Topic number

MODELLING, SIMULATION AND DIAGNOSTICS, 5) & 6)
Invited General Lecture

VUV Radiation from Streamers

A. Neuber[1], A. Fierro[2], J. Stephens[3]

[1] ECE Dept., Ctr. for Pulsed Power & Power Electronics, Texas Tech University, Lubbock, TX, USA
[2] Applied Optical and Plasma Sciences, Sandia National Laboratories, Albuquerque, NM, USA
[3] Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA, USA

The self-produced light emission from pulsed streamer discharges is challenging to characterize through experiment or modeling; on the one hand, the high absorption cross sections make VUV detection often impossible, on the other hand, the large number of radiating species clashes with computer memory limitations. Two principal methods of efficiently detecting VUV radiation from streamers in atmospheric gases, including air, are introduced. These methods cover the wavelength range from 80 to 180 nm. The experimental results are supplemented with modeling the increase in charge carrier density and VUV intensity through implementing a parallel computing Particle-in-Cell /Monte Carlo Collision model, which is capable of discretely tracking photons and their corresponding wavelengths. Radiative transitions from the $c'_4\Sigma^+_u$ (Carroll–Yoshino) singlet state of N_2 are found to be a dominant contributor for streamer propagation in air.

1. Background

It is generally accepted that photoionization, PI, and photoemission play a critical role during discharge inception. Their impact, however, has typically been lumped in the simplest case into a single feedback constant or more sophisticated into some actual spectral modeling. While the former is more of an empirical attempt that is unable to cover a large parameter space, the latter has suffered from the lack of fundamental transition data. This work addresses both: Verification of major transitions in the VUV in gases at atmospheric pressure, including air, and advanced photon modeling [1, 2] in a first principle based approach.

2. Experimental Approach

To reasonably extract VUV radiation from a developing streamer, the propagation distance through the surrounding gas (at ~ 1 atm pressure) has to be kept in the sub-mm range considering that the absorption depth is typically in the mm range. Thus, two methods were successfully explored, a) streamer breakdown across a VUV transmitting surface, which yielded experimental spectra down to 120 nm, and b) pulsed volume breakdown in a high-pressure gas puff, spectral range down to 80 nm.

3. Results

As an example, the theoretical spectra of N I and O I, calculated assuming a Boltzmann distribution of the excited states are compared with the experimentally recorded VUV emission of air breakdown in the streamer phase, see Fig. 1. Other experiments identify PI critical emission as the N_2 $c'_4\Sigma_u^+(0)$– $X^1\Sigma_g^+(1)$ band and O I and O II transitions. The experimentally verified transitions gave rise to the PI driven streamer modeling, see Fig. 2.

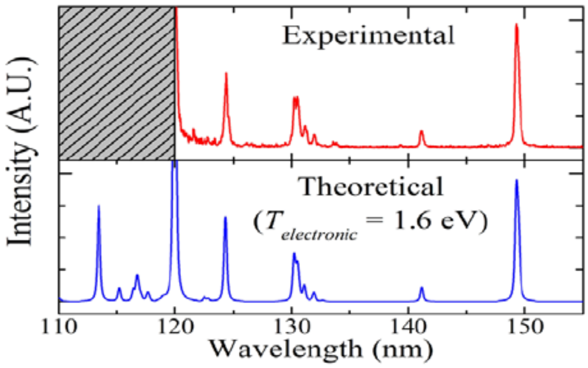

Fig. 1. (top) Experimental VUV spectra of the developing breakdown. (bottom) Theoretical spectra [3]

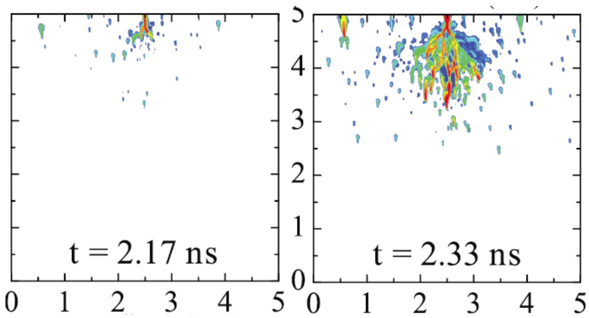

Fig. 2. 2D Streamer modeling with a 2 ns risetime, 60 kV voltage excitation applied to the top plane. Gaussian seed density near anode (top), no other background [2].

4. References

[1] A. Fierro, J. Stephens, S. Beeson, J. Dickens, and A. Neuber, Phys. Plasmas, **23** (2016) 013506.

[2] J. Stephens, A. Fierro, S. Beeson, G. Laity, D. Trienekens, R.P. Joshi, J. Dickens, A. Neuber, Plasma Sources Sci. Technol. **25** (2016) 025024.

[3] A. Fierro, G. Laity, A. Neuber, J. Phys. D: Appl. Phys. **45** (2012) 495202.