The behaviour of particles in liquid films

Due to brilliant synchrotron X-rays at ESRF and high phase contrast, particle trajectories in liquid films could be visualised. One outstanding detected effect was the incident, that single particles and clusters flow continuous, whereby others stop for unrecognizable reasons and don´t move any further. This behaviour was surprising and hitherto never recorded before. One exemplary result of this phenomenon can be seen in Figure 1 (image processed radioscopies), whereby SiC particles and clusters in AlSi9Mg0,6/SiC/20p at 21 % O_2 flow vertical downwards forced by gravity (blurred black lines, integrated over 0.2 s) and stop surprisingly (black solid spots). Furthermore it was shown, that such already fixed cluster (solid black circle) could even catch further particles (dotted black circle) after 2.4 s and hinder their further movements (4 s).

To quantify the fixation event, particles, which were moveable at the beginning and their spatial coverage of the field of view (FOV) when they got fixed, were temporally analysed. For a simplifying evaluation only particles > 1000 µm² were analysed. “0 s” or “at the beginning” indicate the end of the film pulling process, whereby static circumstances of the model system are guaranteed. Figure 2 shows the preferred fixation in the first seconds, whereby approximately 7 % of the FOV were covered by particles of AlSi9Mg0,6/SiC/20p at 21 % O_2. The two graphs of the same material were two independent experiments, whose behaviour were comparable and can be considered as an evidence of statistical certainty and validity of the experiment. In contrast to that, the surface of the same material at 1500 ppm O_2 and of AlSi9/TiB_2/6p at 21 % O_2 exhibits, that both FOVs are covered by just 1 % particles. Furthermore the number of moveable clusters was taken in ratio to the number of fixed clusters, due to avoid a possible misinterpretation based on the total number of particles, which can vary within the individual experiments. Those results are summarised in Table 1 and reflect a comparable implication as the graphs of the diagram. More than twice of moveable clusters were fixed for AlSi9Mg0,6/SiC/20p at 21 O_2 % in comparison to AlSi9Mg0,6/SiC/20p at 1500 ppm O_2 or AlSi9/TiB_2/6p at 21 % O_2. In summary it can be said: the combination of Magnesium and an enhanced oxygen concentration supports the fixation of particles, which is a further step to unravel the mystery of metal foam stability.

The rupture event of a single, liquid film

Via fast synchrotron X-ray radioscopies a hitherto entirely new event was visualised inside the films. Even that AlSi9/TiB2/6p at 21 % O2 was indeed known for its low stability, nevertheless especially this instable material showed how a rupture might get prevented, compare Figure 3. By having a look at the rupture event, with just 1 ms of exposure time, it is obvious, that a particle cluster was pushed by an incipient rupture (red circle). Quite contrary to this, two others clusters (black circles), from a distance of the centre of the rupture, did not changed their position. Those were even so immobile to hinder the expanding rupture to expand any further. Moreover it has to be pointed to the fact, that the edge of the rupture exhibited a wrinkled structure, which indicates a rigidity of the film.

