ATMOSPHREIC PRESSURE GLOW DISCHARGE IN AIR

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Abstract

In this study, an atmospheric pressure glow discharge (APGD) in air using 50Hz power supply was experimentally investigated by means of electrical characterization. The discharge has been generated in a specially designed hemispherical–plane electrode system. The main objective of the study was to identify the conditions to generate AC glow at atmospheric pressure air using 50 Hz power supply. The mode of discharge was characterized by observing the number of current pulses per half cycle in the current waveform of the discharge for different values of applied voltage for different electrode spacing. It was found that with 3mm gap and 18.75 kV of applied voltage, the current waveforms consist of a single pulse per half cycle indicating the formation of AC glow discharge. An attempt to study the effect of dielectric on the mode of the discharge was also made by using three types of materials namely Polycarbonate, Polyethylene and Glass as barrier between the electrodes.

Keywords: Electrical discharge, APGD, Asymmetric electrode, Without dielectric, Air

1. Introduction

Dielectric barrier discharge (DBD) and APGD are well-known plasma sources for the generation of non–thermal plasma. When the local electric field strength in the gas gap reaches the ignition level, then breakdown starts at many points followed by the development of filaments. Since large numbers of such filaments are induced and randomly distributed in space and time, it results in an average uniform distribution of microdischarges over dielectric surface (Eliasson and Kogleschatz, 1991). Appearance of APGD mainly depends on the experimental conditions such as discharge gas, gas pressure, inter-electrode gap, dielectric properties of the barrier and the nature of the applied voltage (Rahel and Sherman, 2005, Gherardi and Massines, 2001, Massines et al, 1998).

As APGDs have great advantages— they do not need expensive vacuum system and possess the capability to produce agents, such as reactive species, charged particles, and UV radiation— they find widespread applications in treatment of polymers (Subedi et al, 2008), plasma coating (Hubi¡cka, 2002), cleaning and activation of substrates (Dumitrascu et al, 2002), thin film deposition (Jiang et al, 2001), water treatment (Subedi et al, 2009), sterilization, cancer cell treatment, dental treatment, surface modification of biocompatible materials (Laroussi, 2005, Fridman et al, 2007).

Various kinds of APGD sources such as the atmospheric pressure plasma jet, the dielectric barrier discharges, the atmospheric pressure plasma needle, and the cold plasma torch have been developed, and their generation has been achieved over a very wide spectrum from DC through kilohertz and megahertz to microwave, and their electrodes are either metallic or coated with a dielectric layer (Iza et al, 2008, Stoffels et al, 2003, Laroussi and Akan, 2007, Leveille and Coulombe, 2005).

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In recent years, several researchers have tried to obtain the homogeneous dielectric barrier discharge and glow discharge at atmospheric pressure using different working gases such as neon, helium, argon, nitrogen, air and their mixture with other gases. Okazaki et al (1993) studied the stabilization of homogeneous DBD at atmospheric pressure with 50 Hz power supply in air, argon, oxygen and nitrogen. Garamond and El-zeer (2009) gave remarkable result of homogeneous DBD at atmospheric pressure with 50 Hz power supply in air using barrier of porous alumina ceramic. In order to improve the stability and the working domain of homogeneous discharges, Topper et al. (2000) studied the spatial and temporal behavior. Kanazawa et al. (1998) purposed stability of homogeneous DBD in helium gas with certain gas mixture with the frequency 10-50 kHz. Trunec et al (2001) showed that atmospheric pressure glow discharge (APGD) can also be generated using high frequency 10 kHz power supply in pure neon. Luo et al (2010) also investigated homogeneous barrier discharge in nitrogen at atmospheric pressure by means of electrical measurement, fast photography and time resolved spectroscopy.

In this report, we present electrical characterization of a glow discharge produced in an especially designed parabolic-plane electrode system without the use of dielectric barrier.

