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Effect of Rise Time on Atmospheric Plasma generated using Micro-triode

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Abstract

Atmospheric pressure plasma has been of interest due to its versatile usages, such as air pollution control and surface treatments. Microstructure electrodes have been reported to be able to generate the atmospheric plasma, which was not easily obtained using a conventional few millimeter gap electrode due to instability of the plasma. Recently, a stable atmospheric plasma generation was demonstrated at a low voltage using micromachined electrodes [1]. The volume of the generated plasma, which is very of importance in practical use to produce reactive ions, was also increased by utilizing an integrated secondary cathode. **In this work, we investigate the effect of rise time of bias voltage on the atmospheric plasma generation using a micro triode.** For the atmospheric plasma generation, a self-aligned micro triode was fabricated as shown in Fig. 1 and a pulse voltage of 300 V was applied in the bias circuit as shown in Fig.2. The transition of a Townsend dark region into glow region was observed in current-voltage (I-V) plots and stable glow plasma was obtained using the micro triode. The visible emission spectrum from the discharge was obtained through the spectrometer (Fig.3). The rise time of the applied pulse voltage was varied from 100 nsec to 800 nsec. The effect of the rise time on the plasma generation is clearly observed in the photographic images. With the short rise time, the glow discharge appears to be more uniformly generated along the electrodes and the volume of the generated plasma increases (Fig.4). The I-V characteristics of the micro triode operated in the glow discharge mode were measured (Fig.5) and show more ionized atoms flow into the secondary cathode when 100 nsec of the rise time is used. Power loading of the plasma was measured at 200 kW/cm^3 for 100 nsec. Capacitance and resistance of the micro triode were measured to be 2 pF/mm and 7 ohms, respectively.

To understand the effect of the rise time on the glow discharge generation, the voltage across the micro electrodes is simulated using SPICE. The simulated results indicate there is a RC delay caused by the capacitance and the resistance of the micro electrodes (Fig. 6). The delay to reach the critical electric field is aggravated by the longer rise time of the applied voltage. Such micro electrodes are found to have a sufficient capacitance between the electrodes due to micron size gap and it leads to a RC delay in gas breakdown. **In conclusion, we report a strong dependence of atmospheric plasma generation on the rise time of an applied voltage and RC delay induced by the micro gap electrodes should be taken into account for plasma generating bias scheme.**

[1]. S.H. Han and Y. M. Kim, JVST 25(2007) 286

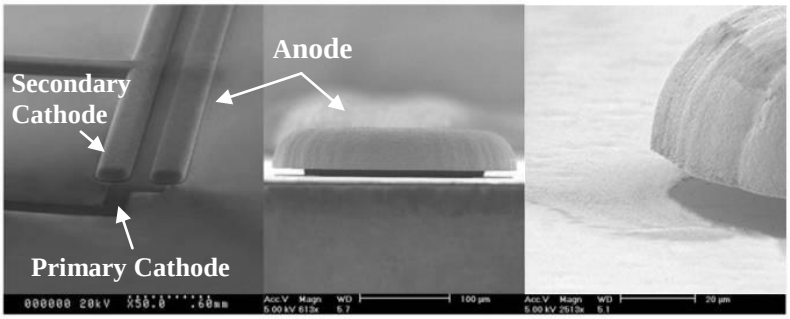

Fig. 1 SEM images of fabricated micro triode.

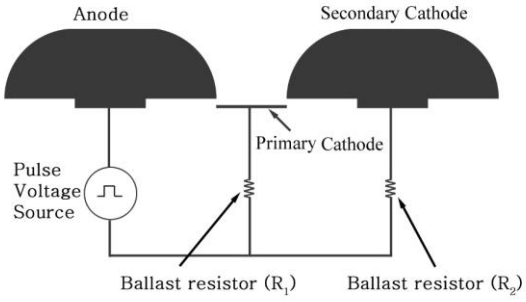

Fig. 2 Schematic of test setup for plasma generation.

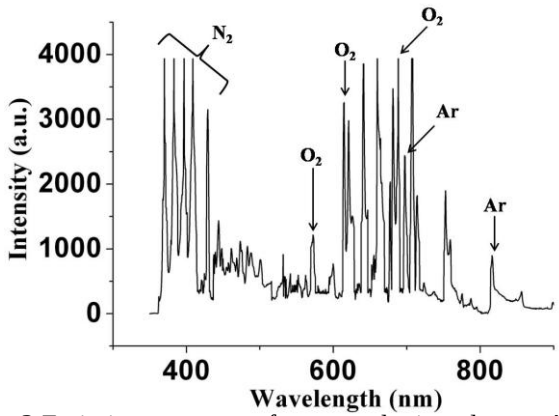

Fig. 3 Emission spectrum of generated microplasma. Argon was used as the carrier gas in ambient air for the discharge experiment.

