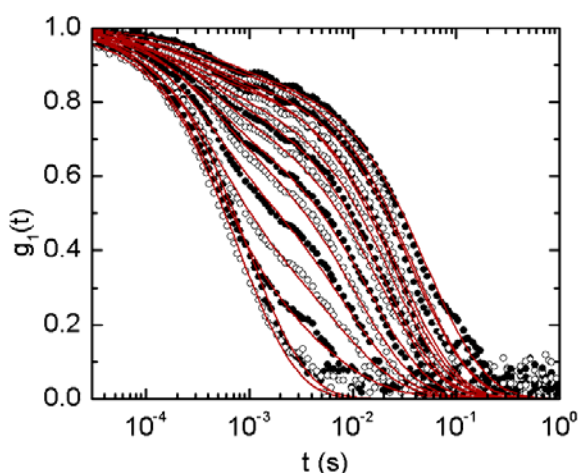
(Left Fig.) Diffusing wave spectroscopy measurements and (Right Fig.) an x-ray tomography image for an aqueous foam stabilised solely by fumed Silica nanoparticles.

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O12

# Indestructible magnetic foams under magnetic fields

Jhonny Rodrigues[1], Julien Bobroff[1], Emmanuelle Rio[1], Dominique Langevin[1], Harald Herzog[2] and Wiebke Drenckhan[1]

[1]*Laboratoire de Physique des Solides, UMR8502, Université Paris-Sud, 91405 Orsay, France.*
[2]*Evonik Degussa GmbH, Rodenbacher Chausse 4, 63457 Hanau-Wolfgang, Germany.*
e-mail: rodrigues@lps.u-psud.fr

Recent years have seen the emergence of super-stable liquid foams stabilised only by partially hydrophobic nano-particles. Here we add an important degree of control over such foams using silica-coated magnetic nano-particles which can be manipulated using magnetic fields. These particles are initially hydrophobic, but rendered partially hydrophilic in water/ethanol mixtures, with water/ethanol/particle dispersions displaying a well-defined range of concentrations for optimum foamability. Contact angles measurements show that the solid wettability can be finely tuned between dewetting and complete wetting by adjusting the ethanol concentration appropriately. These measurements match well the foamability results, relating maximum foamability to intermediate contact angles, as is also observed for the case of standard (non-magnetic) nano-particle foams [1]. Foams stabilised by the silica-coated magnetic nano-particles display the same fundamental characteristic as their non-magnetic counterparts, in particular concerning the complete lack of coalescence and coarsening, rendering them super-stable. We shall show here various techniques of generating super-stable foams comprising silica-coated magnetic nano-particles including the characterisation of their general properties in zero magnetic field. These will be followed by a presentation of their properties and response to various types of magnetic fields (constant or oscillating field, homogenous and gradients, magnetisation of foams, etc.) to demonstrate their versatility. Two illustrative examples of a macroscopic foam and individual bubbles moving in a magnetic field gradient are shown in Figure (a) and (b), respectively.
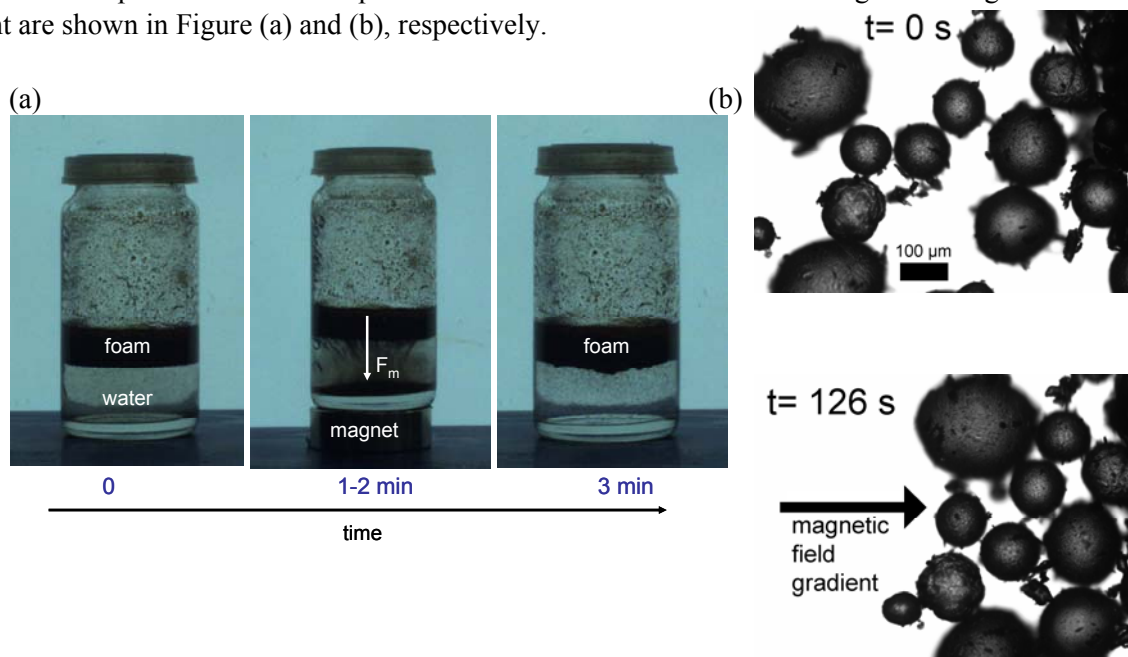
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O13

Effect of particle shape on foam stability

Stoyan I. Karakashev[1], Orhan Ozdemir[2], Marc A. Hampton[2], Emil D. Manev[1],

and Anh V. Nguyen[2]

[1]*Dept. Physical Chemistry, Sofia University, 1 James Bourchier Blvd, 1164 Sofia, Bulgaria*
[2]*Division of Chemical Engineering, The University of Queensland, Brisbane, QLD 4072, Australia*
Email: fhsk@chem.uni-sofia.bg

Effect of particle shape on foamability and foam decay of aqueous surfactant solutions was studied by commercially available Foam Tester (SITA Messtechnik, GmbH, Germany).

The ionic surfactants sodium dodecyl sulphate ($C_{12}H_{25}SO_4Na$) was exploited as foaming agent. Hydrophobic silica particles (d_{90} of 38 μm) and sepiolite micro-needles were exploited for the test.

Foam was produced by a special rotor, spinning at 1000 rpm and stopping every ten seconds to allow automatic measurement of the foam volume by sensor unit ('SITA Foam Tester'). Controlled gas flow was passed through a porous plate to produce a stationary foam column and its height was determined as a function of the flow rate ('Porous-bottom cell'). After formation, the foam was left to decay, and its volume measured as a function of time. Thus, foam volume vs. time was monitored during the foam generation and foam decay sessions. Stability of foam containing 0.01 wt. %, 0.1 wt.% and 1 wt.% silica micro-spheres (or sepiolite micro-needles) was measured and compared with stability of foam with no particles. The silica micro-spheres did not affect the foamability (maximal foam volume) at any particle concentration. The sepiolite micro-needles increased significantly the foamability of the surfactant solution reaching maximum effect at 0.1 wt. % particle concentration. Both, silica micro-spheres (with weaker effect) and sepiolite micro-needles (with stronger effect) increased the rate of foam decay reaching maximum at 0.1 wt. %. Overall, the foams containing sepiolite micro-needles lived longer while foams containing silica micro-spheres lived shorter. The mechanism standing behind these effects could be related with the contact area between particles. For example, spheres can contact only in one point, while cylinders (respectively, needles) can entangle due to their large contact areas. In such condition, aggregates of needles can keep large amount of hydrated water causing local increase of the viscosity.

O14

Structure comparison of dolomite and titanium hydride Al metal foams

D.P. Papadopoulos, H. Omar, N. Michailidis, F. Stergioudi, D. N. Tsipas

Department of Mechanical Engineering, Physical Metallurgy Laboratory, Aristotle University of Thessaloniki, 54124 Thessaloniki, Makedonia, Greece
Email: tsipas@eng.auth.gr

$MgCa(CO_3)_2$ is demonstrated to be an effective foaming and stabilizing agent for aluminum with several notable advantages relative to the currently-used titanium hydride. Characteristic cell structures and microstructural features of foams produced with a dolomite foaming agent are examined and the properties of dolomite based foams produced in the one step process are compared with those produced using titanium hydride based process. The most notable structural feature of dolomite based foams is a smaller cell size and thinner cell faces. Foaming with $MgCa(CO_3)_2$ also gives rise to a marked increase in the stability of molten foams with a large range of foaming temperatures possible, and an almost complete absence of melt drainage even with extended foaming times. Many of these properties are attributed to the cell surfaces being covered by a thin oxide film formed in the foaming process, the composition and morphology of which is characterized in detail.

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IL9

Migration of a bubble towards higher surface tension under the effect of thermocapillary stresses

B. Selva, I. Cantat and M.-C. Jullien

Email: isabelle.cantat@univ-rennes1.fr

A bubble in suspension in a liquid placed in a temperature gradient moves. It is generally believed that the bubble always migrates towards low surface tension, a consideration that must be revisited while the bubble is confined at the microscale. Surface tension variation with temperature induces tangential stresses on the liquid/gas interfaces subjected to a thermal gradient; these stresses are referred to as Marangoni stresses and are at the origin of the bubble motion. We present the results obtained relative to the displacement of bubbles confined between walls of a micrometric Hele-Shaw cell, in which a constant temperature gradient has been imposed within the plane of the cell. From an experimental standpoint, we are able to observe that bubbles move without deforming towards the colder regions, i.e. in the direction of regions with higher surface tension. This finding contradicts the results obtained using an identical geometry at the millimeter scale. The model we developed has been based on solving a set of hydrodynamic equations within the scope of a Hele-Shaw approximation that is able to account for 3D hydrodynamic pressure surges immediately adjacent to the bubble. We predict the functional dependence of velocity with respect to temperature gradient, bubble size and cell thickness, in good agreement with experimental results. We also explain why oppposite velocity directions are expected at micro and macroscales.

IL10

Dynamics of bubbles and films: role of interfacial rheology

Benjamin Dollet

Physics Institute of Rennes, CNRS/University Rennes 1 (France)

Interfacial phenomena at air/water interfaces are fundamental to understand the physics and fluid mechanics associated with bubbles, soap films, and foams, at a macroscopic scale. The surfactant molecules (soap, phospholipids, proteins…) generally covering these interfaces not only lower surface tension, but also often give rise to an interfacial viscoelasticity. We show the crucial influence of surface rheology in two different domains: ultrasound contrast agent for medical imaging, and fast dynamics of soap films.

Ultrasound contrast agents are microbubbles, encapsulated by a phospholipid monolayer, both to prevent them from too fast dissolution and to carry therapeutic molecules for targeted drug delivery. In medical applications, once injected in the blood pool, they constitute very efficient ultrasound scatterers, in relation with their acoustic resonance properties, which enables to image organ perfusion or to detect tumors. We have developed an optical spectroscopy method, and showed that the acoustic resonance of the contrast agents is drastically affected by the viscoelasticity of the phospholipid monolayer [1]. Furthermore, we show that the bubble coating induces striking nonlinear behaviour, even at low applied pressure. Such nonlinearities are rationalised through a simple model [2], mimicking the response of phospholipid monolayers to low compression rate.

To show the influence of surface rheology on the dynamics of soap films, we devise an elementary experiment: we push single films through tubes at high velocity, to study their behaviour as they deviate from equilibrium. The behaviour of SDS films, with negligible surface viscoelasticity, is shown to be totally different from that of films with high surface viscoelasticity [3]: steady deformation up to rupture at several m/s in the former case [4], intermittent flow regime, reminiscent of stick-slip in solid friction, in the latter case.

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O15

Investigation on the interfacial properties of carbonaceous particles plus CTAB dispersions and on the stability of the corresponding foams and emulsions

E. Santini, F. Ravera, M. Ferrari, L. Liggieri

CNR-Institute for Energetics and Interphases, Genoa, Italy
e.santini@ge.ieni.cnr.it

Carbonaceous particles derived from combustion processes may have a relevant impact on the environment pollution and on health. Their effects can also be influenced by the interaction with other classes of common pollutants, such as surfactants. This topic and, in particular, the impact on properties of aqueous interfaces has been little investigated, despite its potential importance in relation to the marine, water courses and shores pollution. An important aspect could be related to the formation of stable foams or other forms of dispersions, which may alter drastically the environmental conditions.

In order to start accessing the subject, carbon soot and carbon black particles, in the presence of a cationic surfactant (CTAB), have been investigated [1, 2] for their effects on water-air and water-oil interfaces and on related foams and emulsions. The aqueous dispersions of these nanoparticles have been studied from the point of view of dynamic interfacial tension and surface dilational rheology, both at water/air and water/hexane interfaces. These properties have been correlated to the formation and stability of the corresponding disperse systems, foams and w/o emulsions. The results showed that the adsorption of CTAB on the particles changes their hydrophobicity grade favouring their transfer into the fluid interface, since different trends of the surface/interfacial tension (γ) and of the dilation visco-elasticity vs. frequency (mod(E)) have been observed in comparison with the pure carbon particles. The investigation on emulsion and foam stability showed a synergetic effect of particles and surfactant, as well, in providing water-in-hexane emulsions stable over several months, even if this effect is less evident for the foam stability.

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O16

Orientational effects in the flow of liquid foams

C. Raufaste[1,2], S.J. Cox[3], P. Marmottant[4], F. Graner[4,5]

[1]*LPMC, UMR 6622, CNRS, Université de Nice Sophia-Antipolis, Nice, France*
[2]*Physics of Geological Processes (PGP), University of Oslo, Oslo, Norway*
[3]*Institute of Mathematics and Physics, Aberystwyth University, Aberystwyth, UK*
[4]*LSP, UMR 5588, CNRS, Université Joseph Fourier, Grenoble, France*
[5]*Institut Curie, UMR 3215, CNRS, Inserm U934, Institut Curie, Paris, France*
Email: Christophe.Raufaste@unice.fr

During the last decade, liquid foams have been used extensively as a model for the study of complex fluids; the use of quasi-2D setups has allowed the observation and tracking of each bubble individually. Liquid foams have viscous, elastic and plastic properties, and it remains an open question as to how to link this complex rheology with the underlying bubble structure; another debate is whether or not it is possible to describe the foam as a continuous material.

We study a 2D flow, experimentally and numerically, in both homogeneous and heterogeneous geometries. Statistical tools directly link the local quantities (bubbles stretching, T1 rearrangements) and the global rheological quantities (elastic deformation, plasticity rate) [1]. We show that in the quasistatic regime, elasticity and plasticity admit a continuous description [2]. We suggest a set of fully tensorial equations describing the amplitude and orientation of the fluid variables. We investigate the elongation of bubbles and direction of internal stresses. We discuss when it is necessary to switch from a scalar description to a tensorial one which explicitly takes into account the effects of bubble orientation. This leads to a possible explanation of the stress overshoot often observed in a sheared foam [3].
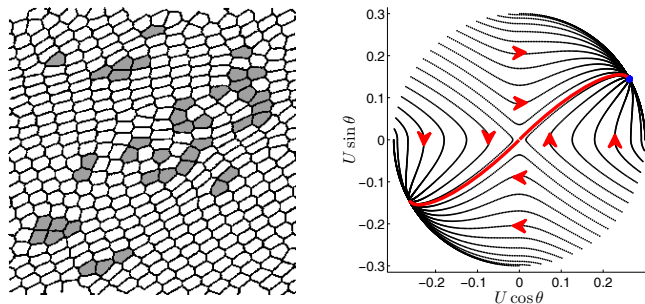

Fig.: Simulation of a 2D foam in Couette flow. Left: instantaneous bubble structure. Right: A representation of the trajectories describing the elasto-plastic behaviour.

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O17

Finite element model for the analysis of a closed-cell metal foam under compression

I. Irausquin[1,2], J.L. Perez-Castellanos[1]

[1]*Dept. of Continuum Mechanics & Structural Analysis, U. Carlos III de Madrid, Leganes, Spain*
[2]*Department of Industrial Technology, Universidad Simon Bolivar, Caracas, Venezuela*
Email address: iirausqu@ing.uc3m.es

Aluminum-based metal foams are novel materials that have shown interesting properties for several industrial applications, especially in structures with large energy absorption capacity. This study deals with the development of a unit cell model which allows the numerical modeling of the quasi-static compression of a closed-cell aluminum foam. For such a purpose the nonlinear finite element code ABAQUS has been used. The geometry of the numerical model has been determined through the material properties and its morphology and afterward has been simulated its uniaxial compression, considering the possibilities of have either free or parallel displacement of the side faces, as well as the presence and absence of entrapped gas. Stress-strain curves obtained from the numerical model were plotted and compared with experimental results found for a reference foam. Despite not been able to fully reflect the localized damage suffered by the foam, the proposed model has shown suitability to reproduce its compression behavior in terms of Young's modulus, yield strength and densification strain.

Keywords: Cellular material, numerical modeling, unit cell model.

O18

The roles of dynamic foam behavior in enhanced petroleum recovery

E. Ashoori[1], D.Marchesin2, W. R. Rossen[1]

[1]*Dept. of Geotechnology, Delft University of Technology, Delft, The Netherlands*
[2]*Institute of Pure and Applied Mathematics, Rio de Janeiro, Brazil*
Email: e.ashoori@tudelft.nl

In applications of foam to enhanced petroleum recovery, complex dynamics of bubble creation and destruction within the porespace of rock control foam properties [1]. Foam experiments show multiple steady states possible for foam at the same injection rates [2]: a strong foam state, a no-foam state, and an unstable state in between. Recently there has been consensus that local equilibrium between bubble creation and destruction adequately describes foam displacements in porous media [3]. Here we reconsider whether and when nonequilibrium effects are important. We assume that throughout a foam EOR process on the large (well-to-well) scale local equilibrium applies, with the exception of an entrance region, where initial foam generation occurs, and at shock fronts in the displacement, where bubble size changes abruptly.

On the small scale, the width of the shock front is controlled by gradients of capillary pressure and evolving bubble size. One expects that slow foam dynamics could widen the shock considerably, since it can take hours to reach steady state in a laboratory experiment. Moreover, theory and simulations show that the width of and mobility inside even a relatively narrow shock front can affect foam sweep of the reservoir [4]. Therefore the width of a shock is important.

If there is no gas ahead of the foam, as is common in published simulations, we show that foam texture is everywhere at local equilibrium within the shock, regardless of the foam model, and *no matter how slow are the processes of bubble creation and destruction*. This confirms and extends a previous simulation study based on one foam model [3].

If there is gas initially in the formation, slow foam generation and coalescence can actually narrow the shock from that assuming local equilibrium of bubble size. In other cases, the dynamics of bubble creation and destruction within the shock lead to oscillations near the shock where foam breaks and reforms; these are not numerical artifacts, but reflections of the physical assumptions in the model. If a foam model predicts multiple steady states [1], consideration of the traveling wave puts conditions on which state can be observed in a given situation.

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O19

Impact of the structure of fatty acids supramolecular assemblies on the interfacial and foaming properties.

A-L.Fameau [1,2], , B. Houinsou-Houssou [1], F. Cousin [2], F. Boue [2], J-P. Douliez [1] and B. Novales [1]

[1] *Biopolymères Interactions Assemblages INRA, rue de la Géraudière, 44316 Nantes, France.*
[2] *Laboratoire Léon Brillouin, CEA Saclay, 91191 Gif sur Yvette Cedex, France.*
anne-laure.fameau@nantes.inra.fr

The use of agricultural resources for industrial purposes will undoubtedly be one of the major challenges of the 21st century. In this context, our works are aiming to demonstrate the potential contribution of biological compounds of plant origin as new classes of surface active agents. The depletion of fossil resources and the need for environmentally friendly molecules make fatty acids good candidates for alternative renewable resources. However, long chain fatty acids and their hydroxylated derivatives are insoluble in aqueous solution. This feature often hampers their use in biochemical and physicochemical studies. An easy method to realize their full dispersion is to produce salts of fatty acids by using specific counter-ions. By this way, when dispersed in water, fatty acids can form various supramolecular architectures from micelles to tubes, twisted ribbons and vesicles according to the nature of the counter-ion [1]. It is reasonable to suggest that the interfacial and foaming properties of those systems will certainly be affected by the polymorphism. The aim of the present work was then to determine the impact of the structure of fatty acid supramolecular assemblies on their interfacial properties, as well as on the formation and stabilization of foams. In this study, fatty acids salts have been produced with 3 different counter-ions, respectively ethanolamine, guanidium chloride and tetrabutyl-ammonium (figure 1). Foams were obtained with a Foamscan apparatus (IT Concept). Foam capacity was studied and correlated to the adsorption kinetics at short times performed on model interface and determined using a drop tensiometer. Foam stability was related to the properties of thin liquid films of fatty acids assemblies. Small angle neutron scattering was used to obtain information in situ on the film thickness and the bubble size.

Our results show that the interfacial and the foaming properties are affected by the polymorphism. More precisely, the structuring of the interface is strongly influenced by the nature of fatty acids assemblies.
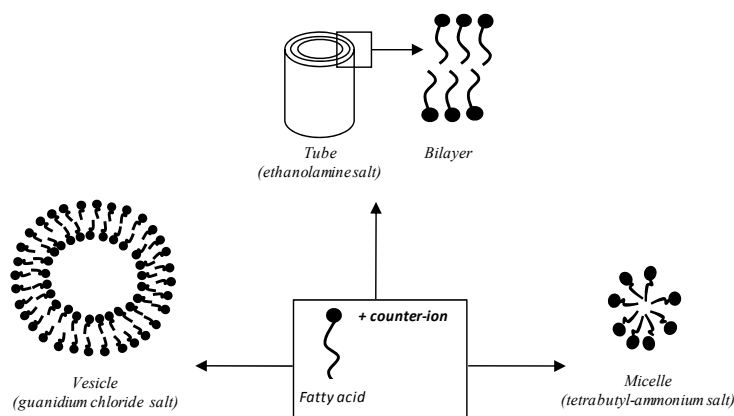

Figure 1 : Fatty acids supramolecular assemblies.

