Diagnostics of Pulsed Powered Microplasma Discharge in N_2 by Emission Spectroscopy

Marius Blajan, and Kazuo Shimizu

Innovation and Joint Research Center, Shizuoka University,

3-5-1 Jyouhoku, Hamamatsu, 432-8561, JAPAN. E-mail : blajanmarius@yahoo.com

Introduction

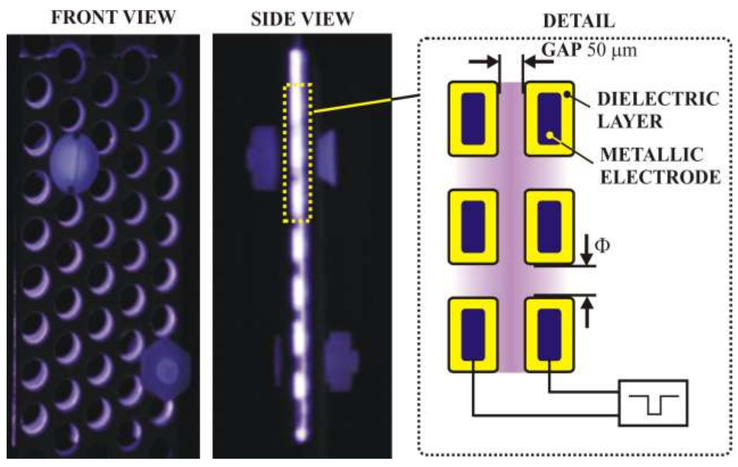
Microplasma can be found in many applications. In the last years, the technology was used in applications such as NOx removal, surface treatment and sterilization or inactivation of bacteria. Emission spectroscopy is one of the methods to analyze plasma process .

Microplasma is atmospheric pressure nonthermal plasma. The microplasma processes in nitrogen were analyzed using emission spectroscopy method since nitrogen gas is a component in environmental applications.

Experimental Setup

(1)Microplasma Electrodes

The electrodes consist in perforated metallic plates covered with a dielectric layer.



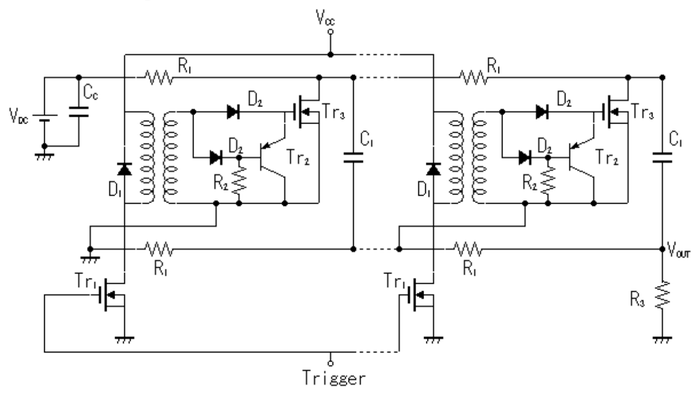
Microplasma electrodes

Electrode size was 20 mm versus 40 mm. Discharge gap was set at 50 μm in this study. Emission spectra of microplasma discharge was observed from the side part of electrodes.

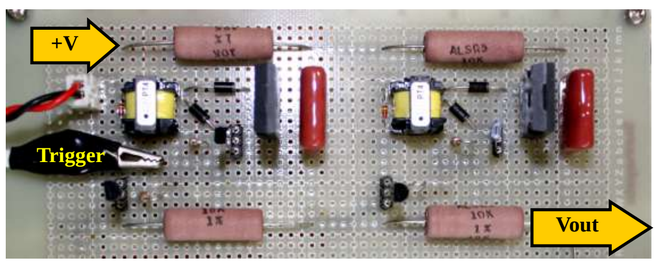
(2) Marx Generator

Capacitors are charged in parallel connection at voltage V.
⇨ When the MOSFET are turned on the capacitors are discharge in series connection with an output voltage V multiplied with the number of capacitors.