2. Experimental Setup

The schematic diagram of experimental arrangement used to study the atmospheric pressure glow discharge (APGD) is shown in Fig 1.

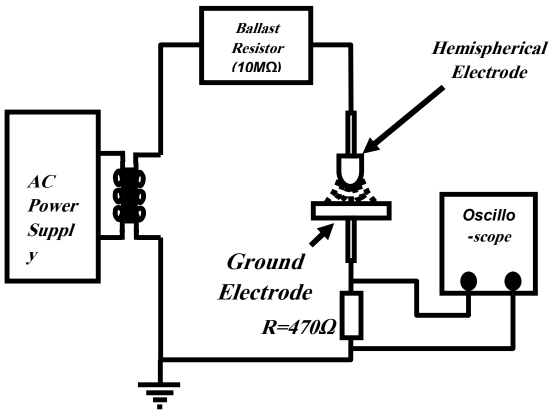
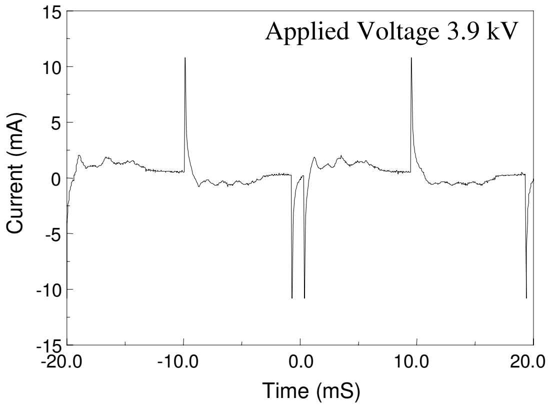


Fig.1. Schematic diagram of experimental setup

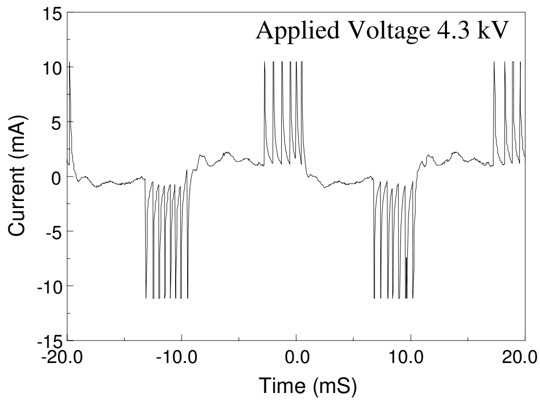
The discharge was generated between two asymmetric electrodes. The upper one is parabolic in shape with 3.15 cm diameter and 1.5 cm height. The lower electrode is circular in shape with 5.05 cm diameter and 1.02 cm thickness made of brass. A high voltage 50Hz AC power supply was connected across the electrode through a ballast resistor of resistance 10 M&! Ohm. The inter-electrode gap was varied from 1 mm to 3 mm. Electrical characterization was made with the help of a high voltage probe using Tektronix TDS2002 digital oscilloscope.

