Radioscopy on Cell wall ruptures to study metal foam stability mechanisms

Introduction

Third-generation synchrotron light sources deliver a polychromatic X-ray photon flux density high enough to perform radiography with micro-resolution in both space and time [1–4]. The rapid development of imaging hardware, especially in the field of CMOS sensors, and their continuously improving sensitivity now allows for extraordinarily high recording speeds, with exposition times down to 1 µs for a considerable (at least 10 × 20 mm^2) field of view. The optimized use of so-called X-ray inline phase contrast (due to the coherence properties of an X-ray synchrotron beam) allows for the best possible contrast for our cellular material. Additionally, radiation hard but highly sensitive and efficient single crystal scintillators such as LuAG:Ce or YAG:Ce crystals are employed. This permits us to follow the overall process and resolve *in-situ* not only slow processes (>1 ms exposition time) such as pore nucleation and growth, foam expansion or drainage, or simply observe the overall foaming process, but also very fast ones (≤1 ms exposition time) such as cell wall rupture, bubble coalescence, rapid bubble motions or oscillations. Figure 1 shows the improvement of time resolution for X-ray synchrotron radioscopy achieved in the past years as reported in the literature [3–7] and our result from the MA 1134 campaign recently published by us [8].

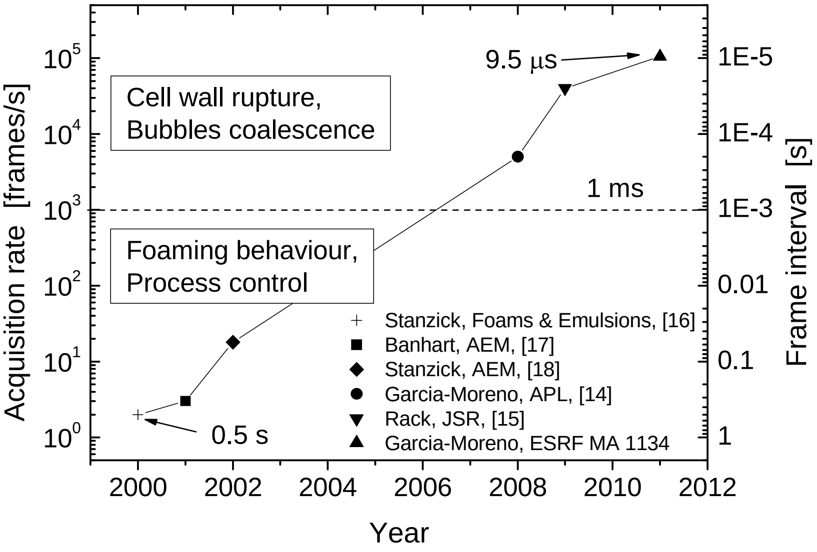

Figure 1. Evolution of time resolution for *in-situ* synchrotron X-ray radioscopy applied to visualize metal foaming.

Results

The stabilization of metal films—or cell walls—in liquid foams is a key issue in metal foam science but still not fully understood. To investigate the nature of rupture, experiments have been performed in which there was a simultaneous demand for both high spatial and high time resolution. It was possible to observe the coalescence of two adjacent bubbles with a recording speed of 105,000 fps with a frame interval of 9.5 µs and effective pixel size of 20 µm. Although the contrast of such images is low due to the short exposure time and consequent limited dynamics of the images, it is clearly visible in Figure 2 that the coalescence of two bubbles is completed in ~475 µs and that the rupture of a film lasts for ~380 µs, if we consider the end of the rupture as the point, where the contour of the new bubble becomes straight before it ends as convex.

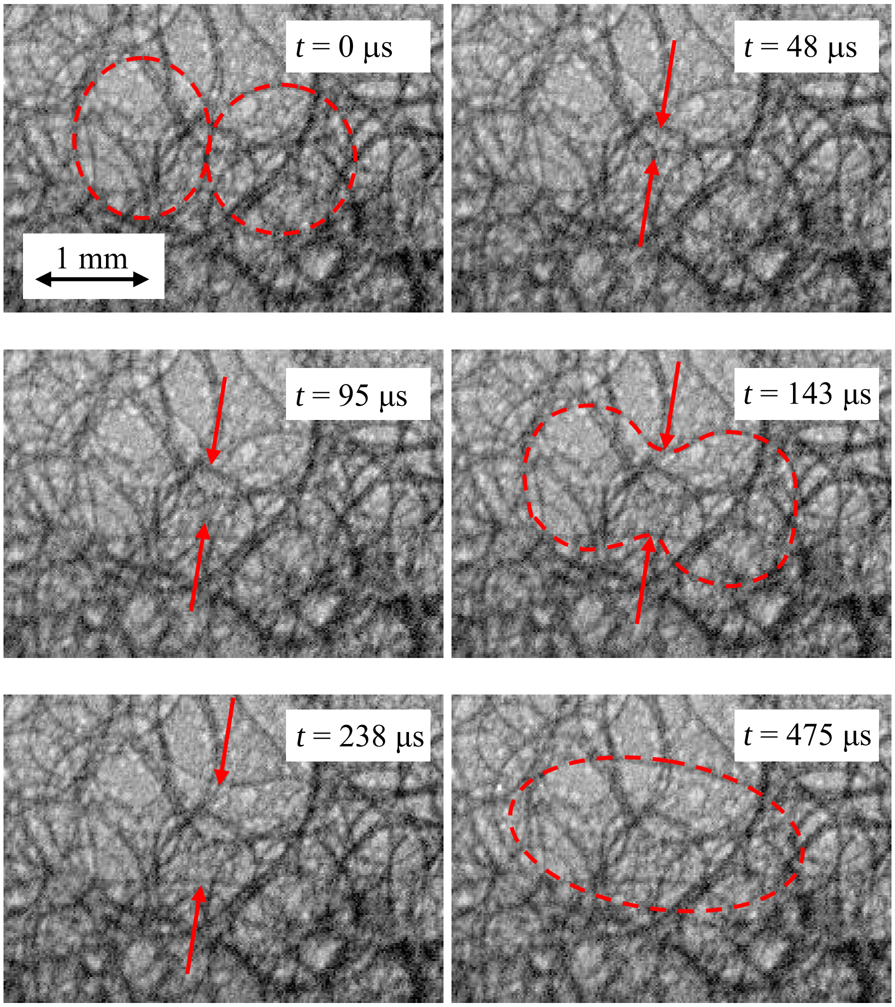

Figure 2. Series of radiographs of an AlSi10 + 0.5 wt.% TiH_2 foam at 640 °C extracted from an *in-situ* fast synchrotron X-ray radioscopic analysis. The coalescence of two bubbles measured with 9.5 µs frame interval (105 kfps) can be observed. Dashed lines indicate the contours of the bubbles and arrows indicate the corresponding ruptured cell wall.

In this experiments it was possible to demonstrate that the rupture time of a film is dominated by the inertia of the fluid and not by its viscosity as rupture occurred so fast [3]. Therefore, it could be demonstrated that stabilization by an effective viscosity only, which would be as high as $\eta = 0.4$ Pa·s (as calculated by Gergely *et al.* [9]) does not apply to metal foams of the type investigated here. Other factors such as bubble size and alloy composition may influence the rupture time and will be studied in future.

References

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