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O20

Solutions of surfactant oligomers: A model system for tuning foam stability by the surfactant structure

A. Salonen[1], M. In[2], J. Emile[1], A. Saint-Jalmes[1]

[1]*Institut de Physique, CNRS 6521 Université de Rennes 1, Rennes, France*
[2]*Laboratoire des Colloïdes, Verres et Nanomatériaux, CNRS 5587 Université Montpellier 2, Montpellier, France*
Email: salonen@lps.u-psud.fr

Surfactants made up of two or more amphiphilic moieties, such as dimers, trimers and tetramers, have attracted interest, both from academia and the industry, due to their special interfacial and bulk properties. Surfactant oligomers are more efficient at decreasing the surface tension of water. The CMC values are significantly lower than those of the corresponding monomers and due to the formation of elongated micelles they show a variety of viscoelastic properties. [1] The surfactants studied were oligomers of dodecyltrimethyl ammonium bromide (DTAB) of the form 12-*s*-12, 12-*s*-12-*s*-12, and 12-s-12-s-12-s-12 where *s* is the spacer carbon number. [2] We have studied both the interfacial dilatational and shear rheology, the single thin film properties, the foamability of the solutions, then the aging and the mechanical properties of the 3D foams. The influence of the degree of oligomerisation (i.e. dimers, trimers or tetramers) and the spacer carbon length were studied and clear
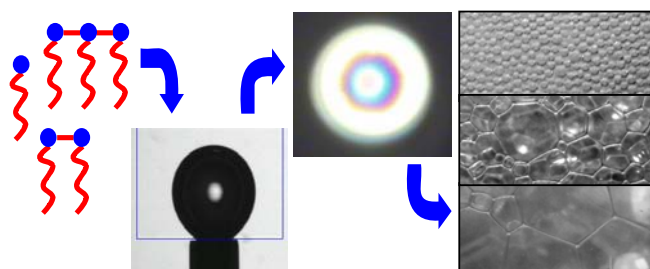
Oligomeric surfactants at interfaces, in films and in foams.

differences between the oligomeric systems were found at all length scales. We then discuss the correlations between the properties at the different length scales and see how the macroscopic features depend on the molecular structure. This work allows us to determine the relevance of each measurement; in that respect, it stresses the important role of the timescales, and the need to monitor the liquid fraction and bubble size in order to perform correct comparisons. Finally the origins of the high stability encountered in some of the systems are discussed and compared with other very different systems where the bulk properties of the solution can change strongly due to the effects of interface and confinement within the foam.

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O21

Molecular structure of "Star-like" diethylenetriamine-based polymeric surfactants and the properties of foam films

H. Petkova[1], Khr. Khristov[1], D. Exerowa[1], J. Beetge[2], J. Venter[2]

[1] *Institute of Physical Chemistry, Bulgarian Academy of Science, 1113 Sofia, Bulgaria*
[2] *Champion Technology Inc., Fresno, Texas 77545, USA*
hpetkova@ipc.bas.bg

The polymeric surfactants used in the study were named A, B, C and D and are products of Champion Technology, Inc, Fresno, USA. All of them belong to the class of branch type star-like diethylenetriamine-based polymeric surfactants and consist of a diethylenetriamine (DETA) nucleus and a number of polymeric branches, containing polypropylene oxide blocks (PPO) and polyethylene oxide blocks (PEO). The molecule of each polymer is designed so that it consists of two parts: a more hydrophobic one, situated in the inner part of the molecule, closer to the DETA center (where PPO blocks are predominant) and a more hydrophilic one, situated in the outer part of the molecule (where PEO blocks are predominant). Surfactants A, B, C have a similar structure, differing only in the number of polymeric branches: 4, 6 and 9 in the mentioned order. Surfactant D is of a dendrites type and its molecule consists of 4 to 6 primary and 2-3 secondary branches.

The aim of the present study was to establish a relationship between the molecular structure of the above surfactants and their physicochemical properties in order to derive information useful to their practical application. Surfactant A is an industrially applied agent while surfactants B, C and D have been recently synthesized. Systematic studies of foam films stabilized by surfactant A (model studies) were performed to further characterise it through specific parameters which can be used as "baseline" features to elicit the properties of the other three polymers.

Results from the studies indicated that differences in polymeric surfactants molecular structure affected the properties exhibited, e.g. value of surface tension (surface activity), critical micelle concentration (tendency of self-assembly of the molecules) and solubility. Foam films stabilized by such surfactants also differed in behavior and in some specific parameters, such as critical electrolyte concentration, surfactant concentration for obtaining a stable film, value of critical pressure of film rupture, etc. The observations gave reasons to believe that model studies may be used to assess the way molecular structure changes could affect surfactant performance. Since film stability correlates directly to foam/emulsion properties it is to be expected that under real conditions the surfactant performance would depend substantially on polymer molecular structure and the surfactant performance could be altered by choosing an adequate molecular design.

IL11

Bubbling, foaming and capsule preparation

Mohan Edirisinghe & Eleanor Stride

Department of Mechanical Engineering, University College London, Torrington Place, London WC1E 7JE, United Kingdom
Email: m.edirisinghe@ucl.ac.uk

This invited lecture will describe recent research carried out in our laboratory to generate bubbles, foamed structures and capsules. The electrohydrodynamic method of generating microbubbles invented in our laboratory has now been developed further to control bubble diameter and size distribution and extended to prepare porous polymer and micro and nano-particles, hollow polymer capsules and monoporous hollow polymer microspheres. This work includes using polymers that can be pyrolysed to the ceramic form while preserving the structure. We have also shown that foam structures can be prepared using this method with protein suspensions. Larger diameter bubbles with an even narrower size distribution can be prepared using our T-junction device and this method can also be used to prepare bubbly films and foam structures. Device and process development continues to expand with the use of multi-needle nozzles and output devices to generate a whole host of structures with potential biomedical engineering, food engineering and climate engineering applications. The work on developing models for drug delivery has resulted in the development of an in-vitro method to characterize diffusion of dye from polymeric particles. A new process for drug encapsulation using a liquid to vapour phase change of a fluorinated hydrocarbon has also recently been investigated and we continue to pioneer new methods of processing and forming bubbles, foams and capsules at the macro, meso, micro- and nano-scale.

IL12

Flow of concentrated emulsions

A. Colin

LOF, University Bordeaux 1, Bordeaux,France
Email: annie.colin-exterieur@eu.rhodia.com

Using various velocimetries tools, we have studied the flow of concentrated emulsion in various geometries (Couette cell, poiseuille flow). We point out the lack of a simple behaviour law linking the local shear stress to the local shear rate. Non-local effects govern flow in concentrated emulsion.

We evidence the role of the boundary conditions. The velocity but also the shear rates at the wall depend upon the roughness of the surface. Using confocal microscopy, we show that the numbers of rearrangements are proportional to the local viscosity. We present a model capturing these non-local behaviour.

IL13

Gas permeability of single foam films

R. Krastev

NMI Natural and Medical Sciences *Institute* at the University of Tuebingen,
Reutlingen, Germany
Email: rumen.krastev@nmi.de

The mass transfer of gas in foams is important for various industrial and biological processes. On the other hand it governs the long term stability of different products varying from cosmetics, medicine to food products. The detailed results on the gas transfer in foams can be also used to better understand the mass transfer in emulsion systems.

The single foam films are the basic building elements of the foams. Their properties govern to large extend the properties of the foams. Single foam films are often used to understand the processes that occur in the real foams. The aim of this presentation is to give a perspective and critical overview of studies carried out to date on the mass transfer of gases through foam films. Contemporary experimental data are summarized, and a comprehensive overview of the theoretical models used to explain the observed effects is given. A detailed description of the processes that occur when a gas molecule passes through each layer that forms a foam film is shown. The permeability of the film-building surfactant monolayers plays an important role for the whole permeability process. It can be successfully described by the models used to explain the permeability of surfactant monolayers on aqueous sub-phase. For this reason, the presentation will briefly discusses also the surfactant-induced resistance to mass transfer of gases through gas–liquid interface. A comparison between the permeability of foam films stabilised with different classes of surfactants will be presented. The permeability of single gases will also be discussed. A special part of the presentation discusses the experimental and theoretical aspects of the foam film permeability in a train of foam films in a matrix. This special case is important to explain the gas transfer in porous media or in foams. Finally, this paper will highlight the gaps and challenges and sketch possible directions for future research.

O22

Study of shear induced drainage of foamy emulsions through MRI

J. Goyon[1, 2], F. Bertrand1, G. Ovarlez[1] and O. Pitois[2]

[1] *Université Paris Est, Laboratoire Navier, LMSGC, Champs sur Marne, France*
[2] *Université Paris Est, LPMDI, Marne la Vallée, France*
Email: Julie.goyon@lcpc.fr

We study experimentally the behavior of concentrated suspension of bubbles in a yield stress fluid (a dense emulsion). The samples we study are stable at rest: the gravity do not induced motion of the objects. We investigate the stability under shear of these foamy yield stress fluids. We use a controlled shear rate Couette cell rheometer to shear the samples in the plane perpendicular to the direction of gravity. Thanks to a Magnetic Resonance Imaging (MRI) technique, we can have access to the local bubble concentration as function of the height of the sample.

Whereas the yield stress stabilizes the system at rest, we observe that an imposed horizontal shear induces the fast vertical drainage of the interstitial material, which behaves as a viscous fluid in the direction of gravity. We investigate the drainage velocity by MRI techniques as function of the bubbles size, the local shear rate and the yield stress of the fluid.

 In contrast to static aqueous foams, it is found that shear induced drainage can not be described with existing drainage theories. A model taking into account the coupling of the liquid flows in foam films and foam channels provides a reasonable quantitative agreement with experiments. Furthermore, foam films are found to spark off the unexpected end of drainage, thus trapping irreversibly a significant amount of interstitial liquid.

O23

Forced foam flow through a pore

A. Delbos, O. Pitois, E. Lorenceau, M. Vignes-Adler

LPMDI, Université Paris Est - Marne la Vallée, Marne la Vallée, France
aline.delbos@univ-mlv.fr

We study the forced invasion of a single pore by a liquid foam. At low invasion flow rates, it is observed that a small bubble cluster forms at the entrance of the pore so that only foaming liquid is entering. At larger invasion flow rates, the bubble cluster cannot resist to the driving pressure and foam bubbles enter as well. It is shown that the characteristics of the entering foam, i.e. the bubble size and the liquid fraction, differ from the initial foam. A parametric study of this effect is presented. Moreover, we observed that if the foam liquid fraction is below a critical value, the foam cannot enter the pore but instead collapses. An optical investigation of the foam films during the experiment provides some physical insight into this behaviour.

Figure 1 : Foam suction through a capillary tube for different suction flows

O24

Non-aqueous foams in lubricating oil systems

B. P. Binks[1], P. D. I. Fletcher[1], M. P. Gahagan[2] and E. L. Sharp[1]

[1]*Surfactant & Colloid Group, Department of Chemistry, University of Hull, Hull, UK*
[2] *Applied Sciences, Lubrizol Limited, Belper, Derby, UK*
Email:e.sharp@chem.hull.ac.uk

Non-aqueous foams are poorly understood in comparison to aqueous foams despite their importance in many industries. When lubricating oils foam, it causes the oil to be removed from the surfaces where it is required. This leads to faster wear, and air entrainment leads to faster degradation of the oil.

Lubricating oils typically consist of a branched, saturated hydrocarbon base oil mixed with various different additives, including thickeners, antiwear agents, antioxidants, dispersant, anti-foam agent and overbased detergents. Many of these low molar mass, polymeric and particulate additives are potentially surface active and may contribute to foam formation and stability.

The foamability of these systems has been studied, and it has been found that foam formation occurs only when the additive concentration and temperature are such that the single-phase mixtures are close to a phase separation boundary. This is the point at which the solvent affinity for the solute is low and is therefore where the solute is most likely to adsorb at the oil-air surface promoting foam formation. Above the solubility boundary two types of behaviour are observed, and foam formation is either supressed or maintained.

The foams produced in this lubricating oil system are all "wet" transient foams consisting of polydisperse spherical bubbles and liquid volume fractions greater than about 20 vol.%. The high liquid fraction and short lifetimes of these foams indicate that the adsorbed solute films at the oil-air interface affect liquid drainage but cannot resist against coalescence between bubbles. This is further backed up by the half-lives of these foams, which are found to scale with the kinematic vscosity of the continuous phase liquid.

O25

X-ray tomography of aqueous foams

F. Garcia-Moreno[1], A. Stocco[2], I. Manke[1], J. Banhart[1,3], D. Langevin[2]

[1] *Institute of Applied Materials, Helmholtz-Centre Berlin for Materials and Energy, Berlin, Germany*
[2] *Laboratoire de Physique des Solides, University of Paris-Sud, Orsay, France*
[3] *Structure and Properties of Materials, Technische Universität Berlin, Germany*
garcia-moreno@helmholtz-berlin.de

X-ray tomography is a well established method for non destructive investigations in material science. It was used to study solid cellular structures like e.g. metallic foams [1]. High spatial resolutions of several micrometer and even down 1 micrometer are possible by using microfocus lab sources and synchrotron beamlines respectively. At the same time short acquisition times are required, if the sample is aging and therefore changing its macrostructure like an aqueous foam.

We studied by X-ray tomography liquid aqueous foams containing different amounts of hydrophobic Silica nanoparticles (Wacker Chemie, Germany) that are used for stabilisation. Additionally we can improve X-ray absorbtion contrast due to these particles. The spatial resolution used (~10 μm @ 80kV and 100 μA) allows us to image the complete foam bubble structure, even observing cell walls with the lab CT. Additionally phase contrast tomography modus for higher resolution (< 1 μm @ 15 keV) was used at the synchrotron (BAMline, Bessy, Berlin) for selected samples. With this method the edge contrast between cell wall and bubble becomes sharper and the spatial resolution is increased. Not only qualitative images of the structure but also quantitative 3D analysis of the pore size distribution were performed for series of hand-mixed foams and turbulent foams for different amount of particles and aging times. The results will be discussed. The results will be compared with multiple light scattering measurements.

Additionally an overview of the potential of this method will be given. The possibilities and a way for continuous in-situ analysis during foam aging will be presented.

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O26

Non-isothermal destabilisation of steam injected milk foams: charcterisation and interface visualisation

K. Niranjan[1], C. Jimenez-Junca[1], J-C. Gumy[2], A. Sher[3]

[1]*Department of Food and Nutritional Sciences, University of Reading, Reading, UK*
[2]*Nestlé PTC Orbe, Switzerland*
[3]*Nestlé PTC Marysville, OH, USA*
Email (K.Niranjan): afsniran@reading.ac.uk

This paper aims to describe the methodologies and techniques used to study destabilization of milk foams formed by steam injection in products such as hot beverages whilst cooling under ambient conditions. Techniques used to characterize transient variations in bubble hold-up, liquid drainage and bubble size distribution will be related to foam textural characteristics, as well as the method used to generate the foam, the operating parameters and milk properties.

Milk foams are complex systems containing a number of different active compounds occupying the interface, which makes interface visualization particularly difficult. Confocal Scanning Laser Microscopy (CSLM) holds great potential for interface visualisation without any special sample preparation, and it can also be used to get a clear idea of the interfacial components as well as their relative abundance. This paper will also include insights into the following:

The simultaneous visualization of fat and protein in foams produced with whole milk: This was made possible by adding stock solutions of Nile Red and Nile blue to the milk immediately prior to foaming. The distinct emission spectrum of the dyes allowed consecutive images to be taken at each wavelength which could be superimposed to observe the specific components at the interface.

Investigating of disproportionation kinetics: CSLM clearly showed that the initial bubble size distribution was highly heterogeneous, which caused small bubbles to disappear after shrinking at high rates and large bubbles to grow initially but stabilise subsequently.

Visualising casein and whey proteins at the interface: This was achieved by labelling these components with specific fluorescent dyes having distinct emission spectrum.

O27

Determining trapped gas in foam in porous media from CT images

R. A. Kil[1], Q. P. Nguyen[2], <u>W. R. Rossen</u>[1]

[1]*Dept. of Geotechnology, Delft University of Technology, Delft, The Netherlands*
[2]*Dept. of Petroleum and Geosystems Engineering, The University of Texas at Austin, USA*
Email: w.r.rossen@tudelft.nl

Foam diverts gas and liquid flow in geological formations in petroleum recovery, oil-and gas-well stimulation and aquifer remediation. Gas trapping by foam is a key mechanism of foam mobility and effectiveness in all these applications.

Previous studies have attempted to quantify the extent of gas trapping by injecting a gas tracer within the foam into a cylindrical core sample and then fitting the effluent profile to a one-dimensional (1D) capacitance model. In this model, at any given axial position along the core, all flowing gas and all trapped gas are each at a single tracer concentration. CT images of experiments using Xenon tracer show that this assumption is not accurate (see sequence of cross-section images with increasing time, below): trapped gas near flowing gas comes rapidly to equilibrium with flowing gas, long before tracer diffuses into trapped gas further away.

We introduce a method that uses the CT images directly to estimate flowing-gas fraction. In the CT images, tracer advances in many small channels and diffuses outwards into surrounding regions of trapped gas a few mm in diameter. The difference between the higher tracer concentration at the center of these channels and the lower concentration at the edge can be related to diffusion coefficient of the gas tracer through foam and the flowing-gas fraction within the channel. For the CT images of Xe tracer in one experiment, this method gives flowing-gas fractions *one or two orders of magnitude smaller* than that estimated using the 1D capacitance model.
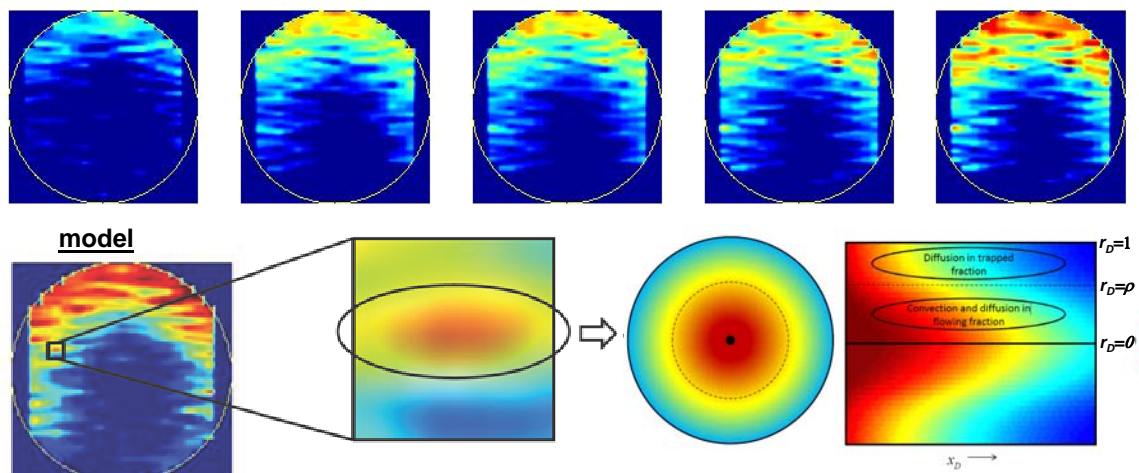
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O28

New experimental results on foam acoustics

R. M. Guillermic, M. Erpelding, I. Ben Salem, B. Dollet, J. Crassous, A. Saint-Jalmes

Institut de Physique de Rennes, Rennes, France
reine-marie.guillermic@univ-rennes1.fr

We report a new set of experimental results on the acoustic properties of aqueous foams. Many issues are still pending on foam acoustics; it is still not well understood how sound propagates and is attenuated inside a foam, and how the acoustic properties depend on the bubble size and liquid fraction. Experimentally, problems often arise from the coupling between such acoustic measurements and the foam aging, which irreversibly modifies both the bubble size and the liquid fraction (also creating vertical gradients of these parameters).

First, we present new measurements of sound velocity and sound attenuation (in the ultrasonic frequency range) on various types of controlled foams, and in particular on foams doped with clay particles in order to obtain a coarsening, but not draining, foam. This allows us to study accurately the dependence of the sound features with the bubble and sample sizes and the liquid fraction. In particular, we observe a non-monotonic behavior for the attenuation as foam ages, strikingly reminiscent of results found for bubbly liquids.

Secondly, we have studied how a sound wave (emitted by an external speaker) induces bubble displacement. We show that it is possible to detect – by a light scattering technique (Diffusive Wave Spectroscopy) – the tiny acoustic-induced motion of the bubbles. Comparisons between theory and experiments allow us to elucidate the non-trivial acoustic displacement profile inside the foam; in particular, we find that the acoustic wave creates a localized shear in the vicinity of the solid walls holding the foam.

O29

Probing foams with ultrasound

A. Bretagne[1], <u>V. Leroy</u>[2], C. Derec[2], F. Elias[2]

[1]*Institut Langevin, ESPCI ParisTech, CNRS UMR 7587, Université Paris Diderot, Paris, France*
[2]*Laboratoire MSC, CNRS UMR 7057, Université Paris Diderot, Paris, France*
valentin.leroy@univ-paris-diderot.fr

Because of their composition and structure, liquid foams have particular acoustical properties. Experimental studies have shown that the velocity and attenuation of sound in a foam depended on parameters such as the liquid volume fraction (ϕ_l) and the average bubble size (R) [1, 2]. The idea of using acoustical measurements for probing foams has recently emerged.

We present an experimental setup consisting of two broadband transducers (40kHz-1MHz) measuring the reflection of ultrasound at the air-foam interface. The complex acoustic impedance of the foam can be measured, which gives access to the velocity and attenuation of sound in the sample.

We first discuss experimental results with controlled samples (monodisperse bubbles, controlled physico-chemistry) and compare them with available models. We show that, in some particular cases, a minimum of reflection occurs for a frequency close to the Minnaert resonance of the bubbles [3].

We also show results with "real foams" (shaving foam, chocolate mousse, …) and discuss the advantages and disadvantages of the technique for practical applications.

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O30

# Superstable foams made from catanionic surfactant mixtures

D. Varade[1], D. Carriere[2], W. Drenckhan[1], E. Rio[1], A. Stocco, D. Langevin[1]

[1] *Laboratoire de Physique des Solides, Université of Paris Sud, Orsay France*
[2] *UMR 3299 CEA/CNRS SIS2M, LIONS (Laboratoire Interdisciplinaire sur l'Organisation Nanométrique et Supramoléculaire), France*
Email: varade@lps.u-psud.fr

We have studied the properties of gas/liquid interfaces and foams of surfactant mixtures of two oppositely charged surfactants which were dialysed in order to remove counterions ("catanionic mixture"). The mixtures of hexadecyltrimethylammonium chloride (CTACl) and myristic acid ($C_{13}COOH$) prepared above the $C_{13}COOH$/CTACl 2:1 ratio form micrometer-sized vesicles with solid-like (gel phase) bilayers [1-2]. By visual observation we have demonstrated that these vesicle solutions produced foams of remarkable stability with respect to bubble coalescence *and* coarsening. Whilst bubble coalescence is almost entirely prohibited, coarsening is slowed down significantly leading to foams having lifetimes up to several weeks. We combine thin film pressure balance (TFPB), confocal microscopy, surface rheology and dynamic surface tension measurements in order to understand the key mechanisms at the origin of this stability, especially in order to differentiate between the influence of the interfacial properties and the presence of the vesicles in the sublayers. For example, confocal laser scanning microscopy of the bubble dispersions suggests the presence of vesicles and aggregates in the Plateau borders of the foams slowing down and completely blocking the drainage of liquid, hence imparting higher foam stability (Figure 1). The film lifetimes measured by TFPB indicate that relatively thick, long-lasting and non-draining films are prepared by catanionic mixtures and the films exhibited significant surface corrugations. Preliminary dynamic surface tension studies showed that after an apparent stabilisation, the surface tension γ decreases sharply to very low values, simultaneously rendering the gas/liquid interface strongly elastic (solid-like). Correlating the results from all the techniques studied we will try to provide a comprehensive picture of factors responsible for the high foam stability.

