Quantifying the flows in a freezing liquid foam

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The manufacture of a solid foam, widely used for its mechanical, thermal, or acoustic properties, always begins with the solidification of a liquid foam. By placing a model aqueous foam in contact with a cold surface, we observe that, as it freezes, the foam undergoes a drastic change in volume and color revealing important water and air migration in the foam.

Through conductivity measurement, we are able to measure the liquid fraction of the liquid foam; coupled with the the information on the height of the freezing front, we can retrieve the density profile in the frozen foam as shown on Figure 1 b). This reveals that a large amount of water flows towards the solidification front, significantly affecting the resulting frozen slab caused. This water flow is partly due to imbibition events during which water penetrates into the porous medium that is the frozen foam. Figure 1 a) shows one such event, where within in a few seconds the front gets filled with water before freezing starts again.

We can show that the density profile measured is indeed coherent with the observed solidification front dynamics. Next, we present scaling laws for the collapse velocity of the foam and for its final volume, which depend on the size of the liquid films and the substrate temperature. Finally, based on these results and the observation of bubbles behaviour at the solidification front, we discuss mechanisms to explain the gas and liquid flows. These results improve our understanding of the mechanisms involved in foam solidification, in particular the flows generated by the presence of a solidification front.

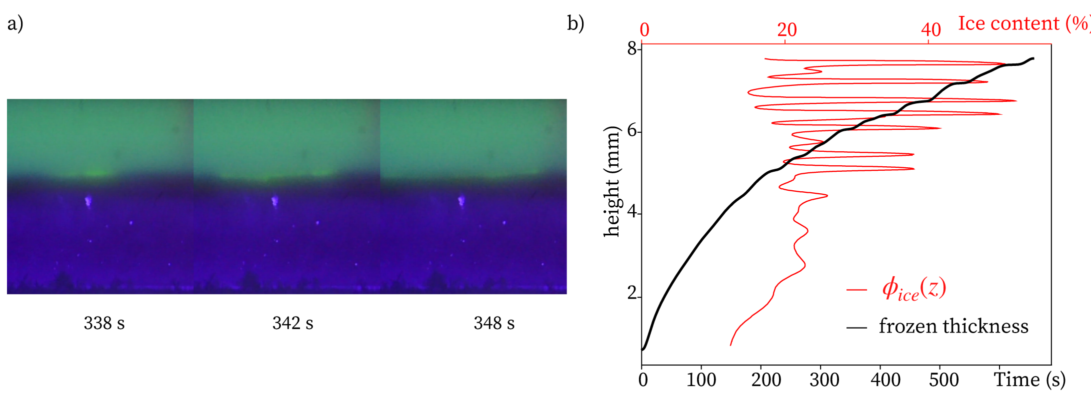

Figure 1. a) Cascading imbibition event during a 1D foam freezing experiment. The liquid foam appears green and the frozen part purple. A bright green line propagates at the solidification front, due to the presence of a large amount of liquid locally. b) experimental measurement of the density of the frozen foam as a function of the height in the frozen slab. the density of the frozen foam increases gradually as the freezing front advances, then is dramatically increased by large imbibition events.