3. Result and Discussion

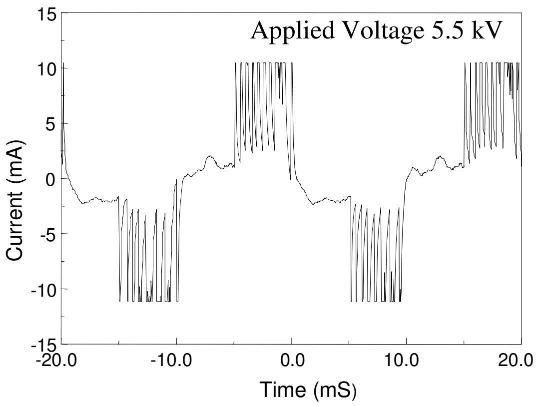
Fig 2(a-f) and Fig 3(a-f) show the current waveforms and Fig 2(g-h) and Fig 3(g-h) the images of an atmospheric pressure discharge in air without using dielectric medium between the electrodes with a high voltage (0-16kV) power supply operating at frequency 50 Hz. As shown in Fig 2(a-f), the discharge in hemispherical plane electrodes system with 1mm gap consisted of number of spikes in current waveform. Initially, these spikes were found to increase gradually and then decrease when the applied voltage was varied from 3.9kV from 8.6kV. It is evident that it is possible to count the number of current pulses per half cycle by the observation of the waveforms of the discharge. For the discharge with 2mm gap as shown in Fig 3(a-f), it is interesting to note that the spikes in the current waveform tend to fuse together resulting in a single spike in the waveform. The relation between applied voltage and number of spikes as shown in Fig 4(a-b) and Fig 4(c-d) show the typical current waveforms of APGD without dielectric and its corresponding images in air applying different voltage 6.25kV and 18.75kV at frequency 50Hz. The current waveform of the discharge in 3mm of electrode spacing exhibits only one current pulse per half cycle. The relation between applied voltage verses number of spikes is shown in Fig 5. This relation indicates that when applied voltage is gradually increased from lower voltage, the number of spikes is gradually increased and after attaining maximum value, the number of spikes is decreased. When the applied voltage was gradually decreased from higher voltage, the numbers of spikes were meagre into single waveform which is clearly shown in Fig 6. Fig 7(a-f) clearly indicate that current waveforms and the images of dielectric barrier discharge using different dielectric materials namely Glass (2.5mm), PC (2mm) and PE (0.16m) consist of several filaments per-half cycle indicating a filamentary mode of the discharge.



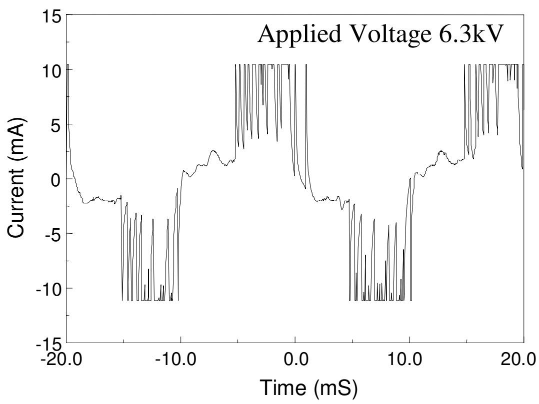
a) Current waveform of discharge with 1-2 spikes per half cycle



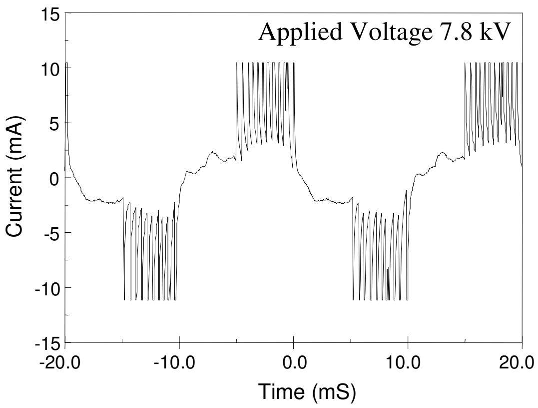
b) Current waveform of discharge with 6-7 spikes per half cycle



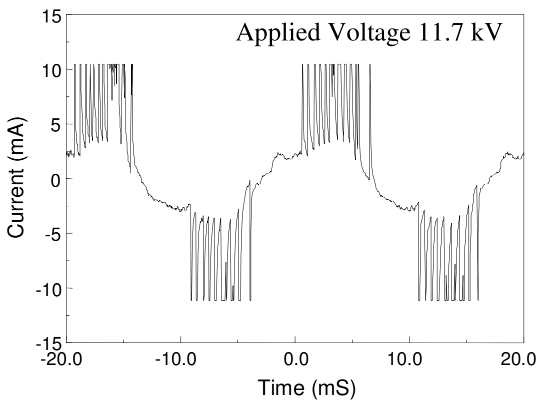
c) Current waveform of discharge with 7-8 spikes per half cycle