(a)



(b)



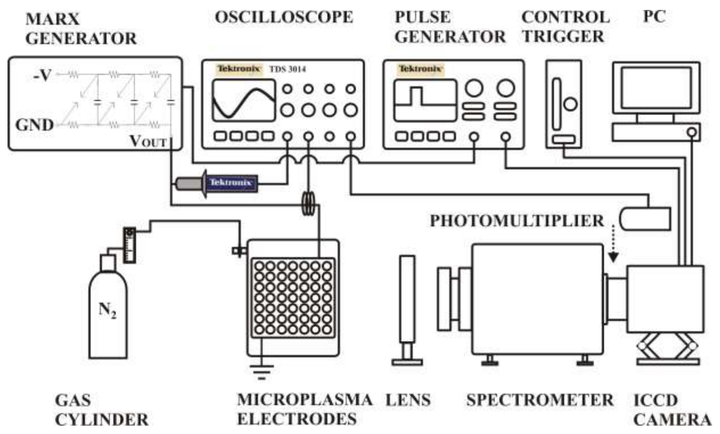
Negative pulse Marx Generator (a) circuit of Marx Generator, (b) photo of Marx Generator.

Marx Generator with MOSFET switches:
- **Negative pulses**
- **2 stages**
- **Charge voltage up to 1 kV**
  - ➢ **Output Voltage: -2 kV**
- **Rise time: 80 ns**
- **Pulse width: 1 μs**
- **Frequency: 1-24 kHz**

(3) Experimental setup

Emission spectrum was measured by a spectrometer, an ICCD camera and a photomultiplier tube. The ICCD camera was triggered by a pulse generator.

Spectrometer was set at narrow and wide gratings.

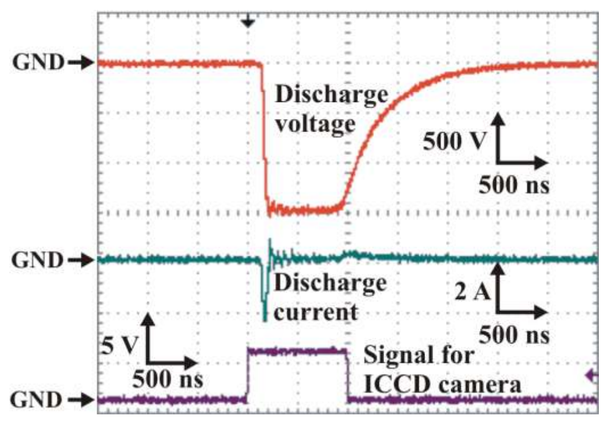


Experimental setup

Gas flow rate: N_2 at 2.5 L/min.

(4) Electrical Characteristics

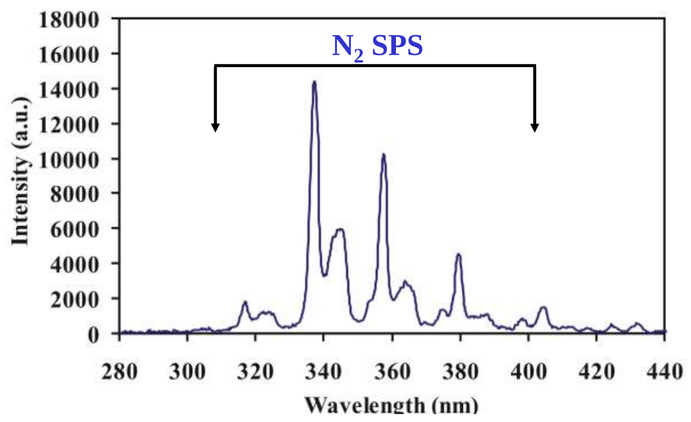
Very small discharge gaps and relatively *low discharge voltages* (about 1 kV)
⇨A *high intensity electric field* (10^7-10^8 V/m) assures the formation of microplasma and a corresponding discharge current.

