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Multibubble sonofluorescence display

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ABSTRACT

Based on the multibubble sonofluorescence display principle of the aqueous luminol-alkaline solution, two experimental applications, displaying the ultrasonic cavitation field and confirming the temperature distribution characteristic of the ultrasonic fountain are introduced.

Keywords: Multibubble, sonofluorescence, display, jetting cavitation field, luminol-alkaline solution, ultrasonic fountain, cavitation concentrating effect , temperature.

1.INTRODUCTION

In this time, more and more scientists think highly of the ultrasonic cavitation, especially its physical, chemical and biological effects. But many of them feel perplexed because of the difficulties they meet with in duplicating some effects. One of the reasons is lack in the understanding for the whole cavitation field. Actually the cavitation field consists of a great number of cavitating bubbles at micron and microsecond dimensions and their bulky host "liquid" .In the past half century, many scientists researched the cavitation field by means of different methods and knew some important characteristics of it, but still the interactions among the bubbles and their impacts on the transmission、 absorption and reflection of the ultrasound haven't been understood [1,2]. The author refers specially to the works of Katsuo Negeshi in 1962 and V. Rauandin et al. in 1994. A common technology adapted by them was to use the sonoluminescence (SL) of aqueous luminol – alkaline solution (luminol $C_8H_7N_3O_2$, a chemiluninescence substance) for real-timely displaying the cavitation field. However, the ultrasounds with some frequencies lower than one megahertz were used, also the sonochemical reactors were alone symmetric in shape [3,4], and even nobody has so far detected the temperature distribution of the field which is very important for the most of the ultrasonic effects as mentioned above[1,2] . Based on the multibubble sonofluorescence (Abbreviated to MBSF) display principle proposed by the author, this paper introduces the MBSF display of the cavitation field in space which generated by the ultrasound with a frequency of 1.45MHz and intensity of 5W/cm^2 in both the symmetric reactor and non-symmetric reactor, and the MBSF confirmation of the temperature distribution characteristic of the ultrasonic fountain(a jetting cavitation field) produced by the ultrasound with a frequency of 1.7MHz and intensity of 18W/cm^2.

2.PRINCIPLE

In the ultrasonic cavitation: field, the excited water molecule ($H_2O^{\cdot}$) is divided into the hydrogen free radical ($H^{\cdot}$) and hydroxyl free radical ($OH^{\cdot}$), and they quickly reform to hydrogen peroxide (H_2O_2), an intermediate product when the two free radicals combine again. It is the hydrogen peroxide that serves as an oxidation substance for clear chemical fluorescence of luminol in the aqueous alkaline solution. From the point of view of the exciting source, such the oxidation goes the name of cavitation oxidation and the chemical fluorescence by name MBSF The sonophysical and sonochemical process of it would be indicated in the following reactions[5,6]:

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$$H_2O + M \xrightarrow{)))))} H_2O^{*} + M \xrightarrow{)))))} H_2O + M + h\nu_0(\,270-290nm\theta, weak\,)$$