(a)   **(b)**
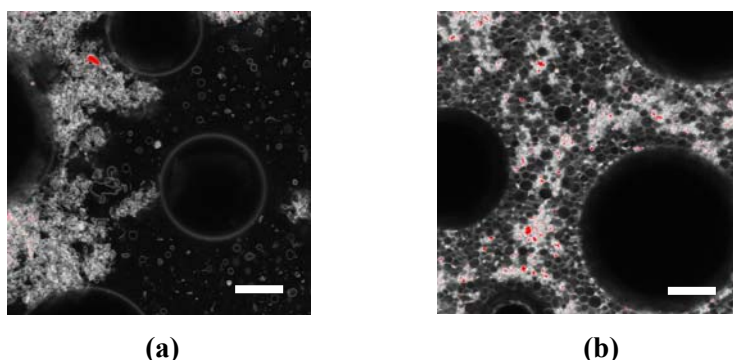
Figure 1: Confocal Microscopy pictures of $C_{13}COOH$/CTACl (2:1) in water dialysed against water for 120h and fluorescently labelled with Oregon green. (a) 0.1% w/w, (b) 1 %w/w. The scale bars are 20 μm. The larger (> 50μm) dark circles are air bubbles, the smaller (< 5 μm) circles are vesicles.

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O31

Highly efficient interface-assisted colloid fabrication

Luben N. Arnaudov[1], Simeon D. Stoyanov[1], Slav A. Semerdzhiev[1], and Martien A. Cohen Stuart[2]

[1] *Unilever R&D Vlaardingen, Olivier van Noortlaan 120, 3133AT Vlaardingen, The Netherlands*
[2] *Laboratory of Physical Chemistry and Colloid Science, Wageningen University, Dreijenplein 6, 6700 EK Wageningen, The Netherlands*
Email: luben.arnaudov@unilever.com

In a previous study [1] we have proposed a colloid fabrication technique. The technique allows assembling composite particles by manipulating three (initially fluid) phases, e.g. gas bubbles or liquid droplets (*phase 1*) in one liquid (*phase 3*), coated by another one (*phase 2*). In this way, we can control (i) the type of disperse phase fluid and its flow rate, (ii) the type of the coating material, its composition, and its flow rate, and (iii) the type of the continuous phase and its composition. Here we study in detail the application of the colloid fabrication technique for *highly efficient interface-assisted colloid fabrication*. We do this by coating nitrogen bubbles with oil into a surfactant solution. The coated bubbles rise through the surfactant solution, reach the water/air interface, and coalesce with it. Upon coalescence with the external water/air surface the bubbles dissipate their surface energy into a thin film region with a thickness of the order of 10 nm. The high energy density in the thin film region leads to the formation of submicron-sized-emulsions from the coating fluid that, in some cases, can be solidified to form colloidal particles. We studied the parameters controlling the size of the obtained emulsion as well as the mechanism of the emulsion formation by video imaging and dynamic light scattering. The lowest emulsion size achieved in our experiments was about 30 nm. We believe that this is a novel and promising way to fabricate extremely fine emulsions.

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O32

Mixtures of *n*-dodecyl-β-D-maltoside and hexaoxyethylene dodecyl ether - surface properties, foam films, and foams –

C. Stubenrauch

Institute of Physical Chemistry, Universität Stuttgart, D-70569 Stuttgart, Germany
e-mail: cosima.stubenrauch@ipc.uni-stuttgart.de

Mixtures of the two non-ionic surfactants hexaoxyethylene dodecyl ether ($C_{12}E_6$) and *n*-dodecyl-β-D-maltoside (β-$C_{12}G_2$) were studied with regard to surface properties, foam films, and foams. The reason for studying a mixture of an ethylene oxide (C_iE_j) and a sugar (C_nG_m) based surfactant is that despite being non-ionic, these two surfactants behave quite differently. Firstly, the physico-chemical properties of aqueous solutions of C_nG_m surfactants are less temperature-sensitive than those of C_iE_j solutions. Secondly, the surface charge density q_0 of foam films stabilized by C_nG_m surfactants is pH insensitive down to the so-called isoelectric point, while that of foam films stabilized by C_iE_j surfactants changes linearly with the pH. Thirdly, foams generated by β-$C_{12}G_2$ are much more stable than foams generated by $C_{12}E_6$. The fourth difference is related to interaction forces between solid surfaces. Under equilibrium conditions very high forces are needed to expel β-$C_{12}G_2$ from between thiolated gold surfaces, while for $C_{12}E_6$ low loads are sufficient. What is the reason for this different behaviour? Under similar conditions and for comparable head group sizes, it was found that the hydration of C_iE_j surfactants is one order of magnitude higher but on average much weaker than that of C_nG_m surfactants. Moreover, C_nG_m surfactants possess a rigid maltoside unit, while C_iE_j surfactants have a very flexible hydrophilic part. Indeed, most of the different properties mentioned above can be explained by the different hydration and the head group flexibilities. The intriguing question of how mixtures of C_iE_j and C_nG_m surfactants would behave arises organically. Thus various properties of $C_{12}E_6$ + β-$C_{12}G_2$ mixtures in aqueous solution have been studied with a focus on the 1:1 mixture. The results are compared with those of the single surfactants and are discussed accordingly.

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O33

Dynamics of free liquid films during formation of polymer foams

T. Gambaryan-Roisman

Chair of Technical Thermodynamics and Center of Smart Interfaces,
Technische Universität Darmstadt, Darmstadt, Germany
Email: gtatiana@ttd.tu-darmstadt.de

One of the routes of formation of polymer foams is based on bubble generation from the condensation products of cross-linking reactions, i.e. water, ethanol and benzene. This self-foaming process is often applied to preceramic polymer precursors, such as phenylmethyl polysilesquioxanes. The polymer foam is converted into ceramic foam by pyrolysis [1]. During the heating-induced cross-linking of polymer melts the bubbles are nucleated on the walls of a vessel, rise due to buoyancy to the liquid surface and form a bubble raft similar to that which can be observed in a glass of champagne [2]. Some of the bubbles collapse due to the thinning and rupture of a free liquid cap-formed film separating the bubble from the surrounding gas. The thinning of the free liquid film depends on the rheological parameters of the melt which change with time due to progressing of the cross-linking reaction. The foaming rate depends on the relation between the bubble collapsing rate and the rate of the growth rate of the bubble raft at the liquid surface.

The dynamics of free liquid films as applied to foam formation and stability has attracted attention of many investigators [3]. However, the effect of viscoelasticity on the film thinning rate during the formation of foams has never been studied. In this work we investigate theoretically and numerically the dynamics of free viscoelastic films during formation of foams from polymer melts. The upper-convected Maxwell model is used for the description of the polymer melt rheology [4]. The results allow to evaluate the time needed for the film rupture and therefore to predict the rate of the foam formation.

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IL14

Highly stable nonaqueous foams in glycerol-based nonionic surfactant/oil systems

L. K. Shrestha[1], K. Ariga[2], K. Aramaki[1]

[1]*Graduate School of Environment and Information Sciences, Yokohama National University, Yokohama, Japan*
[2]*WPI Center for Materials Nanoarchitectonics, National Institute for Material Science, Tsukuba, Japan*
Email: lokkumar@hotmail.com

Nonaqueous foams stabilized by lamellar liquid crystal (L_α) and surfactant solid (α-solid) dispersions in glycerol-based nonionic surfactant/olive oil systems are presented. The foam formation capacity (foamability) was increased with the surfactant concentration up to a certain point and then levelled off [1,2]. However, the foam stability was increased monotonically. In the diglycerol monolaurate ($C_{12}G_2$) system, which consists of L_α dispersion in the dilute regions [3], the foams were stable for a few minutes to several hours depending on the surfactant concentration. Foams were stable for ~ 20 min and 6 h in 1% $C_{12}G_2$ and 10% $C_{12}G_2$ systems, respectively. The stable foam was possible, as the dispersed particles tend to adsorb at the gas-liquid interface. Foam stability of the $C_{12}G_2$ system was comparable to the diglycerol monomyristate ($C_{14}G_2$) system, which is essentially the dispersion of α-solid [3], but only at lower concentration (1%). However, the foam stability of the $C_{14}G_2$ system at higher concentration was drastically enhanced. Foams were stable for several weeks [2]. Fig. 1 shows the evolution of foam volume with time for the 5% $C_{12}G_2$ and $C_{14}G_2$ systems. From the results, it can be concluded that
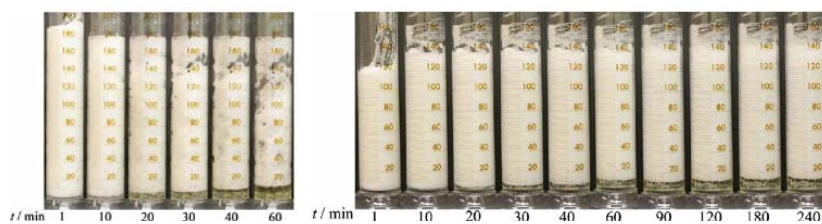

Fig.1 Foam volume vs time: 5% $C_{12}G_2$ system (left), and 5% $C_{14}G_2$ system (right).

the α-solid dispersions would offer nonaqueous foams with better stability compared to the L_α dispersions. This is possibly due to the fact that the solid particles would make gas-liquid interface more rigid. Besides, higher viscosity of the α-solid dispersion compared to the L_α dispersion might have some contribution. Addition of water drastically reduces the foam stability of the $C_{14}G_2$ system as water causes α-solid to L_α phase transition.

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PA1

The minimal perimeter for N confined deformable bubbles of equal area

S.J. Cox, E. Flikkema

Institute of Mathematics and Physics, Aberystwyth University, Aberystwyth, UK
Email: foams@aber.ac.uk

A dry foam is a collection of polyhedral bubbles surrounded by thin films. The surface energy of a two-dimensional foam is the total length of the films multiplied by the surface tension of each one. A foam in equilibrium attains a local minimum of this energy, subject to the constraint of fixed bubble areas. In doing so, it satisfies the Laplace Young Law and Plateau's rules: each film is a circular arc and they meet in threes at angles of 120°. For bubbles filling the plane, the hexagonal honeycomb has been proved to be optimal in this sense of having minimum total perimeter. Instead, we consider finite collections of equal-area bubbles and seek their minimum perimeter topology and geometry.

We calculate candidates to the least perimeter partition of various polygonal shapes into N planar connected equal-area regions for $N \leq 42$. The total perimeter and the number of peripheral regions are presented, and the patterns classified according to the number and position of the topological defects, that is non-hexagonal regions (bubbles). The optimal partitions of an equilateral triangle are found to follow a pattern based on the position of no more than one defect pair, and this pattern is repeated for many of the candidate partitions of a hexagon. Partitions of a square and a pentagon show greater disorder.
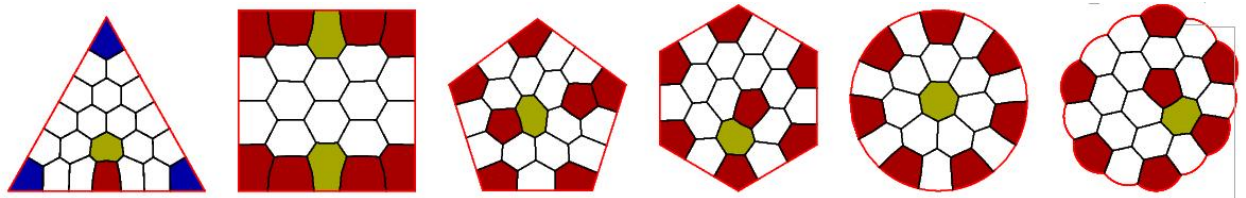

Figure 1: Candidate configurations for the least perimeter division of an equliateral triangle, square, regular pentagon and hexagon and a disc into 22 regions of equal area, compared with the prediction for a free cluster. Bubbles are coloured according to their topological charge.

Candidates to the least perimeter partition of the surface of the sphere into N connected equal-area regions are also calculated. For small N these can be related to simple polyhedra and for $N \geq 14$ they consist of 12 pentagons and N-12 hexagons.

PA2

Viscous froth simulations of sheared bubble staircases with surfactant mass transfer and Marangoni effects

<u>B. Embley</u>, P. Grassia

School of Chemical Engineering and Analytical Science
The University of Manchester, PO Box 88, Sackville St, Manchester M60 1QD, UK
Email: ben.embley@manchester.ac.uk

Confining a single layer of bubbles between two glass plates results in a quasi-2D structure. Various models for flowing or sheared 2D foams exist, but one especially applicable for fast-flowing, 'dry' foams is the viscous froth model [1]. In this model, a viscous term is added to what is otherwise the Young–Laplace law governing film curvature [2]. Recently, the viscous froth model has been used to study a rapidly sheared, periodic staircase of bubbles [3].

We introduce into the viscous froth model an additional element: locally variable surfactant concentration. Since the viscous froth model is most relevant where film velocities are greatest—and thus where the viscous contribution to the model is most noticeable—it is worth considering the effect of the motion of surfactant throughout these rapidly deforming films. Local variations in surfactant concentration imply local variations in surface tension, an important parameter in both the Young–Laplace law and the viscous froth model. In our model, the local surfactant coverage of a film element can change due to two factors: first, a linearized mass transfer term, which considers the surfactant concentration in the surrounding liquid bulk to act as a surfactant 'reservoir' or 'sink'; second, the tendency of Marangoni forces to resist the stretching of film elements [4] and hence resist the redistribution of surfactant molecules along the length of a stretching, shrinking, or sheared film.

In a foam undergoing rapid shear, the bulk transfer effect and the Marangoni effect can compensate one for the other—but at their own distinct time scales. We investigate these two time scales in relation to shear capillary numbers for a periodic bubble staircase. Notably, times to induce topological rearrangements of bubbles may increase, and angles at three-fold vertices may deviate considerably from 120º.

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PA3

Simulation of mass transfer in circulating drops with applications to liquid-liquid extraction

S. Ubal, C. H. Harrison, P. Grassia, W. Korchinsky

CEAS, University of Manchester, PO Box 88, Sackville St, Manchester M60 1QD, UK
paul.grassia@manchester.ac.uk

Liquid-liquid extraction is a common chemical engineering process in which solute is transferred between two solvent phases prepared in a bi-liquid emulsion. Circulation of liquid within emulsion droplets can help to accelerate the rate of mass transfer, by bringing solute from deep within the drop interior to the surface, where it can transfer to the continuous phase. Determining the extent to which mass transfer is enhanced by the droplet circulation requires knowledge of the microfluidic circulation patterns within and around droplets. It is found that simulating the solute mass transfer is inherently expensive because mass transfer is typically much slower than the circulation, typically by a factor of 10000. Simulations must still resolve the rapid streamline orbits, even though the mass transfer processes of interest are orders of magnitude slower. An alternative semi-analytic boundary layer theory of mass transfer in the presence of circulation is developed, but is found to agree poorly with full numerical simulations on the time scales of primary interest. Instead a streamline-averaged theory of mass transfer (in which solvent concentration is uniform along streamlines, but varies both from streamline to streamline and over time) shows much better agreement with the full simulations.

PA4

Spontaneous ordering of oicro-bubbles in a capillary tube

H. K. Chan[1], A. J. Meagher[1], A. M. Mughal[2,3], D. Weaire[1] and S. Hutzler[1]

[1]*Foams and Complex Systems, School of Physics, Trinity College Dublin, Ireland*
[2]*Institute for Scientific Interchange Foundation, Torino, Italy*
[3]*Institute of Mathematical and Physical Sciences, University of Aberystwyth, United Kingdom*
Email of H. K. Chan: epkeiyeah@yahoo.com.hk

Spontaneous formation of ordered structures has been observed experimentally for monodisperse micro-bubbles inside cylindrical capillary tubes of a few hundred microns in internal diameter. Such crystallization into wet foams is analogous to the self-ordering of dry foams in confined geometries [1]. For cases where the internal diameter of the capillary tube is no greater than twice the bubble diameter, ordered zigzag structures of spherical micro-bubbles have been observed (Fig. 1). It was found that such zigzag structures mimic the zigzag structures of close-packed hard spheres as obtained from computer simulations [2] (Fig. 2), which suggests that the micro-bubbles, despite being deformable, self-assemble as if they were frictionless hard spheres. Note that in real experiments hard spheres do not readily self-organize into ordered structures, presumably due to the presence of friction, which is, however, much reduced in the case of micro-bubbles. Further results on the observation of a variety of close-packed structures in cylinders will be reported for both micro-bubbles and hard spheres. [Research supported by the European Space Agency (MAP AO-99-108: C14914/02/NL/SH and AO-99-075: C14308/00/NL/SH) and Science Foundation Ireland (08/RFP/MTR1083)]
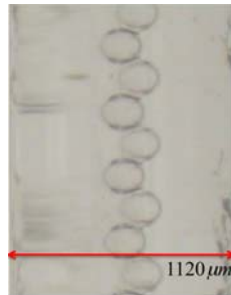
Figure 1 Ordered zigzag structure of micro-bubbles of diameter $\sim (185 \pm 10)$ microns in a capillary tube of internal diameter $\sim (260 \pm 10)$ microns. The ratio between the internal diameter of the tube and the bubble diameter is $D' \sim 260 / 185 \sim 1.4$, and the volume fraction is approximately equal to 0.4.
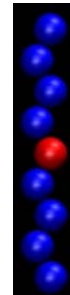
Figure 2 Zigzag structure of close-packed hard spheres for the case of $D' = 1.4$ as obtained computationally from the method of simulated annealing. The volume fraction is equal to 0.37, which is comparable to the experimental value of 0.4.

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PA5

Modelling of sandwich plates with aluminum foam core subjected to drop-weight impact

I. Irausquin[1,2], F. Teixeira-Dias[3], V. Miranda[3], J.L. Perez-Castellanos[1]

[1]*Dept. of Continuum Mechanics & Structural Analysis, U. Carlos III de Madrid, Leganes, Spain*
[2]*Department of Industrial Technology, Universidad Simon Bolivar, Caracas, Venezuela*
[3]*Dept. of Mechanical Engineering, Universidade de Aveiro, Aveiro, Portugal*
Email address: iirausqu@ing.uc3m.es

Sandwich structures are commonly used to improve the impact resistance by using an energy absorbent core like for instance the metal foams. In this research has been conducted the numerical evaluation of aluminum sandwich plates with an aluminum foam core subjected to impact by drop-weight testing (DWT). This has been done through simulations with the finite element (FE) code ABAQUS. A parametric study concerning different elements and conditions, as well as relative thicknesses of the plate specimens, was carried out. Energy absorbed during impact was estimated using the force-displacement (F-δ) curves obtained for various impact velocities. The implementation of the numerical model has involved the considering of an isotropic hardening for the metal foam core whereas for the skins linear elastic with Johnson-Cook plasticity model was assumed. Results have allowed inferring the effect of the geometrical parameters considered on the energy absorption performance of the sandwich and therefore better understand the response to impact loads of these structures.

Keywords: Low-velocity impact, finite element analysis, closed-cell foam.

PA6

Numerical models of metal foams for the simulation of machining

N. Kalchunkova, R. Guerra, U. Teicher, A. Nestler

Institute of Forming and Cutting Manufacturing Technology, Workgroup of Production Automatization, Cutting and Erosion Manufacturing Engineering, University of Technology, Dresden Germany
nina@mciron.mw.tu-dresden.de

Metal foams are generally manufactured to their final shape by sintering, but sometimes additional machining operations are necessary. However conventional cutting and machining techniques cause surface distortion or damage that make them only practical for rough cutting.

Because of the higher productivity, lower costs and versatility of conventional machining, it could be advantageous to widen its applicability and improve its productivity in the manufacturing of metal foam parts. To that end, a deeper understanding of the chip formation in the machining of metal foams is needed.

Machinability tests of titanium foams and stainless steels are possible [1, 2]. However, given the high cost of the foams and the diversity of materials and structures to be evaluated, it would be impractical to perform them.

An alternative to those tests is the development of a numerical model of the metal foams capable of predicting the response of these materials under the machining conditions. It would make possible to analyze the chip formation process and enable the optimization of the machining operations.

In the present work diverse numerical models of metal foams are explored. Guidelines for the development of a model are presented. Finally, the development of a 2D finite element model for metal foams is described. Results for compression tests of this model are also presented and discussed.

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PA7

Jammed static foam packings: contacts, tesselations and forces

G. Katgert[1,2], M. van Hecke[2]

[1]*Institute for Physics, University of Edinburgh, Edinburgh, United Kingdom.*
[2]*Kamerlingh Onnes Laboratorium, Universiteit Leiden, Leiden, The Netherlands.*
Email: g.katgert@ed.ac.uk

We experimentally generate jammed, two-dimensional packings of foam bubbles. We vary the area fraction ϕ of bubbles and investigate the contact network of the bubbles, both locally and globally, the distribution of free area in the foam and finally the distribution of contact forces between bubbles. All these measures compare favourably to theoretical predictions and show that foams are eminently suited to investigate critical scaling at the jamming (= rigidity loss) transition, of which we show the first experimental measurement.

PA8

Point response in foams: correlated rearrangements

G. Katgert[1], <u>W.C.K. Poon</u>[1]

[1]*Institute for Physics, University of Edinburgh, Edinburgh, United Kingdom.*
Email: g.katgert@ed.ac.uk

We inflate a central bubble in a two dimensional jammed packing of foam bubbles, floating on a soapy solution and confined by a glass plate. The resulting stress field is well defined and we study rearrangements in the foam layer as a result of the inflation. We investigate spatial correlations between rearrangements to probe non-local plasticity.

PA9

Processing conditions and structure of sol-gel matrices

Hélder Vila-Real[1], Maria H. Ribeiro[1], <u>M. Emília Rosa</u>[2]

[1]*Faculty of Pharmacy and Institute for Medicines and Pharmaceutical Sciences (i-Med-UL),
University of Lisbon, Lisbon, Portugal*
[2] *Department of Materials Engineering - Instituto Superior Técnico and Institute of Mechanical
Engineering (IDMEC), Technical University of Lisbon, Lisbon, Portugal
Email: emilia.rosa@ist.utl.pt*

In this work, a biocatalytic system was chosen to enable the deglycosylation of natural glycosides in order to improve their biological activity. Naringinase, which has both alpha-L-rhamnosidase and beta-D-glucosidase activities, was the enzyme used. Naringin, the glycoside substrate used in this bioconversion, and its aglycone product naringenin are compounds with interesting pharmacological activities such as anti-oxidant and anti-inflammatory properties; naringenin also acts as an anti-carcinogenic and neuroprotective agent, demonstrating a high potential for use by the pharmaceutical industry [1].

