Bubble formation in the discharge between planar and needle electrodes via laser ablation-induced cavitation bubble

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We observed the formation of a bubble in the discharge process between needle and planar electrodes. A unique experimental condition was that a cavitation bubble, which was induced by liquid-phase laser ablation, was positioned between the electrodes. When the distance between the needle electrode and the gas-liquid boundary of the cavitation bubble became close, we observed the formation of an additional bubble from the tip of the needle electrode. The discharge occurred when the needle electrode and the cavitation bubble was connected by the additional bubble. It should be emphasized that the bubble formation was not induced by the Joule heating of water, since we observed the bubble formation even when the current through the electrode was negligible.

1. Introduction

The discharge processes in bubbles in water attract much attention recently, but the physics of the discharge in a bubble has not been fully understood yet. In addition, we also have insufficient understanding about the effects of electromagnetic fields on the formation processes of bubbles in water. In this work, we observed the bubble formation from the tip of a needle electrode which was connected to a high-voltage power supply. A unique point of the present experiment is that the needle electrode faced the gas-liquid boundary of a laser ablation-induced cavitation bubble.

2. Experiment

A titanium plate, which was electrically grounded, was installed in water, and it was irradiated by focused Nd:YAG laser pulses from the normal direction. A needle electrode, which was connected to a high-voltage power supply, was placed at a distance from the ablation point. The irradiation of the laser pulse induced a cavitation bubble. The cavitation bubble had the dynamics of the expansion, the shrinkage, and the collapse, but the tip of the electrode was separated from the gas-liquid boundary of the cavitation bubble even when the bubble size became maximum.

3. Results and discussion

Figure 1 shows shadowgraph pictures and the waveforms of the voltage and the current. We employed a pulsed power supply in this experiment, and the high voltage was switched on at a delay time of T_0=267 μs after the irradiation of the laser pulse. Figure 1(a) shows the shadowgraph picture at this timing. The shadows of a hemispherical cavitation bubble and the needle electrode are seen in Fig. 1(a). After the spiky displacement current, a conduction current of approximately 20 mA passed from the needle electrode to the grounded titanium plate. At a

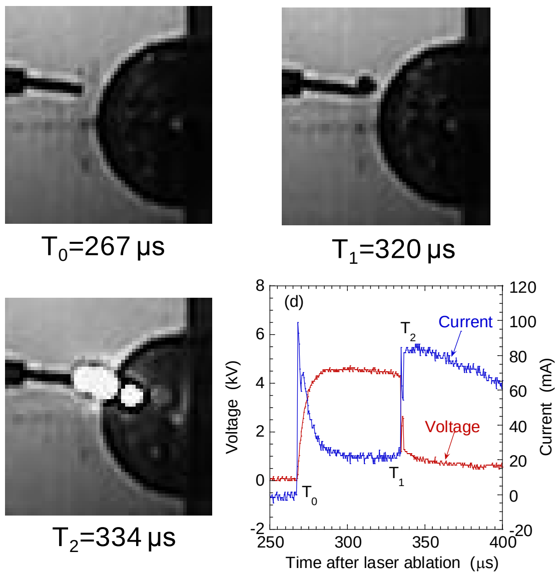

Fig. 1 (a)-(c) Shadowgraph images observed at various delay times, and (d) voltage and current waveforms.

delay time of T_1=320 μs, we observed the formation of a bubble from the tip of the needle electrode, as shown in Fig. 1(b). The bubble was lengthened toward to gas-liquid boundary of the cavitation bubble. The discharge between the needle electrode and the titanium plate occurred at a delay time of T_2=334 μs, when the bubble connected the cavitation bubble and the needle electrode, as shown in Fig. 1(c). It is noted here that a similar bubble formation was observed even when we employed an alumina target. Since the conduction current was negligible in the case using the alumina target, it is considered that the bubble formation was not caused by the Joule heating of water.