Nanosecond pulsed discharges in N2 and N2/H2O mixtures

14th Workshop on the Exploration of Low Temperature Plasma Physics, December 1-2, 2011

Technische Universiteit Eindhoven University of Technology

Nanosecond pulsed discharges in N_2 and N_2/H_2O mixtures

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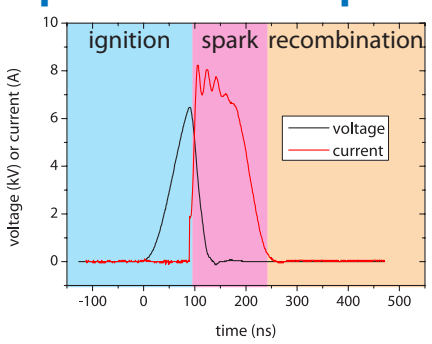
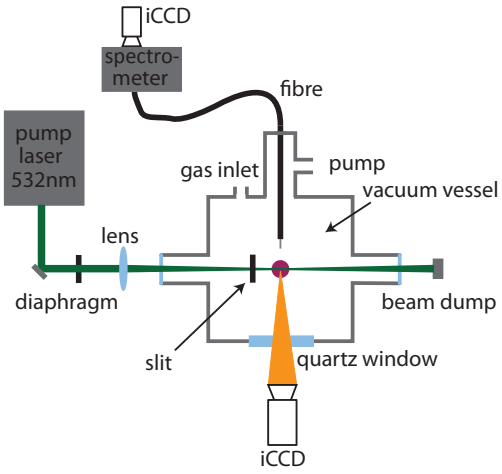
EPG Elementary Processes in Gas discharges

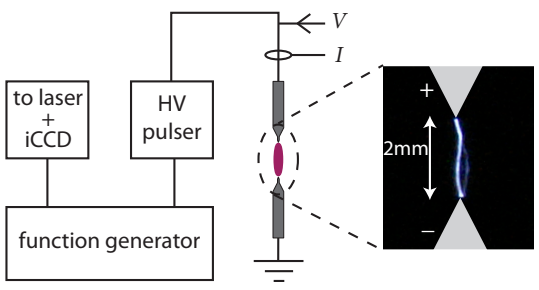
Introduction

Nanosecond repetitively pulsed (NRP) discharges are of increasing interest in a broad range of biomedical, industrial and environmental applications because these discharges are a rich source of radicals at a low temperature. In this contribution NRP discharges are investigated in N_2 and N_2/H_2O mixtures with time-resolved optical emission spectroscopy and Rayleigh scattering.

Experimental setup







Voltage: 9 kV

Frequency: 1 kHz

Width: 170 ns

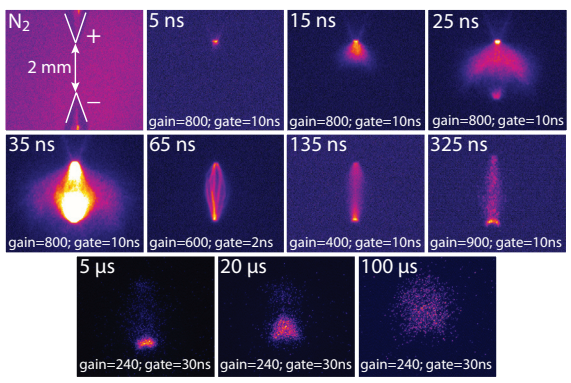
Pressure: 1 bar

Gap distance: 2 mm

Gas: N_2 or N_2+0.9% H_2O

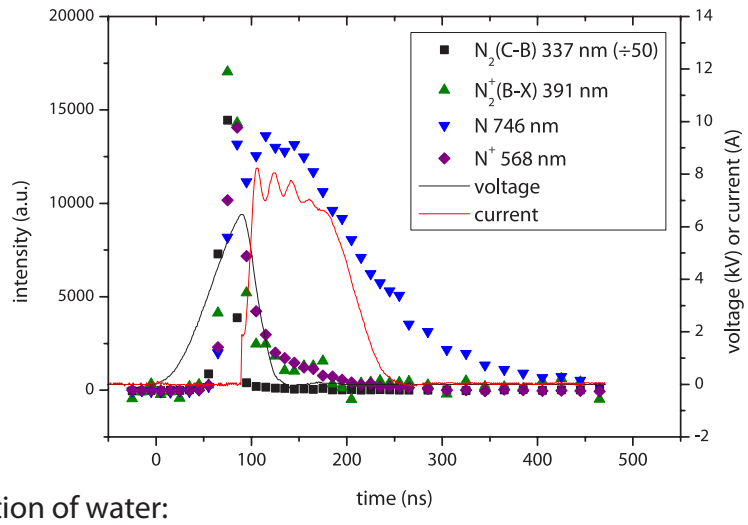
Imaging

- Discharge starts at anode
- Emission 'travels' upward at long timescales (>5 µs)
  - » Gradient in ion density
- No significant difference between N_2 and N_2/H_2O