Sol-gel, an innovative technique performed in aqueous media, was developed for naringinase immobilization in lens-shaped particles.

Two sol-gel precursors, tetramethoxysilane (TMOS) and diglycerylsilane (DGS), were used, separate and mixed. In other experiments glycerol was added to TMOS matrix.
Experiments with different pH values (4, 5 and 6) and different ratios of TMOS/DGS were undertaken.

The samples produced with TMOS/glycerol were dried in open, half-open and closed system conditions.

The structure of the different matrices produced was observed using scanning electron microscopy - field emission gun (FEG-SEM).

The correlations between structure and bioprocessing conditions were established.

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PA10

Structural and finite element analysis of tomographic data for closed cell aluminium foam subject to uni-axial compression

M. Saadatfar[1], A. Jones[1], S. Hutzler[2], M. Mukhrejee[3], G. Schroeder-Turk[4], F. Garcia-Moreno[3], J. Banhart[3], U. Ramamurty[5], D. Weaire[2]

[1]School of Physics, Australian National University, Canberra, Australia
[2]Trinity College, Dublin, Ireland
[3]Helmholtz-Zentrum Berlin, Germany
[4]Institut für Theoretische Physik I, Friedrich-Alexander Universität, Erlangen, Germany
[5]Department of Materials Engineering, Indian Institute of Science, Bangalore, India
mos110@physics.anu.edu.au

In this study we report experimental and numerical results on the mechanical properties of a closed-cell Aluminium foam tested in a uniaxial compression experiment with lateral constraint. We use X-ray tomography to determine changes in the structure of Al foam. By combining the tomographic data with a finite element method (FEM), we investigate the effect of strain hardening by calculating the elastic moduli of the foam sample at each stage of compression.

The tomograms are of sufficient resolution to calculate a range of structural and material properties. Advanced image analysis is carried out to extract geometrical and topological properties of the metallic foam subject to compression. We also search for signatures of anisotropy in the datasets using a novel mathematical approach.

We discuss the effect of compression on the spatial distribution of the relative density of the foam. We show that strain hardening occurs where larger cells with a particular orientation are located. Locally some cells collapse but most change geometry to a pancake-like shape as the sample is compressed.

PA11

Ordered dry foams in tubes with circular, triangular and square cross-section

S. Hutzler, J.D. Barry, S.T. Tobin, B. Bulfin and D. Weaire

Foams & Complex Systems, School of Physics, Trinity College Dublin, Ireland
Email: tobinst@tcd.ie

Soap bubbles of equal volume readily crystallize as ordered polyhedral foam structures when introduced into tubes whose width is of the same order as the bubble diameter and larger than the capillary length [1]. In the past a large number of these structures have been identified experimentally for cylindrical tubes [2]. The surface energy per bubble was computed using Ken Brakke's Surface Evolver software [3]. We have now extended this work to tubes with square [4] and triangular cross-section and present both experimental data and results of Surface Evolver calculations for a variety of new ordered foam structures.
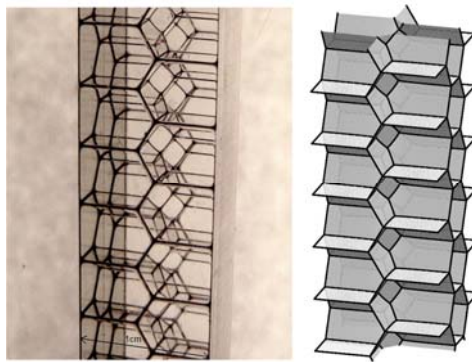
Spontaneous crystallization of equal volume soap bubbles in a column of square cross-section, as seen in experiment and simulation.

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PB1

Droplets rearrangement rates of flowing monodispersed emulsions

N. Bennani[1], P. Jop[1], V. Mansard[1], A. Colin[1], and L. Bocquet[2]

[1] *LOF, unité mixte Rhodia-CNRS-Bordeaux 1, 178 avenue du Docteur Schweitzer,*
F-33608 Pessac cedex – France
[2]*Laboratory, LPMCN, Université Lyon 1, Université de Lyon, UMR CNRS 5586, 69622 Villeurbanne*
– France
Email: Nora.BENNANI-EXTERIEUR@eu.rhodia.com

In the present work, flows of emulsions and of microstructures in confined geometries are investigated. Previously, non local effects have been evidenced and modelled [1]. Fluidity, the number of rearrangement of droplets by unit of time, is the only parameter needed by this model to obtain good agreement with experimental data. It is determined using fast confocal imaging for different types of glassy materials and it is used to go further with this model and to obtain a better understanding of rheological behaviour of complex fluids.

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PB2

Two-phase hydrodynamic model for air entrainment at the advancing contact line

<u>T.S. Chan</u>, J.H. Snoeijer

Physics of Fluids Group, University of Twente, the Netherlands
Email: t.t.s.chan@tnw.utwente.nl

The moving contact line problems are challenging because they involve multiple length scales. One interesting case arises when an advancing liquid of high viscosity entrains the surrounding phase, such as air. In this presentation, we introduce a hydrodynamic model that generalizes the lubrication theory in order to take into account the velocity fields of the two phases. Assuming that the curvature of the interface is small we derive a differential equation for the interface profile at stationary state. We found that there is a critical capillary number above which no steady meniscus can exist and instability will occur. For example, air bubbles will be entrained into the liquid at the advancing contact line. However, we found no instability when neglecting the viscosity of the surrounding phase, illustrating the two-phase nature of the problem.

PB3

Origin of fast linear relaxations in foams

S. Costa, R. Höhler, K. Krishan, S. Cohen-Addad

LPMDI, Université Paris-Est, Champs-sur-Marne, France
Severine.Costa@univ-mlv.fr

Aqueous foam exhibits solid-like or liquid-like behaviours, depending on the applied stress and experimental timescale. It behaves as a linear viscoelastic material for small applied stress, with a large spectrum of relaxation times over 6 decades in frequency [1]. Quasi-static foam elasticity, due to the surface tension of the gas-liquid interfaces, as well as slow relaxations induced by the coarsening dynamics, are now well understood [2]. However, the origin of the fast relaxations, i.e. typically above 1 Hz, has not been elucidated. On one hand, Liu *et al* have predicted a collective relaxation mode where the dissipation involves mesoscopic weak regions, due to the disorder of the bubble packing [3]. On the other hand, dissipation mechanisms depending on the rigidity of the liquid-gas interfaces have been proposed [4, 5].

We investigate the fast linear viscoelastic response of foam using oscillatory measurements of the complex shear modulus G^* as a function of the frequency, in the range 1 to 100 Hz. We use a special purpose sliding plate rheometer that allows sample inertia to be taken into account. We elaborate foams of different physico-chemical constitutions, and characterize their average bubble size, liquid volume fraction, liquid bulk viscosity and interfacial viscoelasticity. The complex surface dilational modulus of the liquid-gas interface is measured using an interfacial tensiometer. We study the variations of the complex modulus G^* with frequency for foams with either mobile or rigid interfaces (low or high surface modulus) and compare our results to the predicted generic law [3]. Moreover, we study how the characteristic frequencies of the relaxations vary with the mentioned physico-chemical parameters and discuss our results in the framework of scaling predictions proposed in the literature [4, 5].

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PB4

The flow of foam through a contraction

S.A. Jones and S.J. Cox

Institute of Mathematics and Physics, Aberystwyth University, Aberystwyth, Wales
Email: saj@aber.ac.uk

An understanding of how foams behave when they move is important due to the wide variety of applications, both personal and industrial, that utilise flowing foams. These applications range from engineering processes, such as ore separation and oil recovery, to the use of foams in food preparation. The behaviour of flowing foams is complex however, as the rheology is governed by a mixture of elasticity, plasticity and viscosity.

Experiments have been carried out on two-dimensional foams flowing through a square 4:1 contraction in a Hele-Shaw cell. Images of the flowing foams were recorded (Figure 1) and analysed to determine a range of physical properties including velocity profile (Figure 2), local strain and local stress. Topological information was also gained by determining the locations of T1 events.

The results from the experiments were used to validate the results of a quasi-static simulation carried out using the Surface Evolver [1] (Figure 3). In general, it was found that there was good agreement between the experimental and simulation results. The biggest discrepancy between the model and experiment occurred in the corners upstream of the contraction (labelled with * in Figure 1). It is suggested that in these regions the experimental foam was behaving elastically.
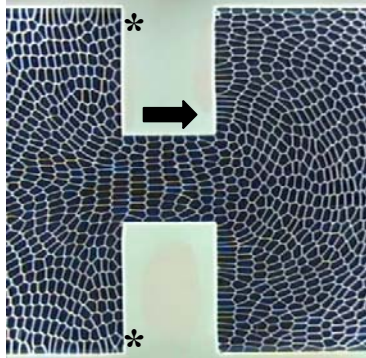

Figure 1. Image of two-dimensional foam flowing through the contraction in the Hele-Shaw cell. Flow is from left to right.
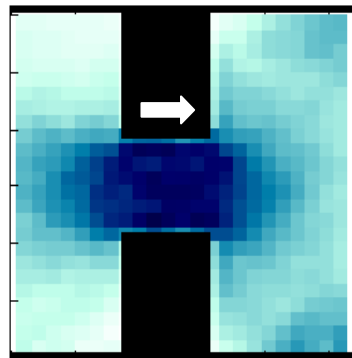
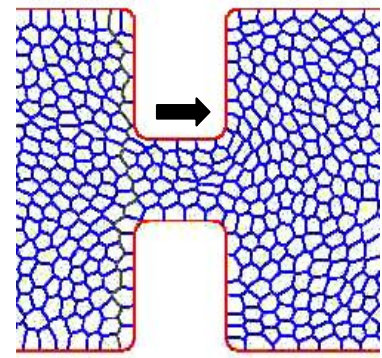Figure 2. Magnitude of the measured velocity through the contraction.

Figure 3. Image from quasi-static simulation carried out using the Surface Evolver.

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PB5

Surface rheological properties of surfactant mixtures

D. Dimitrova,[1] S. Tcholakova,[1] K. Marinova,[1] N. Denkov,[1] K.P. Ananthapadmanabhan[2]

[1]*Department of Chemical Engineering,*
Faculty of Chemistry, Sofia University, Bulgaria
[2]*Unilever Research Center, Trumbull, Connecticut 06611, USA*
Email: dt@lcpe.uni-sofia.bg

The surface rheological properties of surfactant mixtures, which contain anionic or zwiterionic surfactant as main components, and cationic surfactant cethyl trimethyl ammonium chloride (CTAC) as cosurfactant, were measured and analyzed. Characteristic feature of these mixtures is that they exhibit very high surface dilatational modulus. The effects of electrolyte and pH were studied. The experimental results showed that the electrolyte has significant effect on the induction time, required for formation of surface condensed phase in the adsorption layer, whereas pH has no significant effect on any of the surface properties studied. These surfactant mixtures were used for studies of foam rheological properties as well. As observed with other systems with high surface modulus [1], these surfactant mixtures are characterized with higher viscous stress in sheared foams and in foam-wall friction experiments (as compared to the typical synthetic surfactants).

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PB6

Role of surfactants in foam rheology

K. Golemanov,[1] S. Tcholakova,[1] N.D. Denkov,[1] K. P. Ananthpadmanabhan,[2] and A. Lips[3]

[1]*Department of Chemical Engineering, University of Sofia, Sofia, Bulgaria*
[2]*Unilever Global Research Centre, Trumbull, Connecticut, USA*
[3]*Unilever Discover, Port Sunlight, UK*
Email: kg@lcpe.uni-sofia.bg

We present a brief overview of our recent understanding of the effects of surfactant type and bubble surface mobility on foam rheological properties [1]. The focus is on the viscous friction between bubbles in steadily sheared foams, as well as between bubbles and confining solid wall. Large set of experimental results is reviewed to demonstrate that two qualitatively different classes of surfactants can be clearly distinguished The first class is represented by the typical synthetic surfactants (such as sodium dodecylsulfate) which are characterized with low surface modulus and fast relaxation of the surface tension after a rapid change of surface area. In contrast, the second class of surfactants exhibits high surface modulus and relatively slow relaxation of the surface tension. Typical examples for this class are the sodium and potassium salts of fatty acids (alkylcarboxylic acids), such as lauric and myristic acids. With respect to foam rheology, the second class of surfactants leads to significantly higher viscous stress and to different scaling laws of the shear stress vs. shear rate in flowing foams. The reasons for these differences are discussed from the viewpoint of the mechanisms of viscous dissipation of energy in sheared foams and the respective theoretical models. The process of bubble breakup in sheared foams (determining the final bubble-size distribution after foam shearing) is also discussed, because the experimental results and their analysis show that this phenomenon is controlled by foam rheological properties.

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PC1

Thin wetting film from aqueous solution of polyoxyalkylated diethylenetriamine polymeric surfactant

Lidia Alexandrova[1], Michail Nedyalkov[2]

[1] *Institute of Physical Chemistry, Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria*
[2] *Department of Physical Chemistry, University of Sofia, 1126 Sofia, Bulgaria*
Email: lalex@chem.uni-sofia.bg

Thin wetting films from aqueous solution of a polymeric surfactant namely polyoxyalkylated diethylenetriamine (DETA) were studied on hydrophilic silica surface. The wetting (receding) contact angles θ_r of the solution on the silica surface were measured. Also the contact angles θ_{aq} of a drop of doubly distilled water on the same silica surface pre-treated with DETA polymeric surfactant solution were measured, using the sessile drop method, to support the thin film studies. On hydrophilic silica surface the θ_r-values increase with the concentration C_s and after a maximum in $\theta_r(C_s)$ curve at about $\theta_r = 22^o$ they decrease at higher C_s. Similar behaviour show the contact angle θ_{aq} , the maximum however being at about $\theta_{aq} = 35^o$. The thickness h_{eq} of wetting films from DETA, on silica surface pre-treated with surfactant solution, was measured using the microinterferometric method at various concentrations C_s. The $h_{eq}(C_s)$ curves also passing through a maximum. At low C_s below 10^{-6} mol dm^{-3} the equilibrium film thickness h_{eq} increases with increase in surfactant concentration reaching a maximum at 1.5×10^{-6} mol dm^{-3} after which it decreases with further increase in polymeric surfactant concentration. Both θ and h_{eq} show larger values in the concentration range between 2×10^{-8} and 2×10^{-5} mol dm^{-3} C_s. The analysis of the results obtained shows that the stability of wetting films from aqueous solutions of DETA has steric origin**.** The results give a reasonable picture of adsorption and orientation of the polymeric molecules on the silica surfaces.

PC2

New solid particles for liquid foam stabilization

<u>S. Faure</u>[1], Q. Crouzet[2], D. Tiffes2, G. Boutevin[2], C. Loubat[2]

[1]CEA, Nuclear Energy Division/Center of Marcoule DTCD/SPDE/LPAD, Bagnols/Cèze, France
[2]SPECIFIC POLYMERS , Clapiers (34), France
sylvain.faure@cea.fr or cedric.loubat@specificpolymers.fr

The radioactive decontamination of metallic surfaces can be performed by using aqueous foams in contact with the surface to treat: radioactive deposits are for instance removed and solubilized by the reactive liquid in the foam [1]. Because decontamination foam is a non-stable two-phase fluid with the aqueous phase representing not more than 10% of the total volume, it strongly decreases the amount of chemicals used during the decontamination processes and the secondary nuclear waste volume. In 2007-2008, the Advanced Decontamination Processes Laboratory of CEA understood the role of hydrophilic silica particles on the drainage of wet decontamination foam stabilized by alkylpolyglucosides surfactants [2].

The capability of particles to generate foam without organic surfactants was first reported by Alargova *et al, Gonzenbach et al. and Binks et al.* [3,4,5]. In 2009, we focused our work on the synthesis of new foaming spherical solid particles. By using these spherical particles in suspensions without organic surfactants, it is now possible to generate wet decontamination foams with expansion ratio around 6. We obtained wet foams with spherical bubbles of 100μm diameter by a simple flow of air in a suspension of these new fluorinated polymer grafted particles.

We prepared our new foaming particles with the help of Specific Polymers company: different foaming particles were synthesised by hydrophobization of initially hydrophilic particles (silica and alumina) through the chemical grafting on the particle surface of short-chain fluorinated polymers by alkoxysilanes or phosphonics bridges. The foamability and foam stability are strongly dependent on the adsorbability of the particles at the bubble surface, on contact angle at the air-water interface and hence on their wettability. Typical surface pressure–area isotherms and viscoelastic measurements will be discussed.

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PC3

Thin films stabilised by randomly packed spherical particles

G.Morris, S.J.Neethling, J.J.Cilliers

Department of Earth Science and Engineering, Imperial College London, UK

Particle stabilised foams are present in many industrial processes where they form a integral part of the system. One such process is froth flotation, used by the mining industry to concentrate low grade metal ores. Air is bubbled through an ore slurry collecting valuable mineral particles as it rises, a mineralised froth is formed at the top of the slurry, predominantly stabilised by the particles attached to the bubbles. Bubble bursting and coalescence within this froth phase heavily affects the efficiency of the process but is difficult to observe directly due to the dynamic and unstable nature of the froth. A model capable of simulating particle stabilised thin films has been used to investigate the methods through which the particles stabilise the system and it is results from this which will be discussed.

Small hydrophobic particles attached to the interface of a thin film will have a stabilising effect on it which varies according to their size, shape, hydrophobicity and packing arrangement within the film. 2 dimensional (2D) analytical studies by Ali et al.[1] and 3 Dimensional (3D) simulations (Morris et al.[2]) have shown that the distance between particles has a large effect on the film stability when a uniform packing arrangement is present. However in reality particles do not always pack uniformly making it necessary to investigate the effect of non-uniform packing on the stability of thin films.

A model has been created whereby spherical particles are randomly placed in a thin film with a periodic cell boundary and assigned a specific contact angle (Figure 1). The film shape for a given capillary pressure can then be found and the stability of the film ascertained. It is also possible to use the film shape to calculate the direction of particle motion due to surface tension forces and model the clumping behaviour of particles in a thin film.
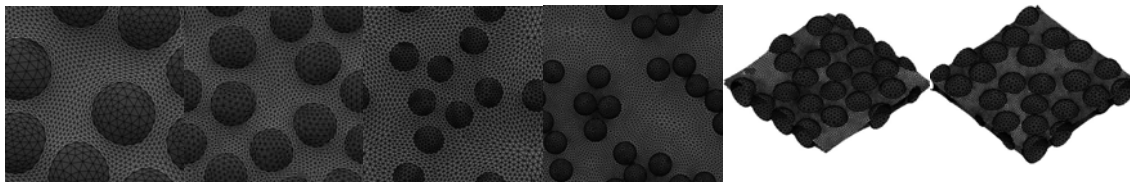

Figure 1. A selection of models used to simulate randomly spaced particles in a periodic thin film. Periods of 5, 7, 10 and 15 times the particle radius are shown.

The model was used to investigate the stability of a thin film with a single layer of randomly placed particles bridging both sides it. By running many simulations with different numbers of particles, contact angles, particle positions and periodic cell areas it is possible to build up a correlation between particle packing density, contact angle and film stability as well investigate the effects of contact angle on clumping behaviour in the film and its effect on the film's stability.

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PC4

Experimental approach of particle – bubble interactions in a flotation system

D. Michalentzaki, E.N. Peleka, Th.D. Karapantsios, <u>M. Kostoglou</u>, K.A. Matis

School of Chemistry, Aristotle University of Thessaloniki, Thessaloniki, Greece
Email: kostoglu@chem.auth.gr

Adhesion of a particle to a liquid/bubble interface is an important phenomenon experienced in many processes, including flotation processes. Particle adhesion depends upon the surface properties of the bubble and particle and upon the fluid mechanics of the system. The probability of particle attachment to a bubble surface is governed by several sub-processes. For adhesion to occur, a particle must be first intercepted by the bubble, then the particle must slide along the bubble surface until, finally, a stable three-phase contact line be formed. The important sub-processes are difficult to directly observe due to the very small length and time scales involved.

In this study, a novel experimental set-up has been built to investigate particle - bubble interaction. Instead of having many bubbles rising and solid particles floating more or less freely in the liquid, the situation is simplified and reversed. That is, there is just a single bubble standing at a fixed position against which a suspension of solid particles is moving. The approaching velocity of particles is adjusted by a miniature pump in combination with a control valve and a rotameter. Particles are initially brought in suspension inside a big tank by means of four high speed liquid streams ejected at each corner of the tank. An axial impeller is used next to maintain the particles in suspension. The experimental convenience in this scheme is apparent, as one need not to follow the swirling trajectory of a rising bubble but merely keep the surface of the stagnant bubble in focus. High-speed, high-magnification imaging allows direct observation of the interactions between a bubble and particles at different experimental conditions. Visualization and digital image analysis for the study of particle adhesion to a stationary bubble in a flow field will be presented. The system allows quantification of the effect of surface active agents, bubble and particle size, approaching velocity of particles on particle-to-bubble attachment and examination of the adhesion stability.

In the current research a well known flotation system was investigated. This consisted of hydrotalcite particles having 15 μm mean diameter and positive zeta potential up to pH 11. Different concentrations of sodium dodecyl sulphate in distilled water gave to the particles different surface degree of hydrophobicity. A commercial flocculant, magnafloc 1011, was also used in order to aggregate the fine particles. During the experiments, it was observed that after colliding with the surface of the bubble, some of the particles move along the circumference down to the bottom and attach stably to the bubble, while others detach from the bubble before or after reaching the bottom of the bubble. It could be stated that with increasing collector concentration, the probability of particle – bubble adhesion increases up to a limiting value. On the other hand, increasing the particles' approaching velocity yields lower adhesion probabilities.

PC5

Functionally graded polystyrene foams as advanced cushioning materials

F. Schüler[1], M. D. Gilchrist[2,3], C. Stubenrauch[1,4],

[1]*School of Chemical and Bioprocess Engineering, UCD Dublin, Ireland*
[2]*School of Electrical, Electronic and Mechanical Engineering, UCD Dublin, Ireland*
[3]*School of Human Kinetics, University of Ottawa, Canada*
[4] *Institut für Physikalische Chemie, Universität Stuttgart, Germany*
Email: fabian.schueler@ucd.ie

Foams are widely used as cushioning materials as they can absorb huge amounts of impact energy. Their mechanical behaviour is mainly related to the material properties of matrix and pores and the foam's cellular structure. The latter depends on parameters such as pore size, pore size distribution, wall thickness and volume fraction [1]. It is well-known that foams with lower densities possess larger stress-plateaus, whereas higher density foams display a higher strength.

