Emission spectroscopy of microplasma in Ar/N_2 mixture for surface treatment applications

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Introduction

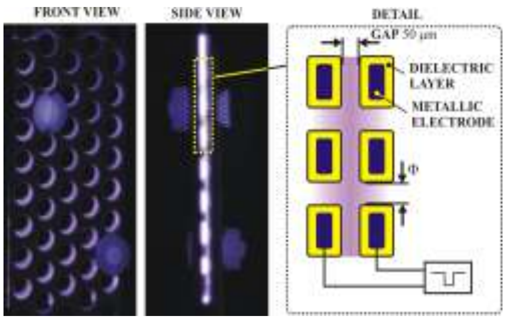
Microplasma can be found in many applications. The technology is used also for surface treatment and one of the discharge gases is argon. Although there is an interest for application driven research many of the microplasma phenomena are not fully understood. Emission spectroscopy is one of the methods to analyze plasma process .

Microplasma is atmospheric pressure nonthermal plasma. The aim of this paper is to analyze the emission spectrum of the microplasma in argon gas and in Ar/N_2 mixture.

Experimental Setup

(1)Microplasma Electrodes

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



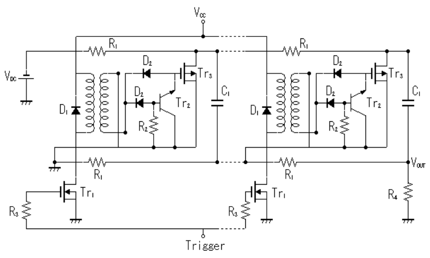
Microplasma electrodes

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.

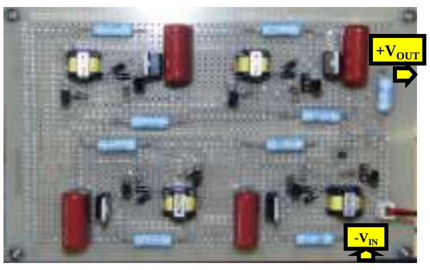
(2) Marx Generator

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)

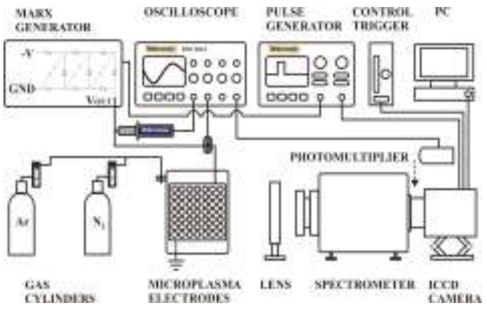


Positive pulse Marx Generator (a) circuit of Marx Generator, (b) photo of Marx Generator.

Marx Generators with MOSFET switches:
- **Output Voltage: -1.8 kV negative; 1.4 kV positive**
- **Rise time: 80 ns for negative, 100 ns for positive**
- **Pulse width: 500 ns**
- **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.

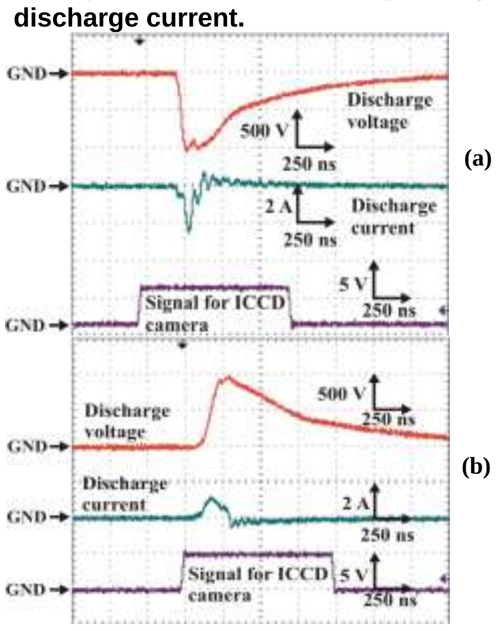


Experimental setup

Gas flow rate: Ar with purity 99.999% and Ar/N_2 mixture and in N_2 at 10 L/min.

(4) Electrical Characteristics

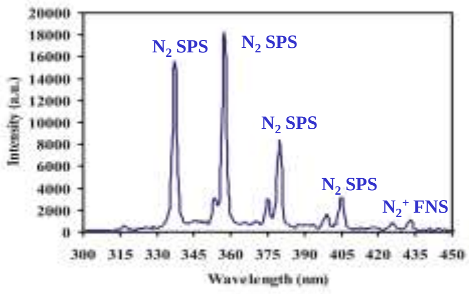
Very small discharge gaps and relatively *low discharge voltages* (about 1 kV)
⇨A *high intensity electric field* (10^7-10^8 V/m) assures the formation of microplasma and a corresponding discharge current.



