IMAGING OF NANOSCALE PATTERNS ON BUBBLES IN FOAMS

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A 200 KeV Transmission Electron Microscope (TEM) has been successfully employed to image a dispersion of gas microcells revealing regular nano-dimensional patterns on their surfaces. These nanometric features appear to be related the long term stability of the foam. Since the rheology and coarsening of foams is closely related to the microstructural characteristics of the small gas bubbles and their surface properties, this TEM study aims at deriving fundamental macroscopic properties from structural observations at the nanometer scale.

Different sample preparation paths are necessary to fully investigate the bubble morphology because of the physical properties of the dispersion. This latter is formed upon shearing a mixture of glucose syrup and sucrose ester. The highly viscous and beam sensitive samples require specific pre-imaging preparation: two distinct but complementary paths were explored. Firstly, the classic and traditional freeze fracture approach was followed to create metal replicas of the foams and bubble surfaces (Fig. 1). Secondly a controlled environmental vitrification system (CEVS) was used to prepare cryogenically frozen foams, which were then imaged via cryo-transfer (Fig. 2). The last step was performed using low dose electron microscopy methods.

Using both freeze fracture replicas and cryo-TEM confirmed that the surfaces of micron-size bubbles are fully covered with regular nano-dimensional, generally hexagonal, patterns, but it also enabled us to explore the two main plausible routes for the formation of these patterns. It is first assumed that the pattern formation is driven by disproportionation of the gas from the small bubble which leads to the buckling of the elastic insoluble surface film. Understanding and controlling the geometry of the freeze fracture process enables the determination of the bubble radius and the size of the domains. It is then possible to correlate these two measurements and to observe that the patterns on the bubble surface form regular hexagons which have a constant size. Since, the buckling wavelength depends on the radius of the elastic shell, it can be concluded that the pattern formation is not driven by a mechanical instability. The second pathway involves the nucleation/crystallization [1] of surfactant domains on the inhomogeneous surface, under disproportionation. The cryo-TEM images obviously display the 3-dimensional morphology of the liquid crystalline islands, also referred to as surface micelles. A comparative study of these patterns and of structures observed in cryogenically frozen micelle solution is considered.

Freeze fracture replicas imaging and cryo-TEM have allowed us to investigate the nanoscale surface features of the bubbles, from which fundamental structural properties can be derived.

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References
2. Carlson et al., Exp.mechanics, 1967
3. Hutchinson, 1967
Figure 1. TEM image from freeze fracture replica of bubble surface

Figure 2. Cryo-TEM image of a bubble in foam, exhibiting identical surface pattern as in Fig. 1.