Foam coarsening

http://users.aber.ac.uk/sxc/infoamal.html

Université Paris Diderot

9-11 January 2013

François Graner
Matière et Systèmes Complexes, Université Paris Diderot
10 rue Alice Domon et Léonie Duquet, 75013 Paris
francois.graner@univ-paris-diderot.fr

Simon Cox
Institute of Mathematics and Physics
Aberystwyth University, Aberystwyth SY23 3BZ, UK
sxc@aber.ac.uk

1. Proposal

1.1 Introduction and motivation

Many materials consist of cellular domains, including foams (gas bubbles separated by liquid films), emulsions (oil droplets dispersed in a continuous aqueous phase), magnetic domains, monocrystalline grains within a polycrystalline metal, etc. Foams are used as a model for those systems, especially because exact numerical simulations can be performed using either the Surface Evolver or the Potts model.

Since the pressure in a foam can differ from one bubble to another, gas slowly diffuses between the bubbles. Some bubbles disappear and, as no new bubbles are created, the average size increases. The dynamics is driven by mean curvature, as for emulsions and grains, and mainly depends on the liquid fraction, up to a material-specific time-scale determined by the foam physicochemistry [1,2].

To understand foam coarsening requires two levels of description. First, the individual bubble growth law rules a bubble's growth rate according to its size or shape. This is a static geometry problem, and may be obtained analytically or by detailed bubble shape simulation. Second, the effect of the individual growth on the statistics of the foam, i.e., bubble size and topology distributions, requires statistical theories or extensive simulations.

To make progress therefore requires that mathematicians, physicists, chemists, chemical engineers and materials scientists each make a distinct contribution. To solve problems of interest to systems such as food products that are based on foams and emulsions further requires that industrial needs guide the discussions. We aim to put particular emphasis on numerical simulations (which is the field of expertise of both organisers, S.C. for the Surface Evolver and F.G. for the Potts model) to establish an integrated understanding.

Our proposal is for a highly-focussed, short discussion meeting to identify, discuss, and hopefully solve, open problems in the coarsening of foam-like systems.

[1] I. Cantat, S. Cohen-Addad, F. Elias, F. Graner, R. Hohler, O. Pitois, F. Rouyer, and A. Saint-Jalmes, Les mousses: Structure et dynamique (Belin, Paris, 2010) [English version, Foams: Structure and Dynamics, edited by S.J. Cox (Oxford University Press, Oxford, to be published), ISBN 978-0-19-966289-0].

[2] D. Weaire and S. Hutzler, Physics of Foams (Oxford University Press, Oxford, 2001).

1.2 State of the art

In the very dry limit, bubbles are polyhedra with thin curved faces that meet by three along thin lines called Plateau borders. Coarsening in that limit has been investigated experimentally, numerically, and theoretically in two dimensions (2D) [3–6] and later in three dimensions (3D) [7–14].

In the very wet limit, bubbles are round, dispersed in the liquid, and far from each other, forming a ‘‘bubbly liquid’’ rather than a foam in the strict sense. Their coarsening follows Ostwald-Lifschitz-Slyozov-Wagner ripening in 3D [15,16], and Ostwald-Marqusee and Ostwald-YEGG in 2D [17,18].

In both limits, the foam eventually reaches a self-similar growth regime: statistical distributions of face numbers and relative sizes become invariant. Intermediate liquid fraction regimes have been addressed in 3D experiments [19] and 2D simulations [20,21] but they still lack a unified theoretical description.

Computer simulations are of two main sorts: either microscopic, taking into account the precise geometry of each surface (e.g. Surface Evolver) to determine the growth rate of individual bubbles, or macroscopic, tackling the problem of the statistical evolution during coarsening by simulating large ensembles of bubbles with a reasonably approximated geometry (e.g. Potts model). To each of these must be added a description of the surface chemistry of real foams, a point made by several of the participants.

[3] J. Stavans, Rep. Prog. Phys. 56, 733 (1993).

[4] J. von Neumann, in Metal Interfaces, edited by R. Brick (ASM, Cleveland, 1952), p. 108.

[5] J. Stavans and J. A. Glazier, Phys. Rev. Lett. 62, 1318 (1989).

[6] J. R. Iglesias and R. M. C. de Almeida, Phys. Rev. A 43, 2763 (1991).

[7] F. Wakai, N. Enomoto, and H. Ogawa, Acta Mater. 48, 1297 (2000).

[8] C. E. Krill, III and L.-Q. Chen, Acta Mater. 50, 3059 (2002).

[9] S.J. Cox and F. Graner, F. Phys. Rev. E. 69, 031409 (2004).

[10] G. L. Thomas, R. M. C. de Almeida, and F. Graner, Phys. Rev. E 74, 021407 (2006).

[11] J. Lambert, R. Mokso, I. Cantat, P. Cloetens, J. A. Glazier, F. Graner, and R. Delannay, Phys. Rev. Lett. 104, 248304 (2010).

[12] P. Streitenberger and D. Zollner, Scr. Mater. 55, 461 (2006).

[13] S. Hilgenfeldt, A. M. Kraynik, D. A. Reinelt, and J. M. Sullivan, Europhys. Lett. 67, 484 (2004).

[14] R. McPherson and D. Srolovitz, Nature (London) 446, 1053 (2007).

