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Influence of liquid height on the mechanical effects and chemical effects at 20 kHz sonication

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1. Introduction

The intensity ultrasound irradiation into solutions in the frequency range from 20 kHz to several MHz results in remarkable mechanical and chemical effects on many chemical reactions.At low frequency, 20 kHz is a common frequency in cleaning experiment tool due to its high mechanical effects. However, the low frequency also has a promise application in industry due to its high intensity. The common sonochemical reactor at this frequency is a horn type transducer. The disadvantage of the bath type at this frequency is its weak efficiency. For the horn type, the disadvantage comes from the unbalance in energy distribution. With the aim of acoustically-induced efficiency improvement, we have proposed a new transducer with the similar structure to that of the horn type one.[1] It showed that this Langevin transducer has the equivalent value of mechanical effects and a higher chemical effects compared to that of horn type transducer.

In order to enhance the performance of the sonochemical reactor with this Langevin transducer, we studied the influence of liquid height on the mechanical effects and chemical effects at 20 kHz sonication using the suggested transducer. Asakura et al.[2] reported the sonochemical efficiency dependence on the liquid height in the frequency range from 45 to 490 kHz. Therefore, in this research we changed the liquid level by times of a quarter of a wavelength (here it is 18.95 mm). Another two special exception liquid height length was 65 and 97 mm. In these two levels, the standing wave was generated.

2. Experiment

The directly irradiation sonochemical reactor was used with a Langevin transducer at 20 kHz. This transducer was fixed at the node of the transducer (Honda Electronics Co. Ltd.) (**Fig. 1**). The details of this transducer were described in our previous paper.[1] Two types of cells were used. A glass cell was used for sonochemical luminescence. For other experiments, a metal cell was used in order to control the temperature of samples. For sonochemical luminescence, 0.1 g luminol (Wako pure chemical industries, Ltd.) was dissolved into solution with 5 g of Na_2CO_3 (guaranteed grade – Kishida Chemical Co., Ltd) to make a 1 L solution. The exposure time was 2 minutes with Nikon D7000, iso 6400 and f = 5.6. In polymer solution, the degradation of polymer was generated by mechanical effects. For mechanical effects investigation, polyethylene oxide (PEO) (SIGMA) with molecular weight 900,000 was dissolved into water at concentration 2 g/L with 7.4 g of *t*-BuOH (guaranteed grade - Wako). *t*-BuOH was used as a radical scavenger to suppress the chemical effects of radicals. The viscosity of five-minute sonicated samples was examined by Ubbelohde at 25 ^{o}C. The oxidation of I^- to I_3^- was used to examine the chemical effects. The concentration of KI solution was 0.1 M. After being sonicated for five minutes, KI solution was evaluated with the UV absorption spectrometer (JASCO V-530). The absorbance of I_3^- at 355 nm was measured. Polymer degradation and KI was carried out at 25 ^{o}C. The temperature of samples was kept constant. The electronic power delivered into solution was kept at 40 W. The room temperature was kept at 25 ^{o}C.

3. Results and discussion:

In **Fig. 2**, the sonochemiluminescence at two liquid heights was shown. The sonochemical luminescence exhibits the region where chemical effects are stronger than the dark region. This method is the visualization of the chemical effects. Within our experiment liquid height range (from 0 to 97 mm), only the 65 and 97 mm liquid height generated standing wave (**Fig. 2**). At 65 mm, sonochemical luminescence formed two layers, in which the distance between three middle layers was around 2/7 a wavelength. In the 97 mm liquid height level solution, the distance betwwen the layer For the bottom and the top layer, they were around 1/3 of the wavelength. This may be responsible for the boundary effects such as surface or bottom.

In **Fig. 3** shows the concentration of I_3^- dependence on the liquid height. The concentration of I_3^- changed up and down. First, it decreases from 18 mm to 56.8 mm. This means that the chemical

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effects also decrease. After 56.8 mm liquid height, the chemical effects changed up and down respectively. This means that the chemical effects depend on the liquid height.

Mechanical effects quantification by using polymer degradation was suggested in our previous research.[3] Viscosity ratio is defined as the ratio of viscosity of sonicated samples to that of samples before irradiation (η_{son} /η_{non}). After five minutes of irradiation, the higher the η_{son} /η_{non} value shows the lower the mechanical effects are. In **Fig. 4**, from 18.9 to 56.8 mm, there was a linear decrease. But after this level, the decrease slows down; then it reaches the unchanged trend in 56.8 to 75.8 mm range. It shows that the higher the liquid level is, the lower the mechanical effects are. This is explained that with the same electronic power the acoustic intensity was attenuated in solution with the increase in volume of solution.

In this work, we can not observe the correlation between chemical and mechanical effects. In further study, the pressure at these liquid levels will be study. The changing of mechanical effects and chemical effects at constant dissipated power is also investigated to clarify the influence.

References

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Fig. 1 Sonochemical reactors.

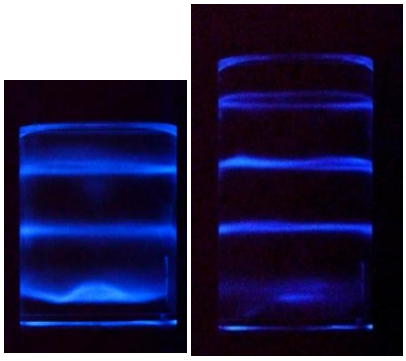

Fig. 2 Sonochemical luminescence. Left hand: liquid height 65 mm. Right hand: liquid height 97 mm.

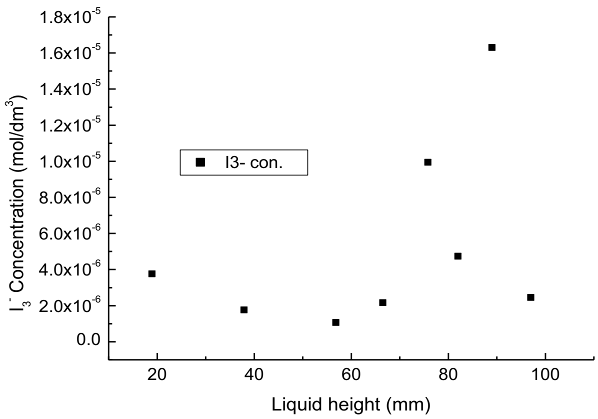

Fig. 3 Concentration of I_3^- at different liquid height.

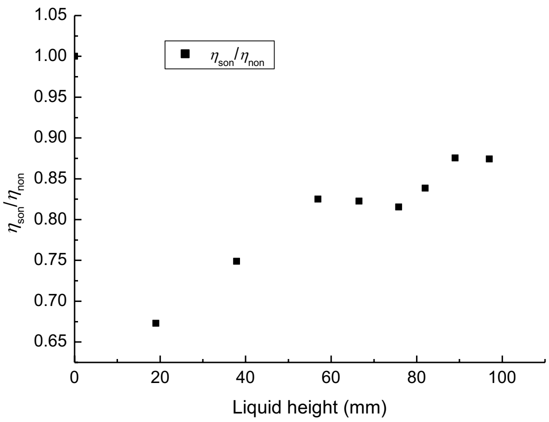

Fig. 4 Viscosity ratio of PEO degradation in aqueous solution with *t*-BuOH at different liquid height.