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Study on sonochemical reaction near focal point in 1.6 MHz focused ultrasound field

1.6 MHz の集束超音波音場の焦点近傍における音響化学作用の検討

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1. Introduction

In general, MHz frequency range ultrasound was used in diagnostic and therapeutic field. It is thought that it is harder to generate acoustic cavitation in frequency range of MHz than in frequebcy range of a few hundreds kHz. However, We think that estimation of acoustic cavitaion generated in frequency range of MHz is important for safety assesment of ultrasound exposure to human body and tissue [1)]. So far the sono-chemical estimation of acoustic cavitaion by ultrasound exposure has been studied [2)] .The objective of this paper is to measure the generated active oxigen togather with acoustic cavitation by using special ultrasound exposure cell and KI oxidation dosimetry [3-4)] at focal point in 1.6 MHz focued ultrasound field and to research relationships between ultrasound exposure condition and the amount of generated active oxigen.

2. Measurement of cavitation at focal point in focused ultrasound with KI oxidation dosimetry

The ultrasound exposure system is shown in **Fig.1**. Continuous waves or tone burst waves (number of cycles in burst : 60 cycles) with voltage amplitude of 800 $mV_{0\text{-}p}$ and frequency of 1.78 MHz from a function generator (8116A, Hewlett Packard) was amplified by using a RF power amplifier (75A250A, Amplifier Research) with gain of 50 dB. Output amplified signals (CW or tone burst wave) were applied to a concave shaped ultrasound transducer (nominal frequency: 1.6 MHz) as the acoustic source. Anti-resonance frequency of the concave shaped ultrasound transducer in room temperature is 1.78 MHz

The polyethylene ultrasound exposure cell (diameter: 10mm, height: 30mm) filled with KI solution (Wako chemical, concentration: 0.1 mol/L) was placed at focal point in focused ultrasound field.

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The ultrasound transducer was driven by using the function generator and the RF power amplifier with duty cycles as follows (0.1, 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 %) and ultrasound was irradiated for 10 minute to the ultrasound exposure cell with KI solution. We prepared the control sample for comparison with the ultrasound irradiated sample. This sample was left in water during the same time as ultrasound exposure time. If the KI solution turns yellow (wavelength: 350 nm) by ultrasound exposure, it shows the existence of active oxygen generated together with acoustic cavitation. Light absorbance by the samples was measured by using ultraviolet-visible spectrophotometer (UV-Vis).

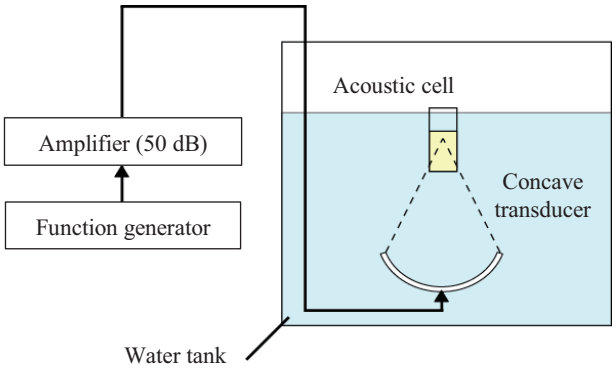

Fig.1 Schematic diagram of ultrasound exposure system and ultrasound exposure cell with KI solution for measurement of cavitation

3. Result and discussion

3.1. Relationship between duty cycles of ultrasound wave and light absorbance by I_3^- ion caused by ultrasound exposure

Figure 2 shows the duty cycles of ultrasound burst vs. change in peak absorbance at 350 nm that representive color reaction of I_3^- ion caused by ultrasound exposure. The peak absorbance at 350 nm was increased in proportion to duty cycles

between 30 and 80 %. However, when the duty cycle is 70, 90 and 100 %, increasing tendency of absorbance saturated. We considered the cause of saturation of measured data as follows. Temperature of the transducer increased with increase of duty cycles. Then, resonance frequency is shifted from driving frequency of the function generator with increase of transducer temperature and duty cycles. Consequently, it was thought that amount of generated active oxygene by cabitation and absorbance were surturated in large duty cycle range. We think that large error bars in Fig. 2 are also caused by same reason as above discussion. When the duty cycles less than 10%, it could not be observed the difference in peak absorbance at 350 nm between ultrasound exposed sample and control one. It was thought that it was the detection limits of the active oxgen with KI oxidation dosimetry.

