



**INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI**  
**SHORT ABSTRACT OF THESIS**

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Thesis Title: Foaming Behavior of Aqueous Solutions Containing Hexadecyltrimethylammonium Bromide and Silica Nanoparticles: Analysis of Stability and Interfacial Properties

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**SHORT ABSTRACT**

Aqueous foams are considered as two-phase fluids in which the gas bubbles are dispersed in the aqueous phase. The bubbles are separated by interconnecting thin liquid films. The liquid content is sufficiently high in wet foams, whereas the same is usually small in dry foams. Aqueous foams belong to an important class of engineering materials due to their numerous applications in industry and daily life such as floatation, firefighting, water treatment, paints and coatings, textile finishing, enhanced oil recovery, cleaning agents, personal care products, food products, and pharmaceuticals. Foams are difficult to characterize because they are thermodynamically unstable (or metastable) systems. In many contexts and applications, it is of fundamental importance to understand the foaming behavior of kinetically-stable foams.

Use of surfactant for the stabilization of foams is a traditional method that has been used for a long time. Particles also act as a stabilizing agent when they are attached to the surfaces of the foam films. However, it is difficult to adsorb particles onto the surfaces because of their hydrophilicity. This can be altered by modifying the surface of the particles using a surfactant. The surfactant molecules adsorb on the surface of particles and thereby change their surface properties. This enables the particles to attach at the air-water interface. Particles adsorbed at the interface not only act as a surface-active agent, but they offer a distinct advantage of creating a more stable foam than their surfactant-stabilized counterparts.

In the present work, we have studied the effect of hexadecyltrimethylammonium bromide (HTAB) on the foaming behavior of dispersions containing silica nanoparticles. It was found that foams were more stable

at low surfactant concentrations, although the foamability was low. This was due to the formation of a strong viscoelastic film of surfactant-laden particles at the air–water interface. Below the CMC, the surfactant-laden particles were adsorbed at the air–water interface, aided by the induced motion of the surfactant molecules adsorbed on the particles. However, above the CMC, the interface was completely occupied by the surfactant molecules and hence, the surfactant-laden particles were accommodated near the sub-phase or in the bulk phase.

Smaller silica nanoparticles (i.e. diameter less than 10 nm) adsorbed at the air–water interface whereas the larger particles remained in the sub-phase or in the bulk liquid phase. Since the silica nanoparticles were hydrophilic, a major portion of these particles was oriented towards the aqueous phase, and hence a lesser portion was present in the air. It was found that these nanoparticles strongly influenced the foaming behavior at the low HTAB concentrations (i.e. below the CMC). A Langmuir-type monolayer was formed. The presence of the nanoparticles at the air–water interface provided mechanical strength to the foam films and prevented their rupture. This hindered coalescence of the bubbles, which resulted in a stable foam.

Rheology is an important tool for characterizing the soft complex materials, such as foams. The multiphase composition of foams gives rise to complex rheological behavior under deformation. It is important to understand this behavior in many applications. Foam shows nonlinear rheological behavior at high deformations, which can be investigated by the large amplitude oscillatory shear (LAOS) experiment. We have performed a systematic LAOS study of foam stabilized by 0.1 mol m<sup>-3</sup> HTAB and 0.5 wt.% silica nanoparticles. The foam exhibited intracycle strain-hardening and shear-thinning at high deformation. Shear-thickening behavior was observed at moderate deformations. The foam films have two air–water interfaces and hence the foaming behavior strongly depends on the properties of these interfaces. We have investigated the interfacial properties by using interfacial shear rheology, which was studied in the linear and nonlinear deformation ranges. Although extensive research has been performed on foams in the past few decades, a number of fundamental issues related to foams stabilized by particles have remained poorly understood. Some of these issues are, the role of nanoparticles in stabilizing the foam films and the air–water interface, the interaction between surfactant-laden particles in the liquid phase and at the interface, and the role of the charge of the surfactant and the nanoparticles in foaming. This thesis has investigated these issues in detail. The aim of this thesis is to understand the behavior of aqueous foams and air–water interface stabilized by a mixture of HTAB (a cationic surfactant) and silica nanoparticles (negatively charged particles).