IGNITION OF COMBUSTIBLE GASES BY AN ELECTRIC EXPLOSION OF AN ELECTROLYTE

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Ignition of a stoichiometric propane–oxygen gas mixture in a bubble located in the vicinity of a dielectric or metallic wall is initiated in experiments. Initiation of ignition of the combustible gas in the bubble is demonstrated to occur owing to an electric explosion (breakdown) of the thinnest layer of the electrolyte along the bubble boundary.

The combustion of an acetylene–oxygen bubble was initiated by an electric discharge in the gap between the metallic electrode and electrolyte [1]. The mechanism of this initiation was not absolutely clear. To optimize the parameters of ignition of combustible gases in water for developing principally new thermal generators [2], it is necessary to elucidate the mechanism of ignition of combustible gases in bubbles by an electric discharge. The presented experiments modeling electrohydrodynamic processes as applied to initiation of combustible gases in the bubbles were aimed at solving this problem.

Arrangement of Experiments

The arrangement of the experiments is illustrated in Fig. 1. A thin electrolyte layer was formed between the gas bubble and the inner surface of a silicon tube filled by an electrolyte (the inner and outer diameters of the tube are 2.5 and 3.5 mm, respectively). A storage with a capacity of 8 μF was used in the experiments. The internal inductance of the setup was 3 μH. The experiments were performed at voltages $U = 300$–1800 V. Water solutions of sodium chloride or potassium carbonate

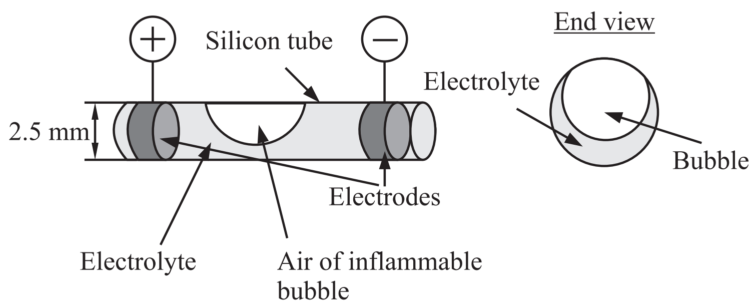

Figure 1 The arrangement of the experiments

with a concentration of 1% were used as an electrolyte. The current and voltage curves were recorded simultaneously with shadowgraphy in all experiments.

Results

The frames in Fig. 2 show the evolution of electrohydrodynamic processes in a silicon tube with an air bubble in a 1 percent water solution

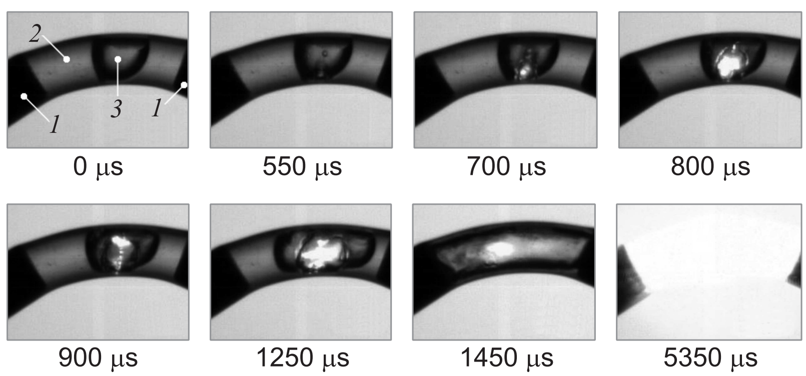

Figure 2 Dynamics of the electric explosion of a thin electrolyte layer on the boundary with an air bubble ($U = 1200$ V): *1* — tubular electrodes $d = 2.5$ mm (the positive and negative electrodes are located on the left and on the right, respectively); *2* — electrolyte, 1% NaCl solution in water; and *3* — air bubble

of sodium chloride. It follows from these frames that current-induced heating of the liquid meniscus in the lower part of the bubble leads to explosive boiling of the liquid with ejection of droplets and vapor into the air bubble. Light flashes are seen in the vapor zone of the bubble, which corresponds to ionization of the gas and the vapor ejected into the air bubble. The breakdown regions have the character of diffuse streamers in the form of flames sliding over the tube surface. Afterwards, the glowing region expands and squeezes the electrolyte through the tubes

