Highly structured porous polymer materials from liquid foam templates

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Porous polymer materials, in particular foams and sponges, play an important role in a vast number of applications. Composed of gas pores integrated into a continuous polymer phase, they form multi-scale materials whose properties are much more than the simple sum of their parts. These properties are governed in particular by the structural parameters of the material, such as the average pore size, the pore size distribution, the overall gas-to-volume ratio, and also whether its pores are open (i.e. interconnected) or closed. The general relationship between these parameters and the overall material properties are by now quite well understood. What is still lacking, however, is the ability to control them to a high degree of accuracy, in particular on industrial scales.

We propose here an elegant solution to this problem which is based on a two-step processes: a liquid foam template with accurately defined structural properties is first generated from a monomer or polymer solution, which is subsequently solidified through polymerisation and/or cross-linking using appropriate initiation mechanisms. We demonstrate here the power of such an approach by using the striking example of aqueous foams with small (some hundred μm) and equal-volume bubble sizes, which order spontaneously under gravity and/or confinement. We generate such foams from aqueous mono- or polymer solutions using micro- and milli-fluidic flow-focusing techniques. Polymerisation time scales and foam stability are adjusted and optimised in such a way that the liquid foam has time to find its equilibrium structure, which is then “frozen” upon polymerisation and/or cross-linking of the liquid phase. We will present this approach for two examples: acrylamid-based hydrogels and chitosan hydrogels. Examples of the latter are shown in the Figure.

Figure 1: Example of a perfectly ordered and gelified chitosan foam in the wet (left) and dried (right) state.