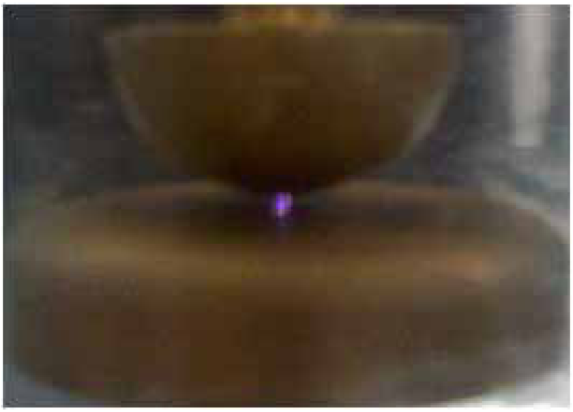
d) Current waveform of discharge with 8-9 spikes per half cycle



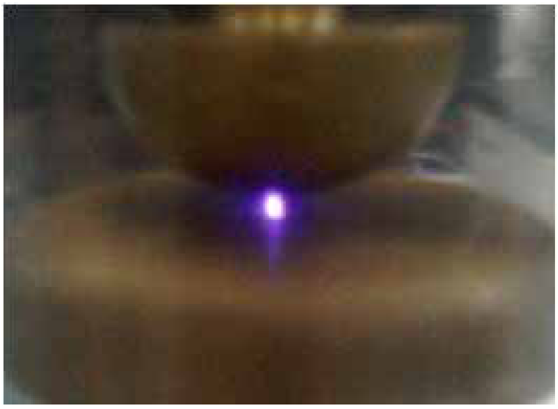
e) Current waveform of discharge with 8-9 spikes per half cycle



f) Current waveform of discharge with 9-10 spikes per half cycle

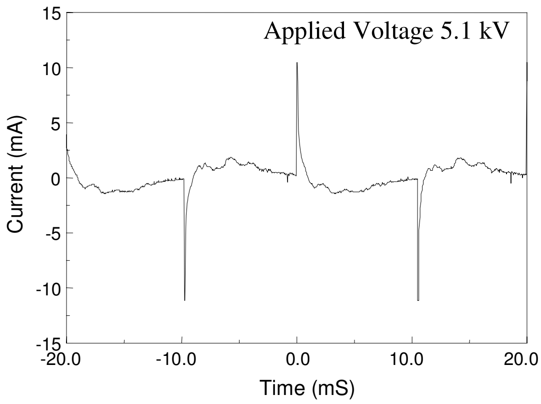


g) Image of discharge using applied voltage 3.9kV

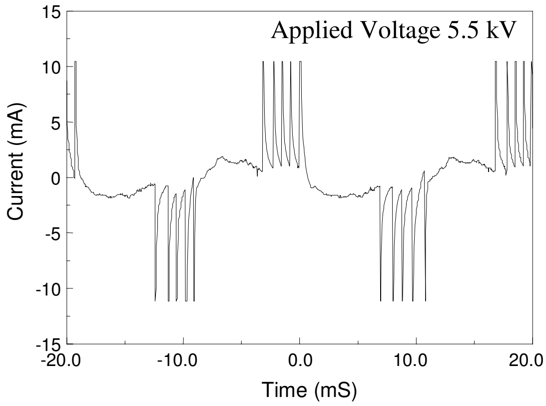


g) Image of discharge using applied voltage 3.9kV

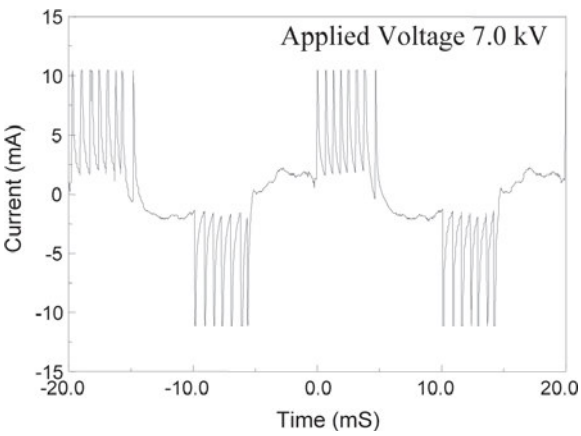
Fig.2. Current waveforms of the discharge produced at 50 Hz with 1 mm inter-electrode gap without dielectric barrier and images of discharge



