Spatial Distribution of Microplasma Light Emission

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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.

The fundamental phenomena of microplasma discharge are not fully understood. The development and optimization of microplasma technologies depend on the clarification of microplasma physics. Emission spectroscopy is one of the methods for plasma analysis. Moreover due to the particularities of microplasma such as small discharge gap, the analysis can be performed only by this non invasive technique. Our microplasma is a dielectric barrier discharge at atmospheric pressure.

Experimental Setup

(1)Microplasma Electrodes

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

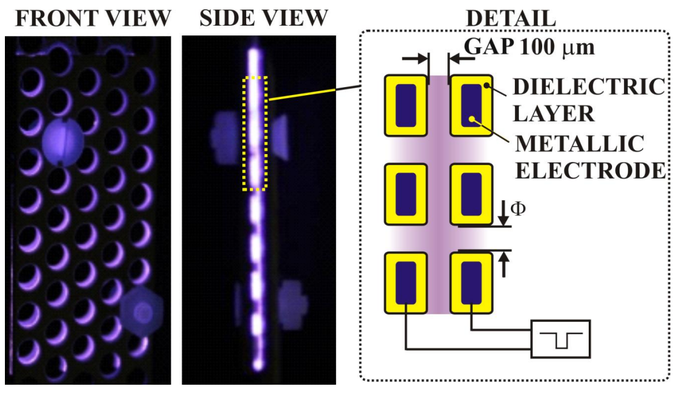

Fig. 1 Microplasma electrodes.

Electrode size was 20 mm versus 40 mm for emission spectroscopy analysis. Discharge gap was set at 30 μm, 100 μm and 200 μm in this study.

(2) Power Supply

Marx Generator **with MOSFET switches:**
- **Output Voltage: -2 kV negative**
- **Rise time: 100 ns**
- **Pulse width: 1 μs**
- **Frequency: 1-24 kHz**

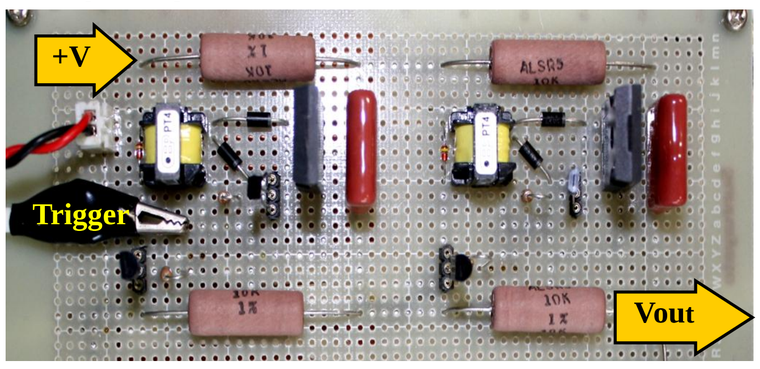

Fig. 2 Photo of negative pulse Marx Generator.

(3) Experimental setup

Emission spectrum was measured by a spectrometer, an ICCD camera and a photomultiplier tube. Photos of microdischarges were taken using a microscope and a digital camera.

Gas flow rate: Ar and N_2/Ar at 10 L/min.

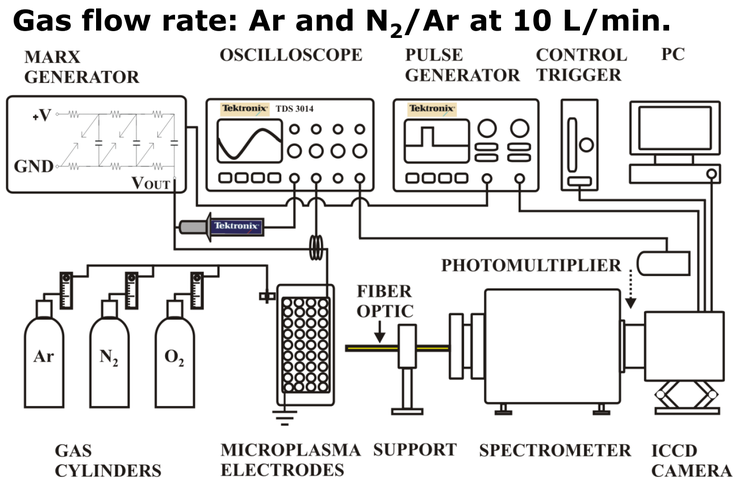

Fig. 3 Experimental setup.

