

Effect of hexylamine concentration on the properties of foams and foam films stabilized by Ludox

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DOI: 10.1016/j.mencom.2012.07.003

The properties of foams and foam films stabilized by silica particles modified with hexylamine, depending on concentrations of hexylamine, are characterised.

The stabilization of foams by different solid particles is of considerable interest.^{1–13} The effects of solid particles concentration, their contact angle and the level of their aggregation on the stability of foams were studied previously.¹⁴ The formation of thixotropic gels in a dispersion medium affects the foams and the stability of the foam films. However, the relation between the thixotropy of gels and the foam stability remains still obscure, although it is known that the level of the hydrophobicity of the particles and the foam stability are related to each other.

For this reason, we studied the effect of degree of the particle modification with hexylamine on the properties of foams and foam films.

The films were obtained from the suspensions of the silica Ludox HS-40 (the 40% sol; particles diameter, 15 nm) with the particles concentration in the range of 2–20%. To prepare the suspension, water was added to the sol Ludox HS-40 and the amphiphilic substance hexylamine was injected in small portions with stirring (to avoid foaming). The hexylamine concentration was 18–100 mM.

The stability of the foam column and a thin layer of the foam was investigated using the foam pressure drop technique (FPDT).¹ As a criterion of the foam layer stability,¹⁶ we used the degree (D , %) of monolayer foam destruction.¹⁴ The film thinning and rupture¹ were studied by conductometry.¹

Table 1 shows the experimental concentrations of the added hexylamine, the surface tensions in the presence (σ_p) and absence (σ) of 2% Ludox particles and their contact angles (θ_c) at 25 °C.

In addition, we investigated the wetting of the Ludox solid particles modified with hexylamine by varying hexylamine concentration from 18 to 66 mM (Figure 1).

The increase in the concentration of hexylamine causes a rise of the contact angles to 50–54°, however, this process is accompanied by the coagulation of particles (at $\theta_c = 51–52^\circ$) for Ludox concentration of 0.5 and 2%. Thus formed, the aggregates size was greater than 100 μm . These large aggregates do not stabilize the foam.¹⁴

Table 1 Surface tension and contact angle as functions of hexylamine concentration. Solid content, 2% Ludox.

Hexylamine concentration/mM	$\theta_c/^\circ$	$\sigma_p/\text{mN m}^{-1}$	$\sigma/\text{mN m}^{-1}$
13.06	26	56.75	58.21
26.12	32	48.02	45.11
35.91	38	45.11	40.75
45.7	46	40.75	34.92

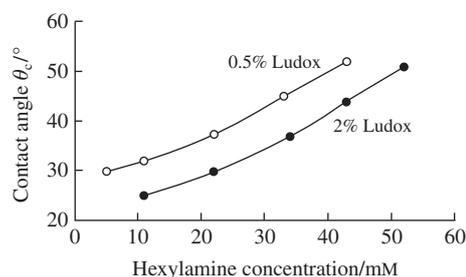


Figure 1 Contact angles vs. hexylamine concentration in suspensions.

Table 2 Rheological characteristics of suspensions.

Ludox content (%)	$\tau_c/\text{N m}^{-2}$	$\eta/\text{Pa s}$
0.5	0	0.001
2	0.098	0.061

The solid phase Ludox (Table 2) and the amphiphilic molecules (Figure 2) influence the shear stress and the viscosity of the suspensions.

Table 2 shows that an increase in the particle content of the initial suspension enhances the shear stress values. The shear stress (τ_c) for 20% sol Ludox is 3.5 times greater than that for the suspensions with a silica content of 2%. The values of τ_c for 2% sol Ludox, in which the initial particles size was 15 nm, are two times less than those for an Aerosil-380 suspension with the same concentration and the initial particle size of 3–30 μm . Previously,¹⁴ similar dependences of the shear stress on solid phase and modifier (hexylamine) concentrations of bulk suspensions were found. However, the values of τ_c calculated graphically for the foam films exceeded the values of τ_c for the bulk suspension to some degree. In addition, we established a maximum of the shear

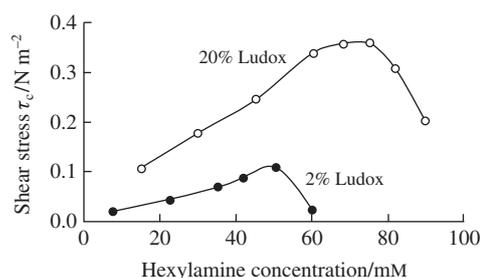


Figure 2 Shear stress in the silica suspensions.

stress τ_c upon the increase of the hexylamine concentration. This maximum shifts to the higher hexylamine concentrations at a larger solid phase content (Figure 2).

An increase in the concentration of hexylamine led to an increase in the values of $\Delta\sigma$, θ_c and τ_c (Tables 1, 2 and Figures 1, 2). Hence, the growth of the modifier content should increase the foam stability. We investigated the stability of the foams and foam films obtained from Ludox.

The foams obtained from Ludox (at contact angles smaller than 40°) displayed the properties similar to those of the foams stabilized by the surfactant. The foam obtained from a silica suspension (2% Ludox + 11 mM hexylamine + 5 mM NaCl) with a height of 2 cm was completely destroyed in layers without gelling of the continued phase at $\Delta P = 0.054$ kPa for 50 min. The expansion ratio is 180 in the foam. The isolated foam films obtained from such suspensions may thin to the bilayer size (8–9 μm).¹⁵ Thin bilayer foam films (10 μm) were obtained from 20% Ludox + 11–44 mM hexylamine. The thin foam layers were unstable under ΔP . For example, the foam obtained with 22 mM hexylamine destroyed completely at $\Delta P = 0.01$ kPa for 9 min. The thin layer (2 mm) also collapsed completely at $\Delta P = 0.05$ kPa.

Thus, the formation of a gel structure occurred in the foam films at 55 mM hexylamine concentration. The thickness of these films, measured under gravitational field, was about 24.5 μm . However, the gel was formed in the foam at smaller hexylamine concentration. For example, the foam column 1 cm in height obtained with 33 mM hexylamine collapsed to a layer of 0.5 cm at $\Delta P = 0.01$ kPa for 50 min. As a result, the gel layer with a height of 0.5 cm was formed and remained stable within several hours. The foam height of 1 cm obtained with 46.2 mM hexylamine did not decay for 1.5 h. Finally, the destruction process occurred with gas bubbles diffusion agglomerations. Only a 1–2 mm foam was destroyed within 4 h.

In our opinion, the inner foam destruction increased the hexylamine and Ludox concentrations in the remaining foam films thus affecting the rheology of the dispersion medium and, consequently, the overall foam stability.

Thus, with 20% Ludox and 11–44 mM hexylamine, thin bilayer films were formed, and the thin foam layers were unstable. The stability of a thin foam layer increased significantly at hexylamine concentrations higher than 54 mM. Under such conditions, gels were formed in the isolated foam film. The inner foam collapse may create appropriate conditions for a local increase in the hexylamine and solid particles contents with the formation of a tixotropic gel within the foam films of the foam body.

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Received: 27th January 2012; Com. 12/3869