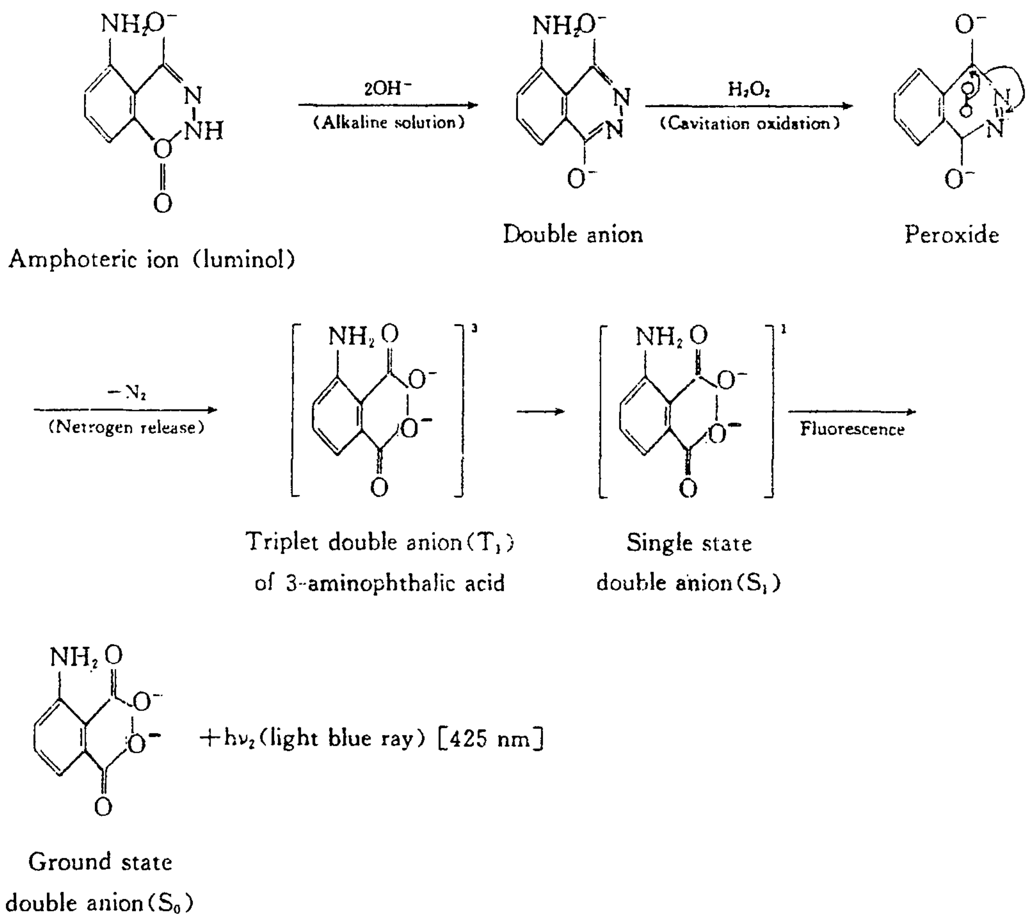
M: dissolved gas molecule or atom)))))): cavitation field

$$H_2O^{\bullet} \xrightarrow{)))))} H^{\bullet} + (OH)^{\bullet} \rightarrow OH^{\bullet} + h\nu_1(310nm,, weak)$$

$$2H^{\bullet} + 2OH^{\bullet} \xrightarrow{)))))} H_2O_2 + H_2$$

$$\overline{M}y \xrightarrow{)))))} (\overline{M}^{\bullet})^{+} + y^{-} \rightarrow (\overline{M})^{+} + y^{-} + h\nu_3 \begin{cases} 554\text{-}590nm(Na) \\ \text{or } 740\text{-}771.1nm(K) \\ \text{or } 393.4\text{-}631.0nm(Ca) \end{cases} \text{weak}$$

$\overline{My}$: alkaline compound, Na_2CO_3、 NaOH、 KOH or $Ca(OH)_2$



Based on the above-stated views, the author has detected the MBSF spectra of the above-described aqueous solutions. The main emission of the solutions is about 375~750nm, a fluorescence range of luminol[5]. One of them is shown as in Fig.1. Apparently the emission region is sensitive to the naked eyes and the color film , and the intensiver the cavitation field is, the more the cavitation oxidation is, and the brighter the MBSF is.

