Enhancement of Ultrasonic Cavitation Yield by a Bifrequency Irradiation and its Frequency Effect

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Abstract: The ultrasonic cavitation yield given by a combining orthogonal irradiation at frequencies of 28 kHz and 0.87 MHz is studied experimentally by using electric detection method. It is shown that the cavitation yield produced by the bifrequency irradiation is much larger than the sum of the yields produced separately by the two irradiations. The ultrasound beams of 28 kHz combined separately with 1.0 MHz and 1.7 MHz are also studied. The result show that the enhancement of cavitation yield by bifrequency irradiation is notably dependent on the used frequencies.

INTRODUCTION

It is well known that the main motivation of sonochemical reaction is sound cavitation. So how to increase the cavitation yield has been an important project in fundamental study of sonochemistry. The studies completed recently in our laboratory have shown that the combining orthogonal irradiation at frequencies of 28 kHz and around 1 MHz can give remarkable enhancement of cavitation yield.

EXPERIMENTS

Setup The setup is presented in FIGURE 1. The main channel consists of an ultrasonic power generator (model CFS-250-5) and a 28 kHz horn transducer T1. In the assistant channel the 0.87 MHz electric signal from a frequency synthesizer (model 5130A) was adjusted by an attenuator (model UAC-77-100A) and an amplifier (model ENI A-500) and then adapted to transducer T2 with effective radiation diameter of 15 mm. The oscilloscope (model COS 5041) was used to monitor the input signal voltage to the amplifier. The sample tube was a right angle-shaped glass tube 1.8 mm in thickness, 50 mm in vertical length, 40 mm in horizontal length and 12.5 mm in inner diameter. The low exit closed with sound-transmission film was located 20 mm from T2. T2 and sample tube was placed in a water bath. The electric detection method of cavitation field has been discussed in Ref. 1.

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**FIGURE 1. Experimental setup**

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Experimental results In experiments the horn end with diameter of 10 mm was put in 20 ml deionized water. We adjusted the generator in the main channel, fixed the plate current of 200 mA and varied sequentially the sound intensity of T2 in ascending order in the assistant channel. Every time a new sample was taken and irradiated for 2 minutes. Before and after irradiating the sample by ultrasound, we measured the electroconductivity $\sigma$ and
of the sample, and got the change $\Delta \sigma$ as shown in FIGURE 2 and FIGURE 3.

The results of FIGURE 2 and 3 are the average values of 6 groups of measured data. The middle dotted line is the sum of results produced separately by the two irradiations in FIGURE 2. The result of the single 28 kHz irradiation is presented in the left of the FIGURE. It is shown in FIGURE 2 that the cavitation yield produced by the bifrequency irradiation appears to be much larger than the sum of the yield produced separately by the two irradiations. For instance, when the intensity of 28 kHz ultrasound is fixed but that of 0.87 MHz ultrasound changes in the range of 4−7 w/cm$^2$, the cavitation yield of the combining irradiation is equal to 1.9−3.4 times of the sum of the yields given separately by the two irradiation. The results in FIGURE 3 shows that when the intensity of 0.87 MHz, 1.0 MHz and 1.7 MHz ultrasound is taken 6.5 w/cm$^2$, the combining irradiation gives 4.4, 3.2 and 1.8 times of the cavitation yield of the single 28 kHz irradiation respectively.

DISCUSSIONS

Bifrequency irradiation disturbs the sample more strongly than any single irradiation and makes more air near the sample surface enter into the sample and more bubble nuclei would be formed, and cavitation yield, therefore, is increased. Besides as we know that under action of a sound field with frequency $f_A$, only the bubbles with resonant frequency $f_r$ near $f_A$ make a contribution to the cavitation yield. Now we have two frequency combined irradiation (28 kHz and 0.87 MHz), the 28 kHz ultrasound contributes a $\Delta \sigma_1$ (electroconductivity change). After implosion of cavitation bubbles, many new bubbles nuclei are formed, some of them, may be, response to 0.87 MHz ultrasound and give additional contribution $\Delta \sigma_{12}$. As the same, 0.87 MHz ultrasound contributes $\Delta \sigma_2$ and $\Delta \sigma_{12}$. Therefore bifrequency combined irradiation contributes $\Delta \sigma_1 + \Delta \sigma_{12} + \Delta \sigma_2 + \Delta \sigma_{21}$, instead of $\Delta \sigma_1 + \Delta \sigma_2$ produced separately by the two irradiation.

The influence of frequency on the cavitation yield observed above is similar to that obtained previously by using single frequency ultrasound irradiation and can be explained that the frequency corresponding to the most probability of the bubble size distribution should be lower than 0.87 MHz$^2$.

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REFERENCES