# Metal foams

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**Fig. 1: left:** aluminium foam blown with air from a particle-stabilised melt and beer, **right:** zinc foam and bread roll, both foamed by internal gas creation (Photographs: Hahn-Meitner-Institut)

## Introduction

*Metal foams* are challenging materials for both fundamental and applied research. They distinguish themselves from other materials by low density, high specific stiffness, and high-energy absorption capability. Therefore, they become increasingly popular for industrial applications. Like all other foams, metal foams are produced in the liquid state. Liquid metal foams, by definition, are collections of gas bubbles uniformly dispersed in a liquid metal separated by self-standing thin liquid films. Two methods for foaming metals, distinguished by the way the gas enters the melt, i.e. by the gas source, are used. Bubble creation can be *external* or *internal*. In the former case, gas bubbles are created by continuous gas injection. The foam accumulates at the surface of the melt and the result resembles a glass of draught beer. In the latter method, gas-releasing propellants – akin to the blowing agents of yeast used by bakers – are added to the melt or compacted powders (Fig. 1 and 2).

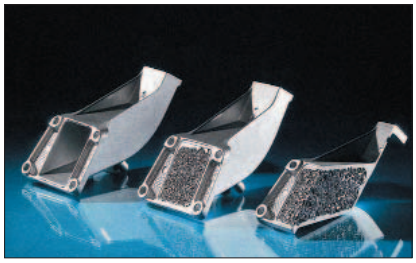

**Fig. 2:** Foamed part of aluminium dedicated for BMW engine mounting bracket (courtesy of HKB, Austria)

Several scientific challenges and industrial problems of metal foams give motivation for further research. From the scientific point of view, the evolution and the stabilisation of the liquids are in the focus, while industry is searching for process optimization and new metal foaming technology. Our group tries to work in both the applied and the fundamental fields collaborating with scientists from Japan, Austria, USA and from spin-off companies.

In the following part, we detail the progress in understanding evolution, stability, 3D architecture and microstructure of metal foams. Only very recently, the issue of metal foam stabilisation was addressed and traced back to the presence of micro- or even nanometre-sized solid particles in the liquid metal [1]. The time has therefore come to understand liquid metal foams as an independent field of research and to look at these systems from the viewpoint of colloid chemistry.

## Evolution of foams blown by using internal gas source

A compact microfocus X-ray source was used to monitor foam expansion kinetics while the temperature ramp and the $TiH_2$ blowing agent treatment were varied [2]. A new pressure furnace was built and used to carry out high pressure ($<10\,bar$) and low pressure ($>0.001\,bar$) experiments in oxidizing or inert atmospheres. A strong influence of the gas pressure on the foaming behaviour was found (Fig. 3). Under low pressures, high coalescence, instabilities and rising big bubbles characterise the foaming. Under high pressures, besides a reduced expansion, an extremely small average cell size and high homogeneity were observed. Release from high pressure to normal pressure led to an increased expansion. Also reversible expansion and compression after several pressure cycles were found with a flexible cell wall structure. An additional expansion with high coalescence followed each cycle increasing the maximal expansion from $F/F_0 \sim 1.5$ at $8\,bar$ to $F/F_0 \sim 4$ at $1\,bar$.

MS, TGA and XRD experiments showed that the decomposition of as-received $TiH_2$ powder in argon occurs in two stages [3]. Heating as-received $TiH_2$ at $10\,K/min$ in argon leads to hydrogen release at $400°C$. Heat treatment at $480°C$ for $180\,min$ eliminates the first decomposition stage completely and increases the temperature at which gas evolution occurs. Oxide layers around the cores of the titanium-hydride particles formed during annealing in air act as very effective diffusion barriers. XRD and TEM experiments showed the formation of $TiH_2$ and $Ti_3O$ during

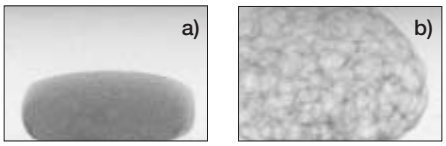


**Fig. 3:** X-ray radioscopy images of **a)** Al99.7 + 0.5 wt% $TiH_2$ foamed under 8 bar in air, **b)** additional expansion of **a)** after release from 8 bar to 1 bar with –0.2 bar/s

heat treatment. We have shown that results from different methods can be combined to form a more complete picture of decomposition of $TiH_2$ and that various methods provide complementary information.

### Evolution of foams blown by external gas injection

External foam evolution strongly depends on the foaming gas being used. The use of an oxidizing gas, e. g. air, results in a thick (100 nm) oxide skin on the cell wall surfaces acting like a rigid stabilizing layer. The role of oxidation in liquid metal foams is revealed by ex-situ and in-situ analysis [4]. A new X-ray transparent foaming furnace was constructed adapting Metcomb technology. The furnace was also used for technology development with our industrial partner. In-situ experiments were performed using microfocus X-ray source at our laboratory at TU Berlin. When blowing Duralcan type metal matrix composites, the drainage and the coalescence rate were quantitatively monitored. Significant drainage was found within the first 20 s of foam decay for argon-blown foam. In air-blown foams, drainage was hardly detectable. Isothermal holding leads to coarsening and a slight degradation of uniformity in argon-blown foams (Fig. 4) while air-blown foams remain almost unchanged even after 100 min. During solidification foams shrink significantly in both cases.

### 3D architecture and microstructure

Synchrotron tomography of aluminium and zinc foams has been carried out at BESSY and evaluated using 3D image analysis. The correlation between the blowing agent's particle position and the pores as well as the critical lamella thickness at different foaming stages were investigated. We obtained various correlations for different alloys, which indicates that the pore formation mechanism depends on the physical properties of the alloy to be foamed. The critical lamella thickness is in the same order of magnitude (20–30 µm) for both aluminium and zinc alloys [5].

Pore-particle correlations in SiC-particle stabilized internal foams were investigated. For the first time, tomographic measurements of liquid metallic foams were performed. The results of the measurements clarified the rearrangement process of SiC particles during foaming. It could be shown that the accumulation process of the SiC particles on the pore surfaces takes place prevailing in the liquid state due to their partially wetting property. However, the process also continues during the solidification. It seems that due to the solidification front the particles were additionally pushed on the pore surfaces [6].

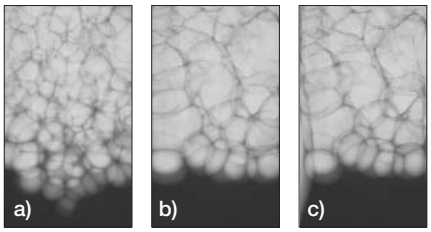


**Fig. 4:** X-ray radioscopy images of the evolution of argon-blown foam produced by gas injection. **a)** just after foam formation, **b)** at the end of isothermal holding (5 min), **c)** after solidification. Sample widths are 40 mm at the bottom.

### Future goals

- X-ray tomography with cone beam
- Comparison of foaming behaviour of tixocasted, hot compacted and hot extruded precursor metal powders
- Metallography investigation on single cell walls
- Surface tension measurement of liquid-metal colloids
- Fast radioscopy monitoring coalescence of single liquid-metal films

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