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Diffusion of the inner gas of a microbubble decorated with poloxamer surfactants under ultrasound exposure

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Abstract— **Microbubbles used as contrast agent in ultrasound diagnosis are expected to find applications as drug delivery system. The application requires bubble to persist in the circulation system for long time. In this paper, the adsorption kinetics of poloxamer surfactants, the oscillation characteristics and lifetime of single bubble under ultrasound exposure were investigated. The volume of bubble around the resonance size was decreased remarkably under ultrasound irradiation.**

I. Introduction

Microbubbles have multiple potentials and are expected to be applied to therapeutic applications such as drug delivery system [1] where the bubbles flow the circulation system via the blood vessels. To deliver the drug or gene to the target, bubbles need to persist for long time while being monitored by ultrasound. Kabalnov et al. examined the dissolution of microbubbles experimentally and theoretically [2]. However, there are few reports on the stability of single microbubble under ultrasound exposure. This paper investigates the adsorption kinetics of poloxamer surfactants and the lifetime of single bubble under ultrasound irradiation. The oscillation characteristics of single bubble by ultrasound was measured to evaluate the lifetime of the bubble.

II. Experimental Section

Pluronic F-68 was purchased from Sigma-Aldrich [(PEO)A(PPO)B(PEO)A; CAS registry no. 9003-11-6; molecular weight (M_w) of ~8400 g mol^{-1} according to the supplier and ~9050 g mol^{-1} according to our light scattering experiments]. The degree of polymerization of each block (NA = 2 × 76, and NB = 29) was calculated from the nominal value of M_w. The polydispersity index (M_w/M_n = 1.15, where M_n is the number-average molecular weight) was obtained from gel permeation chromatography using THF as a solvent. Pluronic F-68 was used as the surfactants for microbubble coating. The adsorption kinetics of Pluronic F-68 on gas-water interface is investigated by a tensiometer at concentration ranged from 0 to 1 mol L^{-1}. The single bubble formed in steel capillary is 5 μm in the aqueous solution, and axisymmetric shape of bubble is analyzed to estimate the surface tension. The vibrational characteristics and the volume change under ultrasound exposure of bubbles coated with Pluronic F-68 were measured. A transparent cell with an ultrasound transducer was filled with an aqueous solution with concentrations of 0 to 10^{-2} mol L^{-1}. Bubbles were deposited on a glass plate fixed at the cell, and the continuous sound wave at a resonance frequency of 38.8 kHz was radiated. A laser Doppler vibrometer with a CCD camera was positioned above the observation cell to measure the radial vibration and the size of the bubble.

III. Results And Discussion

Pluronic F-68 molecules adsorbed on the bubble wall showed two phase transitions as the Pluronic F-68 concentration increased, inducing changes of the surface tension at the gas-water interface. The influence of the Pluronic F-68 molecular shell on micrometric bubble vibration under ultrasound exposure was investigated. The resonance radius of bubble in all conditions ranged from 60 to 70 μm and did not correlate with the Pluronic F-68 concentration. Figure 1 depicts the relationship between the initial radius and the volume change rate of the microbubbles in the acoustic standing wave. The volume of bubble decrease remarkably at resonance radius, meaning that the oscillation of bubble under ultrasound irradiation accelerate the diffusion of inner gas. The lifetime was prolonged as the Pluronic concentration increased because the surfactant film hindered the diffusion of the internal gas.

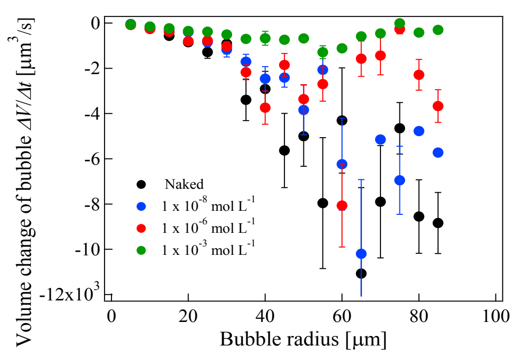

Figure 1. Temporal changes in the volume of air-bubbles coated with Pluronic-F68.

References

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