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Dispersion and Coalescence of Oil Droplet by Ultrasound and Application for Metal Recovery

超音波による油滴の分散・凝集とレアメタル回収への応用

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1. Introduction

The recycling of rare metals is growing in importance to build a sustainable society. Solvent extraction is widely studied for the recovery of rare metals. In conventional method, acid aqueous solution leaches rare metals from electric substrates. Metal extractant dissolved in organic solvent is added to aqueous solution. In order to extract rare metals from water phase to oil phase, mixing by stirrer and separation by still standing are conducted. However, it is necessary to decrease amouts of organic solvent and extractant, and shorten operation time for practical use.

When ultrasound is irradiated into oil-water mixtures, the emulsion is formed at low ultrasonic frequency and the demulsification is observed at high frequency. In this study, the effect of ultrasonic irradiation on the performance of the solvent extraction process is experimentally investigated.

2. Experimental

The mixtures of organic solvent and water were used as a sample. Chloroform, 1.2-dichrothane, p-bromotoluene, bromobenzene, and 1,2-dibromoethane were used as organic solvent. Volumes of water and oil phases were 20 mL and 0.4 mL, respectively. Figure 1 shows outline of experimental procedure. The sample in beaker was emulsified by direct irradiation from a horn type transducer at 20 kHz. Electric power was 40 W and irradiation time was 30 s. The emulsion with 5 mL was put in a glass vessel. The oil droplets in emulsion were demulsified by indirect irradiation from a bath type transducer. Ultrasonic frequency, input power to a transducer, and inclination angle of vessel were changed and the demulsification time was measured.

3. Results and Discussions

Figure 2 shows the effect of ultrasonic frequency on demulsification time. Chloroform was used as organic solvent. The demulsification time without ultrasound was 60 minutes. The demulsification time decreases with increasing frequency. Oil droplets are driven toward pressure antinodes of the acoustic field by the primary bjerkness force F as shown a next equation.[1)]

$$F = 4\,\pi\,R^3 \kappa E\,A\,\sin(2\kappa x) \qquad (1)$$

Here, R is the droplet radius, κ is the wave number of ultrasound, E is the energy density of ultrasound, A is the acoustic contract factor, and x is the distance from a pressure antinode of the standing wave. As the ultrasound frequency increases, the primary bjerkness force increases and the distance between antinodes decreases.

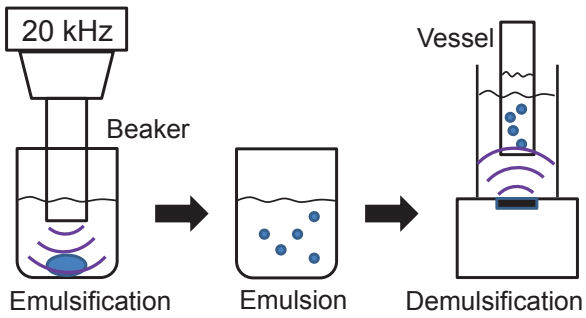

Fig. 1 Outline of experimental procedure

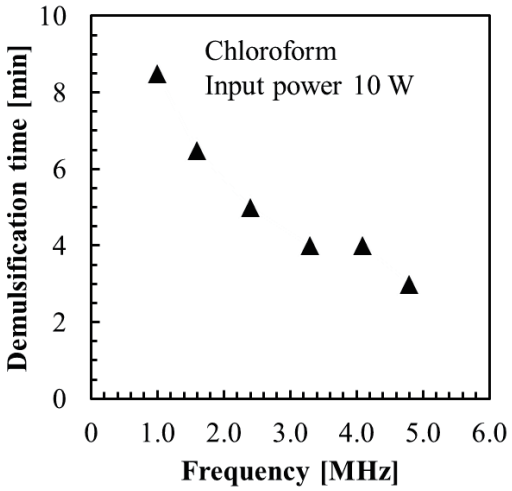

Fig. 2 Effect of ultrasonic frequency on demulsification time

The demulsification time decreased with increasing input power to the transducer. Figure 3 shows the effect of inclination angle of vessel on demulsification time. When the inclination angle is 5°, the demulsification time becomes a minimum value. It was observed that agglomerated droplets came down along vessel wall at 5°. It is considered that inclination of vessel prevents from the redispersion of droplets caused by ultrasonic streaming. However, as the inclination angle of vessel becomes higher, ultrasonic power inside vessel decreases.