[15] W. Ostwald, Principles of Inorganic Chemistry (Macmillan, London, 1902), p. 58; Grundriss der Allgemeinen Chemie (Macmillan, London, 1908), p. 96; The Scientific Foundations of Analytic Chemistry (Macmillan, London, 1908), 3rd ed., p. 22.

[16] I. M. Lifschitz and V. V. Slyozov, Zh. Eksp. Teor. Fiz. 35, 479 (1958) [Sov. Phys. JETP 8, 331 (1959)]; C. Wagner, Z. Elektrochem. 65, 581 (1961)

[17] J. A. Marqusee, J. Chem. Phys. 81, 976 (1984).

[18] J. H. Yao, K. R. Elder, H. Guo, and M. Grant, Phys. Rev. B 45, 8173 (1992).

[19] J. Lambert, I. Cantat, R. Delannay, R. Mokso, P. Cloetens, J. A. Glazier, and F. Graner, Phys. Rev. Lett. 99, 058304 (2007).

[20] F. Bolton and D. Weaire, Philos. Mag. B 65, 473 (1992).

[21] S. Hutzler, D. Weaire, and F. Bolton, Philos. Mag. B 71, 277 (1995).

1.3 Objectives

The meeting will last for four half-days, from wednesday 9th, at noon, to friday 11th, at noon. It is organised so that participants will spend the majority of the time in self-organised discussions, on subjects chosen at the beginning of the meeting for their immediacy and agreed scientific interest. Only a few five-minute slots will be devoted to short computer-assisted presentations of their work.

The goal is to address the following questions :

- How to interpolate the growth rate between the limits of wet and dry foam: statics, dynamics, statistics?
- How to predict the fate of a foam containing a mixture of gases.?
- How to understand and take into account in simulations the role of interfacial viscoelasticity in coarsening foams?
- What is the coupling between coarsening and drainage, rupture, and rheology?

- Static calculations for one bubble: how to describe and understand shape, topological and geometrical charge, and the integral of mean curvature?
- The dynamics of a single bubble: how to calculate the effective diffusion coefficient and the role of physico-chemistry?
- Statistics: what is the evolution of shape distributions, size distributions, and the self-similar growth regime? How do foams reach a scaling state regime? Are all foams able to do so? Is it possible to prove that this state is stable and unique?
- Is it possible to make precise the link between foam coarsening and grain growth?

as well as questions collected from the participants themselves.

1.4 Participant List

To foster discussions, the number of participants will be strictly limited to 30. Registration is open until Nov 23rd, so we don't yet have the definitive list of participants. We are continuously receiving applications from international researchers and have already received 25. We have already accepted the following participants, who are actively engaged in this field of research and cover both academic and industrial interests, and both senior and junior researchers:

• Sylvie Cohen-Addad, Université Pierre et Marie Curie, France, sylvie.cohen-addad@insp.upmc.fr
• Nikolai Denkov, Sofia University, Bulgaria , nd@dce.uni-sofia.bg
• Myfanwy Evans, Universität Erlangen-Nürnberg, Germany, <myfanwy.e.evans@physik.uni-erlangen.de>
• Deniz Gunes, Nestle research Centre, Lausanne, Switzerland zeyneldeniz.gunes@rdls.nestle.com
• Ismael Fortuna, Universidade Federal do Rio Grande do Sul, Brazil <ismaelfortuna@gmail.com>
• Reinhard Hohler, Université Pierre et Marie Curie, France <hohler@insp.upmc.fr>
• Marie-Caroline Jullien, ESPCI ParisTech, France <marie-caroline.jullien@espci.fr>
• Dominique Langevin, University Paris-Sud, France <dominique.langevin@u-psud.fr>
• Vincent Miralles, ESPCI ParisTech, France <vincent.miralles@espci.fr>
• Rajmund Mokso, Paul Scherrer Institute, Switzerland <rajmund.mokso@psi.ch>
• Gerd Schröder-Turk, Universität Erlangen-Nürnberg, Germany <gerd.schroeder-turk@physik.uni-erlangen.de>
• Simeon Stoyanov, Wageningen University & Research Centre, The Netherlands <simeon.stoyanov@wur.nl>
• Slavka Tcholakova, Sofia University, Bulgaria <sc@dce.uni-sofia.bg>
• Gilberto L. Thomas, Universidade Federal do Rio Grande do Sul, Brazil <glt@if.ufrgs.br>
• Denis Weaire, emeritus professor from Trinity College Dublin, Ireland <dweaire@tcd.ie>

2. Financial Support

The Université Paris Diderot will support the workshop by providing meeting rooms for plenary discussions and short presentations, and breakout areas for small group discussions. It will also partially support financially the invitation to Gilberto Thomas.

The French consortium CNRS GDR ``Foams and emulsions'' will provide financial support for the non-french organiser, S. Cox.

Due to the proposed informal nature of this workshop, we will not charge a registration fee.

The CFCAM structure of funding is particularly suitable for our meeting.

We ask for the following support :

- 200 euros/person for transportation for 20 non-french European participants	4 000 E
- 1000 euros/person for transportation for Brazilians namely G. Thomas (professor) and I. Fortuna (student)	2 000 E
- 300 euros/person for accommodation for participants without adequate funding namely I. Fortuna (brazilian student) and D. Weaire (emeritus professor)	600 E
Total for four half-days of meeting :	**6 600 E**