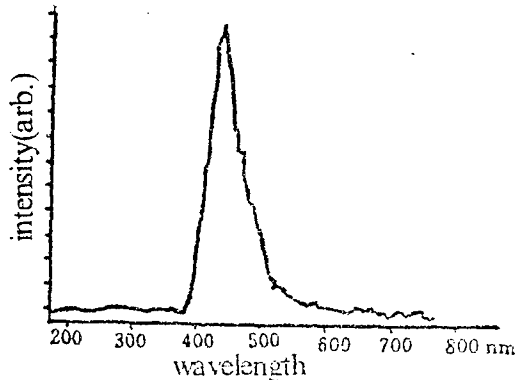
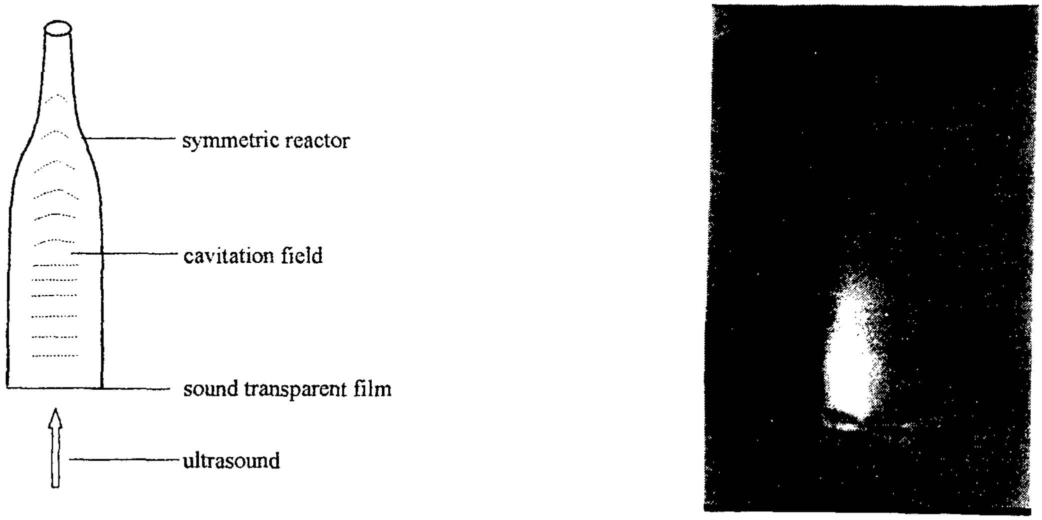


Fig.1 MBSF spectrum of $C_8H_7N_3O_2$-H_2O-Na_2CO_3 (Used by SPEX 1403 monochrometer , USA)
Ultrasonic frequency: 1.45MHz, acoustic intensity: 5W/cm^2

3.APPLIED EXPERIMENTS AND RESULTS

3.1 Displaying the Cavitation Field

In doing the experiments, the display set-ups and processes must be conducted in the dark room, the ultrasound applied is equal to that in Fig.1. The exposition time of the color film is about 15 minutes. Figs.2-3 represents the display set-ups with a symmetric reactor or non-symmetric reactor, and the MBSF pictures of the cavitation fields induced in the reactors



(a) (b)

Fig.2 (a) set-up for display; (b) MBSF picture of the cavitation field induced in the symmetric reactor with the aqueous luminol - NaOH solution

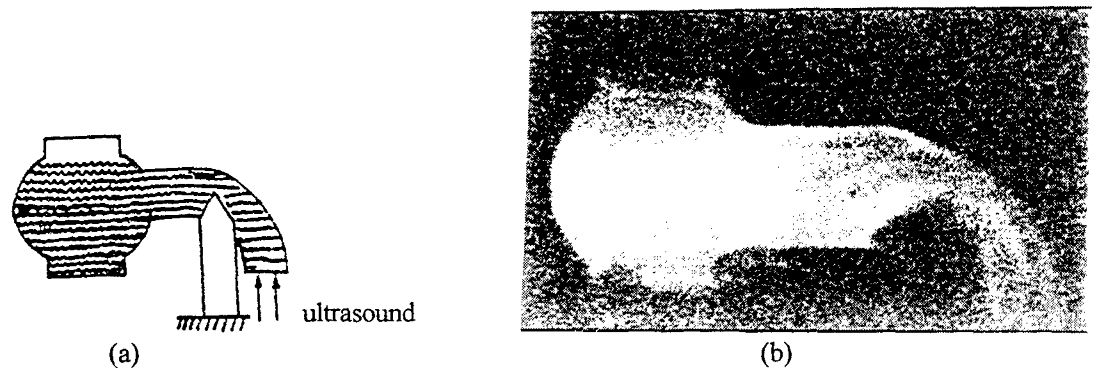


Fig.3 (a) set-up for display; (b) MBSF picture of the cavitation field induced in the non-symmetric reactor with the aqueous luminol-KOH solution.

