

## Medical application of micro-bubbles

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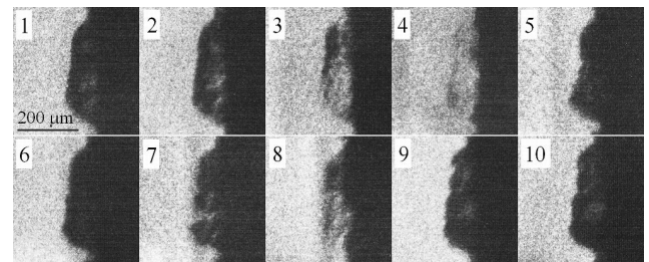
### Abstract

In the medical ultrasound applications, microbubbles are closely tied to the diagnostic and therapeutic uses. For diagnostic applications, their sound scattering properties yield improved imaging, when the microbubbles are used as ultrasound contrast agents. The harmonics and subharmonics responses from the bubbles assist in distinguishing the acoustic scattering of blood from that of the surrounding tissue.

The therapeutic use of microbubbles has recently been the subject of much interest. In a HIFU (High Intensity Focused Ultrasound) treatment, the heat generated by the bubble oscillation can enhance localized heat effect. In previous studies about the HIFU treatment, *in vivo* experiments with contrast agents have been conducted and it is suggested that the heat effect is enhanced by the existence of contrast agents (Umemura et al. 2005). In order to practically use the microbubble-enhanced HIFU treatment, it is important to predict the coagulation shape, volume and position and control them. Chavier et al. (2000) numerically investigated the relationship between the special distribution of microbubbles and the coagulation profile. In the lithotripsy of renal calculi, the acoustic cloud cavitation contributes to the comminution of the renal stones. A number of studies suggest the importance of the cavitation collapse in the lithotripsy, and the control of the cavitation has been attempted.

In all these applications, it is essential to understand the microbubbles and bubble cloud dynamics. The bubble motion and bubble cloud behavior are strongly influenced by the internal phenomena of the bubbles, such as evaporation, condensation, and heat and mass transfer through the bubble interface. Numerical results of the microbubble oscillation and bubble cloud collapse are introduced with considering the internal thermal phenomena. Some experimental results are also introduced. High speed photography of the cavitation bubbles and temperature monitoring with thermocouples and a thermal liquid crystal sheet are conducted in *in vitro* experiments to investigate the behavior of the microbubbles and its effect on the therapy. Figure 1 shows photographs of the bubble cloud oscillation on the solid surface (Ikeda et al. 2006). Ikeda et al. proposed a method to control the bubble cloud collapse for the lithotripsy. In *in vivo* experiments, monitoring with an

ultrasound diagnostic system, microbubble-enhanced HIFU and Cavitation Control Lithotripsy (CCL) (Ikeda et al. 2005) are applied. It is shown that microbubbles are utilized to enhance the therapeutic effect of HIFU.



**Figure 1:** Forced collapse of cloud cavitation. Hemispherical cloud cavitation generated by the 2.75 MHz focused ultrasound is forced into collapse by 545-kHz ultrasound. The camera interframe time is 325 ns with an exposure of 50 ns. During the first frame, the low-frequency ultrasound second positive phase starts. During the fourth frame, the bubble cloud collapses with each bubble radius decreasing in size. At that time, high pressure is hypothesized to be localized at the solid surface. The bubbles rebound during the fifth frame and the next collapse occurs during the eighth frame.

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