Enhancement of Acoustic Cavitation Effects by Simultaneous Multifrequency Excitation

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Abstract: Acoustic cavitation effects caused by simultaneous multifrequency excitation, frequencies in the range of power ultrasound (20-100 KHz), are studied. Subharmonic acoustic emission and iodine release are utilized as indications. The results show that simultaneous multifrequency excitation can reduce the cavitation threshold and enhance the chemical effect of cavitation. It implies this method is useful for sonochemical applications.

INTRODUCTION

Acoustic cavitation can produce many physical, chemical and biological effects. Promoting or inhibiting acoustic cavitation depends on different practical purposes [1]. The production of as many cavitation activities as possible and enhancement of cavitation effects are always expected in sonochemistry.

There are many methods of altering acoustic cavitation. Modifying or disturbing the sound field, such as optimizing sound parameters, sweeping the sound frequency, pulsing the sound field, rotating or agitating the sample, may enhance cavitation effects [2]. Recently, the studies of some researchers show that the superposition of two ultrasonic fields with different frequencies can lower cavitation threshold and enhance cavitation effects. These include the superimposition of the second-harmonic (1 MHz) onto the fundamental (0.5 MHz) ultrasonic field [3], the addition of a low-frequency (20 KHz) field to a high-frequency (700 KHz) pulsed field [4], the presence of a high-frequency (30 MHz) auxiliary field in a low-megahertz acoustic field [5]. These results imply that the superposition of different frequency ultrasonic fields is a potential useful method to enhance acoustic cavitation. In principle, various frequencies may be used for different practical applications. However, frequencies in the KHz range are probably used more commonly in sonochemistry.

In this work, acoustic cavitation effects caused by simultaneous multifrequency excitation, frequencies in the range of power ultrasound (20-100 KHz), are studied experimentally. One ultrasonic transducer is used to produce multiple ultrasonic frequencies at the same time, rather than several transducers with different frequencies. Subharmonic acoustic emission and iodine release indicate cavitation effects. On the basis of the cavitation bubble dynamics theory, a theoretical analysis proposed attempts to explain the results, and further discussion is presented.

EXPERIMENT

The experimental apparatus is shown in Figure 1. Multifrequency electric signal is generated by a programmable signal generator, amplified by a power amplifier, and applied to an ultrasonic transducer. A watt meter shows the input electric power of the transducer. The ultrasonic transducer used here is a piezoelectric sandwich transducer, which is designed specially by adjusting locations of piezoelectric ceramic discs in the sandwich transducer so that it can work at multiple frequencies efficiently. In the present experiment, the transducer can operate at several frequencies at the same time besides 25 KHz.

A calibrated probe piezoelectric ceramic hydrophone (1.5 mm diameter) is utilized to record the acoustic emission. The hydrophone output signal is taken through a A/D board, and sent to a computer. The A/D board has a maximum sampling frequency 20 MHz, SRAM 128 kbytes × 12 bit/channel. The frequency spectrum of acoustic emission and intensity of subharmonic emission can be obtained by signal processes. The chemical effect of cavitation is determined by the method of iodine release. By changing different experimental parameters, the dependence of subharmonic emission intensity and iodine release yield on the input electric power, in the cases of simultaneous and separate excitation of various frequencies, is investigated respectively.
RESULTS AND DISCUSSION

The experimental results show that subharmonic emission can appear at a lower level of input electric power than only one single frequency when the transducer is excited by multiple driving frequencies simultaneously. This suggests that simultaneous multifrequency excitation can reduce the cavitation threshold. From the experiment of iodine release, the yield of iodine release under the condition of simultaneous excitation at both 25 and 45 KHz is much higher than the simple sum of the results induced by two frequencies acting respectively. It demonstrates that a cooperative effect existing in the multifrequency sound field can enhance the chemical effect of cavitation. Using one transducer driven by multiple frequencies simultaneously is more effective and more convenient for the study of these phenomena, even for practical applications.

According to the cavitation bubble dynamics theory [6], bubble nuclei in a liquid, in the presence of a suitable sound field, can grow by rectified diffusion to a resonance size. The growth and collapse of bubbles are relative to the pressure, exciting frequency and bubble size. When a bubble reaches the transient threshold, it expand, then implode and disintegrate into small bubbles. Some of these may act as extra nucleation sites and grow again. Therefore, one of the primary mechanisms for the enhancement of acoustic cavitation by the superposition of multiple frequency ultrasonic fields is due to the acceleration of the rectified diffusion [3]. Another possible mechanism is that one sound field with a certain frequency provides new bubble nuclei for another during cavitation.

This method seems to have a potential application in sonochemistry. However, the multifrequency sound field is far more complicated than the single frequency one, since the nonlinear interaction of sound waves exists. In theoretical analyses, some nonlinear factors must be taken into account. On the other hand, in practical applications, in order to set up a multifrequency sound field effectively, the design of transducer systems, including structure of the transducer, acoustical and electrical matches, must be also considered carefully.

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REFERENCES