Temporal evolution of the $N_2(C^3\Pi_u)$ vibrational levels produced by single surface streamer in N_2-O_2 mixtures

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ICCD spectrometry with time resolution of 2 ns was used to study temporal evolution of the $N_2(C^3\Pi_u)$ vibronic leves produced by single surface DBD streamer in N_2-O_2 mixtures. Streamers were periodically produced in coplanar surface DBD electrode geometry by amplitude-modulated AC high-voltage waveforms with superimposed HV pulse. Emissions of the N_2 second positive and N_2^+ first negative systems were registered during the first 200 nanoseconds after the streamer ignition. Experimental observations may be reproduced fairly well by a simplified 0-D kinetic model considering direct electro impact-excitation from the ground electronic state, collisional quenching of radiative states and, in the case of pure nitrogen, excitation due to $N_2(A^3\Sigma_u^+)$+$N_2(A^3\Sigma_u^+)$ energy pooling.

Optical emission of a propagating streamer taken at sufficiently high spatial, time and spectral resolutions can provide important information on the morphology and propagation velocity of the streamer head, local electrical field, and radial distributions of excited species within the streamer channel. Suitable conditions for streamer formation can be obtained by applying DC, AC or pulsed power in various electrode configurations. Relatively simple filamentary streamer generator utilizing relatively low (<30 kV) AC high-voltage (HV) is a surface dielectric barrier discharge (SDBD). One of the basic SDBD configurations, so called coplanar SDBD (CSDBD) geometry is based on metallic electrodes embedded in dielectric material. In this work, we used a fast ICCD detector to acquire emission of a single streamer micro-discharge developing and propagating along the dielectric surface in the CSDBD electrode arrangement for pressure range 50-760 Torr.

As shown in figure 1, the discharge was produced in the coplanar surface DBD electrode geometry on the surface of a disc made from MACOR® machinable glass-ceramic sealed in a polyamide holder.

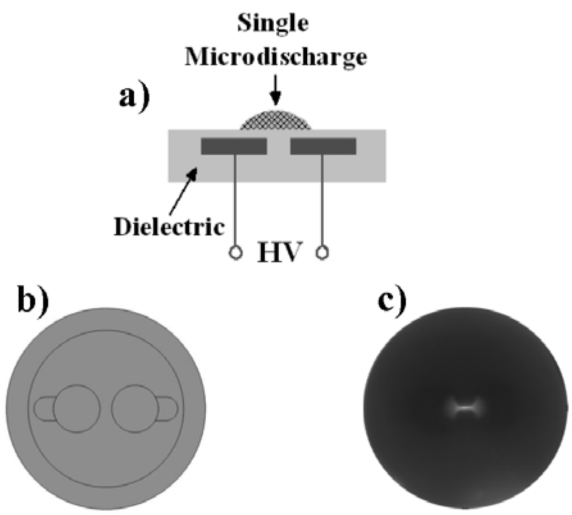

Fig. 1: Single streamer micro-discharge experiment a) sketch of the coplanar surface DBD configuration , b) drawing of the the electrode geometry and c) photograph of AC CSDBD micro-discharge generated in atmospheric-pressure nitrogen.

The micro-discharges were repetitevely initiated by the high-voltage waveform imposed between two silver electrodes embedded approximately 0.4 mm below the disc's surface with a minimum distance of 1 mm between them [1-2]. High-voltage waveforms used in this study were applied with the repetition frequency of 10 Hz and they were composed of a single sine-wave (f_{AC} = 1kHz) superimposed with ~ 100 ns positive pulse during the positive half-cycle. The discharge was fed either with pure nitrogen or with $N_2 + O_2$ mixture (up to N_2:O_2 = 4:1) with a fixed total flow of 1 slm.

The streamer induced was collected perpendicularly to the discharge surface by the quartz optical fibre bundle through the pair of iris diaphragms and pair of quartz lenses. The output of the fibre bundle was coupled to the iHR-320 (Jobin-Yvon) imaging spectrometer equipped with the DH740i-18U-03 iStar ICCD camera (Andor). Emission was registered with time-resolution defined by the ICCD gate (2 ns), which was synchronized and delayed with respect to the rising edge of the positive high-voltage pulse and the acquisition was made by accumulating 5×10^3 samples for a given delay. With a suitable phase shift imposed between the sine-wave and positive pulse, the streamer ignition was triggered by a positive pulse with a quite small jitter (<2 ns).

Emissions of the three pricipal electronic systems can be observed during the streamer initiation, namely $N_2^+(B^2\Sigma_u^+ \rightarrow X^2\Sigma_g^+)$ first negative (1.NG), $N_2(C^3\Pi_u \rightarrow B^3\Pi_g)$ second positive (2.PG) and $N_2(B^3\Pi_g \rightarrow A^3\Sigma_u^+)$ first positive (1.PG) systems. In this contrubution we focus on 375-415 nm spectral range providing detailed analysis of the $N_2(C^3\Pi_u)$ state vibrational distribution evolution at various oxygen content in the N_2-O_2 mixture as shown in figure 2. Experimental observations may be reproduced fairly well by a simplified 0-D kinetic model considering direct electro impact-excitation from the ground electronic state and collisional quenching of radiative states. In the case of pure nitrogen, an enhancement of vibrational excitation (delay > 60 ns) is due to the $N_2(A^3\Sigma_u^+)$+$N_2(A^3\Sigma_u^+)$ energy pooling.

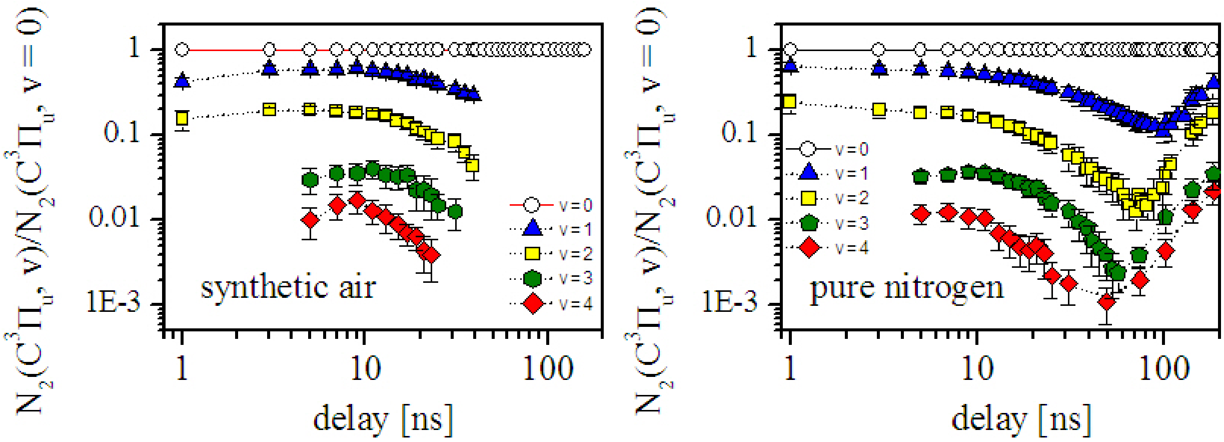

Fig. 2: Evolution of the the $N_2(C^3\Pi_u$, v=0-4) state vibrational distributions in synthetic air and in pure nitrogen at 50 torr.

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References

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