Figs.2-3 shows that all the cavitation fields are clearly non-uniform in space no matter what sonochemical reactors used in shape, and the cavitation intensity of any point in the field changes with its space position in the field.

3.2 Confirming the Temperature Distribution of the Ultrasonic Fountain

According the heating phenomenon by the ultrasonic fountain, the authors made a point that the fountain, a cavitating water, should be considered as a jetting ultrasonic cavitation field, and the heat would result from the cavitation concentrating effect in the field[7,8]. Based on the physical concepts of the fountain, it is easy to get the rough and relative temperature distribution along with the axis of the fountain produced by an ultrasound with a frequency of 1.7 MHz and intensity of $18W/cm^2$ in the reactor with the aqueous luminol-Na_2CO_3 solution even with the tap water (Fig.4). In order to confirm the characteristic of the temperature distribution, in a similar way, the space picture of the fountain can be taken by using the MBSF display as mention above.

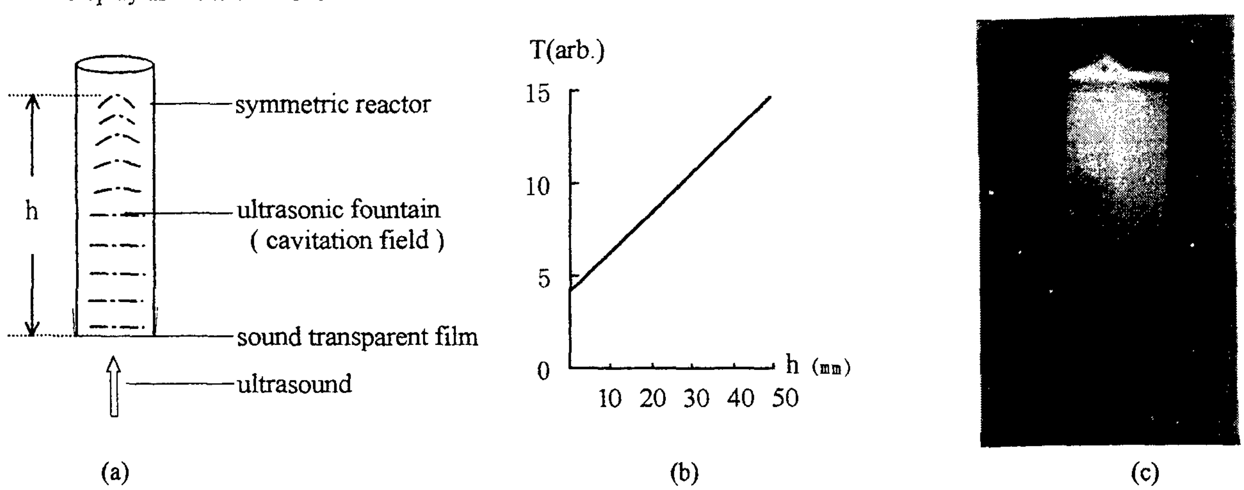


Fig.4 (a) ultrasonic fountain and its display set-up; (b) Rough temperature distribution along with the axis of the ultrasonic fountain (h: height of the fountain; T: reading in one minute when the thermometer is set into the fountain); (c) MBSF picture of the ultrasonic fountain.

The result shows that the stronger the cavitation region is, the brighter the region is, so the higher the temperature is in the region and that the cavitation effect is upward concentrated in the jetting cavitation field.

4. CONCLUSSIONS AND DISCUSSIONS

The MBSF can be used to display the whole ultrasonic cavitation field directly and real-timely. In the mean time, used to confirm the rough temperature distribution characteristics of the jetting cavitation field. As a simple method, it might be used to improve the ultrasonic reactor, and to explain the some effects in the cavitation fields.

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