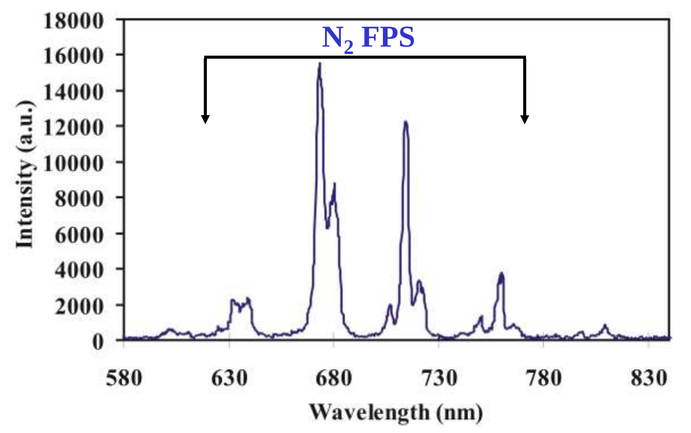


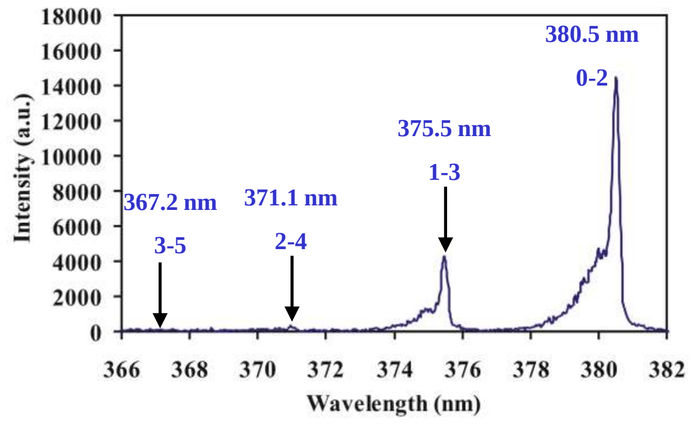
Waveforms of the discharge voltage, corresponding discharge current and gate signal for ICCD camera.

Emission Spectroscopy

Emission spectrum of microplasma discharge in pure N_2 shown *N_2 second positive system*, *N_2 first positive* band peaks and *N_2^+ first negative system* band peaks.
Camera shutter was open for *1 μs*.