Due to the conventional manufacturing methods most commercial foams have uniform microstructures. However, property uniformity is in many cases an inefficient approach to optimizing material performance [2]. Simulations by *Cui et al.* [3] conclude that functionally graded foams can perform significantly better than uniform materials. In order to synthesize such materials, the development of new manufacturing strategies is required.

We are currently investigating an approach to generate graded hydrophobic foams from polymerizable water-styrene emulsions. Stabilization is expected to be provided by emulsion droplets, as it is known that particles can be applied to foam synthesis [4,5]. We found that foams remain stable for several hours from mixtures containing styrene and SDS surfactant with a water content of about 30 vol.-%. First results show that styrene droplets assemble around gas bubbles inducing stability. Structuring is expected to be achieved by a layer-wise build-up, applying microfluidic techniques. It is this layered liquid precursor which has to be polymerized in the final step in order to obtain a solid graded foam material with a defined gradient of the pore size.

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PC6

Highly stable pickering-emulsions and the role of interfacial network formation

R. Wüstneck, J. Krägel, R. Miller

Max Planck Institute of Colloid and Interface Science, Potsdam, Germany
Email: Rainer.Wuestneck@mpikg.mpg.de

O/W Pickering emulsions spontaneously formed by silica or magnetite particles, water and methacryloxypropyltrimethoxysilane (TPM) were described by Sacanna et al. [1,2] to be thermodynamically stable. The driving force for the stability of these emulsions is an inverse Ostwald ripening, which re-establishes constantly the starting size distribution of emulsion droplets and implies the existence of a favoured curvature at the droplet interface.

This new type of thermodynamically stable emulsions was found to form so far only with TPM as an oil phase. TPM can polymerise by both, polymerisation of the methacryl, and a hydrolysis of the silane groups. The first process can be controlled by temperature, and/or UV light, and the presence of a initiator. The second one starts immediately when TPM comes into contact with water, forms visible structures at the interface in presence of adsorbed nanoparticles, and can not be stopped. It only can be reduced at low temperatures which allowed us to control the interfacial purity of the oil phase used by interfacial tension measurements. In order to characterise the role of the formation of an interfacial silane network including nanoparticles adsorbed for the emulsion stability we investigated a number of different emulsions formed by using trimethylsilylmethacrylate, methacryloxypropyltris (trimethylsiloxy) silane, and octadecyltrimethoxysilane, i.e. oil phases which differ only slightly from the TPM structure. The results show that the formation of an interfacial network is one of the prerequisites to form extremely stable emulsions thus opening up further possibilities to create similar emulsions and to test other interfacial stabilizing mechanisms.

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PD1

Foam films from mixed solutions of proteins and *n*-dodecyl-β-D- maltoside

<u>Zh.K. Angarska</u>[1] A.A.Elenskyi[2], G.P.Yampolskaya[2] and K. D. Tachev[1]

[1]Faculty of Natural Sciences, University of Shumen, Bulgaria
[2]Department of Colloid Chemistry, Moscow State University, Russia
Corresponding author: angarska@shu-bg.net

The model foam film study is an ideal tool to learn about the film and foam stability which usually is discussed in terms of surface forces act in the film. New data for foam films from mixed aqueous solutions of important components (sugar-derivative surfactant and proteins) are of interest in large–scale technical and highly specified biotechnological products, including foams.

The present study is dealing with the *non-ionic surfactant n*-dodecyl-β-D-maltoside (β-$C_{12}G_2$) and its mixtures with *globular proteins* - bovine serum albumin (α- hylical type) or lysozyme (α+β type).

The aim of the study is to find the region of total surfactant concentrations where protein-surfactant complexes are formed and to investigate the drainage, stability and properties of foam films obtained at these conditions.

The equilibrium surface tension isotherms of mixed aqueous solutions of bovine serum albumin or lysozyme with *n*-dodecyl-β-D-maltoside are obtained by Wilhelmy method. It is found that protein-surfactant complexes are formed at concentration regions 5×10^{-6} -2×10^{-5} and 1×10^{-5} -3×10^{-5} mol/l of bovine serum albumin and lysozyme, respectively.

Thinning of the films stabilized by mixtures of protein (10^{-6}, 10^{-5} mol/l bovine serum albumin; 3.5×10^{-7} mol/l lysozyme) and varied *n*-dodecyl-β-D-maltoside concentration is recorded and compared with this of the individual components. It is found that the films from mixed protein-surfactant solutions, exhibit irregular thinning behaviour and thickness nonhomogeneity. An attempt to analyze the rate of film drainage with a new formula accounting the dynamic structure by a fractal dimension is demonstrated. The equilibrium thickness of stable films is measured interferometrically and discussed based on the specificity of interactions between the components.

Keywords: bovine serum albumin; lysozyme; surface tension; film drainage; equilibrium thickness.

PD2

Foam films stabilized by *n*-dodecyl-β-D-maltoside, hexaethyleneglycol monododecyl ether, and their 1:1 mixture

N. Buchavzov[1], D. Varade[2], E. Carey[3], <u>J. Boos</u>[1], C. Stubenrauch[1]

[1] *Institute of Physical Chemistry, Universität Stuttgart, D-70569 Stuttgart, Germany*
[2] *Laboratroire de Physique des Solides, Université Paris Sud, 91405 Orsay, France*
[3] *School of Chemical an Bioprocess Engineering, University college Dublin, Dublin 4, Ireland*
Email: j.boos@ipc.uni-stuttgart.de

The behaviour of foam films stabilized by a 1:1 mixture of two non-ionic surfactants, namely *n*-dodecyl-β-D-maltoside (β-$C_{12}G_2$) and hexaethyleneglycol monododecyl ether ($C_{12}E_6$), at different concentrations (0.1 cmc, 0.5 cmc, cmc, 2 cmc, 5 cmc) was studied. The disjoining pressure Π was measured as a function of the film thickness *h* (Π-*h* curves) with the *thin film pressure balance* (TFPB) [1, 2]. At *c* < cmc, the β-$C_{12}G_2$:$C_{12}E_6$ = 1:1 mixture shows the same behaviour as that of the single non-ionic surfactants [3, 4]: 1) an increase of the surfactant concentration leads to the formation of thinner CBF; 2) the stability of the CBF increases with increasing surfactant concentration; 3) the surface charge density does not change at small concentrations and decreases significantly at higher concentrations; 4) with increasing concentration the formation of a stable NBF is observed. At *c* ≥ cmc, some unforeseen observations were made, namely: 1) the formation of a CBF at *c* > cmc, which has never been observed for single non-ionic surfactants at pressures > 100 Pa; 2) the duration of the CBF-NBF transition which was very slow (some hours) compared to that of single surfactants (some minutes); 3) the irreproducibility of the Π-*h* curves. In this contribution a possible explanation for the unusual behaviour of the β-$C_{12}G_2$:$C_{12}E_6$ = 1:1 mixture is discussed. In particular, the high surface charge density at high concentrations and the slow CBF-NBF transition are explained assuming a slow microscopic phase separation into a surfactant-rich and a surfactant-poor phase. If the surfactant-poor phase formed a CBF, while the surfactant-rich phase formed an NBF, two film thicknesses would coexist over a long time (because of slow phase separation) in agreement with the experimental observation.

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PD3

Foam film studies of a rhamnolipid biosurfactant produced from a new Pseudomonas aeruginosa BN10

R. Cohen[1], N. Christova[2], Boryana Tuleva[2], I. Terziev[1], I. Stoineva[3]

[1]*Institute of Physical Chemistry, Bulg. Acad. Sci., 1113, Sofia, Bulgaria*
[2]*Institute of Microbiology, Bulg. Acad. Sci., 1113 Sofia, Bulgaria*
[3]*Institute of Org. Chemistry with Centre of Phytochemistry, Bulg. Acad. Sci., 1113 Sofia, Bulgaria*
Email: cohen@ipc.bas.bg

Studies of the formation and stability of different types of foam films formed from novel rhamnolipid biosurfactants are carried out using the Scheludko-Exerowa method for microscopic foam film studies. Biosurfactants gain importance in the recent years because of the broad range of potential applications in different technologies as well as for bioremediation of polluted environment. In the present study rhamnolipids were produced by *Pseudomonas aeruginosa* BN10 isolated from hydrocarbon-polluted soil when cultivated on 2% glycerol, glucose, n-hexadecane and n-alkanes. Eight structural homologues of these rhamnose-containing lipids were identified: $Rha-C_{10}-C_8$, $Rha-C_{10}-C_{10}$, $Rha-C_{10}-C_{12:1}$, $Rha-C_{10}-C_{12}$, $Rha_2-C_{10}-C_8$, $Rha_2-C_{10}-C_{10}$, $Rha_2-C_{10}-C_{12:1}$ and $Rha_2-C_{10}-C_{12}$. The obtained rhamnolipid mixture reduced the surface tension of pure water from 72 to 29 mN m^{-1} at a critical micelle concentration of 40 mg l^{-1} and the interfacial tension was 0.9 mN m^{-1}. The foam stabilizing properties of the rhamnolipid mixture were characterized by measurements of the probability for black film formation of films formed from the rhamnolipid mixture with NaCl added at concentrations 0.15 mol dm^{-3} (common black films) and 0.8 mol dm^{-3} (Newton black films). It was found that below the critical rhamnolipid concentration $C_c = 16$ mg ml^{-1} it was not possible to obtain black films. Black foam films were formed with a probability of 100% in the region of the C_t concentration of 40-50 mg ml^{-1}. The thickness of the obtained foam films was measured at a concentration of 50-60 mg ml^{-1}, where stable black films are formed with a probability of 1. Using a special procedure, the rhamnolipids were separated and foam films were formed from solutions of rhamnolipids with one rhamnose group (Rha_1) and with two rhamnose groups (Rha_2). It was found that the properties of the films formed from the mixture were to a larger extent determined from the adsorption of the less soluble and more surface active Rha_1.

PD4

Effect of rhamnolipids on pulmonary surfactant foam films

R. Cohen, R. Todorov, G. Vladimirov, D. Exerowa

Institute of Physical Chemistry, Bulgarian Academy of Sciences, Acad. G. Bonchev str. bl.11, Sofia 1113, Bulgaria.
Email: cohen@ipc.bas.bg

The effect of a rhamnolipid biosurfactant (RhL) on pulmonary surfactant is studied employing the Scheludko-Exerowa microinterferometric black foam film method. Pulmonary surfactant is modeled by a commercially available lung surfactant preparation (LSP). RhL of microbial origin was kindly donated by Jeneil Biosurfactant Company, USA, as a mixture of Rh2/Rh1 at a ratio of 0.69. Rh1 (α-L-rhamnopyranosyl-β-hydroxydecanoyl-β-hydroxy-decanoate) has one rhamnose group. Rh2 (2-O-α-L-rhamnopyranosyl-α−L-rhamnopyranosyl- β-hydroxydecanoyl-β-hydroxydecanoate) has two rhamnose groups linked with an ether bridge of oxygen. The effect of RhL concentration on the formation and stability of films formed from mixtures of LSP and RhL is experimentally studied by measurements of the probability W of formation of black foam films as a function of the concentrations of LSP, RhL, and their mixtures at the physiologically relevant electrolyte concentration C_{el} = 0.15 mol dm^{-3} NaCl. The obtained curves show that addition of RhL at a concentration C_{RhL} = C_c (critical concentration of black foam film formation) to LSP suspensions causes destabilization of the foam films. In this case additional quantities of LSP are needed to obtain black films with probability W = 100%

The monitoring of the effect of electrolyte and RhL concentrations on the thickness *h* of the foam films evidence the adsorption and charging of the solution/air interfaces of foam films formed from mixtures of LSP and RhL. Direct measurements of the disjoining pressure isotherms isotherms demonstrate that the added rhamnolipids change the surface electric parameters of the films, their thickness and stability at higher pressures. The obtained results show that the different molecular components in the mixture and the increased surface charge at the film interfaces originating from the rhamnolipid ions have significant effect on the surface forces operative in the studied films.

The presented experimental studies demonstrate that the parameters C_c and C_t can be used to characterize complex systems, such as the studied rhamnolipid-LSP mixtures. The results show that rhamnolipids can impair the surfactant function not only by making lung surfactant phospholipids more accessible to cleavage by phospholipases but also by intercalation into the alveolar surface layer.

PD5

Vibration of a soap film

C. Derec[1], W.Drenckhan[2], S.Hutzler[3], V. Leroy[1],

A. Möller[4], M. Saadatfar[3], C.Stubenrauch[4], F.Elias[1]

[1]*Matière et Systèmes Complexes, CNRS UMR7057 and Université Paris Diderot, Paris, France*
[2]*Laboratoire de Physique des Solides, Université Paris-Sud and UMR8502, France*
[3]*School of Physics, Trinity College Dublin, Ireland*
[4]*School of Chemical and Bioprocess Engineering, University College Dublin, Ireland*
caroline.derec@univ-paris-diderot.fr

The fast dynamics of liquid foams is at this stage a little explored subject. At the macroscopic level, the problem is to understand the propagation of an acoustic wave in the foam. At the bubble scale, the question is to identify all the local sources of elastic restoring forces and viscous dissipation.

Here, we focus on the fast dynamical properties of individual soap films, which are the elementary building blocks of a foam. In particular, we are interested in describing the viscous and elastic contributions involved in an oscillating soap film. In our experiments, a soap film is vibrated using a loudspeaker and a transversal wave appears on the thin liquid membrane. Depending on the amplitude of the wave, the behaviour of the vibrated soap film is extremely rich. Here we present results for which the film is vibrated with a sufficiently low amplitude to prevent the formation of thickness gradients due to the vibration. The corresponding undulation mode of the soap film (also called "antisymmetrical mode"), is generally attributed purely to capillary waves on the liquid membrane. The dispersion relation takes into account the inertia of the air surrounding the film.

We show that, using a wide frequency range (200 Hz - 10 kHz) and well-defined surfactant solutions, the dispersion relation must also include the coupling between the capillary wave and the elastic wave, which results from the interfacial elasticity of the surfactant layer at the gas/liquid interfaces. The complete dispersion relation is derived analytically and compared to experimental results.
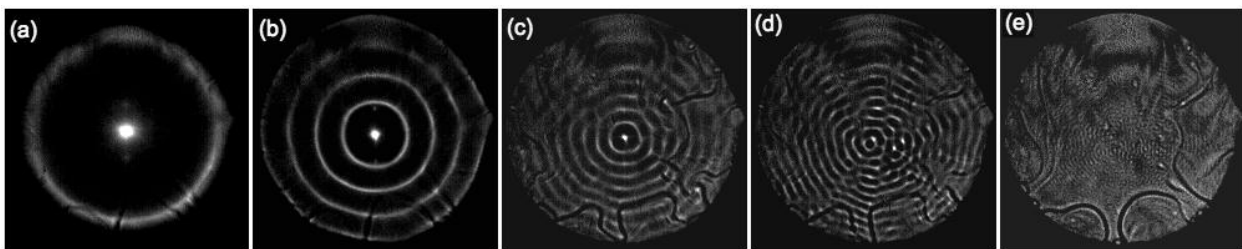
Standing waves on a soap film (16mm diameter) for increasing frequency:
(a) f = 450 Hz; (b) f = 1.6 kHz; (c) f = 4 kHz; (d) f = 5.6 kHz; (e) f = 15 kHz.

PD6

Steric stabilization of black foam and oil-in-water emulsion films from polymeric surfactants

G. Gotchev, H. Petkova, Khr. Khristov, T. Kolarov and D. Exerowa

Institute of Physical Chemistry, Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria
Email: gochev@ipc.bas.bg

Interaction forces in foam and oil-in-water emulsion films stabilized by non-ionic polymeric surfactants were studied. Two types of polymeric surfactants were used: 1) four graft co-polymers, namely hydrophobically modified inulin (HMI) surfactants (INUTEC[®]) having equal inulin chains and different degree of hydrophobic modification (DHM) and 2) a PEO-PPO-PEO triblock co-polymer, namely Pluronic[®] F108. The adsorbing macromolecules at oil (air) / water interfaces formed a PEO-'brush' in the case of F108 and a 'quasibrush' of inulin-loops in the case of HMI-surfactants. Disjoining pressure (Π) and equivalent thickness (h_w) of the foam and emulsion films were measured at various NaCl concentrations (C_{NaCl}) or pH. At constant Π, the critical electrolyte concentration ($C_{el,cr}$) and the critical pH (pH$_{cr,st}$) were found, both representing the transition from electrostatic to steric stabilization of the films. At $C_{NaCl} \geq C_{el,cr}$ or pH $\leq$ pH$_{cr,st}$, the electrostatic interaction in the films was suppressed and black foam and emulsion films were obtained. These black films were stabilized by repulsive forces due to steric interaction between the PEO-'brush' layers (for F108) or the layers of inulin-loops (for HMI-surfactants). Disjoining pressure isotherms (Π vs. h_w curves) were measured for the black films from both types of the co-polymers and for the first time transitions to emulsion Newton black films (NBF) from polymeric surfactants were found. For all the foam films, NBF formation was not observed at all. The experimental Π vs. h_w curves for the black emulsion films from F108 were fitted to the scaling theory of de Gennes for steric interaction between polymer 'brushes' with the 'brush' thickness as a fitting parameter. The black emulsion films from the co-polymer with the highest DHM (smallest loop size) jumped to NBF at lower disjoining pressure in comparison with that for the emulsion films from the other three co-polymers. For the black foam films, the stability against rupture decreased with reduction of inulin-loop size. The experimental Π vs. h_w curves for these black foam films were fitted to the scaling theory of de Gennes with the inulin-loops layer thickness as a fitting parameter. All the results on the black foam and emulsion films from the polymeric surfactants used were interpreted on the basis of 'brush-to-brush' and 'loop-to-loop' steric interaction forces.

PD7

Interfacial properties of mixed *β*-lactoglobulin/C$_n$TAB layers at the Hexane/Water interface

Georgi Gotchev[1,2], Vincent Pradines[3], Valentin. B. Fainerman[4], Jürgen Krägel[1], Reinhard Miller[1]

[1] *Max Planck Institut für Kolloid und Grenzflächenforschung*
Wissenschaftspark Golm, Am Mühlenberg 1, 14476 Potsdam-Golm, Germany.
[2] *Institute of Physical Chemistry, Bulgarian Academy of Sciences, 1113 Sofia, Bulgaria*
[3] *Laboratoire de Chimie de Coordination, 31077 Toulouse cedex 04, France*
[4] *Medical University Donetsk, 16 llych Avenue, 83003 Donetsk, Ukraine.*
Email: gochev@ipc.bas.bg

Oil/water systems such as emulsions find many applications in numerous technologies. In food technology emulsions are mainly stabilised by mixtures of proteins and low molecular surfactants and their complexes. The formation of aqueous protein/surfactant complexes is caused by electrostatic and/or hydrophobic interactions between the protein and surfactant molecules. Such complexes can modify the properties of the oil/water interface in a different way as compared to the individual components. The present work deals with the thermodynamics, adsorption kinetics and dilational rheology of mixed adsorption layers of β-lactoglobulin/alkyl trimethylammonium bromides (C$_n$TAB with n = 10, 12, 14 and 16) at the hexane/aqueous solution (under buffer conditions of pH 7 in order to control the net charge of the protein) interface involving drop profile analysis tensiometry (PAT1, SINTERFACE). For all protein/surfactant mixtures, similar interfacial behaviours are observed, including the surface tension isotherm and the dilational rheology. However, the displacement of the protein/surfactant complexes from the interface due to the effects of intermolecular interactions by the different surfactants is increasingly efficient with increasing surfactants' chain length. The experimental data gathered are compared with a recently developed thermodynamic theory, which describes the composition of mixed protein/surfactant adsorption layers on the basis of models using the characteristic parameters of the single components.

PD8

Thermo-responsive interfaces, films and foams

R.M. Guillermic, J. Emile, A. Saint-Jalmes

Institut de Physique de Rennes, Rennes, France
reine-marie.guillermic@univ-rennes1.fr

An aqueous foam is potentially an interesting template for conceiving responsive materials ; in particular, this is due to the hierarchical organization at different lengthscales and to the fact that tiny effects at interfaces can have strong macroscopic impact.

We report results on the development of a thermo-sensitive foam, based on the use of a thermo-sensitive polymer (poly(N-isopropylacrylamide), PNIPAM) which easily adsorbs at air-water interfaces. Depending on the temperature, water is a good or a bad solvent for pnipam, resulting in various reversible configurations of the polymer in bulk. As well, the behaviour of this polymer at the water-air interface is known to change with the temperature.

Here we show a detailed study of how both the dilational and shear interfacial viscoelastic moduli depends on temperature, and how the mixing with small surfactant molecules (like SDS) modify the effect of the temperature on the interfaces. We also show how the structure, thickness and stability of thin liquid films are reversibly modified by temperature. We then present our attempt to make a thermo-sensitive 3D foam, containing PNIPAM associated or not with SDS : we discuss if and how the foam properties can be strongly and reversibly tuned by the external temperature.

PD9

Drainage of foam films stabilized by an ionic- or a non-ionic surfactant and their mixture

D. Ivanova[1], Zh. Angarska[1], S. Karakashev[2], E. Manev[2]

[1]Faculty of Natural Sciences, University of Shumen, Bulgaria
[2]Department of Physical Chemistry, University of Sofia, Bulgaria
Email: D.Ivanova@shu-bg.net

Non-ionic or ionic surfactants and their mixtures are widely used in science and technology as foam and emulsion stabilizers. It is well known that the nature of the surfactant strongly affects the thinning of foam films. The basic theory of drainage has been developed for planar thin films stabilized by nonionic surfactants. The theory has been advanced further by accounting for the film thickness inhomogeneity [1], dynamic effects originating from the electric double layers [2], and the film dynamic structures [3]. The aim of the present study has been to obtain experimental data for the thinning of foam films with *n*-dodecyl-β-maltoside [$C_{12}G_2$] and dodecyl trimethylammonium bromide [$C_{12}TAB$], as well as their mixture, in order to probe the rate of drainage by different equations, and especially to validate the new kinetic equation, accounting for the film dynamic structure. The important role of the latter for the rate of film drainage has been shown by the introduction of a dynamic fractal dimension, as a number between zero and two to describe the process. Thus, $\alpha=2$ corresponds to Reynolds type of film drainage, while $\alpha=0$ corresponds to drainage independent on the film radius.

The thinning of foam films from solutions of the individual surfactants $C_{12}G_2$ and $C_{12}TAB$ and from mixtures of $C_{12}G_2 : C_{12}TAB = 50:1; 1:1; 1:50$ was investigated in the presence of 0.1 M NaBr. The *h*(film thickness) *vs. t*(time) dependence for films with radii 0.05 mm or 0.1 mm was determined by the interferometric method. The total surfactant concentrations were equal to 1.0 cmc of the individual surfactants and the surfactant mixtures.