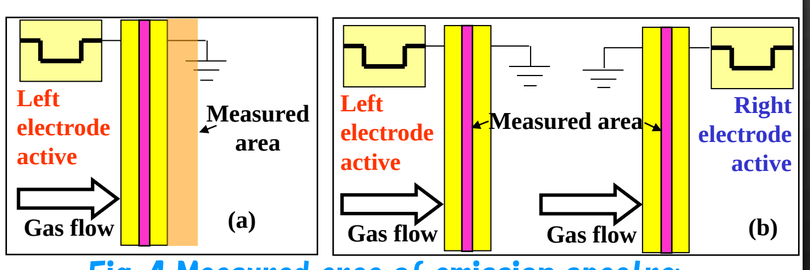

Fig. 4 Measured area of emission spectra: (a) outside the electrode: (b) in discharge gap.

(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.

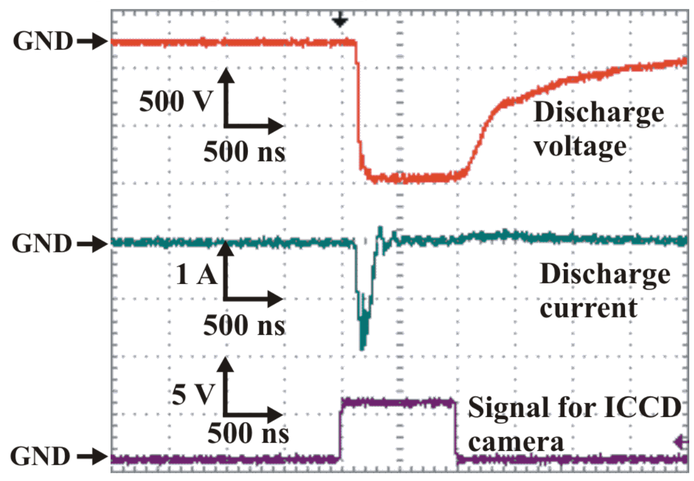

Fig. 5 Waveforms of the discharge voltage, corresponding discharge current and gate signal for ICCD camera.

Emission Spectroscopy

Emission spectrum was measured with camera shutter opened for ***1 μs***.

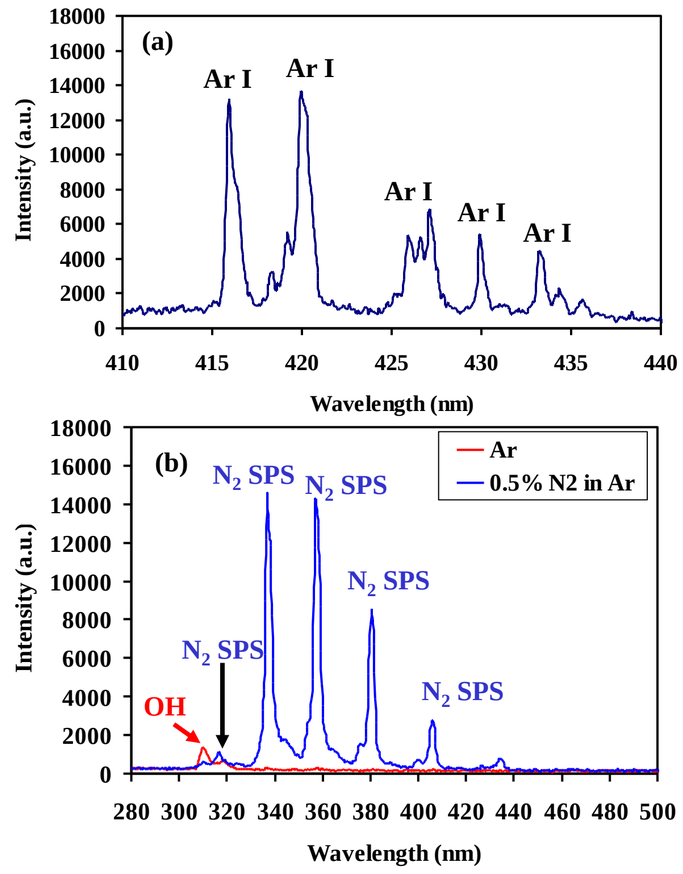

Fig. 6 Emission spectrum of microplasma in: (a) Ar: (b) N_2/Ar at -1.2 kV.