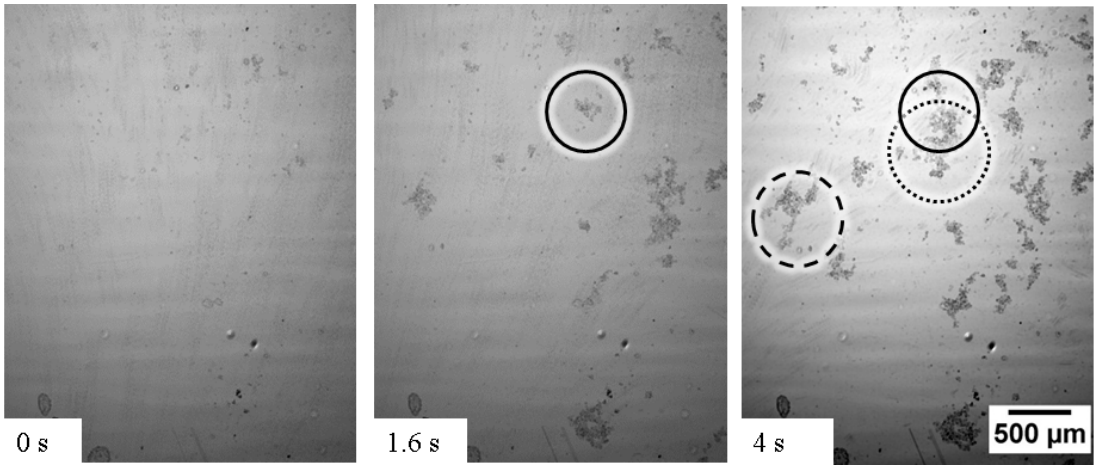

Figure 1 Synchrotron X-ray radiographies show the phenomenon of particle attachment (processed and integrated images over 0.2 s per image) of SiC clusters in AlSi9Mg0.6/SiC/20p at 21 % O_2 after 1.6 s (solid circle), 4 s (broken circle) and the attachment of a further cluster (dotted circle) at an already fixed cluster (broken circle). Blurred lines indicate particles in motion. Sharp, clearly recognisable spots mark particles in idle state (fixed).

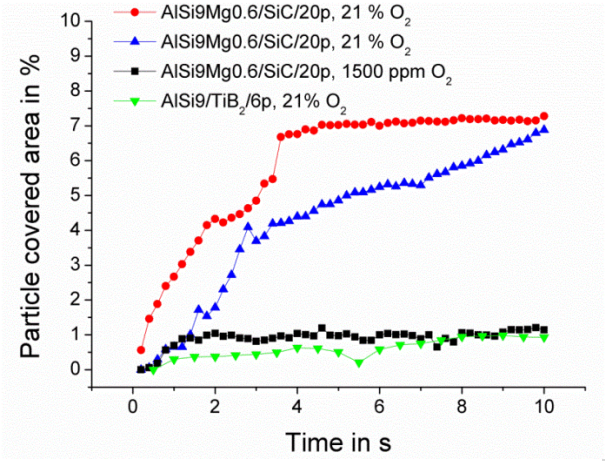

Figure 2 Particle covered area for varied materials and oxygen concentrations using the VD-Model. Minimal particle respectively cluster size was determined to 1000 µm².

Table 1 Ratio of fixed to free clusters (> 1000 µm²) per mm² after 10 s.

Material	Fixed clusters	Free Clusters	Ratio
AlSi9/TiB_2/6p, 21 % O_2	1.8 ± 1	17.6 ± 10	10.0 ± 3 %
AlSi9Mg0.6/SiC/ 20p, 21 % O_2	6.2 ± 1	31.2 ± 10	20.8 ± 3 %
AlSi9Mg0.6/SiC/ 20p, 1500 ppm O_2	2.3 ± 1	24.3 ± 10	9.4 ± 3 %

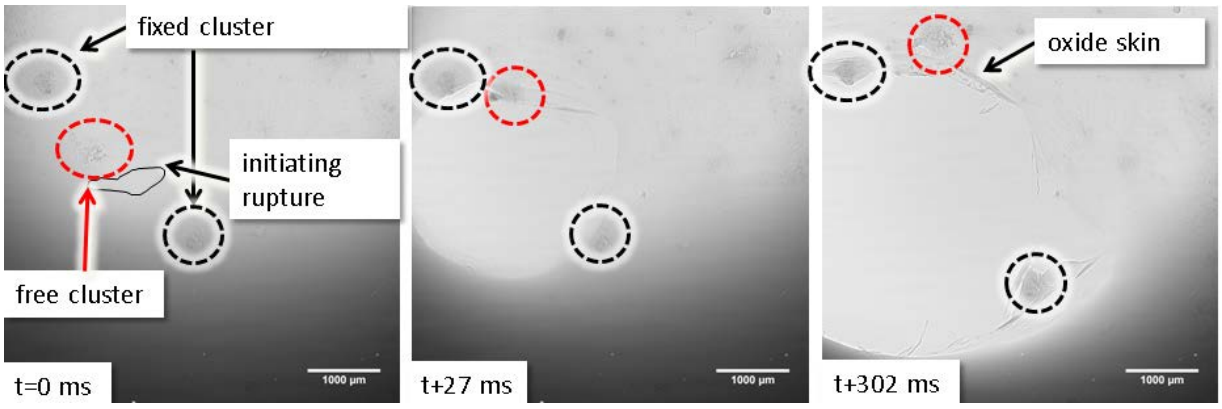

Figure 1 Synchrotron radioscopy of the rupture event of an AlSi9/TiB2/6p film at 21 % O_2 acquired with 1000 fps.