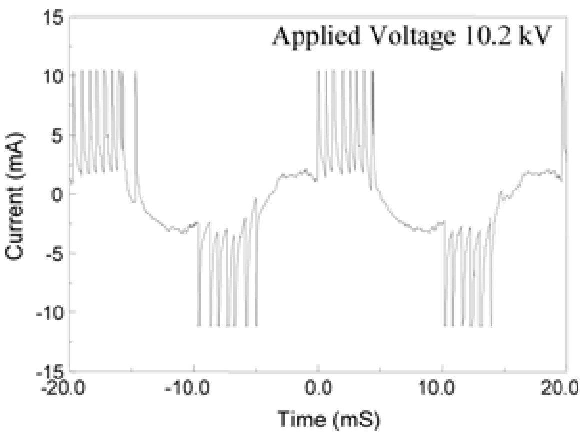
a) Current waveform of discharge with one spike per half cycle



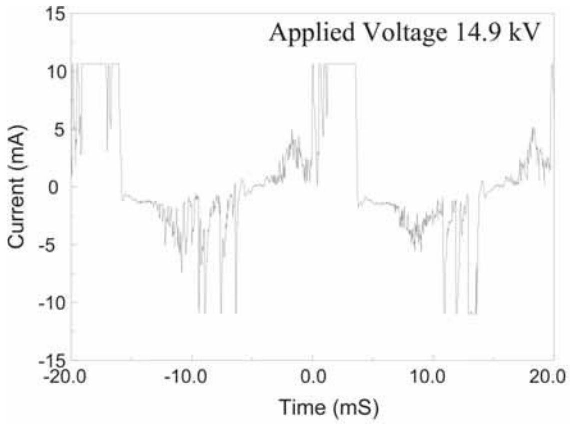
b) Current waveform of discharge with 5 spikes per half cycle



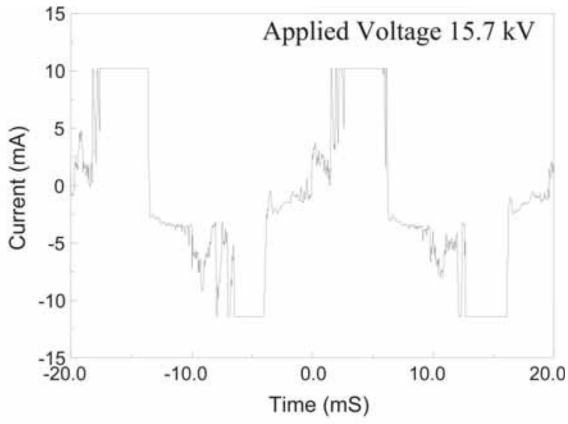
c) Current waveform of discharge with 7-8 spikes per half cycle



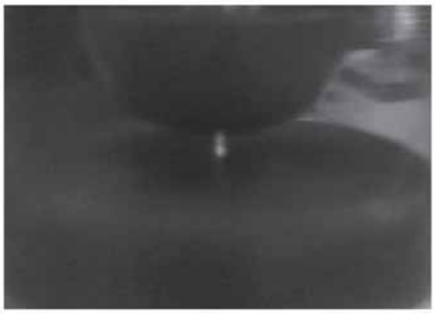
d) Current waveform of discharge with 6-7 spikes per half cycle