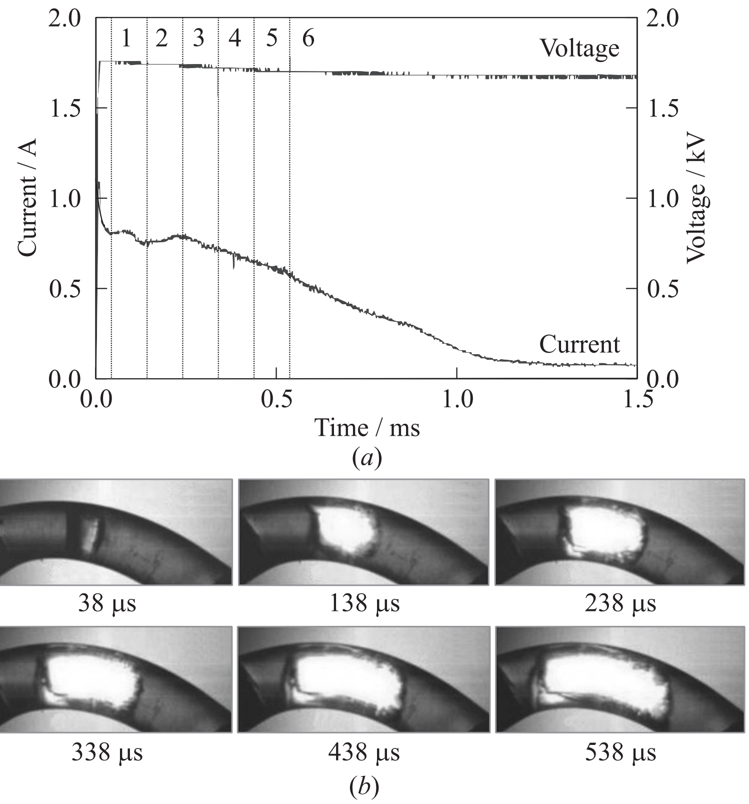

Figure 3 Current and voltage oscillograms (a), and the frames that illustrate the dynamics of hydrodynamic processes during initiation of combustion of a propane–oxygen bubble (b)

of the metallic electrodes. When the expanding bubble touches the metallic electrodes, a breakdown between the metallic electrodes occurs (the last frame in Fig. 2). On the average, the velocity of motion of the bubble boundary along the tube axis does not exceed 1 m/s. It should be particularly noted that the glowing zone does not fill the entire space of the expanding bubble until breakdown occurs.

Figure 3 shows the current and voltage oscillograms and also the frames that illustrate the dynamics of initiation of ignition and combustion of a propane–oxygen bubble in a tube.

In contrast to the processes in the air bubble (see Fig. 2), the glowing in the entire volume of the growing bubble is observed here. This fact testifies that ignition occurs at the instant of the first frame (38 μs). The mean velocity of motion of the bubble boundary along the tube axis is 5 m/s, which is five times greater than the velocity of the air bubble boundary in the first case. Radial expansion of the silicon tube is observed (see frames 1 and 4 in Fig. 3). Thus, the change in the bubble expansion dynamics, glowing in the entire bubble volume, and tube deformation are indicative of gas combustion. If the combustible gas is not ignited, the bubble growth rate corresponds to the values obtained for the air bubble, and glowing is not observed in the entire bubble volume until a breakdown occurs.

Based on the results of filming and on the current and voltage oscillograms, the energy of initiation of gas ignition in the bubble can be estimated for each experiment. It is determined by the energy necessary for evaporation of the electrolyte layer. Direct initiation occurs when the electrolytic bridge is broken owing to the gas breakdown at this place. For the data in Fig. 3, for instance, the ignition energy was below 0.1 J.

Concluding Remarks

These experiments show that ignition of combustible gases in bubbles occurs as a result of an electric explosion (breakdown) of thin electrolyte layers.

Acknowledgments

This work was supported by the Russian Foundation for Basic Research (Grant No. 10-08-00788).

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