平成 11 年度博士論文要旨

平成 9 年度入学　大学院博士後期課程　物質生産工学専攻　材料物理工学講座

氏　名　柳田 裕隆（ Hirotaka YANAGIDA ）

論文題目：超音波場の時空間的制御によるソノケミストリの反応制御の研究
英訳題目：Control of sonochemical reaction by control of sonicationcondition

- **Abstract**

In this thesis, the relationship between the efficiency of sonochemicalreactions and various sonication conditions have been studied in detail.A mechanism of multi-bubble sonochemical reactions shall be proposed basedon the kinetics of the cavitation bubbles. Clarification of this relationand mechanism is of great use to control the sonochemical reaction by sonicationcondition. In order to obtain quantitative and reproducible results, itis essential to measure and control the sound field quantitatively. To achievethis, the spatial distribution of the sound wave was visualized by the shlierenmethod, and the sound pressure was determined by Ramann-Nath parameter.The chemical reactions induced by sonication were monitored by the sonochemicalluminescence of luminol solution. These methods enable us to measure thesound field and reaction field without disturbing the sound field.

By using these methods, the sound field and reaction field were comparedin various configurations. It has been found that:

1) Turning off the sound even for a very short period caused a decreasein the luminescence efficiency.

2) Traveling wave has higher threshold sound pressure than standing wave.

3) When a concave transducer is used, the luminescence is observed on theconverging side only. The diverging side shows no luminescence at soundpressure twice as high as that of the converging side.

4) Superposing two sound waves produces stronger luminescence than the sumof the luminescence induced by each wave alone.

These results show that that the sonochemical reaction is not determinedby the sound pressure alone, but strongly depends on the sound wave forms.In order to obtain high efficiency, important condition seems to be toconcentrate bubbles in pressure antinode region and keep them there sufficientlylong. Since the acoustic streaming would interfere with the aggregationof the bubbles into the pressure antinode, it may suppress the sonochemicalluminescence. This expectation has been confirmed by experiment, which showsthat the streaming velocity of 15 cm/sec in the water makes the thresholdsound pressure double. In order to get further insight into the effect ofthe spatial and temporal sound wave shape, the growth and decay processof the cavitation bubbles are studied in detail by measuring the transientresponse of the luminescence. The results suggest the following model; Cavitationbubbles are created at nuclei such as small impurity particles which presentin water, and grow in two steps. In the first step, small bubble createdat nuclei gradually grows. Then the second

step starts, probably when thebubble detaches from the impurity. In the second step, the bubbles concentratein the pressure antinode and grow rather rapidly. Finally the bubble collapses,and the resulting fragments are reused as the seeds for the second step.The first step takes 10 msec ~ 1 sec and the second step needs 1 ~ 50 msec.When the sound field is turned off, the bubbles in the second step dissolvein a few seconds, but bubbles in the first step remain for about 1 min.This model can explain most of the observed effects of the soundwave shape.For example, the burst wave has lower efficiency than the continuous wavebecause the short off period of the sound causes rapid decay of the bubblesin the second growth step. The traveling and diverging waves can not concentratethe bubbles, and consequently have low efficiency. If two perpendicularsound waves are superposed, bubbles are concentrated in narrower regionand reused more efficiently than the single wave case, and the luminescenceintensity is strongly enhanced.

To summarize, it has been found that the spatial and temporal shapes ofthe sound waves have very strong effects on the efficiency of the sonochemicalreaction. The mechanism of these effects were discussed by using a modelof the formation, growth and decay of the cavitation bubbles. In order toachieve high efficiency, it is important to confine many bubbles near thepressure antinode, and keep there for sufficently long time (forexample10 msec).