2P4-6

Effect of Ultrafine Bubbles on Ethanol Enrichment from Aqueous Solution by Ultrasonic Atomization
超音波霧化による水溶液からのエタノール濃縮に及ぼすウルトラファインバブルの影響

Keiji Yasuda[1†], Yumi Nohara[1], and Yoshiyuki Asakura[2]
([1]Grad. School Eng., Nagoya Univ.; [2]Honda Electronics.)
安田　啓司 [1†]，野原　勇己 [1]，朝倉　義幸 [2] ([1] 名大院工, [2] 本多電子)

1. Introduction

When ultrasound irradiates toward surface from bottom in liquid, fine droplets are generated from liquid surface. This phenomenon is called ultrasonic atomization. Recently, it was found that ethanol was enriched from aqueous solution by ultrasonic atomization. Ethanol enrichment is due to hydrophibic interaction of ethanol molecules in water.[1)] Advantages of ultrasonic atomization separation are that the operation is easy, heat-sesitive materials are able to use and maintenance is not required.

Small bubbles with a diameter of less than 1 μm are called ultrafine bubbles (UFBs).[2)] UFBs are able to persist for more than a few months in water because rise velocity by buoyancy is negligibly low. They also have very large specific surface area and bioactivivty, and are negatively charged on the surface in a neutral region. The UFBs water attracts great attention in many fields of cleaning, agriculture, wastewater treatiment, medicine, surface treatment, fuel, and fisheries.

In this study, ultrasonic atomization was conducted to ethanol aqueous solution with UFBs. Effect of UFBs on ethanol enrichment characteristics was investigated in various ethanol concentraion and carrier gas flow rate.

2. Experiment

Fig. 1 shows outline of experimental apparatus. The cylindrical vessel was made from transparent polyvinyl chloride resin. The inside diameter and height of vessel were 78 and 300 mm, respectively. A disc transducer was attached at vessel bottom. The frequency and power applied to transducer were 2.4 MHz and 15 W. The transducer was driven by a power amplifier and a signal generator. Ultrasonic irradiation time was 60 min.

Sample was ethanol aqueous solution. Sample volume was 200 mL. As carrier gas, dry nitrogen was used and flows through the vessel. Mist generated by ultrasonic atomization were collected by a glass tube immersed in liquid nitrogen. The ethanol concentration in collected mist was determined by a gas chromatograph equipped with a TCD detector. Mass change of sample during ultrasonic atomization was measured by an electric balance.

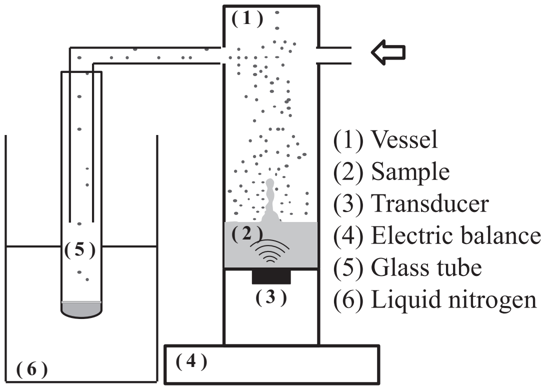

Fig. 1　Outline of experimental apparatus.

Sample with UFBs was prepared from water with UFBs which was generated form ultrapure water (Millipore) and air by pressurized dissolution method (ultrafineGaLF, IDEC). The number density and mean diameter of UFBs in sample measured by nanoparticle tracking method (NanoSight, Malvern) were about 2.0 x 10^9 and 100 nm, respectively.[3)]

3. Results and discussion

Fig. 2 shows effect of ethanol concentration in sample on mist collection mass with and without UFBs. Carrier gas flow rate was 0.2 L / min. Mist collection mass increases with increasing ethanol concentration. Mist collection mass of sample with UFBs are almost same as those without UFBs. Mass change during ultrasonic atomization also increased with increasing ethanol concentration. Regardless of alcohol concentration and UFB existence, mist collection rates were about 70 %.

Enrichment factors were calculated as the ratio of ethanol concentration in collected mist to that in sample and are plotted against ethanol concentration in sample as shown in **Fig. 3**. As ethanol concentration in sample becomes lower, the enrichment factor becomes higher. The enrichment factor with UFBs is higher than that without UFBs.

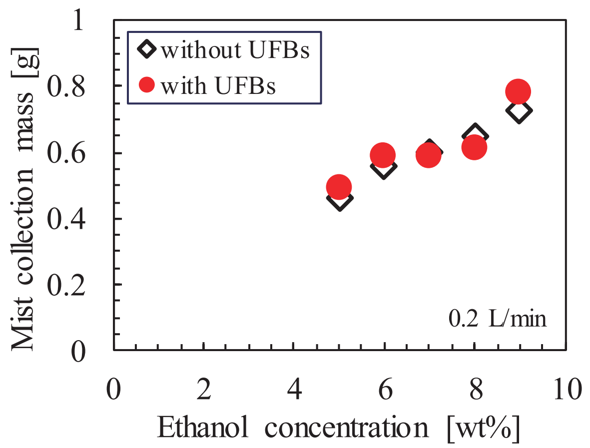

Fig. 2 Effect of ethanol concentration on mist collection mass with and without ultrafine bubbles.