The films with radii 0.05 mm, irrespectively of surfactant type or mixture composition, exhibited regular thinning almost in line with the classical Reynolds equation. It was confirmed by the values of fractal dimension: $\alpha = 1.84$ for films from $C_{12}G_2$ and $\alpha = 1.5$ for films from $C_{12}TAB$. The films with radii 0.1 mm irrespectively of surfactant type or mixture composition drained significantly faster than the prediction of the Reynolds equation. The obtained values are $\alpha= 1.06$ for foam films from C12G2, $\alpha= 0.7$ for foam films from $C_{12}TAB$ and $\alpha= 0.7$ for films from the mixture $C_{12}G_2 : C_{12}TAB = 1:1$. Therefore these films have mobile surfaces or are broken to multiple uncorrelated sub-domains.

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PD10

Equilibrium and dynamic surface properties of aqueous solutions of trisiloxane surfactants

N.A. Ivanova[1], R.G. Rubio[2], V.M. Starov[1], V.B. Fainerman[3]

[1]Department of Chemical Engineering, Loughborough University, Loughborough, LE11 3TU, UK
[2]Department of Quimica Fisica I, Universidad Complutense, 28040-Madrid, Spain
[3]Medical Physicochemical Centre, Donetsk Medical University, 83003 Donetsk, Ukraine
Email: N.Ivanova@lboro.ac.uk

Equilibrium and dynamic surface tension, as well as adsorption at the liquid-air interface, of trisiloxane surfactants have been measured by tensiometry, ellipsometry and Brewster angle microscopy techniques. Inflection points in adsorption curves have been found for the surfactants with long etoxylated chains, which demonstrate superspreading behavior on moderately hydrophobic surfaces at room temperature. For those trisiloxanes formation of surface aggregates has been found, while no aggregates have been detected for trisiloxanes with short ethoxylated chains, which do not show superspreading behavior. This suggests that the surface aggregates may act as reservoirs of surfactant molecules to maintain the required surface tension in the course of spreading.

It is shown that experimental results on equilibrium and dynamic interfacial tension agree well with a combined theoretical model, which is based on reorientation and aggregation models [1,2]. According to the reorientation model there are two states of trisiloxane molecules on the surface layer: molecules in those two states occupy different surface area. The aggregation model accounts for specific properties of trisiloxane molecules occupying the lowest area on the interface: they can form two dimensional aggregates. It was assumed that trisiloxanes molecules include two kinetically independent trimethylsilyl groups, that allowed us to agree the aggregation model and experimental data on ellipsometry measurement of adsorption.

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PD11

Thermal properties of oil-in-water highly concentrated emulsions

A. Jamil[1,2], S. Caubet[1,3], T. Kousksou[1], K. El Omari[1], Y. Zeraouli[1], B. Grassl[2], Y. Le Guer[1]

[1] *Laboratoire de Thermique Energétique et Procédés (LaTEP),*
[2] *Ecole Supérieure de Technologie de Fès - Route d''Imouzzer B.P.2427 - Atlas Fès 30000*
[3] *Institut Pluridisciplinaire de Recherche Environnement et Matériaux (IPREM UMR 5244) - Equipe de Physique et Chimie des Polymères (EPCP),*
[1,3] *Université de Pau et des Pays de l'Adour (UPPA) - Hélioparc - Avenue P. Angot - 64000 Pau*
yves.leguer@univ-pau.fr

In this work we study the thermal properties of highly concentrated oil-in-water emulsions stabilized by surfactant molecules.

A low energy mixing process [1] has been used to obtain the highly concentrated emulsions (91 % of ricin oil in deionized water with Triton X405 non-ionic surfactant). This process allows the production of highly concentrated emulsions with controlled mean droplet size distribution. At such high concentration, droplets present multifaceted shapes and the water-surfactant film thickness are very thin. A Differential Scanning Calorimetry (DSC) technique was used to study the thermal properties of these concentrated emulsions for different mean droplet sizes that are obtained for several mixing times. During the freezing of the O/W concentrated emulsion only the thin water-surfactant films crystallize because the ricin oil presents an amorphous behavior. To our knowledge, this study was not previously made in the litterature. We have observed for the different droplet size large degrees of supercooling (from 10 to 18 °C) and that the temperature of crystallization of the aqueus-surfactant films is linearly dependant on the mixing time. The width of the film between deformed droplets and the confined volumes in the plateau borders decrease with the mixing time. Thus we obtained a crystallization temperature very different from that observed in a bulk phase, this crystallization temperature is limited by the availability of cristallizing material and largely influenced by the confinement size imposed by the deformed droplets.

We have also investigated from the DSC measurements the heat capacity of the concentrated emulsions at different mixing times (i.e. different mean droplet diameters). Each sample studied contains the same proportions of materials (oil, water, surfactant) but the morphology of the emulsion changes. We have found that the heat capacity is dependant on the surface to volume ratio of the emulsion (which increases with the mixing time). The heat capacity increases with the growth of the surface to volume ration. Our results clearly show the importance of the interfacial energy between the dispersed and continuous phases for the evaluation of the heat capacity of highly concentrated emulsions.

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PD12

Effect of ionic strength on drainage of planar foam films

Stoyan I. Karakashev, R. Tsekov, R. Slavchov, and E. D. Manev

Dept. Physical Chemistry, Sofia University, 1 James Bourchier Blvd, 1164 Sofia, Bulgaria
Email: fhsk@chem.uni-sofia.bg

The effect of ionic strength on the drainage of planar foam films stabilized by a non-ionic surfactant (tetraethylene glycol mono-n-octylether, C_8E_4) and films with an ionic surfactant (sodium dodecyl sulphate SDS) was examined.

Foam films containing C_8E_4 in the concentration range 10^{-6} - 10^{-2} M were studied in the presence of 0.02, 0.2 and 2 M sodium chloride. The prediction of the standard drainage theory describes very well the obtained experimental results at 0.02 M NaCl , while at 0.2 M and 2 M NaCl the foam films thin slower. Moreover, the film thinning rate in the latter cases is even slower than the velocity according to the Stefan-Reynolds equation, which requires complete tangential immobility of the foam film surfaces. In addition, the dependence of the film thickness on time at 2M NaCl is almost linear, which signals for alteration in the regime of film drainage.

The drainage of planar foam films with SDS were studied in the presence of 0.02 M NaCl in the SDS concentration range of 10^{-6} – 10^{-3} M. In all of the cases the films thinned slower than the prediction of the Stefan-Reynolds equation. This is explained by arising of a streaming potential along the film radius causing reversed electro-kinetic fluxes near to the film surfaces. A new kinetic equation accounting for this effect was derived. The investigation of the electro-kinetic flow with different types of ionic surfactants and in the presence of different electrolytes is currently in progress.

PD13

Comparison of foaming activity of lupin protein solutions obtained with isoelectric precipitation versus ultrafiltration

V. Papoti, T. D. Karapantsios and G. Doxastakis†

Division of Chemical Technology, School of Chemistry, Aristotle University of Thessaloniki, Univ. Box 116, 54124 Thessaloniki, GREECE.
e-mail : karapant@chem.auth.gr
†: deceased

This study examines the foamability and foam stability of lupin protein solutions produced by two different techniques: (a) modified isoelectric precipitation and (b) ultrafiltration. The former technique extracts from the lupin seeds primarily globulins whereas the latter extracts both globulins and albumins. As regards foaming activity, the role of parameters such as the pH of the primary solution, xanthan gum concentration and the presence of sodium chloride, is investigated. The instantaneous liquid fraction at two heights along the foam is obtained non-intrusively by ring-shaped electrical conductance probes running the internal circumference of the test vessel. Global volumetric measurements allow estimating the volumes of the sustaining foam and drained serum with respect to time. Electrical and volumetric measurements yield supplementary information that is essential for the evaluation of the system's foaming activity. It is seen that lupin protein solutions from both production techniques offer satisfactory foaming properties and their use as foaming agents should be judged on the desired characteristics of specific foodstuffs.

PD14

Comparative investigation aqueous solutions of C12E3, C12E4 and C12E5

B. Soklev, D. Arabadzhieva, E. Mileva

Institute of Physical Chemistry, Bulgarian Academy of Sciences;
Email: mileva@ipc.bas.bg

This contribution presents an investigation on surface tension isotherms, the dynamic properties of the adsorption layers at the air/solution interface and the foam film drainage kinetics of aqueous solutions of nonionic surfactants: C12E3 (triethyleneglycol monododecyl ether), C12E4 (tetraethyleneglycol monododecyl ether) and C12E5 (pentaethyleneglycol monododecyl ether). The adsorption studies are performed by Profile Analysis Tensiometer (PAT-1). The foam film experiments are performed by microinterferometric thin liquid film technique, equipped with Scheludko-Exerowa measuring cell. The presented results outline important links between the film drainage kinetics and the properties of the adsorbed surfactant layers.

PD15

Foam film drainage of aqueous solutions of glycine compounds

I. Grozev, R. Todorov, E. Mileva

Institute of Physical Chemistry, Bulgarian Academy of Sciences;
Email: mileva@ipc.bas.bg

Aqueous solutions of some glycine compounds are investigated via microinterferometric thin liquid film instrumentation equipped with Scheludko-Exerowa cell. The impact of pH-variation is studied for broad concentration domain.

PD16

Understanding the role of protein aggregates at air/water interfaces: a multiscale approach

B. Rullier[1], M. Axelos[1], D. Langevin[2], B. Novales[1]

[1][1] *UR1268 Biopolymères Interactions Assemblages Inra, rue de la Géraudière, 44316 Nantes, France.*
[2] *Laboratoire de Physique des Solides, Université Paris-Sud, Bâtiment 510, 91405 Orsay, France.*
Email : bruno.novales@nantes.inra.fr

The foam formation depends on the nature of proteins and their ability to form and stabilize air/water interfaces. Proteins are aggregated in self-assembled structures because of thermomechanical treatments during industrial processes. The properties of aggregates are usually different from those of isolated proteins. It appears important to study protein aggregates in order to better understand the correlation at different scales between aggregation, interfacial and foaming properties.

Our study was conducted to highlight the role of β-lactoglobulin aggregates in foam structuration and stabilization. β-lactoglobulin is the major whey protein and it is possible to modulate according to experimental parameters the shape, structure and amount of aggregates obtained upon heat-induced denaturation of isolated proteins. We report results on protein aggregates with different sizes obtained by heat-induced denaturation of β-lactoglobulin.

Foams were produced to show the influence of aggregates on foam formation and stabilization. The behaviors of aggregates and isolated proteins were compared and discussed at different scales : in 3-D foam (by using the Foamscan apparatus of IT-Concept), in interfacial films (thin liquid film balance experiments) and at air-water interfaces (drop tensiometer).

Our results show that whatever the aggregate size, solutions containing exclusively protein aggregates lead to less stable foams than that of non aggregated proteins alone, due to the low capacity of aggregates to adsorb at the air/water interfaces. With non aggregated proteins, aggregates are able to improve the foaming properties. The viscoelasticity of the interfacial adsorbed layers is reinforced and a gel-like network is formed within the foam film, rigidifying the interface and slowing down the foam drainage. In the case of the gel-like network cannot be formed, protein aggregates can locate in the Plateau borders, slowing down the flow in the foam.

PD17

## Withdrawn films: The importance of surface rheology

J. Delacotte[1], E. Rio[2], F. Restagno[2], D. Langevin[2]

[1]*Laboratoire de Physique du solide, Université Paris Sud, Orsay, France*
[1]*Laboratoire de Physique Statistique, ENS Ulm, Paris, France*
rio@lps.u-psud.fr

Foams are networks of bubbles separated by thin films. Understanding the behaviour of these films is very important to explain foam formation as well as foam rheology. Our experiment consists in pulling a solid plate out of a surfactant solution. The thickness of the withdrawn film is measured for different pulling velocities, different surfactants and surfactant concentrations by a multi wavelength interferometry method..

In this way, we revisit of the old Landau Levich problem which is very well understood for pure liquids but remains poorly explained in presence of surfactants. We showed that the film thickness is controlled by the surface rheology that depends on the surfactant concentration and solubility but also by the thickness of the film. This allowed us to evidence a new dynamic thickness transition.
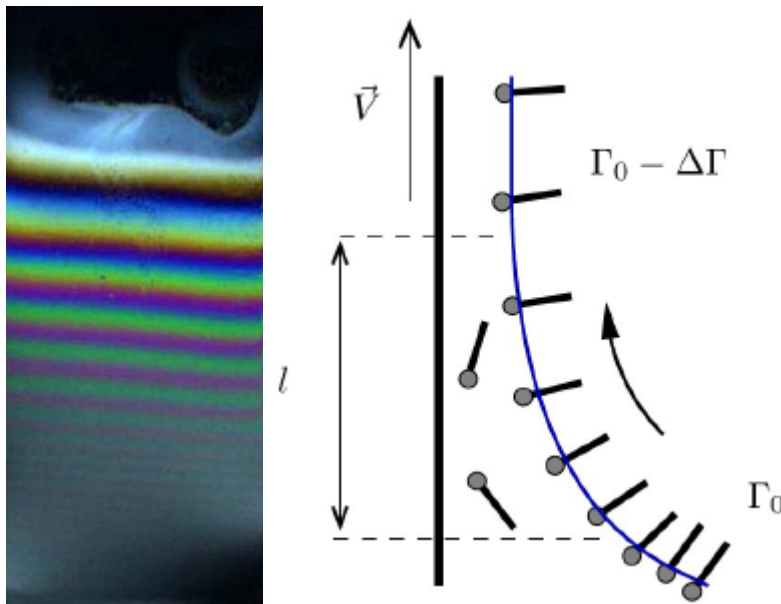
(a) Soap film during drainage   (b) Influence on surface rheology on film thickness

PD18

A novel pyrene-based surfactant: bulk, interfacial and foaming behaviour

A. Salonen[1], A. Knyazev[1], N. Von Bandel[1], J. Degrouard[1], D. Langevin[1], W. Drenckhan[1]

[1]*Laboratoire de Physique des Solides, CNRS 8502 Université Paris sud, Orsay, France*
Email: salonen@lps.u-psud.fr

We have synthesised a novel pyrene-based, fluorescing surfactant (Figure 1) from which we can create reasonably stable (1 hour) and fluorescing foams (Figure 2), whose fluorescing colour changes from blue to green around the critical micelle concentration. In comparison to standard surfactants, this one has an "inverted structure" consisting of a hydrophobic pyrene head-group, coupled with a hydrophilic tail (ethylene oxide). As a consequence and in combination with the
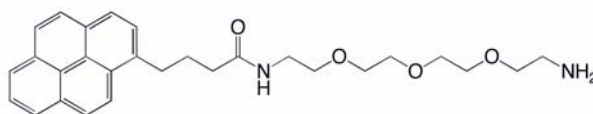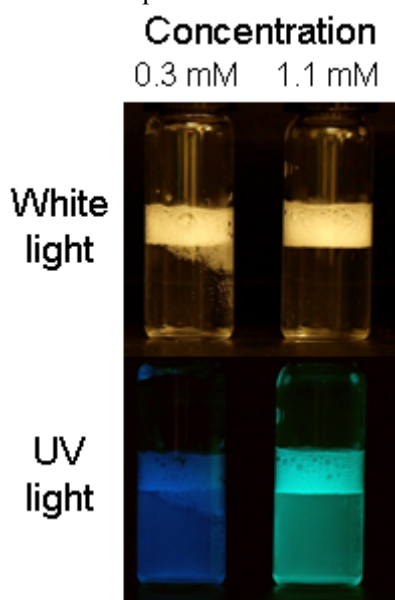

Figure 1. Chemical structure of the surfactant.

importance of pyrene-pyrene interactions, beyond its *foaming ability*, the molecule has very interesting *bulk* and *interfacial properties*. Establishing a link between these three aspects is at the focus of the present contribution.

We determined the critical micelle concentration of the molecule using fluorescence and interfacial tension measurements and find that both correlate very well with the foaming behaviour of the solutions. The molecule shows very slow dynamics of interfacial adsorption, possibly because of packing constraints at the interface due to the form of the pyrene headgroups.

In the bulk we find a rich selection of concentration-dependant aggregates, ranging from micelles and large vesicles (order of micrometer) to giant objects, such as tubes (order of 10 micrometers). We investigated their form and structure using cryo-TEM and optical microscopy. Especially at higher concentrations, liquid crystalline structures are observed, which may be responsible for the giant object formation.

Figure 2. Blue and green fluorescing foams.

PD19

Shear rheology of mixed ß-lactoglobulin/surfactant adsorption layers at the water/oil interface

V. Ulaganathan[1,3], J. Krägel[1], V. Pradines[2], R. Wüstneck[1], B. Bergenståhl[3] and R. Miller[1]

[1] *Max Planck Institute of Colloids and Interfaces, 14424 Potsdam-Golm, Germany*
[2] *Laboratoire de Chimie de Coordination, 31077 Toulouse, France*
[3] *Lund University, Department of Food Technology, 22100 Lund, Sweden*
Email: vamseekrishna.ulaganathan@mpikg.mpg.de

Studies of protein-surfactant mixtures attract much interest due to the large number of applications, most of all in food industry for stabilizing emulsions or foams. Indeed, the ability of proteins to unfold may lead to adsorption layers with high surface elasticity and a significant decrease in surface tension. Thus, high interfacial visco-elasticities are obtained at very low bulk concentrations. In the presence of surfactants, a fast decrease in interfacial tension occurs at the expense of a subsequent competitive adsorption between surfactants and proteins or protein/surfactant complexes, which can drastically change the surface layer properties. The adsorption isotherm and the interfacial rheological properties are highly influenced by the protein structure (random coil or globular) being more or less flexible, by the nature of added surfactants (ionic or nonionic), and by the concentration ratio of both components. Models to describe the interfacial layers involving these compounds are rather complex and many phenomena are still not fully understood.

The present contribution is dedicated to the response of mixed layers against shear deformation. Such studies are very rare at water/oil interfaces. We use a torsion pendulum rheometer ISR1 (SINTERFACE) and a biconical disc rheometer MCR 301 (Physica). Both instruments are working in oscillatory mode to measure the viscoelastic properties of interfacial layers. In contrast to the forced oscillatory mode of the conventional rheometer the torsion pendulum technique is performing damped oscillations. Due to this measuring principle lower torques can be transferred to the interfacial layer and give access to very low values of interfacial shear moduli. The obtained results for the protein and the different mixtures show a rather complex interfacial rheology. The addition of surfactants changes the shear rheology significantly. The obtained results allow to gain information about the composition of the mixed interfacial layers. It is demonstrated that in analogy to the water/air interface similar mechanisms apply.

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PD20

Dynamics of a thin liquid film: A proxy for bubble bursting

G. Varas, V. Vidal and J.-C. Géminard

Laboratoire de Physique, Ecole Normale Supérieure - CNRS, 46 Allée d'Italie 69364 Lyon Cedex 07, France
Email: german.varas@ens-lyon.fr

Understanding the physics of bubble bursting is of importance in fundamental physics as well as in natural phenomena. For example, on volcanoes, large gas bubbles rise and explode at the top of the magma conduit. The huge overpressure inside the bubble before bursting, inferred from numerical models [1,2], is responsible for the violence of the explosion. In previous works, the dynamics of bubble bursting has been investigated for different types of fluids (for example, soap films, viscous fluids or liquid crystals) [3,4]. In order to understand what determines the overpressure inside a bubble at bursting, and the role of the fluid rheology, we performed laboratory experiments. A bubble of well-controlled geometry is mimicked by a thin liquid film stretched at the open end of a cylindrical cavity [5]. A constant air flux is injected inside and the film inflates until it break. The overpressure inside the cavity, the film shape and the dynamics are reported for different fluids and inflation rates. In particular, we investigate the relationship between the overpressure, the film rupture dynamics and the acoustic signal produced at bursting. We contrast our results with similar experiments performed in the case of a static bursting [5].

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PD21

The antifoam behaviour of saturated fatty-acid triglyceride mixtures in aqueous surfactant solutions

P.R.Garrett, Li Ran

CEAS, Manchester University, UK
p.garrett@manchester.ac.uk, Li.Ran@postgrad.manchester.ac.uk

Mixtures of fatty acids and triolein are often used as models for naturally occurring soils such as sebum. Here we compare the antifoam behviour of mixtures of stearic acid and triolein with a simulated sebum consisting of a blend of triglycerides, fatty acids and other hydrophobic ingredients.

It is known [1] that mixtures of triolein and oleic acid are only effective antifoams when introduced to surfactant solutions at relatively high pH and containing calcium. In these circumstances oleic acid reacts at the oil-water interface to produce particles of calcium oleate which can rupture, otherwise stable, pseudoemulsion films. Emergence of the oil into the air-water surface is thereby facilitated permitting antifoam action by bridging oil drops.

By contrast mixtures of stearic acid and triolein will be shown to show similar antifoam activity regardless of pH and calcium concentration. In this system particles are always present even when formation of soaps is suppressed at low pH since stearic acid has only limited solubility in triolein. At high pH some conversion of stearic acid particles to sodium or calcium stearate is likely. The particles in all cases invert the O/W emulsion behaviour shown by triolein alone to W/O. Similar overall behaviour as a function of solution composition is also shown by artificial sebum, although the latter is a more effective antifoam.

If particles are to rupture pseudoemulsion films it is necessary that they satisfy certain wetability criteria. In the case of spheres it is necessary that $\theta_{AW} > \theta_{WO}$ and $\theta_{WO} < \pi/2$ where θ_{WO} is the contact angle at the oil-water interface measured through the oil phase and θ_{AW} is the air-water contact angle measured through the aqueous phase [2]. However stearic acid forms platelets with sharp edges in triolein - similar crystals are present in artificial sebum but are strongly aggregated. The effect of this geometry on the criteria for pseudoemulsion film rupture will be considered.

All these fatty acid–triglyceride antifoam systems exhibit isomorphous plots of foam volume against log(antifoam concentration) as expected from theoretical considerations [3]. However in the case of stearic acid-triolein mixtures continuous mechanical agitation in rotating cylinders results in marked deactivation of the antifoam effect which is more marked at high pH in the presence of calcium. In all cases spreading at the air-water surface is absent and number droplet size distributions show no significant change after deactivation. The relative deactivation effects are consistent with a first order rate process with different rate constants. By complete contrast the artificial sebum surprisingly does not deactivate under these conditions.

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PE1

Decay of beer foam

[1,2]Martin Baszczynski, [1,2]Pavel Novák, [2]Tomas Branyik, [1]Marek C. Ruzicka, [1]Jiří Drahoš

[1]*Institute of Chemical Process Fundamentals, Academy of Sciences of the Czech Republic, Rozvojova 2, 165 02 Prague 6 – Suchdol, Czech Republic*
[2]*Department of Fermentation Chemistry and Bioengineering, Institute of Chemical Technology, Technická 5, 166 28 Prague, Czech Republic*
e-mail: baszczynski@icpf.cas.cz

This work is devoted to detailed study of physical properties of foam decay. Several model solutions consisting of basic beer compounds (water, ethanol, proteins, carbohydrates, acids and ions) and also real beers of different composition were tested. The rheological properties of these liquids such as viscosity, surface tension, density, etc. were measured. A high-speed imaging system was used to monitor the foam behaviour, at high resolution. This method consists of application of visualization setup and image analyzing software.

