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Time Resolved Imaging of Pulsed Streamer Discharge at the Air/Water Interface

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Pulsed positive streamers over the water surface were observed in the needle-to-plate electrode configuration with a gap of 20 mm. The characteristics of streamer propagation were investigated by using the ICCD camera. The filamentary streamers propagate in radial direction from the needle electrode and their progression distance increases with the increase of the applied voltage. A branching discharge pattern with the channel diameter of 250-450 μm was observed. When the tip of the needle is set on the water surface, the streamers start from the needle stem located above the water surface and then reach the water surface, where they propagate on it. The propagation velocity of the streamer head was 7-8 x 10^4 m/s at the early propagation stage and 4-5 x 10^4 m/s in the middle of water surface propagation stage. Moreover, the discharge features were evaluated in terms of the fractal aspect and the fractal dimension was estimated for our surface streamer discharges.

Keywords: Pulsed discharge, Discharge over water, Atmospheric-pressure, Surface discharge, Streamer, Water treatment, Fractal

1. Introduction

The research of surface discharges along solid insulator surfaces has long history since the discovery of the Lichtenberg figure [1-3]. As a discharge on a liquid surface, some researches have been conducted so far in relation to the surface flashover phenomena on wet and polluted insulators [4, 5]. Recently, the extension in the use of such discharge over the water surface has been received considerable attention from the view point of the treatment of polluted water aimed at removal of dye and harmful components [6, 7]. In this case, features of the surface discharges over water surface are considered to be different from those of the discharges over a solid insulator. In addition, it is known that the discharge pattern depends on the polarity of the stressed electrode for both the discharges on the insulator and water [2-5].

In this paper, we present the results of the time resolved imaging of pulsed positive streamer discharge over water surface because the positive polarity is suitable for water treatment. The characteristics of the discharges (streamer length and its diameter, propagation velocity, branching structure and its fractal dimension) are determined using an ICCD camera and compared with the discharges in air and in water.

2. Experimental Apparatus and Methods

Fig. 1 shows the schematic diagram of the experimental setup. A pulsed high voltage circuit with a self-trigger spark gap switch was used to generate streamers. A needle-to-plate discharge electrode system shown in Fig.2 was set into an acrylic reactor. A stainless-steel needle (0.31 mm in inner diameter, 0.57 mm in outer diameter) was used as the stressed electrode, while a brass plate (70 mm in diameter) with the cover of carbon plate (80 mm in diameter, 2mm in thickness) was used as the grounded electrode. The use of the carbon plate is to reduce the reflection light when we observe the discharge from the top side. The water level was adjusted for the needle-to-plate discharge electrode and for the experiment of surface discharges the tip of the needle electrode is in contact with the water surface. The electrical conductivity of the water was measured by a conductivity meter (Delta OHM, HD2156.1). An intensified charge coupled device (ICCD) camera (Andor, i-Star) was used to observe the streamers. In order to synchronize the discharge and the ICCD camera, a PIN photodiode detected a light emission from the spark gap switch and sent a signal through a delay generator (Stanford DG535) to trigger the ICCD camera. The time relationship between the voltage pulse, discharge current pulse and gate opening time of the ICCD camera was monitored with a digital oscilloscope (Tektronix, TDS5104, 1.5 GHz, 5 GS/s). Hence, although the pulse high voltage circuit with the spark gap switch had a jitter, knowing the timing of the high voltage pulse, discharge current pulse and exposure time of the ICCD camera, it was possible to determine the phase of streamer evolution. The streamer emission spectrum was measured by a spectrometer

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