Trapped gas-induced effects under pulsed DBD dynamics

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Experimental study is made on the effects induced by trapped gas in the pulsed dielectric barrier discharge (DBD) operating in helium gaseous atmosphere, in symmetrical electrode configuration. Using electrical measurements, emission spectroscopy and fast photography techniques, the differences in the discharge dynamics between the stationary and the flowing helium are investigated. The paper focuses on the space-time distribution of the representatives' excited species. The experimental results demonstrate that the discharge is initiated at the anode for DBD working in flowing gas atmoshere (FGA). On the contrary, the breakdown of DBD working in trapped gas atmosphere (TGA) starts simultaneosly at both electrodes.

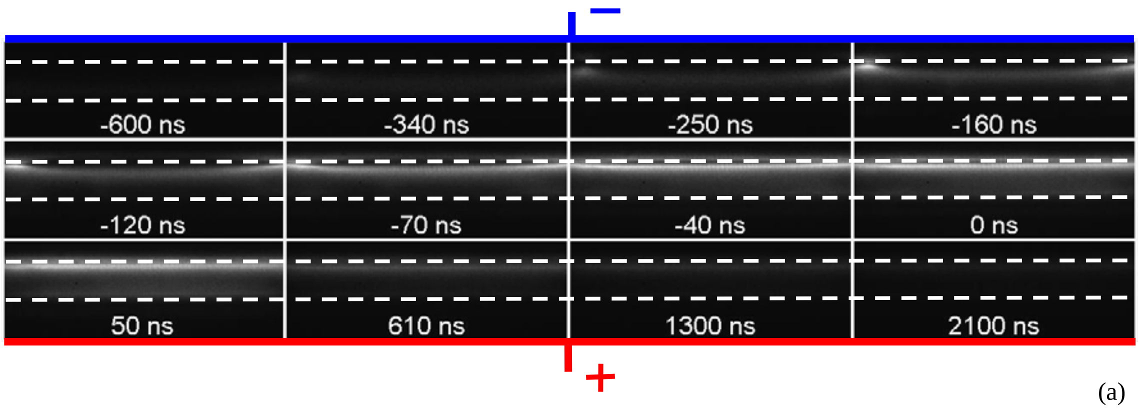
The study of the discharge produced in trapped and stationary gas at atmospheric pressure became rapidly an interesting subject due to potential applications of the plasma generated inside of a closed package asked by some practical use as, e.g., disinfection of wrapped medical instruments [1], surface modifications of closed plastic bags for adherent cell cultivation [2] or micro-organisms inactivation in order to extend food product shelf-life [3]. Based on the electrical parametes and diagnostic techniques as emission spectroscopy and fast photography, the differences in the discharge dynamics between the stationary and the flowing helium are pointed out in the present paper.

The experimental set-up consists of a dielectric barrier discharge (DBD) cell using two glass plates as barriers, each of 1 mm in thickness. The inter dielectric gap was kept constant at 3 mm. Monopolar voltage pulses with 50 μs pulse width, 2 kHz repetition frequency and 3 kV pulse amplitude were used to excite the discharge. All experiments were performed in He (99.996% purity and 3000 sccm flow rate) at atmospheric pressure, without outgases by vacuum pumping. Under our experimental conditions, the energy transfered to the discharge system during one pulse was (0.35±0.03) mJ. The DBD cell was equipped with a gas inlet and outlet controlled by valves in order to investigate the discharges operating in trapped or flowing gas atmosphere in the same set-up. Due to experimental conditions, the DBD system presents a secondary discharge [4], which corresponds to the negative current pulse besides the primary discharge (which corresponds to the positive current pulse). The results reported here are obtained during the primary discharge only.

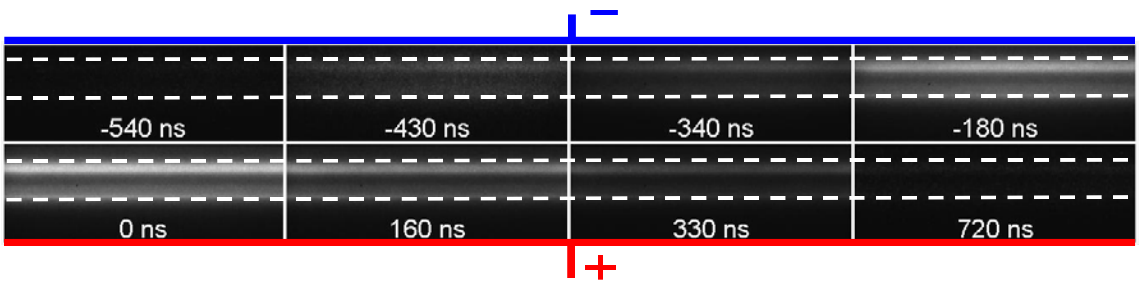
The electrical measurements emphasize important differences in the number and the amplitude of the current peaks, coresponding to each voltage pulse, between discharges operating in trapped and flowing gas atmosphere. Moreover, emission spectroscopy reveals a different mechanism in production of excited species by the discharge operating in flowing gas atmosphere (FGA) and trapped gas atmosphere (TGA) modes.

A fast camera technique combined with bandpass filters is used in order to get time-space distribution of some excited species of DBD plasma produced in a symmetrical configuration, working in two distinct modes of operation (FGA and TGA). Using an intensified charge coupled detector (ICCD) camera (Hamamatsu, model C9546-03), temporal behavior of the DBD system was studied by synchronizing the camera gate (10 -50 ns) with the applied voltage pulse. An adjustable delay was used in order to follow the temporal evolution of the discharge current pulse, which was of the order of microseconds. Using appropriate bandpass filters with different central wavelengths, the spatio-temporally evolution of He (706.5 nm and 728.1 nm), N_2 (337.1 nm), N_2^+ (391.4 nm) and O (777 nm) lines and bands in the discharge gap were studied. Note that all the reactive species (oxygen, nitrogen, hydroxyl molecular system, etc.) are originated from residual working gas and outgas of the DBD housing system, as well as desorbed from dielectric barriers surfaces.

The experimental results show that under FGA mode, the discharge is initiated close to the dielectric layer covered anode, where a small bright region appears. Then this region increases in luminosity and propagates towards the temporary cathode where it arrives around the maximum of the discharge current (Fig.1. (a)). On the other hand, experimental data emphasize that, for a discharge gap filled with stationary helium, the breakdown starts simultaneoslly at both glass barrier covered electrodes, as shown in Fig.1. (b). Concluding, it was shown experimentally that the trapped gas has a notable impact on the DBD dynamic compared with the influence of the flowing gas atmosphere.



(a)



(b)

Fig. 1: The integral light emission from He-DBD working in FGA mode (a) and TGA mode (b) at different time moments (the first picture of each graph coresponds to the beginning of the breakdown and t=0 ns coresponds to the maximum of the current pulse). The upper electrode is the grounded electrode (temporary cathode, during the primary discharge); the bottom electrode is the HV electrode (instantaneous anode, during the primary discharge). The glass barrier (dashed lines) covered both electrodes.

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References

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