The emulsification time with ultrasound were 1/10 – 1/20 of those by still standing for several organic solvents. In figure 4, the emulsification time are plotted against the zeta potential of droplets. The demulsification time become shorter as the zeta potentials are close to zero. This is because the repulsive force between droplets is weaker. Chloroform was used as organic solvent, the effect of the solution pH on demulsification time and zeta potential were measured. With decreasing solution pH, the zeta potential was close to zero and demulsification time decreased.

The solvent extraction of gallium from its aqueous solution was conducted by using 8-quinolinol[2)] as extractant. Gallium concentration in aqueous solution was 10 mg/L. The extractability of gallium increased with increasing solution pH and becomes about 100 % above the solution pH of 5. This is because chelate complex of 8-quinolinol and gallium is difficult to form at low pH.

Figure 5 shows the change in extractability of gallium with separation time for ultrasound and still standing. Still standing was conducted after stirrer mixing at 400 rpm for 12 minutes. Organic solvent was p-bromotoluene. The ultrasonic irradiation shortens the time needed for the solvent extraction. For all organic solvents, the superiority of ultrasound was observed.

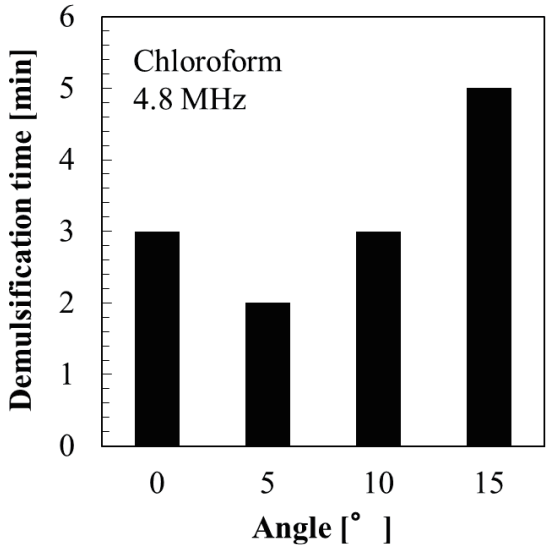

Fig. 3 Effect of inclination angle of vessel on demulsification time

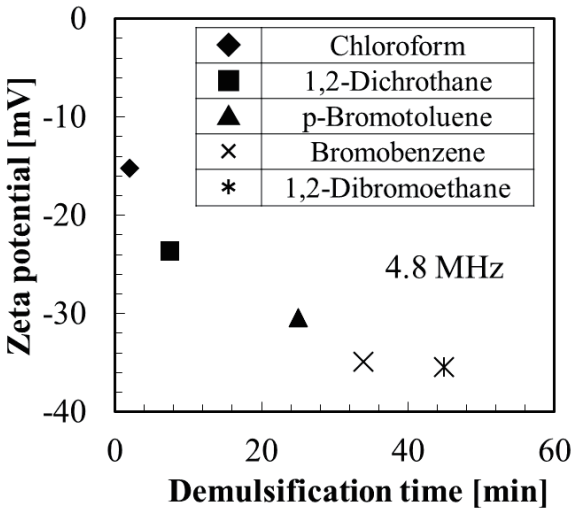

Fig. 4 Plot of demulsification time against zeta potential for different organic solvent

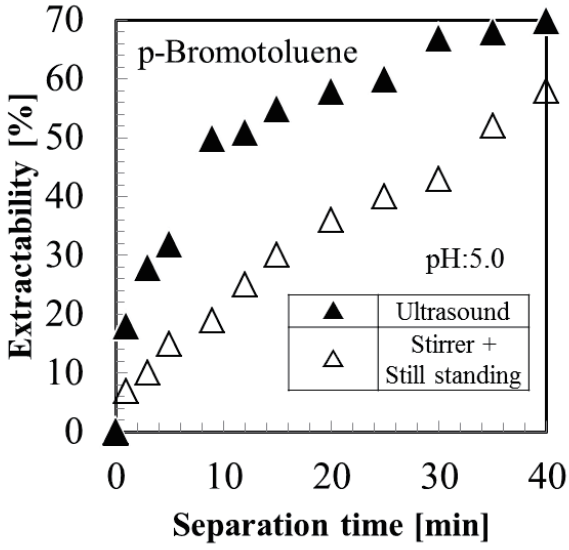

Fig. 5 Change in extractability of gallium with separation time for ultrasound and still standing

4. Conclusion

The following facts were clarified in this study.
1) The demulsification time decreased with increasing ultrasonic frequency.
2) The demulsification time became shorter as the zeta potential is close to zero.
3) The ultrasonic irradiation shortened the time needed for the solvent extraction.

References

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