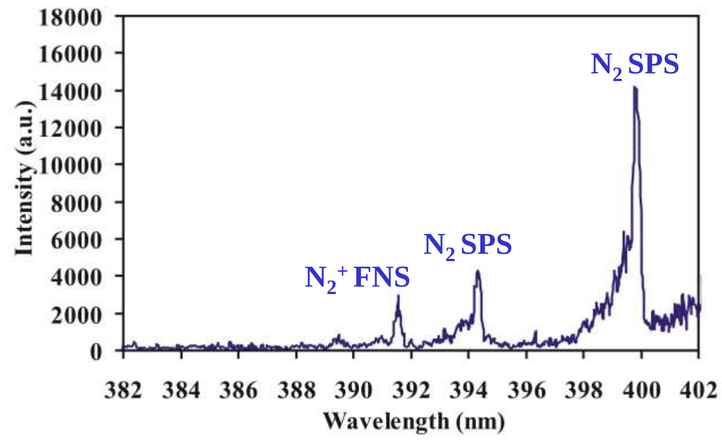






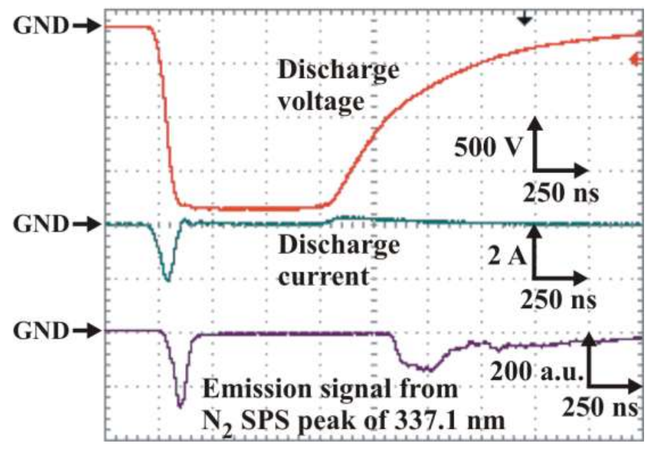
Emission spectrum in N_2 shows:
- ***N_2 second positive band system peaks*** **at 315 nm, 337.1 nm, 357.7 nm, 380.4 nm, 400 nm and 405 nm.**
- ***N_2 first positive band system peaks*** **at 632.2 nm, 670.5 nm, 676.4 nm, 678.6 nm, 705.9 nm, 716.5 nm and 762.7 nm.**
- ***N_2^+ first negative band system peak*** **at 391.4 nm.**

Intensity of the N_2 SPS peaks at *367.2 nm, 371.1 nm, 375.5 nm and 380.5 nm* were used to calculate vibrational temperature:
Tv = 3400 K
The ratio of the intensity peaks corresponding to *N_2^+ FNS at 391.4* nm and *N_2 SPS at 394.3 nm* was used to calculate electron temperature. Thus at -1.5 kV:
Te = 3.1 eV



Emission spectrum in UV region.

N_2 second positive band system 337.1 nm:
Excitation of nitrogen molecules in the ground state by direct electron impact:
$e + N_2(X^1\Sigma_g^+)_{v=0} \rightarrow N_2(C^3\Pi_u)_{v'=0} + e$ (ΔE=11eV)
Spontaneous radiation of formed excited state of nitrogen:
$N_2(C^3\Pi_u)_{v'=0} \rightarrow N_2(B^3\Pi_g)_{v''=0} + hv$ (τ_o^C=40 ns)



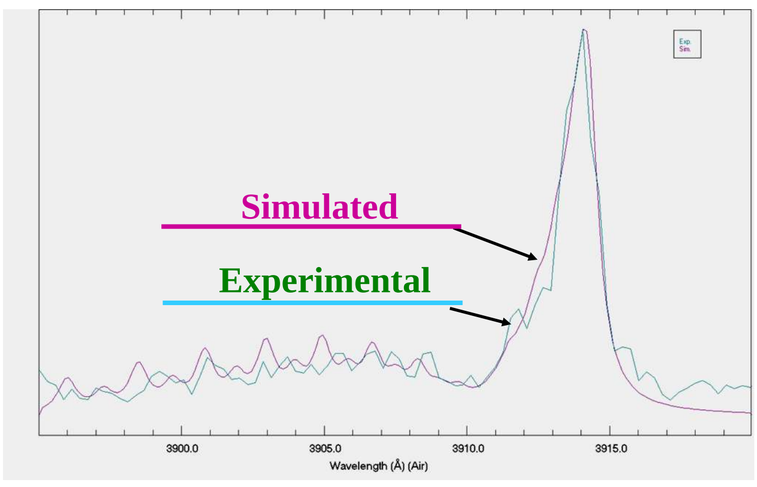
Waveform of the discharge voltage, discharge current and emission signal of microplasma discharge (337.1 nm) in N_2.

Lifetime emission signal of *N_2 SPS* peak at 337.1 nm was *60 ns*.

LIFBASE **software was used for the calculation of the rotational temperature.**

Tgas = Trot = 400 K

⇨*Microplasma=Nonthermal plasma*



Experimental and simulated spectrum corresponding to N_2^+ first negative system peak of 391.4 nm emitted by microplasma discharge in N_2.

Conclusions

- **Emission spectrum of microplasma in N_2 shown intensity peaks of *N_2 SPS, N2 FPS and N_2^+ FNS*.**
- **Lifetime emission signal peak of the 337.1 nm N_2 SPS peak for microplasma in N_2 was after *60 ns*.**
- **Temperature calculation showed that microplasma is nonthermal plasma:**
  - ➢ ***Te>Tvib>Trot***