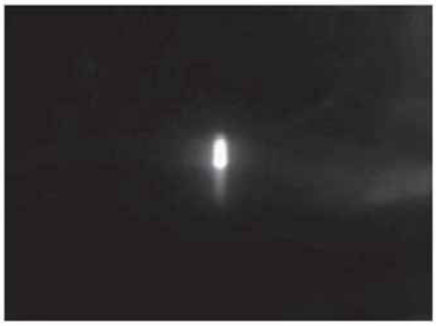
e) Current waveform of discharge with 3-4 spikes per half cycle



f) Current waveform of discharge with 2-3 spikes per half cycle

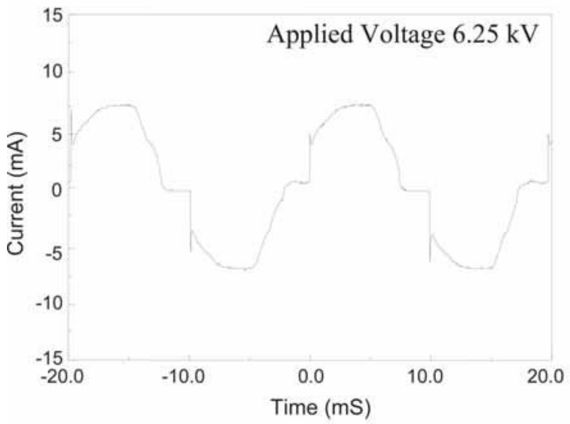


g) Image of discharge using applied voltage 5.1kV

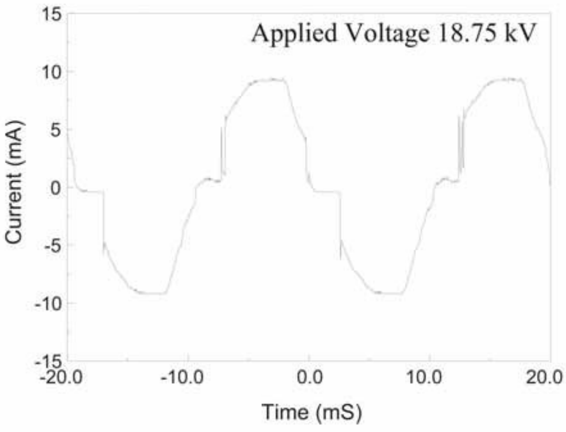


h) Image of discharge using applied voltage 15.7kV

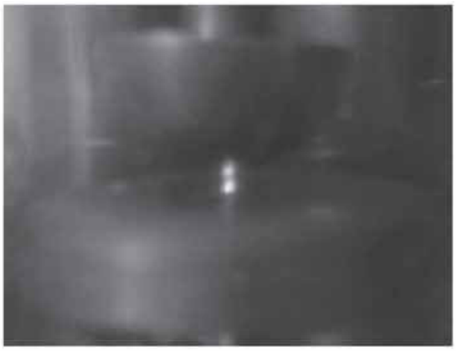
Fig.3. Current waveforms of the discharge produced at 50 Hz with 2mm inter-electrode gap without dielectric barrier and images of discharge



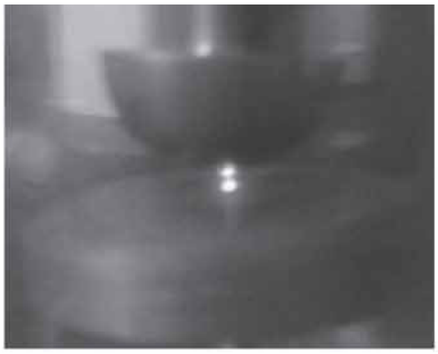
a) Current waveform of APGD with one spike per half cycle



b) Current waveform of APGD with one spike per half cycle



c) Image of APGD using applied voltage 6.25kV



d) Image of APGD using applied voltage 18.75kV

Fig.4. Current waveforms of the APGD produced at 50 Hz with 3 mm inter-electrode gap without dielectric barrier and the images of APGD