The main attention was focused on the few last layers of bubbles on the beer surface. The stability and continuity of the last foam layer is significant for many customers, since this represents the boundary (breakpoint) between beer with and without foam. The results show interesting relations between rheological properties of model solutions/real beers and their foam behaviour. This work also presents a novel and detailed description of foam decay kinetics.

PE2

Rupture criterion of a 2D foam subject to a sudden overpressure

I. Ben Salem[1], I. Cantat[1], B. Dollet[1]

[1]Rennes Institute of Physics, CNRS/University Rennes 1, Rennes, France
Email: imen.bensalem@univ-rennes1.fr

Foams are known to absorb well the energy, but the mechanisms of absorption are still not well known. To better understand them, we propose an experiment where a 2D foam is submitted to a controlled overpressure, where we can follow the foam response, with a fundamental question: What is its limit of resistance, below which its resists and absorbs the overpressure (Fig. 1), and above which it breaks (Fig. 2)?

To have a 2D foam, we confine the bubbles between two circular glass plates (Hele-Shaw cell) separated by a gap of the order of 1 mm. The bottom plate is connected to a flowmeter or a reservoir of pressure, permitting to inject air in the foam. We measure the evolution of pressure, and we record the evolution of the foam by a high-speed camera.

We quantify the limit of the resistance of the foam according to different parameters: air pressure or flow rate, bubble size, gap between the two plates, liquid fraction. We also study the influence of interfacial rheology using different surfactants, giving either very mobile interfaces (SDS), or very rigid ones (SLES/CAPB/MAc [1]). We compare the rupture threshold with a theoretical criterion based on the friction of liquid films against the walls. In the regime where the foam does not break, we study the morphology of the front of injected air (Fig. 1), and we discuss the similarities and differences with Saffman-Taylor instability.
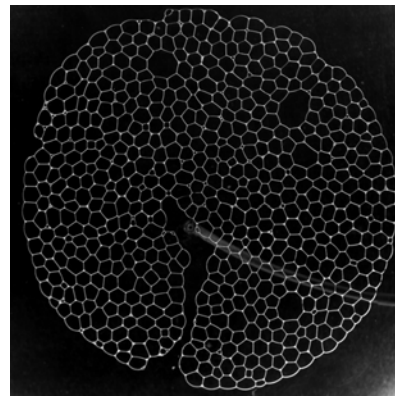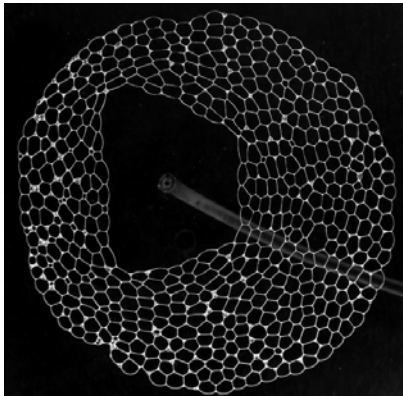

Fig. 1 Blowing of pressurised air in a foam.   Fig. 2. Ruptured foam consecutive to a violent air injection.

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PE3

The micro-macro link for liquid foam stability

A.-L. Biance[1], A. Delbos[2], O. Pitois[2]

[1]LPMCN, Université de Lyon et CNRS, Lyon, France
[2]LPMDI, Université Paris-Est, Marne-La Vallée, France
Email: anne-laure.biance@lpmcn.univ-lyon1.fr

The stability of liquid foams at rest is strongly dependent on the behaviour of foam films. Traditionally, the intrinsic stability of those films is studied within quasi-static conditions using the *thin film balance* apparatus, and the disjoining pressure acting against the film rupture is measured. However, it has been recently reported that this latter parameter is meaningless for the prediction of the maximum height of foam generated in a column [1]. It was therefore suggested that the stability behaviour of the macroscopic sample at rest is strongly related to dynamical events occurring at the scale of the bubble and induced by drainage and Ostwald ripening.

We investigate the stability behaviour of foam films within dynamical conditions, at the scale of the foam as well as at the scale of two bubbles. Results show that within such conditions and for both scales, film stability is subjected to the presence of a minimum amount of liquid in the system. Indeed, the volume of liquid required for the dynamical foam film formation is greater than the volume of liquid available in the system at equilibrium.

These results suggest that both disjoining pressure and surface rheology are involved in local dynamical events.

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PE4

On foam disproportionation and surface rheology
of molecular food foaming agents

T.B.J. Blijdenstein, P.W.N. de Groot, S.D. Stoyanov

Structured Materials and Process Science, Unilever R&D Vlaardingen, 3133 AT, Vlaardingen, The Netherlands.
Email: theo.blijdenstein@unilever.com

Here we have investigated the stability of foams made from Trichoderma reesei HFBII hydrophobin, Quillaja saponin, β-lactoglobulin and β-casein. Our experimental design eliminates the effects of coalescence and creaming, allowing us to study Ostwald ripening effect primarily. In HFBII foams, disproportionation is effectively stopped and the air bubbles size remained practically constant over a timescale, at least three orders of magnitude larger, compared to other two systems. We attributed this large difference to differences in surface rheological properties of the adsorbed layers, which were studied using small and large deformation surface dilatational and shear rheology experiments. At low surface coverage we have mapped the system behaviour to the equivalent 2D polymer network having similar dilatational modulus vs. surface pressure dependence, allowing us to introduce an equivalent molecular "hardness". This comparison indicates that even at low surface coverage, HFBII molecules behave as harder entity at the interface, when compared to other systems. We find similar behaviour at high surface coverage, where HFBII layers can form microscopic wrinkles at the interface. At large surface deformation the HFBII dilatational modulus increases nearly monotonically, over a much larger range of surface pressures, and much higher moduli are reached compared to the other three systems. These observations correlate well with the observed difference in the foam behaviour.

PE5

Tuning foam properties of a non-ionic/cationic surfactant mixture

E. Carey[1], C. Stubenrauch[2]

[1] *University College Dublin, School of Chemical and Bioprocess Engineering,*
Belfield, Dublin 4, Ireland
[2] *Institut für Physikalische Chemie, Universität Stuttgart, Pfaffenwaldring 55,*
70569 Stuttgart, Germany
enda.carey@ucd.ie

This study aims to shed light on the behaviour of foams and foam films in both technical mixtures and processes, which is of relevance for the scientific and industrial community. An extensive study of the foam properties of a non-ionic dodecyldimethyl phosphineoxide (C_{12}DMPO) and cationic dodecyltrimethylammonium bromide (C_{12}TAB) mixture is performed using several techniques including a home-built Foam Conductivity Apparatus (FCA) [1] and commercial available FoamScan method. By adopting a non-ionic/cationic mixture it has been previously demonstrated using a home-built Thin Film Pressure Balance (TFPB) that the surface charge density and thus the type of foam film (*Newton Black Film* or *Common Black Film*) can be tuned [2,3]. This work specifically aims at studying the influence the type of film has on the foam stability of this mixture.

The foamability and foam stability of cationic C_{12}TAB was found to be larger than that of non-ionic C_{12}DMPO [4]. The foamability continually increased with increasing C_{12}TAB content in the surfactant mixture, which reflects the reduction of the diffusion relaxation time (*i.e.* faster adsorption). We observed during destabilization that drainage dominated until an equilibrium state (*i.e* a well drained "dry" foam) is reached at which stage the type of foam film stabilizing the foam comes into play. At this stage a negligible change in the drainage rates was observed, with coalescence and Ostwald ripening appearing to dominate foam destruction processes. It is only at this stage that we see a significant variation in the foam volumes of the various surfactant mixtures. Interestingly, the 1:1 mixture shows weak/negligible surfactant interactions but – counter intuitively - an increased foam stability compared to the single surfactant systems. However, at this ratio charge neutralization occurs, which leads to the formation of a *Newton Black Film* thus suggesting that the foam film type plays an important role in the foam stability.

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PE6

Foam permeability: a reappraisal of Lemlich's assumptions

N. Louvet[1,2], E. Lorenceau[1], F. Rouyer[1] and O. Pitois[1]

[1]*LPMDI, UMR 8108, Paris-Est Marne-la-Vallée University, Champs-sur-Marne, France*
[2]*LOF, UMR 7608 Rhodia-CNRS-Bordeaux1, Pessac, France*
Email: Nicolas.louvet-exterieur@eu.rhodia.com

Nowadays, existing models for foam drainage are based on one of the major Leonard and Lemlich's assumptions which is that the surface shear viscosity μ_s, to model the interface mobility for a given soap solution. The Boussinesq number $Bo = \mu_s/\mu r$, where r is the Plateau borders' width and depends on the foam liquid fraction ε, is used to determine the Plateau borders permeability coefficient $k(Bo)$ which is used for the foam permeability K. In this approach, $k(Bo)$ is not a constant for a given foaming solution, but varies with the bubble diameter D_b and ε. In fact, it is claimed that the knowledge of the surface parameter µs allows to predict the foam permeability K as a function of D_b and ε.

Here, we report on new experimental data of dimensionless foam permeability K/D^2_b which are better described with a constant value for Bo rather than a constant μ_s. We think that a consensus could be between existing models and our. As the channels permeability is essential to all macroscopic models, we perform a drainage experiment at the scale of a single Plateau border. We compare the obtained data from these two scales and found a good agreement.

Finally, we explore another Lemlich's assumptions: the interface elasticity. From a simple model including the Gibbs elasticity, we propose a first explanation of a constant Bo to predict foam permeability.

PE7

Evolution of a monodisperse crystalline microfoam containing a component of insoluble gas

A. Meagher, D. Weaire, S.Hutzler

Foams and Complex Systems, School of Physics, Trinity College Dublin, Ireland
Email of Aaron Meagher: meagheaj@tcd.ie

Recent work of van der Net et al. investigated the spontaneous ordering of monodisperse microbubbles into crystal structures and the intricate sequences of bubble re-arrangements in the first layer of such a structure exposed to air [1]. Examining ways to increase the stability of ordered structures formed from monodisperse samples, we now add a slow diffusing gas component Perfluorohexane (PFH) into the foam [2]. This reduces coarsening within the foam sample by limiting inter-bubble gas diffusion. When the foam sample is exposed to air the bubbles remain monodisperse, but their size increases with time. When an expanding monolayer is contained, an ordered multilayer crystal is formed as the microbubbles form successive layers in order to accommodate the growth of the diameter of the top layer bubbles. A diffusion model derived from dimensional arguments predicts the growth of the top layer bubbles with time according to a power law with exponent 1/4. This prediction is in agreement with our experiments and also with numerical simulations of the same process by Fortes and Deus [3].

(A) 0 Minutes   (B) 5 Minutes   (C) 10 Minutes

(D) 15 Minutes   (E) 20 Minutes   (F) 25 Minutes
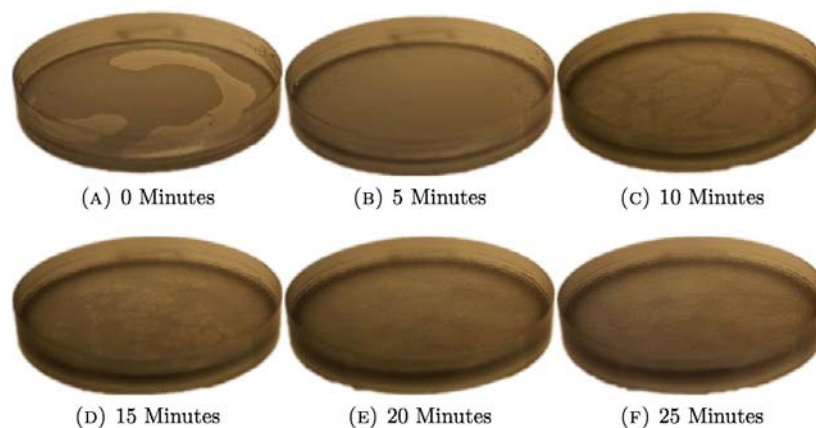
Figure 1   Evolution of a confined monolayer to a multilayer bubble crystal

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PE8

Gas injection in high temperature metal melts

T. Mönch, S. Odenbach

Institute of Fluid Mechanics, Chair of Magnetofluiddynamicst, TU Dresden, Dresden, Germany
Email: Theresa.Moench@tu-dresden.de

Gas injection into metal melts is mainly used for the reduction of impurities during casting processes. Another minor application is the production of metallic foams from liquid metals. This class of materials combines different properties like high stiffness as well as good energy and sound absorption at low weights [1]. Up to now there is almost no acceptance for this material in industry because a homogeneous foam structure all over the final product can hardly be guaranteed.

The preferential method of foaming metals is the powder metallurgical route which has the advantage that parts can be shaped before processing and therefore easily be implemented as foam. The control of process parameters like pore size and its distribution is difficult, though [2]. A further method of metal foam production is generating bubbles directly in the metal melt stabilized by particles. By injecting gas through a nozzle the bubble size and therefore the pore size of the later foam can be adjusted. Drainage, mainly driven by gravity, is one big problem which causes bubble rupture and coalescence so that the foam structure becomes irregular. It has been shown that arising bubbles in liquid metals can be influenced by magnetic fields due to Lorentz force effects on the flow of the metal [3]. So the bubble rise and agglomeration at the top of the melt will be influenced depending on the direction of an applied field. In this work we want to reduce drainage effects by application of magnetic fields acting against gravity to get more homogeneous foams.

Preliminary tests, i.e. foaming experiments and investigations on metal melts without magnetic field have to be done for reference. In order to verify the results the samples are analyzed with X-ray radiography and tomography as non-destructive methods. Actual results will be presented.

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PE9

Foam stability: effect of physico-chemical properties of beer

P. Novak[1,2], M.Baszczynski[1,2], T.Branyik[2], M. Ruzicka[1], J.Drahos[1]

[1]*Institute of Chemical Process Fundamentals, Academy of Sciences of the Czech Republic, Rozvojova 2, 165 02 Prague 6 – Suchdol, Czech Republic*
[2]*Department of Fermentation Chemistry and Bioengineering, Institute of Chemical Technology, Technická 5, 166 28 Prague, Czech Republic*
Email: novakp@icpf.cas.cz

Physico-chemical properties of beer play an important role in the formation and stability of foam. In this experimental work the behaviour of bubbles (shape, rising velocity, coalescence time) in dependence on material properties of the model liquid was studied and subsequently related to beer foam stability. Gas bubbles were introduced into liquid phase in a controled way by a capillary tube with defined avarage. The rising velocity and the collision of bubbles with liquid/air interface were studied with a high-speed digital camera (RedLake) and image analyzing software (MathLab). A model foam standard which contains main beer components necessary for foam formation and stability (proteins, hop acids, metal ions, ethanol, water, carbohydrates) was used as a liquid phase. The physico-chemical properties of this model liquid were characterized by the relevant parameters (density, viscosity, static surface tension, dynamic surface tension). The results show an interesting relationship between the bubble behaviour and the material properties of the model liquid system. For instance, a small change of the dynamic surface tension provoked significant changes in bubble lifetime and foam stability.

PE10

Liquid foams aging

L. Saulnier[1], E. Rio[1], W. Drenckhan[1], D. Langevin[1]

[1]*Laboratoire de Physique des Solides, Université Paris-Sud 11, Orsay, France*
Email: saulnier@lps.u-psud.fr

Liquid foams are metastable arrangements of bubbles in liquid networks that experience instabilities leading to disappearance. If the different instability processes are well known, it is still difficult to describe them quantitatively and to control them. Especially, coarsening and coalescence lead to very different foam evolution as illustrated in fig. 1. Despite the fact that they are closely related, it is possible to generate foams that experience coarsening alone or coalescence alone using suitable surfactants and/or gas.
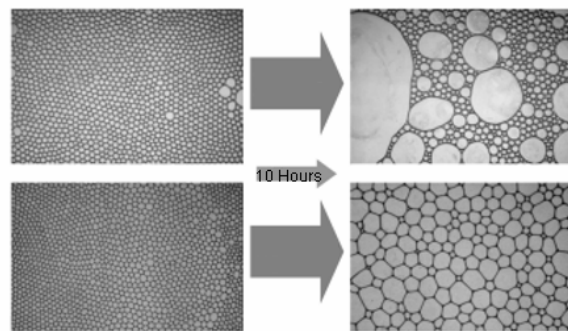
Fig. 1 : Aging of two different 2D foams. The first one (top) experiences localised coalescence events and the second one (bottom) evolves by homogeneous coarsening

The aim of this project is to study the aging of 2D foams (free of drainage) stabilized by various surfactants at different concentrations across a range of liquid fractions. *n*-dodecyl-β-D-maltoside (β-$C_{12}G_2$) and hexaoxyethylene dodecyl ether ($C_{12}E_6$) are potentially interesting surfactants since they are both non-ionic but generate foams that behave quite differently.

Monodisperse foams are generated by bubbling between two parallel transparent plates separated by a small gap. They are observed during days using a high resolution camera (10 Megapixels). The corresponding images are processed in order to extract length-scaling behaviour.

The questions we would like to answer are: Can we describe coalescence and coarsening with length-scaling laws using parameters like average bubble size, average number of bubble edges...? What drives the competition between both regimes?

PE11

An interactive study of the lifetime distribution of soap films

S.T. Tobin, A. Meagher, B. Bulfin, M.E. Möbius, D. Weaire and S. Hutzler

Foams and Complex Systems, School of Physics, Trinity College Dublin, Dublin 2, Ireland
Email: tobinst@tcd.ie

We present experimental data for the lifetime distribution of soap films made from commercial dishwashing solution (Fairy liquid) and contained in sealed cylinders. Data for a total of over 2500 films was gathered during a two-month lasting exhibition on the science and art of bubbles and foams in Dublin's Science Gallery (www.sciencegallery.com/bubble).

Visitors to the gallery were invited to create (using a constant gas flow) between 10 and 20 parallel soap films in acrylic tubes which were then sealed off with cork stoppers. Individual films burst at random. The total number of remaining films in the tubes was counted every day and recorded. Visitors could monitor the status of "their" soap film tube and the daily updated histogram of the lifetime of all films.

The histogram of the bubble lifetimes is well described by a Weibull distribution. This non-exponential distribution and its corresponding hazard function indicate that the failure rate is not constant and increases over time. Liquid evaporation is the main limiting factor of the soap film lifetime based on experiments with soap films in unsealed cylinders.

This public experiment is well suited to illustrate the difference between unpredictability of the lifetime of individual films and the existence of a well-defined lifetime distribution.
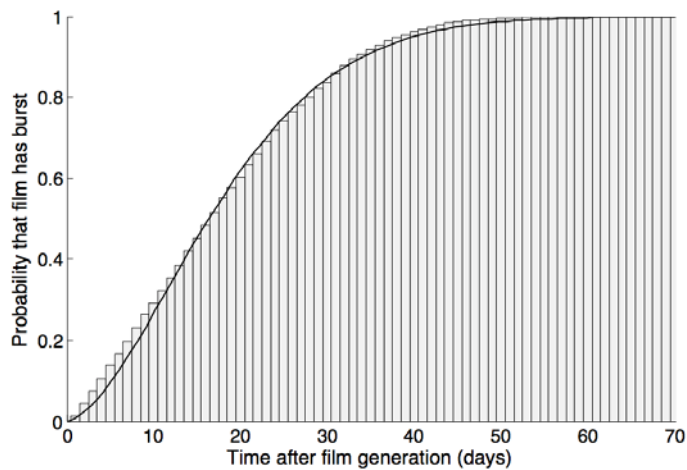
Weibull distribution as fit to experimental data

PE12

An integrated numerical model for predicting the evolution of the bubble size distribution in 2D foam

M. Tong, K. Cole, S. Neethling

Department of Earth Science and Engineering, Imperial College London, London, UK
Email: k.cole07@imperial.ac.uk; m.tong@imperial.ac.uk

Within a foam, the bubble size distribution and its evolution is of critical importance to many of the processes within the system. For instance in detergent suds, the bubble size distribution dominates the mean size of bubbles and the liquid content, which are major factors determining the appearance and tactile properties of the foams that the detergent products produce. These are key criteria that customers normally use to evaluate the detergent products. Although it is possible to measure the bubble size at the surface of the detergent suds, it is very difficult to measure the evolvement of the bubble size distribution over the depth of the suds, which is very important to understand and worthy of intensive study. In this research, in order to approach this problem, we developed an integrated numerical model for the prediction of bubble size distribution over the depth of foam. This integrated numerical model combines the population balance model and liquid drainage model. The population balance model is used to predict the evolution of the bubble size distribution as films fail and bubbles coalesce. The liquid drainage model describes the drainage of liquid through the Plateau border network, which is a key factor in film stability that dominates the coalescence of bubbles. The population balance and liquid drainage models are fully coupled, by providing the respective outputs to each other as mutual inputs. In order to validate this integrated numerical model, the simulation results are compared with relevant experimental results. In the experiments, we set up a pseudo-2-D foam column, which is a flat container composed of two parallel transparent walls. The gas bubbles, which have a diameter that is larger than the gap between the parallel walls of the foam column, enter the foam column by gas injection at the bottom. After the foam reaches a steady height, photos of the foam are taken. With image analysis, the bubble size distribution is measured at different vertical position in the 2-D foam. It is found that, over the depth of the 2-D foam, the simulation results of the mean size of bubbles and bubble size distribution are very close to the measured ones. With some minor revision, this integrated numerical model is capable of predicting the bubble size distribution in a fully 3-D foam as well.

PE13

Thermotropic liquid crystal foams

T. Trittel[1], Th. John[1], A. Eremin[1], R. Stannarius[1]

[1]Institute for experimental physics, Otto-von-Guericke university, Magdeburg,Germany
Email: torsten.trittel@st.ovgu.de

We investigate two-dimensional foams made from the pure liquid crystal 8CB. Because of the layered structure in the smectic mesophase, LCs can form stable foams, see Figure 1.
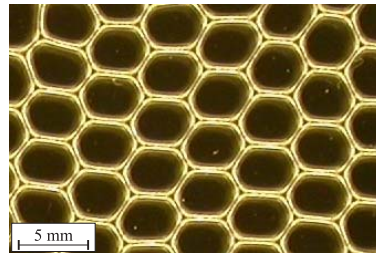
Figure1: Nearly regular and monodisperse cells in a freshly prepared foam of 8CB,
container thickness 2 mm.

