



# Fast Imaging of the Atmospheric

## Pressure Glow Discharge

## Application Note

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### Introduction

The rare diffuse low current and high current varieties of the atmospheric pressure dielectric barrier discharge (DBD) referred to atmospheric pressure Townsend discharge (APTD) and atmospheric pressure glow discharge (APGD), are advantageous for a cost effective thin film deposition on various substrates and attract nowadays an increasing scientific and industrial interest. In the standard DBD system the discharge is ignited by applying a variable voltage between two metal electrodes, one or both of them being covered by a solid dielectric layer. The purpose of the dielectric layer is to limit conduction current, avoiding transition to the arc. While a non-uniform filamentary discharges being common at atmospheric pressure, the processes and conditions leading to the appearance of diffuse plasma are still under scientific investigation. Since the DBD is a highly transient phenomenon with current pulse duration being less than 1 microsecond (in this study), fast imaging becomes a valuable plasma diagnostics tool.

### Experimental Set-up

In the present work images (taken with ICCD detector iStar DH734-18U-03 from Andor Technology) of the atmospheric pressure barrier discharge were recorded for the conditions very close to practical applications of the silica-like thin film deposition. A schematic draft of the experimental setup and visual appearance of the discharge are shown in Fig. 1 (a,b).

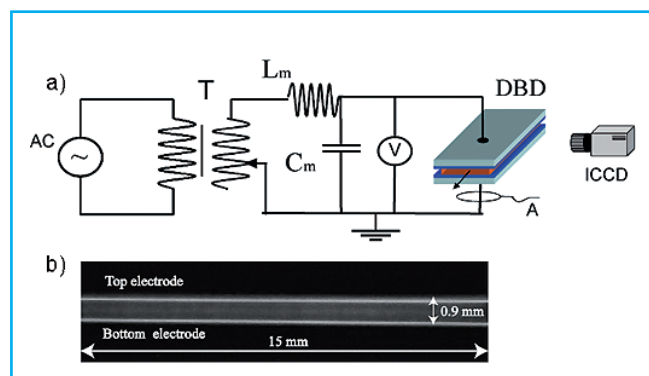


Figure 1.

- a) Scheme of the experimental setup. DBD and ICCD are the dielectric barrier discharge cell and ICCD camera. Arrow shows direction of gas flow. T, L<sub>m</sub> and C<sub>m</sub> are indicating step transformer, inductive and capacitive matching elements respectively. V and A denote positions of the voltage and current probes.
- b) Typical appearance of the diffuse atmospheric pressure DBD recorded at 10 ms exposure time.

A polyethylene-2,6 naphthalate foil (100 μm thick) served the purpose as dielectric barrier on both metal electrodes. The gaseous discharge gap is 0.9 mm. The discharge area was 40 x 15 mm<sup>2</sup>. The gas flow rate of the mixture 1 (Ar:N<sub>2</sub>:O<sub>2</sub>+HMDSO/80:20:2+50 ppm) and mixture 2 (Ar:N<sub>2</sub>:O<sub>2</sub>/80:20:2) is 0.5 slm. The discharge is powered by an AC generator with a voltage amplitude of 1.5-2 kV at 100 kHz. The maximum current density is up to 100 mA/cm<sup>2</sup>. The brightness scale of the presented ICCD pictures was independently normalized to show all the stages of the discharge development in one plot, while it should be considered that the glow mode is significantly brighter compared to the Townsend-like discharge.

### Results

In the carried out experiments different pathways of the atmospheric glow formation and evolution are observed. The "diffuse" temporal development is illustrated in Fig. 2a when first a Townsend discharge appears occupying the whole electrode surface with light emission coming from the region next to the instantaneous anode. The Townsend discharge brightness increases with time. At a certain moment at one or several places a transition to glow discharge occurs. The glow forms a diffuse localized current spot or spots with a pronounced bright sheath (negative glow) close to the instantaneous cathode, Faraday dark space and bulk regions.

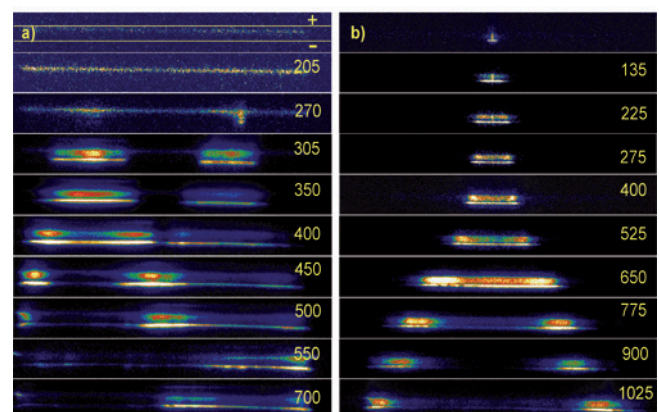


Figure 2 Time evolution of the atmospheric barrier discharge recorded by ICCD camera at 5 ns gate time. The discharge gap and electrode width are 0.9 mm and 4 cm, respectively. The frame delay time (ns scale) is also reported.

- (a) Gas mixture 1. The discharge starts from the uniform Townsend-like mode and develops toward the expanding glow via a positive streamer.
- (b) Gas mixture 2. The discharge starts as a single filament and transits to the expanding glow.



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The current spot induces a horizontal ionization wave, which expands over the electrode surfaces while the discharge extinguishes at the position of the initial glow appearance. While the glow current spot was not occupying the whole electrode surface momentarily, time integrated images of the discharge are pointing out a uniform distribution of light emission over the discharge area.

The lateral expanding behavior of the glow can be explained by the following considerations. After the arrival of the positive streamer front to the cathode region, a surface charge is quickly deposited on the dielectric, strongly reducing locally the electric field. The resulting field becomes too low to support the ionization and the plasma starts to recombine. However, the transverse electric field is still high at the radial periphery of the initial current spot, providing a development of the "retarded" transverse ionization wave which results in the lateral expansion of the glow observed in experiment.

A remarkable behavior, observed to our knowledge for the first time, is shown in Fig.2b when the diffuse atmospheric glow is initiated from a single contracted filament. In our experiments we also observed the ignition of the glow discharge from multiple filaments.

More details on the described subject can be found in the references [1,2]

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### References

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- [2] S A Starostin, P Antony Premkumar, M Creatore, E M van Veldhuizen, H de Vries, R M J Paffen and M C M van de Sanden, Plasma Sources Sci. Technol. 18, 045021 (2009).

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