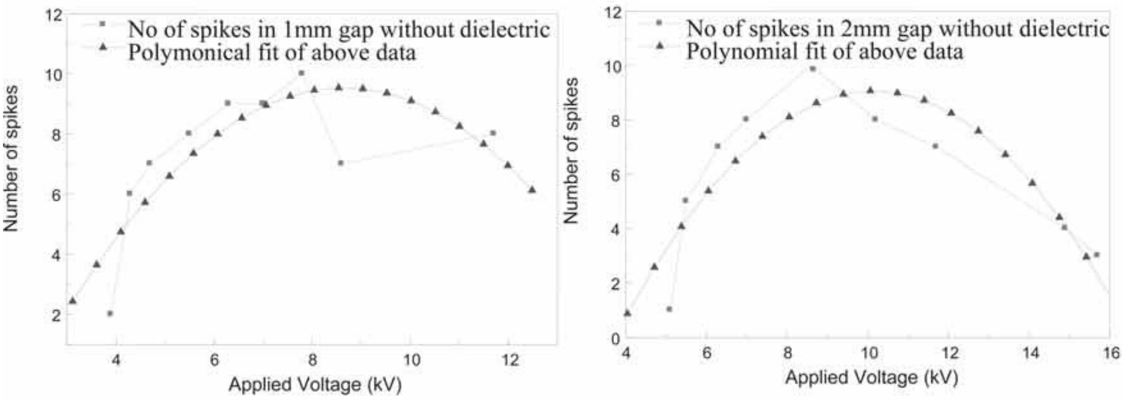


Fig.5. The relation between applied voltage and number of filaments or spikes.

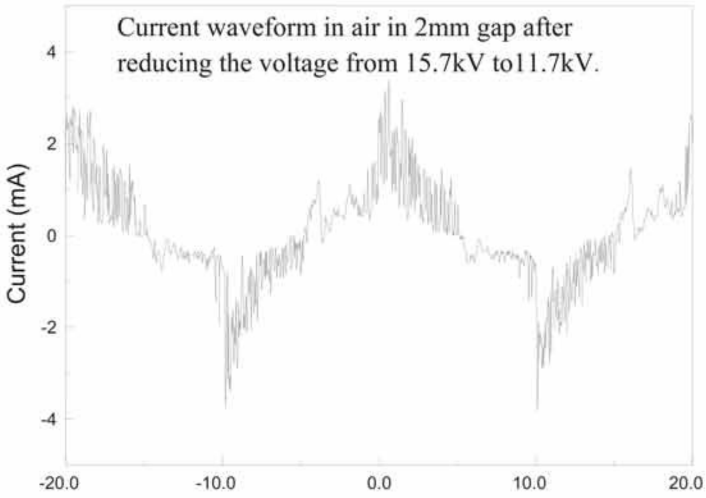
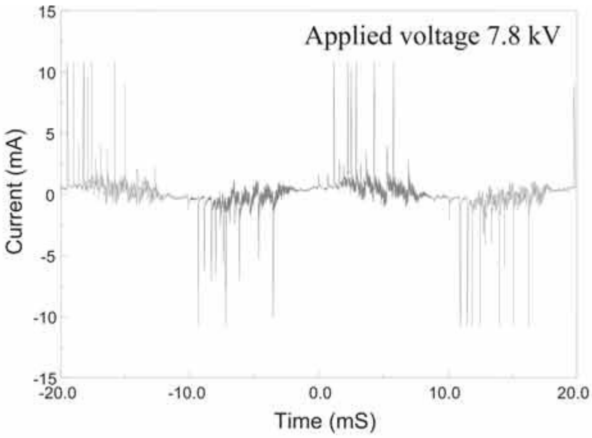
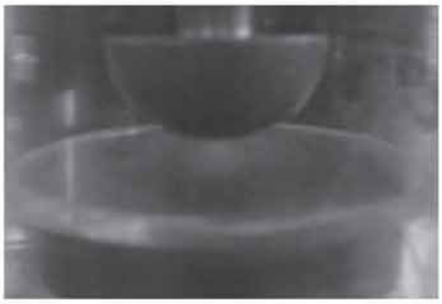