Emission spectrum in Ar and Ar/N_2 shows:
- ***N_2 second positive band system peaks*** **at 315.9, 337.1, 357.7, 380.4, 400 and 405 nm.**
- ***OH peaks*** **at 306.4, 307.8 and 308.9 nm.**
- ***Ar I peaks*** **were measured at 415.8, 419.1, 419.8, 420.1, 426.6, 427.2, 425.9, 433.3, 696.5, 706.7, 727.3, 738.3, 703.2, 750.4 and 772.4 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:

$$N_2(C^3\Pi_u)v'=0 \rightarrow N_2(B^3\Pi_g)v''=0 + hv$$

Spatial distribution outside of electrodes shows a distribution of about 1 mm for the OH peak at 309 nm and 500 μm for the Ar I peak at 696.54 nm respectively.

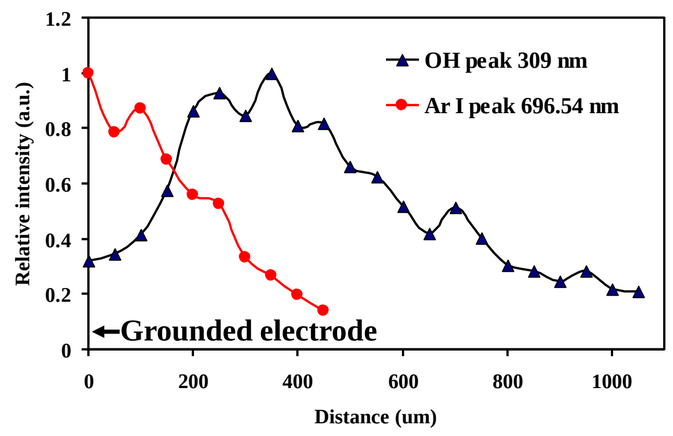

Fig. 7 Spatial distribution of OH radical and Ar I at the outside of grounded electrode for electrode arrangement shown in Fig. 4 (a).

