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Micron-sized antibubbles with tunable stability

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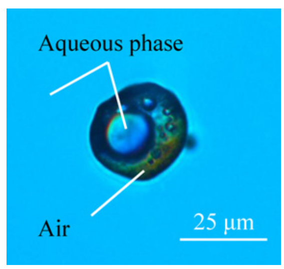
HIGHLIGHTS

- ► Micron-sized bubbles containing droplets, i.e. antibubbles, have been produced.
- ► The lifetime of the antibubbles can be tuned from a few minutes to at least hours.
- ► The gaseous shell of the antibubbles provides a good barrier against solutes.
- ► When triggered to release, antibubbles release their core very fast and completely.

GRAPHICAL ABSTRACT



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ABSTRACT

Stable antibubbles, i.e. droplet-containing bubbles, with sizes in the micron range were produced. The antibubbles derive their stability from colloidal particles adsorbed at their interfaces. Antibubbles were produced by first making a particle-stabilized water-in-oil-in-water emulsion in which the water phases contain a solute that becomes glassy upon drying and in which the oil is volatile. This double emulsion was subsequently freeze-dried to remove both the water and the oil. Reconstituting the resulting powder in water led to the formation of antibubbles. It was shown that thus produced antibubbles have good barrier properties and that their stability, and thus their sensitivity to release triggers, is controlled by the hydrophobicity of the colloidal particles at the interfaces. When made to release, antibubbles release their core droplets almost instantaneously. This makes antibubbles excellent candidates for controlled release applications.

1. Introduction

Antibubbles, which are also referred to as inverse bubbles, have intrigued many and potentially have several applications [1–6]. Antibubbles can be particularly useful for controlled release purposes because they combine two important properties. First, the gaseous shell of antibubbles represents an insurmountable barrier to all non-volatile substances. Second, if this gaseous shell is made to rupture, e.g. by applying pressure, the core is released completely and instantaneously [7,8]. This combination is rarely found in conventional controlled release systems which often suffer from gradual leakage of the encapsulated substance through the capsule wall or, when triggered to release, release their contents too slow and incompletely [9,10]. Also, solid capsules often contain imperfections such as cracks [11]. A gaseous capsule wall, as is the case in antibubbles, is expected to solve these problems.

Practical applications of antibubbles have hitherto not been achieved, most likely because of their short lifetime of at most a few minutes [12–14]. The reason for this short lifetime is that surfactants cannot stabilize a gas shell and as a result the lifetime of antibubbles is determined by the speed at which the gas shell drains [7,12,13]. In addition, many possible applications require antibubbles with a size in the micron range. It can be calculated that for antibubbles in this size range the gas shell will drain within seconds

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