We determine the structures of the foam cells and we are especially interested in the ageing dynamics of this new type of foam. In our experiment, we distinguish three stages of foam evolution. In the first stage the fresh prepared foam consists of multilayers of small cells. It takes several hours until the foam reaches stage two, which consists of a monolayer of foam cells with predo-minantly hexagonal shapes. After several days the foam develops an asymptotic structure (natural foam) with a characteristic distribution of *n*-polygons, see Figure 2, and self-similar scaling behavior of the coarsening. We confirm predicted structural parameters, like the Aboav Weaire relation and Lewis´s hypothesis and asymptotic scaling laws quantitatively. In the nematic phase, stable foams could not be produced, but smectic foams survive a transition into the nematic state up to several degrees above the phase transition. With the LC 5CB, which has no smectic phase, we were not able to prepare foams.
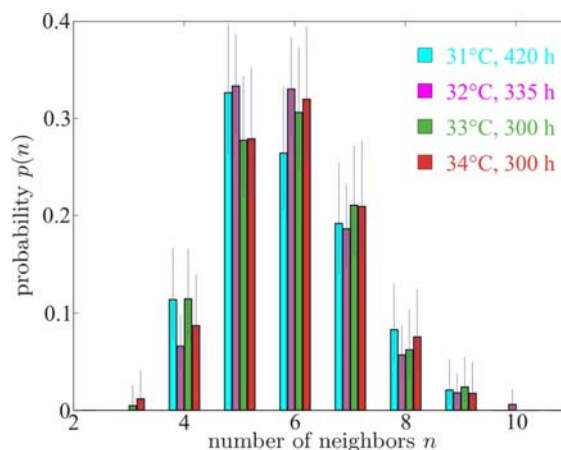
Figure2: distribution of n-polygons in the scaling state

PE14

Fluid dynamics of evolving foams

R. Verdejo,[1] F.J. Tapiador,[2] M.M. Bernal,[1] N. Bitinis[1] and M.A. Lopez-Manchado[1]

[1] *Institute of Polymer Science and Technology, (CSIC), Madrid, Spain*
[2] *Institute of Environmental Sciences (ICAM), Department of Environmental Sciences, University of Castilla-La Mancha (UCLM), Toledo, Spain.*
Email: rverdejo@ictp.csic.es

The physical properties of many multiphase systems are determined by coarsening phenomena. From raindrops to polycrystal grains and foams, the formation and stability of these systems continuously evolve towards lower-energy configurations through events such as coalescence, Ostwald ripening and drainage. Here we present a procedure to identify and characterise key topological transformations of coarsening phenomena using a physically-based fluid dynamic framework [1]. In-situ, real-time foaming processes of a polymeric matrix reinforced with two morphologically different nanofillers, carbon nanotubes and graphene sheets were observed by synchrotron x-ray radioscopy. We obtained detailed information on the evolution of the growth patterns and coarsening events. Filled samples showed differences in both trend and speed compared with the unfilled sample. Furthermore, we found different dominating coarsening phenomena due to the wetting nature of carbon nanoparticles. Our procedure can be extended to sequences of any type of 2D projection or 3D images and to other multiphase systems.
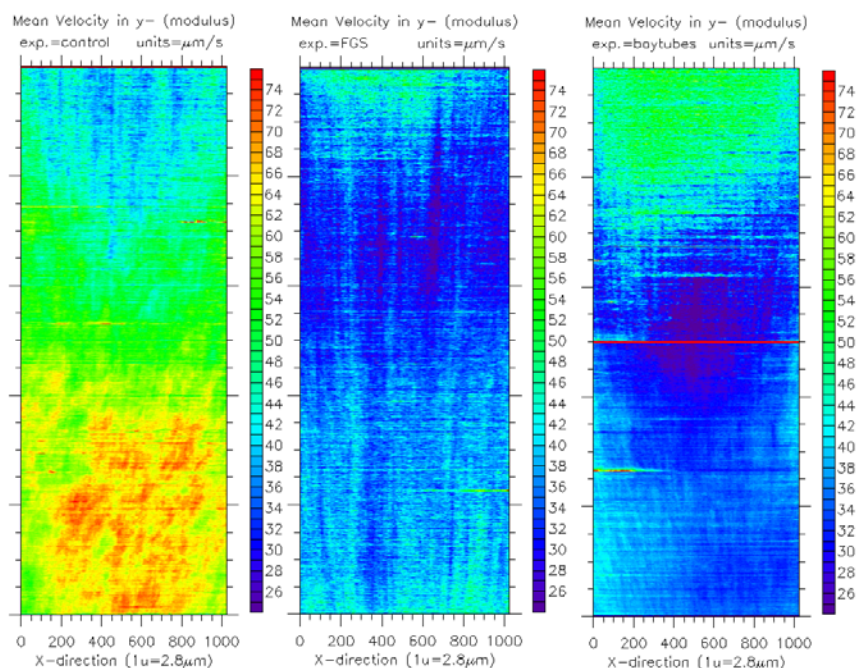
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PE15

Role of polymer-surfactant interaction
for foam formation and stability

Radka Petkova, Slavka Tcholakova, Doroteia Sidzhakova, Nikolai Denkov

Department of Chemical Engineering, University of Sofia, Sofia, Bulgaria
e-mail: sc@lcpe.uni-sofia.bg

The solutions of surfactant-polymer mixtures exhibit different foaming properties from the solutions of the individual components, due to the strong tendency for formation of polymer-surfactant complexes in the bulk and on the surface of the mixed solutions. Generally shared view in the literature is that the electrostatic interactions govern the formation of these complexes, for example between anionic surfactants and cationic polymers (and vice versa). In our studies we used a combination of model experiments (such as optical observations of thin liquid films, ellipsometry, surface tension measurements) and foam tests to evaluate the effect of the formation of polymer-surfactant complexes on the foaminess and stability of foams, generated from the corresponding mixed solutions. Different types of surfactants and polymers were mixed to clarify the main factors, which govern the complex formation. We found that the presence of opposite charges is not a necessary condition for forming polymer-surfactant complexes in many of the studied systems. For example, surfactant-polymer complexes were observed in mixtures of cationic surfactant and cationic polymer, cationic polymer and non-ionic surfactant, non-ionic polymer and non-ionic surfactant, and many other combinations of that type. The model experiments showed that adsorption layers with thickness of the order of 100 nm (or larger) can be formed on the air-water interface of the mixed solutions, even at very low surfactant concentrations (orders of magnitude below the CMC of the individual surfactant). These adsorption layers are very efficient to stabilize foams generated from mixed polymer-surfactant solutions, via a combined mechanism of electrostatic and steric stabilisation of the foam films.

PE16

Effect of the EO-groups and counterions on the surface dilatational rheology, foamability and foam stability

Nikola Alexandrov,[1] Krastanka G. Marinova,[1] Christine Bilke-Krause,[2] Krassimir D. Danov[1]

[1] *Dept. Chem. Eng., Chem. Fac., Sofia University, 1 James Bourchier Ave., 1164 Sofia, Bulgaria*
[2] *Krüss GmbH, Borsteler Chaussee 85-99a, D-22453 Hamburg, Germany*
Email: na@lcpe.uni-sofia.bg

We compare surface dilatational rheological properties of the low molecular ionic surfactants sodium dodecyl sulfate (SDS) and sodium dodecyl laureth-3 sulfate (SLES) by using two experimental techniques: oscillating and expanding drop methods. The rheological behavior of the adsorption layers for both surfactants in the presence of a given amount of sodium ions was found to be the same in the frame of experimental error, which shows that the EO-groups in SLES have negligible impact.

Parameters determined from the oscillating and expanding drop measurements are compared with the predicted Gibbs elasticity and diffusion relaxation time from the thermodynamic adsorption isotherm describing the values of equilibrium surface tension of SDS. Experimental error of rheological measurements is especially analyzed and the reliability of the obtained parameters is estimated.

For SLES adsorption layers we compared the role of different counterions (Na^+, Ca^{2+} and Al^{3+}) on the values of surface moduli. The storage modulus increases significantly with the increase of the counterion valency.

Results obtained by the expanding drop method are fully consistent with those from the oscillating measurements and confirm that the dilatational behavior of the SLES and SDS adsorption layers is predominantly elastic with a small surface dilatational viscosity for frequencies lower than 1 Hz. Kelvin-Voight rheological model describes the data from both types of experiments. The observed larger values of the surface dilatational elasticity of SLES in presence of Ca^{2+} and Al^{3+} counterions might be related to possible surface aggregation similarly to that described by Alargova et al. [1,2].

SLES foams in presence of Na^+ and Al^{3+} were observed and compared. It turned out that foamability and foam stability in presence of Al^{3+} is very poor in spite of the higher elasticity.

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PE17

Impact of the SLES structure (number of EO-groups) and the additives on the surface rheology and foam drainage

R. Stanimirova,[1] K.G. Marinova,[1] N. Alexandrov,[1] T. Schörck,[2] T. Winkler,[2] C. Bilke-Krause[2]

[1] *Dept. Chem. Eng., Chem. Fac., Sofia University, 1 James Bourchier Ave., 1164 Sofia, Bulgaria*
[2] *Krüss GmbH, Borsteler Chaussee 85-99a, D-22453 Hamburg, Germany*
Email: rs@lcpe.uni-sofia.bg

Sodium laureth sulfate (SLES) is anionic low molecular weight surfactant with a wide application in personal care and cosmetic products due to its low Kraft temperature and good foaming capabilities. Pure SLES is produced only when especially synthesized for small scale scientific investigations. The commercial products by different manufacturers however vary well in terms of structure and properties. We measured and analyzed the foaming properties (drainage and stability) and surface dilatational elastic (E') and viscous (E'') parameters of several SLES batches having different number of EO groups and different origin. Results showed that the foaming properties correlated well with the values of E' and E'' and the relation was not imparted by the number of EO-groups but rather to the presence of small amount of impurities (similarly to the effect of lauryl alcohol on the foam of sodium dodecyl sulfate).

PG1

Foam bubble size characterization: comparison between different techniques

E. Kolodziejczyk[1], S. Garcia[1], C. Appolonia-Nouzille[1], C. Curschellas[2], J.-M. Jung[1], M. Leser[1], C. Gehin-Delval[1]

[1]*Food Science and Technology Department, Nestlé Research Center, Lausanne, Switzerland*
[2]*Institute of Food Science and Nutrition, Food Process Engineering, ETH Zurich, Switzerland*
Email: jin-mi.jung@rdls.nestle.com

The stabilization of dispersed systems, like aerated products (foams), still is a major challenge in the food industry today. Foam-based products, such as ice cream, mousse, whipped cream or aerated confectioneries, are very much appreciated by the consumers, therefore the food industry is always looking for new and better approaches to produce these high quality products in a reproducible way. In order to do so, great care must be taken to strictly control all the important parameters during the foaming process, such as the gas and fluid flow rates or the rotational speed of the whipping device. This is important since these parameters determine two of the key characteristics of a foamed product, (i) the mean bubble size and (ii) the bubble size distribution. These characteristics have a direct impact on the texture, thus on the mouth feel experienced by the consumer, and on the shelf-life of the product. Therefore, it is crucial for the product developer to use suitable analytical methods which allow quantitative analysis of the bubble size distribution in aerated products.

Various microscopy techniques combined with image analysis are available for the characterization of bubble sizes. However, obtained results may slightly differ depending on the technique used. In this work we compare different analytical techniques. For this we used two model foams, one made with β-lactoglobulin, and a second one made with a polyglycerol ester (PGE), which is a lamellar phase forming surfactant [1]. Mean bubble size and bubble size distribution of these two foams were characterized using different techniques: inverted microscopy, Accusizer and a dispersion method developed at the Nestlé Research Center. This comparison highlights the advantages and drawbacks of each characterization technique and the interest of combining at least two methods in order to get a correct overview on the mean bubble size and bubble size distribution of the foam.

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PG2

Ultra-fast X-ray tomography as a tool to study foams behaviour in 3 dimensions

R. Mokso [(a)], U. Kaydok[(b)], F. Marone[(a)] and M.Stampanoni[(a,b)]

[(a)]*Swiss Light Source, Paul Scherrer Institut, 5232 Villigen, Switzerland*
[(b)]*Institute for Biomedical Engineering, University and ETH Zurich, Gloriastr. 35, 8092 Zurich, Switzerland*
e-mai:l mokso@psi.ch

We report on recent advances towards ultra-fast three dimensional imaging of complex systems such a liquid foams.

The penetrating power of X-rays coupled with the high photon flux of 3rd generation synchrotron sources makes X-ray tomography to excel among fast imaging techniques. One of the fields that has already benefitted from this nondestructive analysis technique is the foam physics. Efforts to experimetally access the dynamic behaviour of 3D foams meet numerous difficulties most of which can now be overcome thanks to the rapid developments in ultra-fast X-ray tomographic instrumentation. The state of the art setups at synchrotron sources offer routinely a temporal resolution of tens of seconds in tomography mode, sufficient for imaging of certain evolving systems such as stabilized liquid foams at pixel size of 1-10 microns [1]. However for some key questions about the behaviour of 3D complex systems like liquid or metallic foams exposed to external forces, such a temporal resolution is insufficient. Therefore a new ultra-fast tomographic data acquisition scheme [2] is being developed at the TOMCAT beamline [3] of the Swiss Light Source. We acquire the full set (500-800 images) of tomographic projections in typically 0.5 seconds with the voxel sizes ranging from 0.5 to 11 microns.

We will highlight the limitations and new solutions towards the imaging of liquid foams with the ultimate aim to achieve sub-second temporal resolution in three dimensions and at the same time ensuring high quality tomograms suitable for segmentation and labeling of relevant features such a individual bubbles.

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PG3

FOCUS: Foam evolution and stability in microgravity

Pál Bárczy[1], János Szőke[1], Béla M. Somosvári[1], Péter Szirovicza[1], Tamás Bárczy[1]

[1]*ADMATIS Ltd. Miskolc, HUNGARY*

The magnitude and the direction of gravity force beside surface forces has an important role in the life of foams. Using a new type of foam generator it is possible to investigate foam formation in different directions measured to gravity vector.

Foam Casting and Utilization in Space (FOCUS, Project ID: SURE AO-019) is an industrial materials science experiment to investigate foam formation and stability in microgravity. Main objective of the experiment is to demonstrate that the new foam generator is capable to produce foams with particles under microgravity conditions. Scientific objective is to collect data on the quantity and the structural evolution of the foam produced. A similar assemblage had been tested on aqueous systems under normal and elevated gravity conditions. These tests showed that the behavior of the foam generator and thus the foam structure highly depends on the foaming direction and gravity level[1]. FOCUS "switches off" gravity in order to see what happens when the magnitude of gravity falls to zero, and so the direction is undefined.

FOCUS Experiment has been successfully executed on board of the ISS on the 7th February 2010 showing that the foam generators are capable to blow foams in micro-g. Using an aqueous suspension of SiO_2 nanoparticles at 2wt% containing 0.05wt% SDS, foams were created in three foaming cartridges with three different flow rates. Foam volumes and the average cell sizes has to be determined from the images taken of the foam evolution and decay. These data shall be compared to the experiment series under terrestrial conditions, where several technological parameters can be varied, like flow rate, foaming direction, suspension amount, etc.
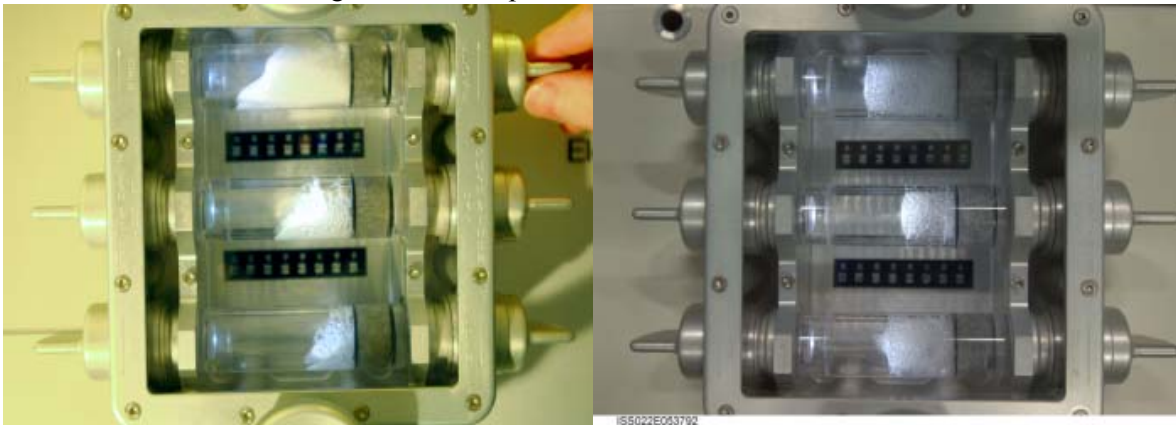
Left: Pre-experiment on ground, foaming direction is horizontal. **Right:** Experiment on the ISS, micro-g.

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PG4

Experimental and FEM analysis of the material response of porous metals imposed to mechanical loading

N. Michailidis, F Stergioudi, H. Omar, D. Papadopoulos, D.N. Tsipas

Physical Metallurgy Laboratory (PML), Mechanical Engineering Department, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece
Email: nmichail@eng.auth.gr

An experimental-computational study of the mechanical behavior of several porous metals is reported. Scanning electron microscopy with in-situ micro-tension tests were carried out to study and determine the mechanical properties of these porous materials. A serial sectioning image-based method was used to build the 3D geometries of the porous metals thus facilitating the simulation of their mechanical behavior with the aid of a computational procedure supported by Finite Element Method modeling.

To date, the majority of the three-dimensional micromechanical calculations of foams have been performed on idealized microstructures having simple geometry using analytical techniques or simplified equivalent FEM models [1-3]. To obtain high-quality predictions of porous material response, it is critical to construct FEM models that provide a reasonably accurate description of the actual complicated and heterogeneous structure of the foam. The developed models were based on actual metallographic cross sections of the porous materials. The 3D structures of the produced porous materials derived from the synthesis of serial digital cross sectional images of the porous materials. The generated 3D geometries were appropriately adjusted to build a FEM model simulating the deformation conditions of the foam. The distributions of the global and local stresses and strains developed in the Al foam were determined and visualised in mapping plots. The experimental results, obtained from the micro-tension tests, were correlated with those resulting from the FEM model, enabling thus the identification of the critical local stresses that led to yielding and fracture for each porous metal.

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PH1

Novel surface active chelating agents with potential applications in sustainable industrial processes

I. Högberg, F. Andersson, A. Almesåker, M. Norgren, E. Hedenström, H. Edlund

Department of Natural Sciences, Engineering and Mathematics, Fibre Science and Communication Network (FSCN), Mid Sweden University, SE-851 70 Sundsvall, Sweden
Email: hakan.edlund@miun.se

In this study we have chosen to investigate separable chelating agents that can be regenerated and reused, and that the separated metal ions can be recovered. The study is based on flotation and surface active chelating agents. The chelating agents were synthesized with multiple chelating sites, represented by carboxyl units and tertiary amines, whereby coordination complexes with metal ions can be formed.

We report on the amphiphilic characterization of the surface active chelating agents and results from studies from metal recovery in different applications such as; treatment of paper pulp; purification of leachate water from landfills; and in ex-situ washing of metal contaminated soil.

By flotation in an in-house customized flotation cell the metal-chelator complexes were collected in a foam-phase and removed from water. From a 1 ppm copper solution more than 90 % of the copper could be recovered.

PH2

Interfacial properties of green coffee oils

M.Ferrari[1], F.Ravera[1], E. De Angelis[2], F.Suggi Liverani[3] and L. Navarini[3]

[1]*Istituto per l'Energetica e le Interfasi – CNR, via De Marini 6, I-16149 GENOVA (Italy)*
[2]*AromaLab, illycaffè S.p.A., AREA Science Park, Padriciano 99, I-34012, TRIESTE (Italy)*
[3] *illycaffè S.p.A., via Flavia 110, I-34147 TRIESTE (Italy)*
Email: luciano.navarini@illy.com

The two commercially relevant coffee species, *Coffea arabica* (Arabica) and *Coffea canephora var. Robusta* (Robusta) contain between 7 and 17% fat with an average lipid content of Arabica significantly higher (15%) than that of Robusta (10%). Differently from other coffee components, the lipid fraction is relatively understudied and most of the published works are focussed on chemical characterization. In spite of the fact that both green and roasted coffee oils are industrially exploited, the former in the cosmetics and the latter in food applications as flavouring agent, very little literature data are available on physicochemical properties of coffee oil. Very recently liquid-liquid interfacial properties of roasted coffee oils have been preliminarly investigated by our group. The study suggested that several polar compounds as well as liposoluble dark-coloured Maillard reaction products generated by roasting may be considered efficient surface active compounds in view of the low equilibrium Interfacial Tension (IT) values observed.

In order to assess the effect of the roasting process, the present work reports on interfacial properties of coffee oil extracted from raw green coffee beans. Several coffee oils from green Arabica and Robusta samples as well as from decaffeinated sample have been investigated. On selected samples, the coffee oil has been extracted before and after roasting and both oils have been characterized. Water-oil dynamic IT data have been compared wit those of commercial vegetable oils.

PH3

Foaming and rheological properties of the soluble phase
of wheat flour dough

A. Turbin, G. Della Valle, JL. Doublier, D. Marion, B. Novales

INRA, UR 1268 Biopolymères, Interactions & Assemblages (BIA), Nantes , France
Email: arnaud.turbin@nantes.inra.fr

During fermentation, the porosity of wheat flour dough increases from 0.1 to 0.7 and CO_2 bubbles become interconnected without any collapse [1]. This is related to the formation of a liquid foam, co-continuous to the viscoelastic starch/gluten matrix. To delineate the role of the dough liquid phase in the creation of the cellular structure of bread crumb, the soluble phase of dough, i.e. the dough liquor (DL), can be extracted by ultra-centrifugation [2]; it is composed of lipids, soluble proteins and polysaccharides, mostly arabinoxylans. DL accounts for 6% of total dry matter of dough and is considered as a good model of the dough liquid phase. Our objective was to determine the relationships between the rheological properties and the foaming properties of DL. DL was extracted from dough pieces of various compositions, within which the bubbles growth has already been characterized [1]. The flow behaviour of fresh DL has been described, using a a RFSII with a cone-plane geometry. DL displayed a shear-thinning behaviour together with a yield stress evidenced at low shear rate. This suggests that polysaccharides govern the overall flow properties, while soluble proteins interact with the polysaccharide giving rise to the yield stress. Meanwhile, fresh DL was diluted (1/10) and studied in a Foamscan (IT-Concept) by nitrogen bubbling across a filter and measuring foam volume as well as DL drainage for 10 min, with a CCD camera. Drainage kinetics were analyzed in relation to flow behaviour as it has been shown that elastic properties of macromolecular solutions may induce a faster drainage [3]. Once compared with bubbles growth kinetics in dough, the interpretation of the foaming behavior might be improved by determining the surface rheological properties of DL.

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