

Controlling the atmospheric glow stability

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Generation mechanism of the atmospheric glow in a DBD configuration

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In this paper a discussion of the generation and stability mechanisms of the atmospheric glow plasma is presented. It is concluded that the generation of the stable atmospheric glow is unlikely to be related to a pre-breakdown preionization mechanism. The key issue that must be overcome is the prevention of the glow to arc transition.

1. Introduction

The physics of the atmospheric glow remain poorly understood and efficient industrial reactors are yet to be developed. Conventional wisdom attributes the generation of atmospheric glow plasma to suppression of streamer formation via gas preionization which in his turn is related, thermal desorption of trapped electrons from the dielectric surface [1], Penning ionization, or metastable-surface collisions [2,3]. Therefore, in relation to this important aspect of plasma generation, our work has been focused on investigating the validity of the preionization hypothesis.

As we will argue in this paper, from our experimental data it appears that not the preionization is the key issues for stable atmospheric glow generation but instead the large value of the cathode secondary ionization.

2. Experimental

The experiments described were performed in Ar, N₂, He and air in a standard dielectric barrier discharge configuration (gap distance 0.3-5 mm, $U = 0.3-8$ kV, sinusoidal pulse shape, $f = 0.1-300$ kHz). In most of the experiments PEN or PET foils 100-200 μm thick were used as dielectric. In order to study the metastable quenching effect beside the standard sine waveform we used also a sequence of sinusoidal pulses with a delay between them. Due to the capacitive coupling the current measured by the current probe consist of a plasma current component plus a displacement current component. The precision subtraction of the displacement current component is essential for the identification of the eventual afterglow tail that is a fingerprint of a strong preionization. We did this by measuring the displacement current through a capacitor in parallel with the plasma reactor and subtracted it subsequently from the total current. The light

intensity spatial distribution was monitored using a DALSA Eclipse fast CCD camera (integration time 13 μs).

3. Preionization level estimation

In the papers of Massines et al. [2,3] the presence of a long afterglow tail of the current pulse was given as possible proof for the preionization hypothesis. However, in our experiments we found no afterglow tail in the current. This disagreement may be related to the numerical procedures used by Massines et al. for subtracting the displacement current. Apart from the question marks related to displacement current subtraction no long afterglow tail in the total light emission was observed in ours in the experiments performed by Massines et al. Thus certainly is either no afterglow current tail at all or the current tail observed in [2,3] can be related to ions that can not generate light but due to their mass are residing for a longer time in the interelectrode space.

For a more precise estimation of the pre-ionization level we measured the statistical fluctuation of the breakdown development time, defined as the time required for the breakdown development after applying the breakdown voltage. For generating the breakdown one must have produce at least one electrode in the interelectrode space during the time interval when the applied sine voltage is larger than the breakdown voltage. Thus the breakdown development time is inversely proportional with the amplitude of preionization current. Depending on the gas type and the frequency we found that the pre-ionization level is in the range of $10^{-3}-10^{-5}$ nA/cm² which is at least six order of magnitude smaller than the level of $1\mu\text{A}/\text{cm}^2$ required by the streamer formation suppression theory. Also it is clear that such small preionization level cannot sustain any detectable current pulse afterglow tail. The negligible pre-breakdown preionization of the atmospheric plasmas put in serious doubt if the pre-

ionization is indeed required for the atmospheric glow generation.

3. Do we need pre-ionization ?

An experiment demonstrating that glow generation at atmospheric pressure using specific dielectric surfaces is possible in the absence of pre-ionization is shown in Figs. 1. In Fig. 1a it is shown that the light intensity distribution in the reactor during the first three pulses is very uniform and does not have peaks of random intensity and position which are the fingerprint of a filamentary plasma. Also the current waveforms (Fig. 1b) do not reveal the random multi-pulse fingerprint, which is characteristic for a filamentary discharge.