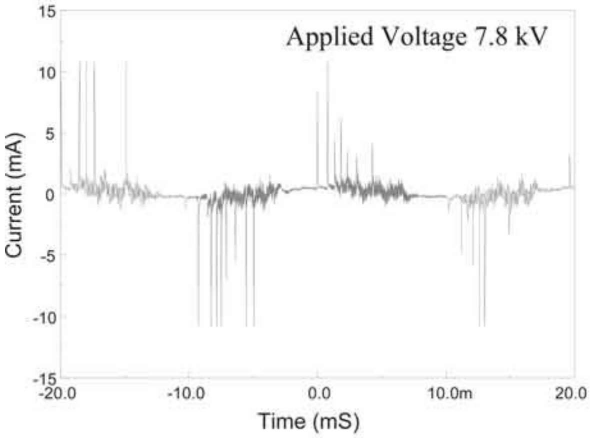
Fig.6. Current Waveform of discharge in air without dielectric after decreasing the applied voltage.



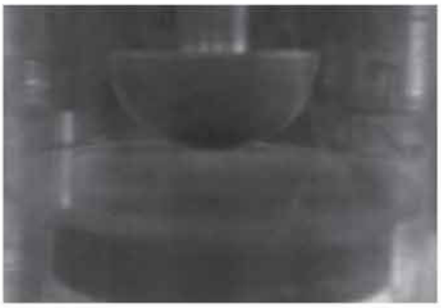
a) Current waveform of DBD in air with dielectric of Glass (2.5mm) in 2mm gap



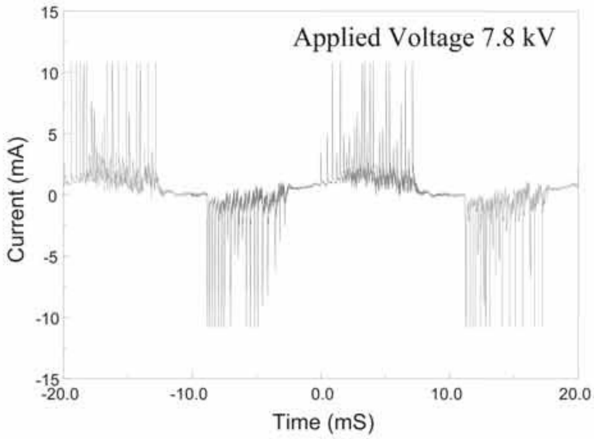
b) The image of DBD in air with dielectric of Glass (2.5mm) in 2mm gap using applied voltage 7.8kV



c) Current waveform of DBD in air with dielectric of Polycarbonate (2mm) in 2mm gap



d) The image of DBD in air with dielectric of Polycarbonate (2mm) in 2mm gap using applied voltage 7.8kV



e) Current waveform of DBD in air with dielectric of Polyethylene (0.16mm) in 2mm gap

f) The image of DBD in air with dielectric of Polyethylene (0.16mm) in 2mm gap using applied voltage 7.8kV

Fig.7. Current Waveforms and images of discharge in air with different dielectric in 2 mm gap using applied voltage 7.8 kV

4. Conclusion

A filamentary mode of discharge in 1-2mm gap could be generated in air with 50Hz power supply even without using dielectric medium. Atmospheric pressure glow discharge in air could be generated using 50Hz power supply without dielectric barrier for specific gap of 3mm. Number of peaks obtained in discharge current depends on applied voltage and electrode gap. The effect of dielectric material on the quality of discharge could be detected by electrical signal. Electrical signals could be helpful in understanding the transition of filamentary mode of the discharge into glow mode.

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