Foam freezing

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ABSTRACT

Foam solidification is of major interest as an ideal candidate to study the freezing dynamics of a multi-scale object and also as a promising path in the design of new metamaterials. We present an experimental and theoretical study on the solidification of a slab of liquid foam. A foam of controlled liquid fraction (between 5 and 15%), with a bubble size around 100 μm in diameter is produced. We use fluorinated gas C_6F_{14} and a concentration of surfactant (SDS at 5 g/L) so that the foam is stable under normal conditions for several tenth of minutes. Figure 1 shows a typical experiment where a column of such a foam is placed on an aluminum substrate held at -40°C. A solidification front advances through the foam from the bottom, following a classical Stefan law [1]: $h_i(t) = \sqrt{D_{\text{eff}}\, t}$. D_{eff} is an effective diffusion coefficient varying with the foam parameters (its liquid fraction ϕ and the surfactant concentration).

Interestingly, the foam-air interface at the top collapses during the freezing experiment while it doesn't evolve if resting at ambient temperature. A measurement of the air-content in the solidified slab show an enrichment of liquid of a factor 2 at least. The freezing process drains water toward the solidification front, similarly to the frost heave mechanism [2](the presence of the solid decreases the pressure through the Clapeyron effect).

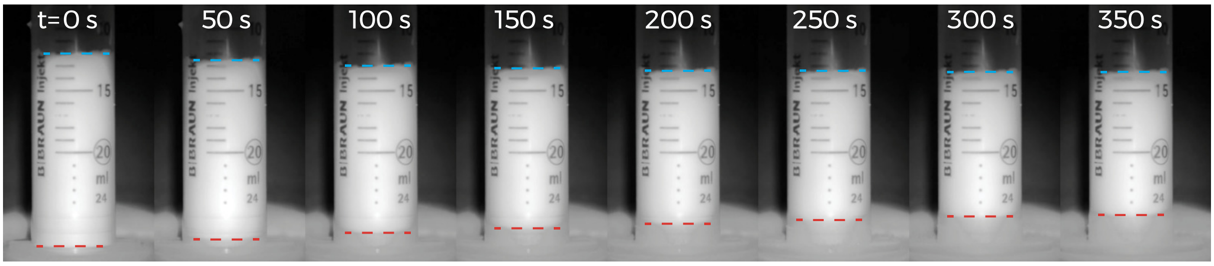

Figure 1: Freezing of a dry liquid foam. The solidification front grows (red dashed line) while the top of the foam collapses (blue line).

[1] Stefan, J. (1891) Annalen der Physik 278.2

[2] Peppin, S. S., & Style, R. W. (2013) Vadose Zone Journal, 12(1).