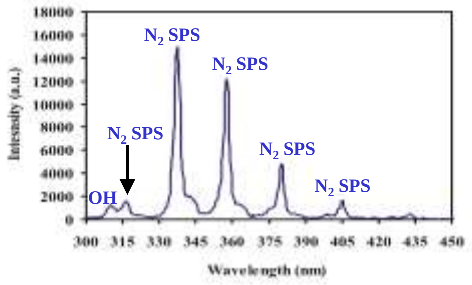
Waveforms of the discharge voltage, corresponding discharge current and gate signal for ICCD camera; (a) for negative pulse; (b) for positive pulse.

Emission Spectroscopy

Emission spectrum of microplasma discharge in pure N_2 shown *N_2 second positive system* band peaks and *N_2^+ first negative system* band peaks.



Emission spectrum of N_2 at -1.8 kV



Emission spectrum of 0.1%N_2 in Ar at -1.1 kV

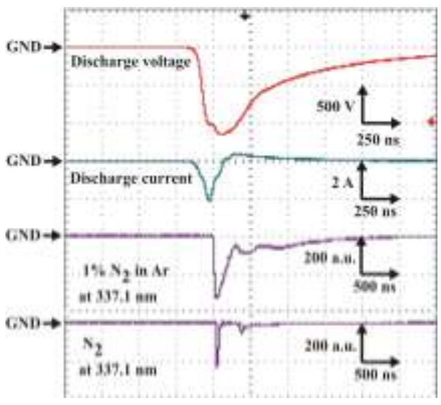
Emission spectrum in 0.1% N_2 in Ar for UV and Violet region shows:
- **Intensity peaks *between 305 nm and 310 nm attributed to OH***
- ***N_2 second positive band peaks***
- **Small peaks of *Ar I* at 415.74 nm, 419 nm, 420.06 nm, 425.29 nm, 426 nm and 426.75 nm.**

N_2 molecules excited argon neutrals and reaction in argon plasma with N_2 addition:

$$Ar^* + N_2(X^1\Sigma_g^+)_{v=0} \rightarrow N_2(C^3\pi_u)_{v'=0} + Ar$$

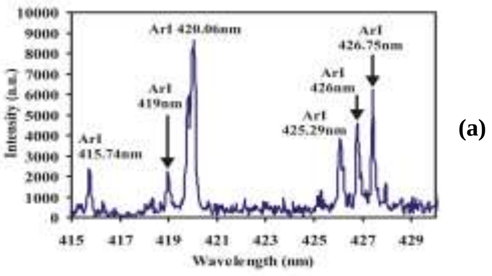
Spontaneous radiation of formed excited state of nitrogen:

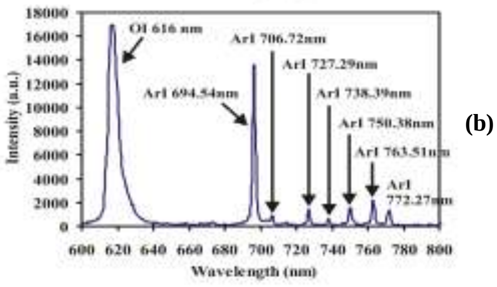
$$N_2(C^3\pi_u)_{v'=0} \rightarrow N_2(B^3\pi_g)_{v''=0} + h\nu$$



Waveforms of the discharge voltage, discharge current and emission signal of microplasma discharge (337.1 nm) in N_2 and N_2/Ar mixture.

Lifetime emission signal of *N_2 SPS* peak at 337.1 nm increased at *from 40 ns to 260 ns* when 1% N_2 was added in Ar.
Emission spectrum in Ar for violet and red region shows intensity peaks of *Ar I*.



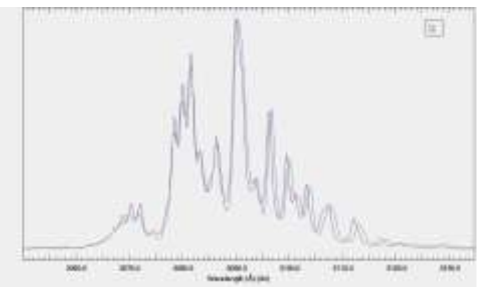


Emission spectrum of dry Argon at 1 kV (a), violet region (b), red region.

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

Tgas = Trot = 300 K

⇨*Microplasma=Nonthermal plasma*



Experimental and simulated spectrum corresponding to OH peaks emitted by microplasma discharge in Ar.

Conclusions

Emission spectrum of microplasma in Ar/N_2 mixture shown intensity peaks of *N_2 SPS, Ar I and OH*.

- **Lifetime emission signal of the 337.1 nm N_2 SPS peak for microplasma in Ar/N_2 shown an increase due to the Ar metastable.**
- **Microplasma discharge in Ar/N_2 is suitable for surface treatment processes due to the presence of active species and low gas temperature.**