ESRF	Dynamics of liquids foams: coarsening and drainage	number: SC-1111
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Report:

Experiments - We have performed the first X-ray micro-tomographic study of the time evolution of liquid foams. This in-situ, non destructive method allowed us to follow the aging of several thousands of bubbles, which is one to two orders of magnitude more than studies published in the literature. The conditions of operation were good, thanks to the excellent contribution of Peter Cloetens both during the experiments and through scientific discussions.

Since the study of coarsening was successful, we have chosen to record in detail the aging of 14 foams of various compositions and coarsening rates, alternating in the beam over up to 1.5 days. We have thus chosen to leave the study of drainage to future experiments, but checked its feasability in our sample cell (designed to control the amount of fluid in the foam, using two pumps mounted in opposition).

A clean and sharp 3D image of a foam containing 10-20% of water was obtained in 2.5 min, with 10 μm resolution, and 10 min repetition time. 900 radiographs with an exposure time of 50 ms each were recorded to reconstruct a volume containing 850x850x1024 voxels. The X-ray energy was set to 15 keV with a sample-to-detector distance of 150 mm in order to enhance through phase contrast the visibility of the thin faces that separate the bubbles. The best series of images consisted in a SDS-dodecanol foam with gelatin, for which we recorded 96 3D images, with ages ranging from $t = 30$ to 2200 min (almost two decades in time), see Fig. 1 (a,b).

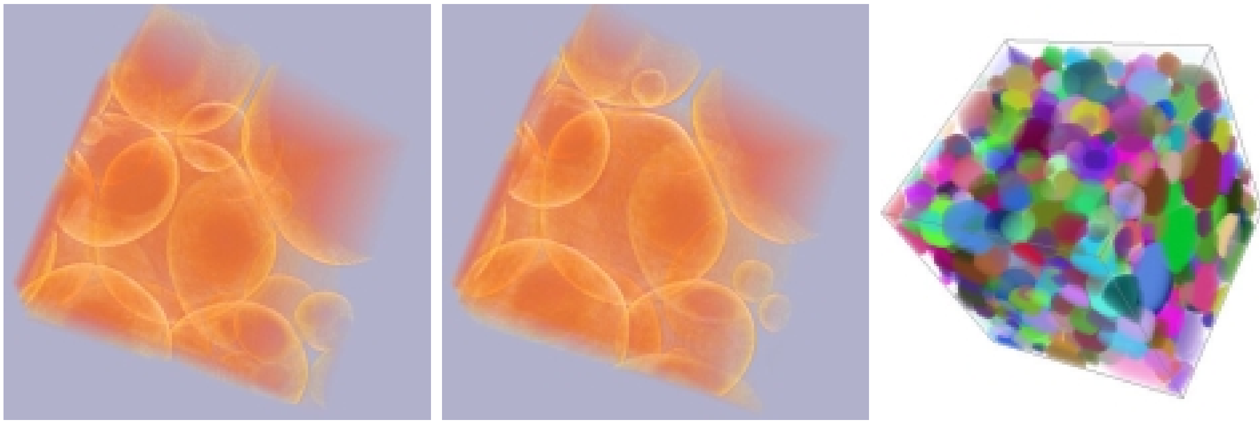

Fig. 1.: (a,b) Two 3D snapshots of the coarsening of a liquid foam evolving as a function of time (scan time = 150 s, separation between images = 1 hour). Large bubbles grow at the expense of small ones. (c) Each bubble is tracked individually.

Results - The quality of the images was good enough to roughly binarise them by thresholding. The image segmentation (separation and labelling of the individual bubbles) proved to be very long and difficult due to the thin faces separating the bubbles in some regions. However, it is now performed on the full series of images we obtained (Fig. 1c). Each individual bubble can thus be followed during its life time, providing a very good statistics on the bubble volume variation as a function of its structure: number of faces, volume ...

We obtain the distribution of bubble sizes at different times (see for example Fig. 2). This yields information both on the global statistics (growth of characteristic bubble volume with time) and individual growth law (growth of a bubble, as a function of its number of faces, and of the fluid fraction of its environment). We currently develop a theoretical understanding of this growth law, combining the numerical and analytical studies, in close interaction with these experimental progresses.

Our images, already used in "ESRF Highlights" and in "Pour la Science" (french version of "Scientific American"), as well as in a 6-minutes movie produced by University of Grenoble, are currently presented in congresses (including two with proceedings: "EMC 2004" and "Eufoams 2004"). The results, when complete, will be submitted to a scientific journal.

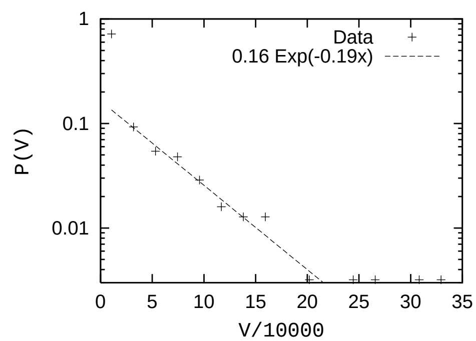

Fig. 2.: Histogram of volume distribution is exponential, $\mathcal{P}(V) \propto \exp(-V/V_c)$, with a characteristic volume V_c (here 50 000 voxels) which grows with time.