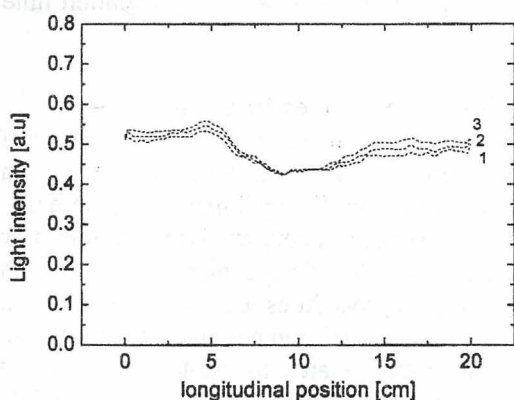


Figure 1a

Light intensity distribution during first three pulses. Fast camera images, integration time 13 μ s, Ar APG, $d=1$ mm, $f=11.8$ kHz, dielectric PEN

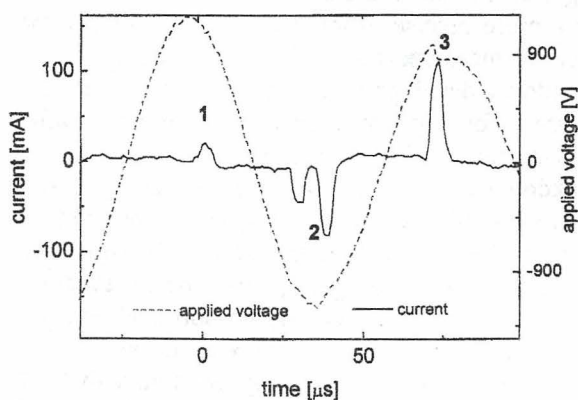


Figure 1b.

Current-voltage waveforms during first pulses in an Ar APG $d=1$ mm, $f=11.8$ kHz, dielectric PEN

One must keep in mind that the pre-ionization was introduced to suppress streamer formation by decreasing the space charge at the breakdown. The

streamer breakdown occurs when the charge density in the avalanche is so high that near the avalanche tip the electric field reaches the breakdown value. In such a case about 10^8 electrons are generated in the avalanches. Strikingly most of the atmospheric glow plasmas reported in the literature are ignited at electric fields and gaps much lower than those required for streamer breakdown. In our system for these electric fields and interelectrode gap distances, instead of 10^8 electrons in the avalanche we have only 5-20 electrons in an avalanche. In other words there is simple no problem of a huge space charge so there is no need for preionization. The low value of space charge allows avoiding the streamer breakdown and reflects an abnormally low breakdown voltage and a high cathode secondary ionization. A value of secondary ionization coefficient γ around 0.1 can be readily obtained for a typical atmospheric glow plasma which is two orders of magnitude larger than typical values for other types of cold atmospheric plasmas like corona's and silent discharges. To our opinion this is related to an enhancement of the secondary emission due to the field emission effects at the dielectric surface. The field emission is favored on a dielectric material by the local charge concentration due to low mobility. However field emission is conditioned by the existence of hot spots of low work function. Thus a strong dependence on a nature of cathode material can be expected. Indeed we observed that the glow generation is possible only with few dielectric surfaces [4].

4. Conclusions

In this paper it is demonstrated that the pre-ionization level in atmospheric glow plasma is negligible and that the atmospheric glow generation cannot be attributed to a pre-ionization mechanism. The experimental data suggests that the surface of the dielectric plays a major role in glow generation. The surface effect is probably due to a high secondary emission at the surface.

5. References

- [1] Yu.B. Golubovskii, V.A. Maiorov, J. Behnke, J.F. Behnke, J. Phys. D: Appl. Phys. **35**, 751(2002)
- [2] N. Gherardi, G. Gouda, E. Gat, A. Ricard, F. Massines, Plasma Sources Sci. Technol. **9**, 340 (2000).
- [3] F. Massines, A. Rabehi, P. Decomps, R. Ben Gadri, P. Segur, J.Appl.Phys, **83**, 2950 (1998)
- [4] H.de Vries, F.Mori, E.Aldea, M.C.M van de Sanden, US Patent 20040007985 (EP 1383359)