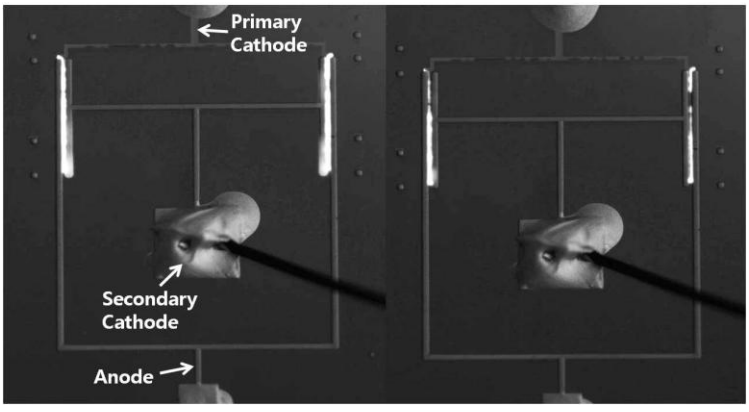

Fig. 4 Photographic images of microplasma operated in glow discharge mode at atmospheric Ar ambient. (a) rise time: 100 ns (b) rise time: 800 ns

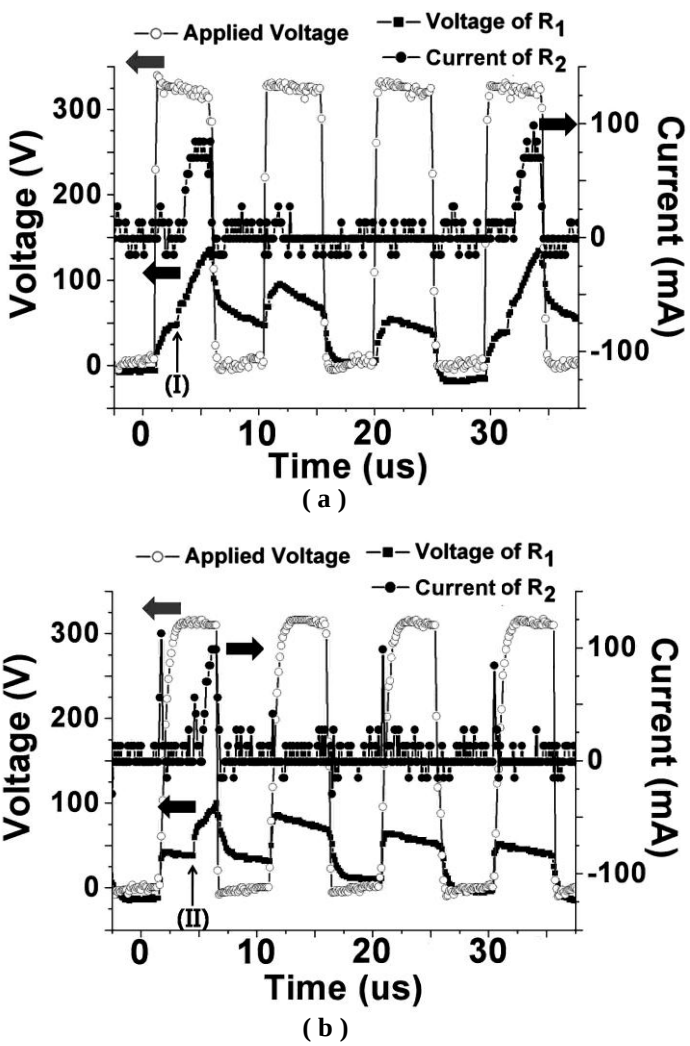

Fig. 5 I-V characteristics of micro triode operated in the glow discharge mode. Arrows point out initiation of gas breakdown, indicted by region (I) and (II). (a) rise time: 100 ns (b) rise time: 800 ns

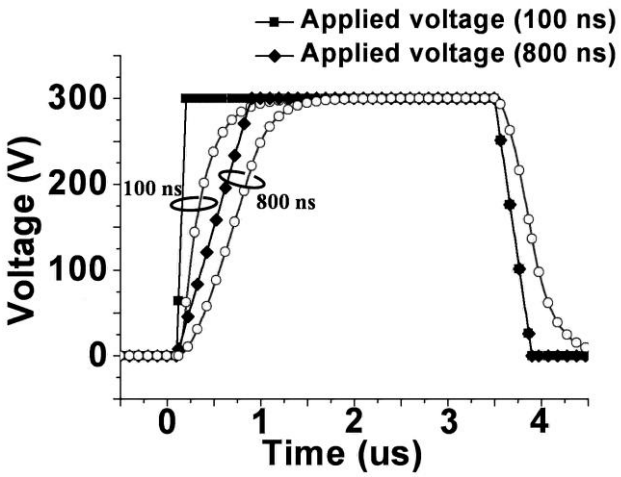

Fig. 6 Simulated voltage delay at microelectrodes prior to gas breakdown using SPICE. Open symbol: induced voltage across electrodes. Note that a RC delay of nearly 1 us between two pulses is caused by capacitance and resistance of microelectrodes.