3.2. Relationship between duty cycles of ultrasound wave and concentration of H_2O_2

To evaluate quantitatively the amount of generated active oxygen together with acoustic cavitation, relationship between concentration of hydrogen peroxide (H_2O_2) and light absorbance by I_3^- ion was measured. H_2O_2 is a kind of active oxygen.

The relationship between duty cycles of ultrasound wave and concentration of H_2O_2 is shown in **Fig. 3** by using Fig. 2 and above relationship between concentration of H_2O_2 and absorbance by I_3^- ion. The oxidation reaction induced by acoustic cavitation and ultrasound exposure could estimate as the equivalent oxidation by H_2O_2. However, the generated active oxygen by acoustic cavitation is not necessarily only one type and also it is thought that many types of active oxygen influenced on the amount of generated I_3^- ion in KI solution.

4. Conclusion and future works

We measured the amount of active oxygen generated together with acoustic cavitation by KI oxidation dosimetry near focal point in 1.6 MHz focused ultrasound field. The amount of generated active oxygen increased with increase of duty cycles of ultrasound burst waves. When the duty cycle is 0.1 % same as diagnosis ultrasound, it was not found the difference in peak absorbance at 350 nm between ultrasound exposure sample and control one. It was thought that it was the detection limits of KI oxidation dosimetry.

We will measure the amount of active oxygen with higher detection sensitivity method than KI oxidation dosimetry in the acoustic field with similar acoustic power as one of diagnostic ultrasound in our future works. By using this method, we will research about relationships among ultrasound exposure condition, generated active oxgen and Mechanical Index (MI) [5-7] in medical ultrasound diagnostic field.

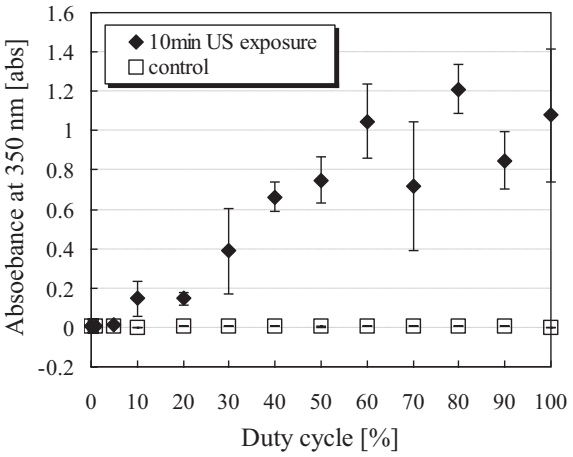

Fig. 2 Change of peak absorbance at 350 nm representing color reaction of I_3^- ion with KI solution for different duty cycle of ultrasound wave.

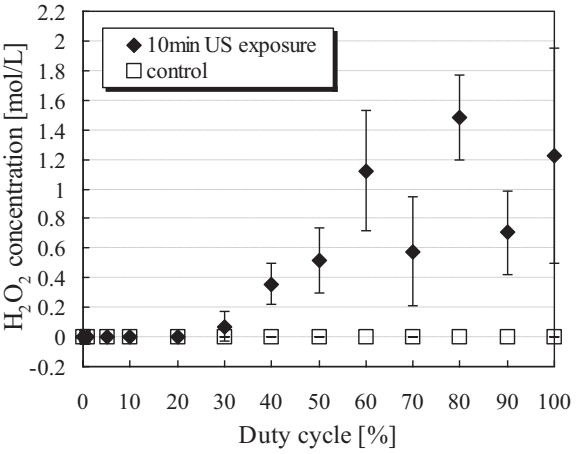

Fig. 3 The relationships between duty cycle of ultrasound wave and concentration of H_2O_2.

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