



Froth flotation via microparticle stabilized foams

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ABSTRACT

There is a still growing interest in the recovery of rare earth elements due to their manifold industrial and technological applications. We present here a simple and effective method for the enrichment of micrometer sized La_2O_3 particles via microparticle stabilized foams. By using the short chain amphiphile (1-hexyl)trimethylammonium bromide (C_6TAB) foam that is generated by surface modified particles only can be generated. This technique allows a more selective and specific particle transport mechanism. The results are discussed in terms of surface charges and transport mechanisms. Furthermore, the effects of particle concentration, pH and amphiphile concentration are studied and evaluated.

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1. Introduction

Colloidal structures in a nonequilibrium state, i.e. systems that are kinetically hindered to minimize their surface energy, are nowadays implemented in manifold applications [1]. Among those, Pickering emulsions [2] and stimuli responsive Pickering emulsions [3–6] are prominent examples. In this context, foams stabilized by solid nano- or microparticles have attracted remarkable attention in recent years because of their unique foaming properties and the wide field of potential applications [7–9].

It is well-known that the combination of surfactant molecules with solid particles, which results in an adsorption at solid/liquid interfaces, can be used to either stabilize or destabilize foams [7,10,11]. However, it is only recently that foams solely stabilized by nanoparticles have been reported [12,13]. For example, Binks et al. investigated aqueous foams stabilized by silica nanoparticles with different hydrophobicity depending on the degree of silanization of surface silanol groups [12]. The case of foam stabilization with nanoparticles only, i.e. in the absence of surfactant is extremely delicate, but stable foams can be obtained in a narrow range of contact angles [14].

A very important case in applications is the case of mineral flotation. As reviewed by Fürstenau and Pradip, the most important parameter is the zeta potential and coverage of the particle by the

adsorbed surfactant layer [15]. Double and triple chain surfactants are of large usage due to their low *cmc*, and hence loss: mixtures of those, added to co-surfactants and modifiers can be used even in high volume fraction of particles as present in slurries produced from ores.

Further attempts have been made by surface lyophobicization of colloidal particles (e.g. Al_2O_3 , ZrO_2 , $\text{Ca}_3(\text{PO}_4)_2$) by short-chain amphiphilic molecules [16,17]. High volume macroscopic foams have been obtained, whereby the use of short-chain amphiphiles (<8 carbon atoms) is a key parameter of this approach. In this case, the initial concentration of microparticles is high, typically 35%, and a short chain amphiphile is used. The reduction in surface tension results from a combination of the one due to surfactant covered particles and the one induced by the surfactant introduced in high concentration. Gonzenbach and co-workers have shown that stable foams with up to 85% of air were produced by this route [16]. In this work, we examine the diluted regime, when the particle concentration in the bulk is low, typically of less than 1 g/l, fifty times less than in other cases; This is to evidence the influence of particles adsorbed on the surface. In a film even of the order of 0.01–0.1 μm , the amount of microparticles adsorbed on the air–water interface is larger than that of particles in the bulk of the foam film. The situation of low initial microparticle concentration is therefore adequate to investigate separation effects.

In froth flotation science and industry one generally distinguishes between ion flotation [18–22] and particle flotation [23–26]. Ion flotation is a separation process involving the adsorption of a surfactant and counterion at an air/water interface. In simple ion flotation, a continuous gas flow is applied to an aqueous

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