Production of Nitrate and Nitrites Ions from Single Bubble Cavitation in Water

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Abstract

The stable light emission from a single bubble was observed over 30 h on sonication. Production yields of nitrate and nitrite ions in water were measured as a function of the irradiation time by ion chromatography. The concentrations of two ions increase linearly with irradiation time and the concentration ratio of nitrate and nitrite ions was 1:1 within experimental errors. The formation rate for these two ions was $2.4x10^{-8}$mol/(l.h).

Introduction

Sonochemical effects are caused by growth and collapse of bubbles produced in liquids and solutions under the appropriate sound field. The light emitted from acoustic cavitation bubbles is observed and the phenomena termed sonoluminescence (SL) [1-4]. Gaitan first reported single-bubble sonoluminescence (SBSL) is a light emission phenomena from a stable bubble in a liquid driven by the acoustic wave [5]. Since then, many workers have studied experimentally and theoretically. The time dependence of the bubble size and the light intensity has been clarified. Recently, the results were reviewed in the literature [6]. However, there is few works on the chemical reactions induced by SBSL. It is important to know the sonochemical effects caused by a single bubble in order to elucidate the mechanism of single bubble cavitation and the chemical effects. LePoint et al. reported the formation of I_3^-in 1M NaI solution containing starch and CCl_4 [6]. Recently, Dideinko and Suslick reported the energy efficiency of photon, radicals and ions during single bubble cavitation [7].

In this work, we will report the chemical effect during single bubble cavitation by realizing the stable SBSL. We examined the formation of nitrate and nitrite acids as a representative sonochemical reaction in water. To measure the product yields in the condition of SBSL, a stable sonoluminescence was realized for a long time.

Experimental

Figure 1 shows our experimental set up. The Langevin type transducer was used. The transducer was driven with a power amplifier (EMI, 1140AL) and function generator (Wave Factory, 1942). The diameter of the sample cell is 42mm and the height is 100mm. Deionized and degassed water of 60ml was immersed in a cylindrical cell made of acrylate. The cell was set in temperature-controlled room bath. The driving frequency was 32.6 kHz. In this work, the air was controlled at 13.0±0.5°C. The surface of water was covered with a paraffin film. In addition, the top of the cell was also covered with a paraffin film. To do so, the cell is considered to be in the quasi-closed system.

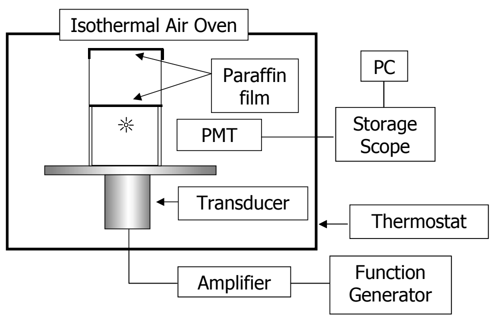

Figure 1 Experimental set-up

The sonoluminescence intensity was measured by a photomultiplier tube (Hamamatsu Photonics, Co.Ltd., R-585). The dissolved oxygen (DO) in water was measured by a DO-meter (DDK Toa Co., DO-55G). The concentrations of nitrate and nitrite ions were measured by ion chromatography (Japan Dionex, Co. Ltd., IC-20)

Results and Discussions

It is well known that the intensity of SBSL depends on the temperature and the concentration of dissolved gases. In particular, the intensity of SBSL is influenced by the concentration of dissolved oxygen. Figure 2 shows the time dependence of the concentration of the dissolved oxygen without sonication. In the open system, the quantity of the dissolved oxygen increases steeply. On the other hand, in the quasi-closed system, the concentration gradually increases and the value is below DO=6 mg/l after 30h.

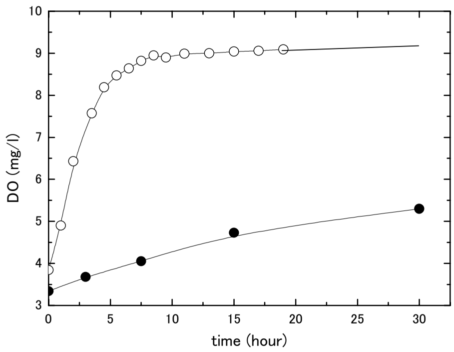

Figure.2 Time dependence of concentration of dissolved oxygen. (○): open system and (●) quasi-closed system.

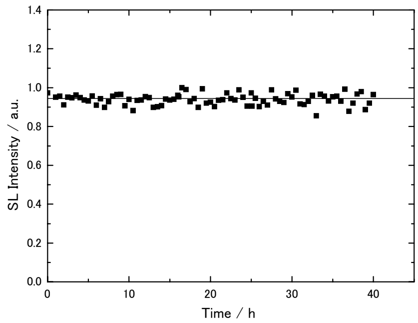

Figure.3 Time dependence of the SBSL intensity for 40 h.

Figure 3 shows the plot of the sono-luminescence intensity against the irradiation time. The fluctuation of the intensity is within ±5% of the averaged intensity. This result shows that the stable light emission continues over 30 hours. This enables us to measure the concentrations of NO_3^- and NO_2^- ions by ion chromatograph. The concentrations of nitrate and nitrate ions increase linearly with the irradiation time within experimental errors. The product yields of NO_3^- are nearly equal to those of NO_2^-. In other words, the concentration ratio of these ions is about 1:1. The reaction rates of these two ions are roughly estimated as $2.4X10^{-8}$ mol/(l·h). The number of nitrite ions are $7.1X10^{6}$ per cycle. This value is about twice larger than that reported by Suslick [7]. The difference may be due to the experimental conditions.

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