Characteristics of DC Corona Streamers Induced by UV Laser Irradiation in Non-Thermal Plasma

T. Ohkubo, S. Kanazawa, Y. Nomoto, M. Kocik[1], and J. Mizeraczyk[1]

Department of Electrical and Electronic Engineering, Oita University, 700 Dannoharu, Oita 870-1192, Japan
[1]Centre for Plasma and Laser Engineering, Institute of Fluid Flow Machinery, Polish Academy of Sciences, Fiszera 14, 80-231 Gdańsk, Poland

***Abstract*:** Positive corona streamers are widely used in the field of air pollution control such as NOx or SOx removal and VOCs decomposition based on non-thermal plasma chemical process. In this study, the characteristics of DC positive corona streamers induced by UV laser irradiation are investigated in the tube-to-plane electrode configuration with electrode gap spacing of 3 cm. The streamer images were recorded using an ICCD camera with a nanosecond order time resolution. During the DC corona discharge, regular streamers appear with tens of ms intervals, the duration of which considerably fluctuates. This makes time resolved streamer observation by the ICCD camera extremely difficult. However, additional streamers with a predictable inception time can be induced by UV laser irradiation. As a result, the current waveform characteristics of the laser-induced streamers were obtained. In this work, three-dimensional streamer structures including the streamer propagation and branching were studied. Also the streamer propagation velocity was evaluated.

Introduction

The research of the corona discharge has a long history over 100-years (*1-5*). The corona discharges have the form of avalanches, bursts, burst pulses, glows, primary streamers, and secondary streamers (*3*). The mode of the corona discharge depends on the electrode configuration, applied voltage, working gas, etc. Especially, the positive corona streamers became of interest in recent years because of their potential to be utilized in new technologies for the plasma-chemical treatment of gases and liquids (for example, removal of NOx and SO_x from flue gases, destruction of hazardous gaseous pollutants, and conversion of hydrocarbons) (*6-12*). A detail understanding of the streamers is important not only for improving the efficiency of gas treatment but also supplying the advanced data concerning to the corona discharge. Up to now, it is known that the positive corona streamers consist of the ionization region formed by the space charge of positive ions (called the 'streamer head'), propagating through the ambient gas towards the cathode, and the quasi-neutral channel (called the 'streamer channel'), which is formed on the track passed by the streamer head. The streamer head, difficult to be observed, is considered to be a disk of a diameter and thickness of 200 μm and 20 μm, respectively (*13-15*). The streamer head velocity is 10^5-10^6 m/s (*15-17*). In spite of these understandings, the insufficient understanding of corona discharge process for the gas treatment is due to the complexity of physical and chemical phenomena, which occur in the spatially and temporally complex plasma of corona discharges. These phenomena could not be studied with the required spatial and temporal resolution due to the lack of the appropriate equipment. However, recent progress in the development of an intensifier-gated charge-coupled device (ICCD) camera, imaging spectrographs and fast digital image processing has made the investigation of the filamentary discharges, including the corona discharges, possible with higher sensitivity and spatial and temporal resolution than ever.

For the temporally resolved imaging of corona discharges, the synchronization of the discharge pulse and the opening of the ICCD camera (gate start and exposure time) is a crucial point. The DC corona discharge consists of regular self-repetitive current pulses with pulse duration up to several hundred nanoseconds and repetition frequency in the range of 1 to 100 kHz depending on the electrode configuration, gas composition, etc. However, the time interval between the current pulses of the DC corona streamers usually fluctuates. In order to perform time resolved imaging of the transient discharge (e.g. corona discharge), a reference time must be assigned to the characteristic event related to the discharge, e.g. related to the inception of the current pulse. This reference time is required to establish the delay of the imaging (the moment of opening of the ICCD camera) with respect to the characteristic event, and

Keywords: DC positive corona discharge, regular corona streamer, streamer structure, laser-induced streamer