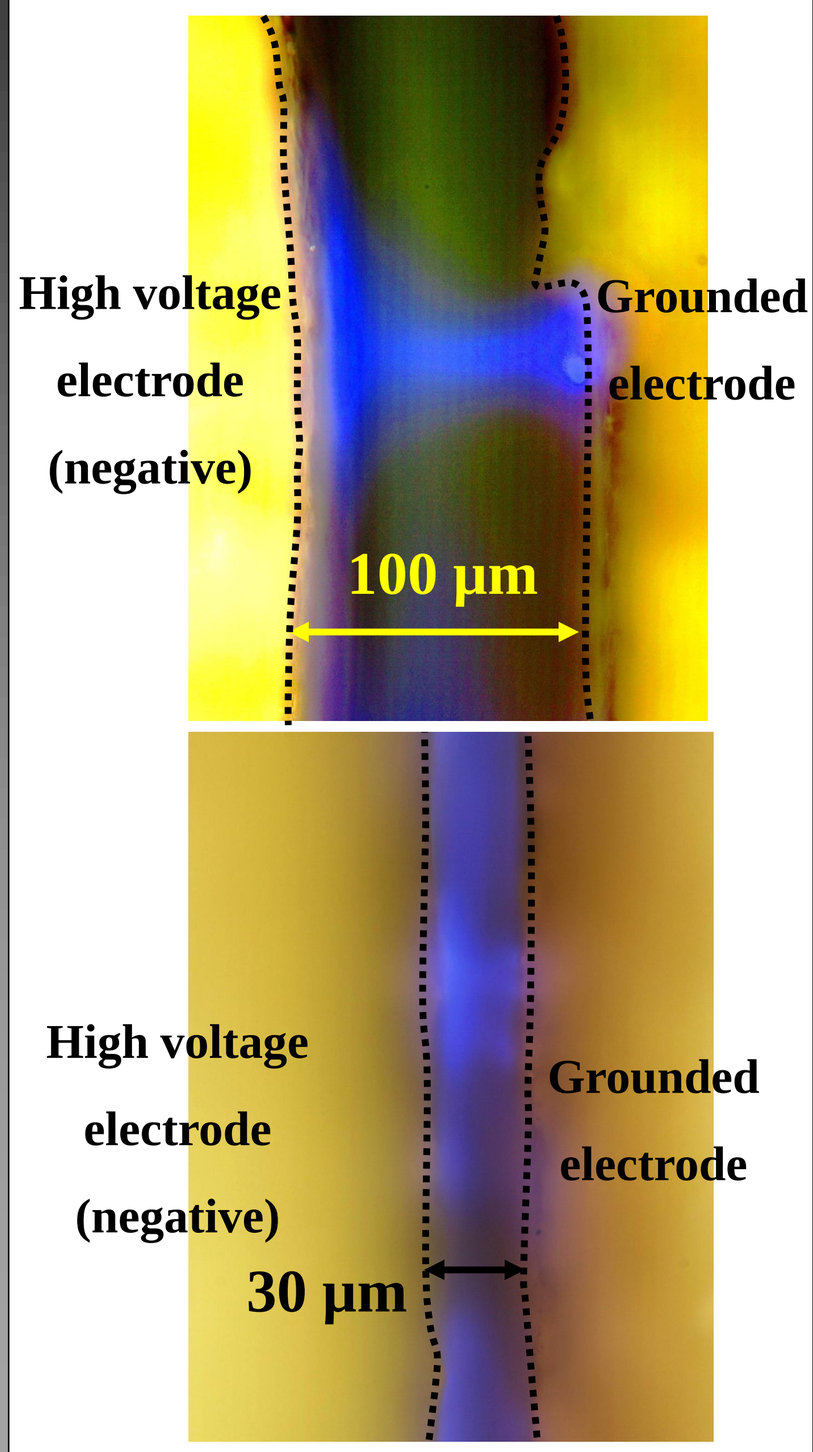

Fig. 8 Photo of a streamer from microplasma discharge.

The streamer diameter was proportionally with the discharge gap and thinner than previously reported. It has a wider area towards negative electrode and a smaller towards the grounded or positive one.

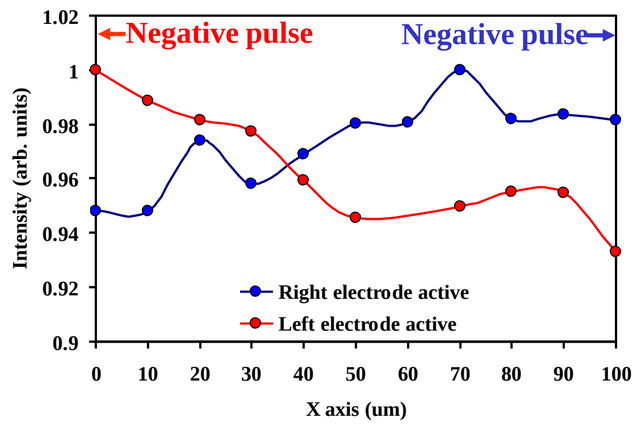

Fig. 9 Spatial distribution of N_2 SPS peak at 337.1 nm in the discharge gap for electrode arrangement shown in Fig. 4 (b).

Spatial distribution inside the discharge gap shows a higher intensity towards the negative electrode as also shown in the streamer photos.

Vibrational temperature was Tvib=3160 K.
Electron temperature was Te = 23000 K.
Rotational temperature Tgas = Trot = 300 K.
⇨***Microplasma=Nonthermal plasma***

Conclusions

- **Emission spectrum of microplasma shown intensity peaks of *N_2 SPS, OH and ArI*.**
- **Spatial distribution of *ArI* peak at *696.54 nm* and *OH* peak at *309 nm* outside the grounded electrode was measured up to 500 μm for ArI peak and 1 mm for OH peak respectively.**
- **Streamer diameter was proportionally with the discharge gap.**
- **Spatial distribution of *N_2 SPS* peak at *337.1 nm* in the discharge gap shown a higher intensity near the negative electrode.**