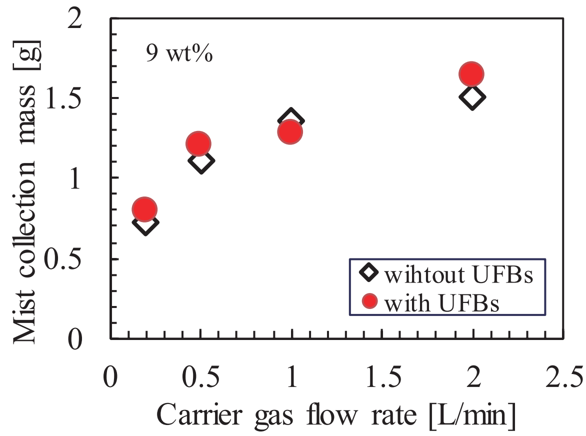

Fig. 4 Effect of carrier gas flow rate on mist collection mass with and without ultrafine bubbles.

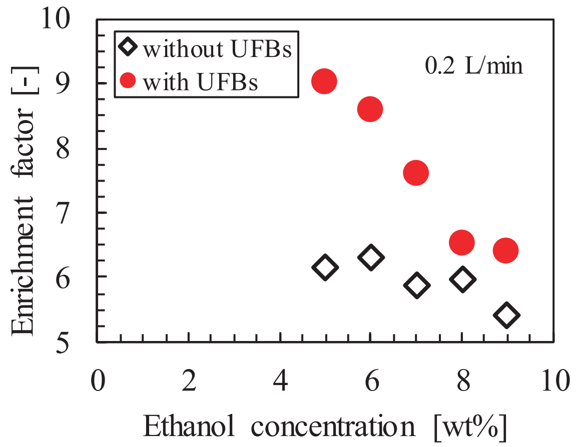

Fig. 3 Plot of enrichment factor against ethanol concentration with and without ultrafine bubbles.

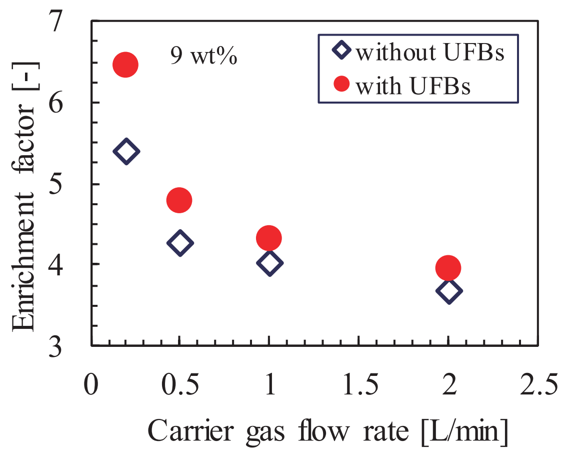

Fig. 5 Plot of enrichment factor against carrier gas flow rate with and without ultrafine bubbles.

It is thought that ethanol attaches on the surface of UFBs, UFBs aggregate or coalesce by secondary Bjerknes force, UFBs move to liquid surface by radiation force,[3] and ethanol concentration in droplets increases. The enrichment factor difference between with and without UFBs becomes higher as ethanol concentration in sample decreases. This is because the rate of the number of UFBs to that of ethanol molecules is high at low concentration.

Fig. 4 shows effect of carrier gas flow rate on mist collection mass with and without UFBs. The ethanol concentration in sample was 9 wt%. Mist collection mass increases with increasing carrier gas flow rate. This is because gas at high flow rate is able to carry large droplets. Mist collection mass with UFBs are close to those without UFBs. The mist collection rate decreased with increasing carrier gas flow rate increased since residence time of mist in glass tube was short at high gas flow rate.

Plot of enrichment factor against carrier gas flow rate for sample with and without ultrafine bubble is shown in **Fig. 5**. The enrichment factor increases with decreasing carrier gas flow rate. From this result, it is considered that ethanol concentration in droplet becomes higher as droplet size becomes smaller. The enrichment factors for sample with UFBs are higher than those without UFBs. The enrichment factor difference between with and without UFBs increases with decreasing carrier gas flow rate. Assuming that ethanol concentration at liquid surface became high by UFBs, it is thought that small droplets with high ethanol concentration increases and are carried by carrier gas at low flow rate.

References

1. K. Yasuda, K. Mochida, Y. Asakura, and S. Koda: Ultrason. Sonochem. **21** (2014) 2026.
2. M. Alheshibri, J. Qian, M. Jehannin, V.J. Craig: Langmuir **32** (2016) 11086.
3. K. Yasuda, H. Matsushima, and Y. Asakura: Chem. Eng. Sci. **195** (2019) 455.