Optical emission spectroscopy

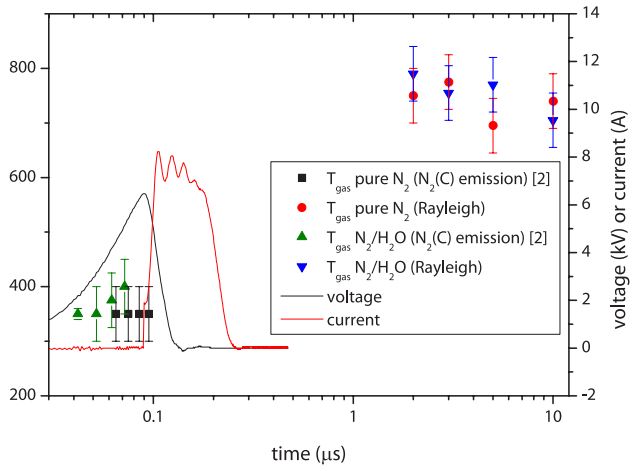
- Molecular emission only during ignition phase
- Decay time of N is (92±3) ns > 51 ns (NIST) in recombination phase
  - » Source present: $N^+ + 2e \rightarrow N + e \quad (k = 1.1 \cdot 10^{-33}\ m^6 s^{-1})$ [1]



- Addition of water:
  - » N_2(C-B) emission weaker due to quenching by H_2O
  - » NH(A-X) and H_α emission visible

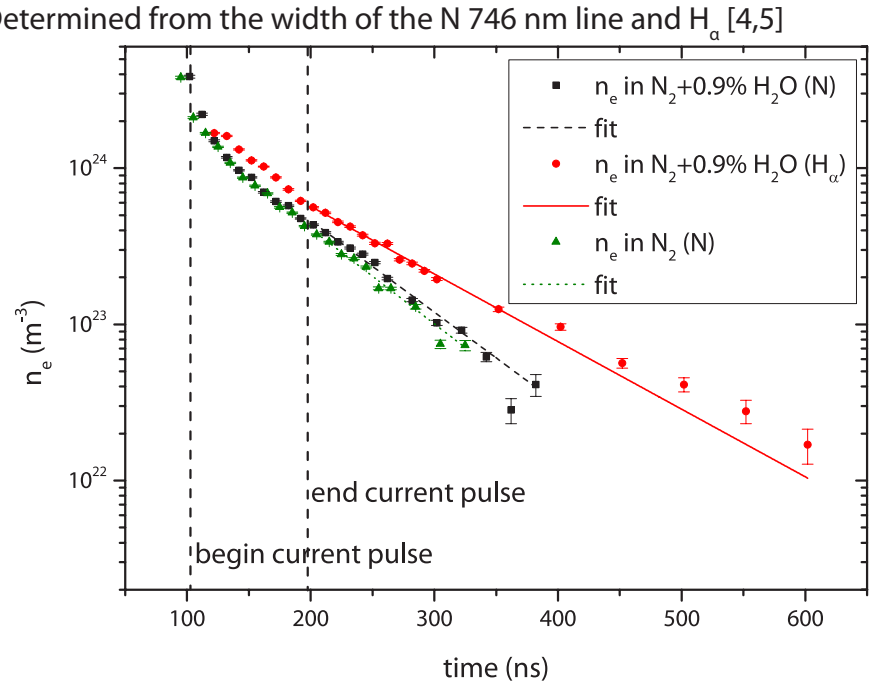
Gas temperature

- High temperature in the recombination phase
  - » Elastic collisions too slow
  - » Due to quenching of excited N_2, recombination of N and electron-ion recombinations [3]



Electron density

- Determined from the width of the N 746 nm line and H_α [4,5]



- Are these densities realistic? Other contributions to FWHM:
  - » External electrical field: <1%
  - » Additional Van der Waals: <1%
  - » Self-absorption: <5%

  } yes
- E-field can be determined from the current and electron density
  - » $n_e = 10^{24}\ m^{-3} \rightarrow V_{electrodes} = 70$ V
  - » $n_e = 10^{22}\ m^{-3} \rightarrow V_{electrodes} = 125$ V

  } current density measurements not reliable to obtain n_e
- Decay different than expected from electron-ion recombination and a slow rate ($\approx 10^7\ s^{-1}$)
  - » Source present: Penning and associative ionization and vibrational pumping

Conclusion

The temperature in the recombination phase is 750 K. The electron density reaches values up to 10^{24} m^{-3} and decreases slowly during the recombination phase. Both illustrate the energy stored in metastable species.

References

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4. M.A. Gigosos *et al.*, *Spectrochim. Acta Part B.* **58**, 1489-1504 (2003).
5. H.R. Griem, *Plasma spectroscopy* (1964).