

# Characteristics of microplasma in small discharge gaps

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## Introduction

Microplasma can be found in many applications. In the last years, the technology was used in applications such as NO<sub>x</sub> 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. 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.

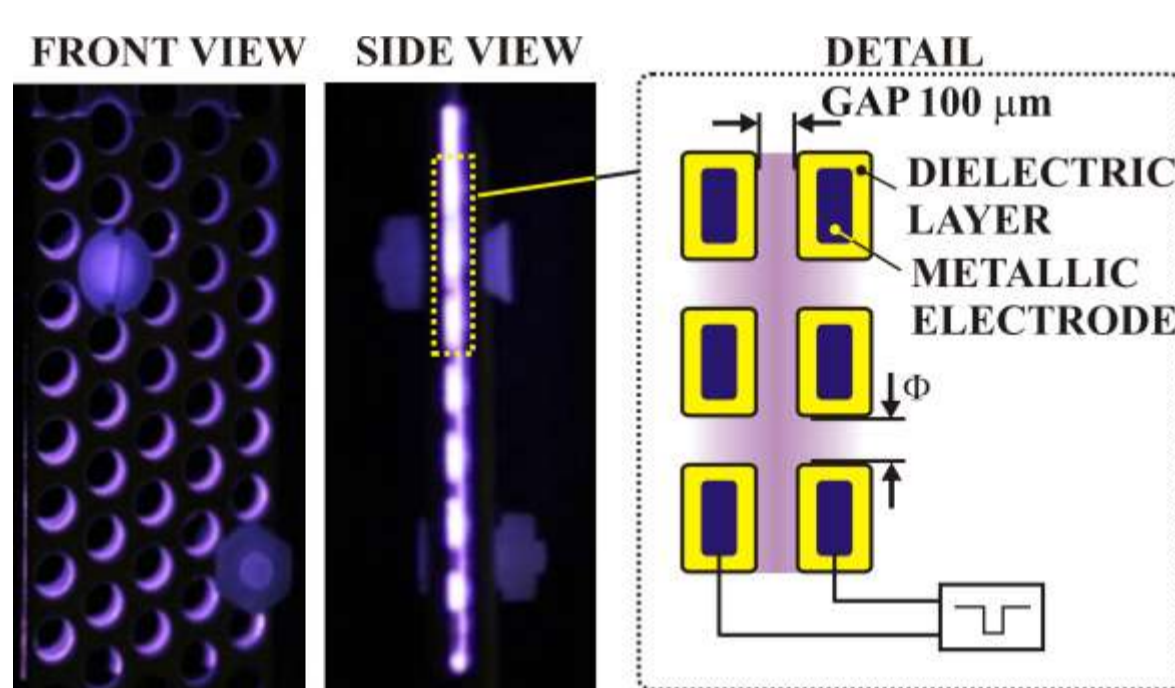


Fig. 1 Microplasma electrodes

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

A Marx Generator with MOSFET switches as pulse power supply:

- Output Voltage: -2 kV negative
- Rise time: 40 ns
- Pulse width: 1 μs

### (2) 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<sub>2</sub>/Ar at 10 L/min.

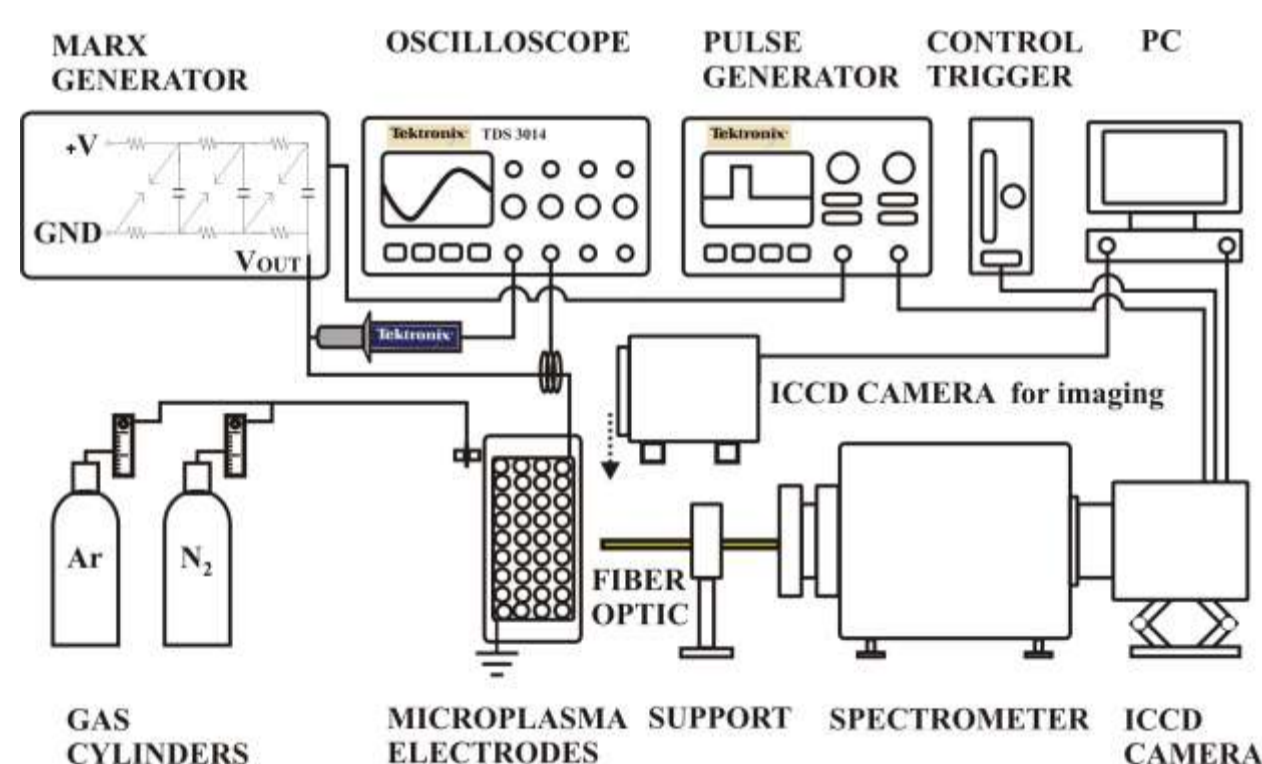


Fig. 2 Experimental setup.

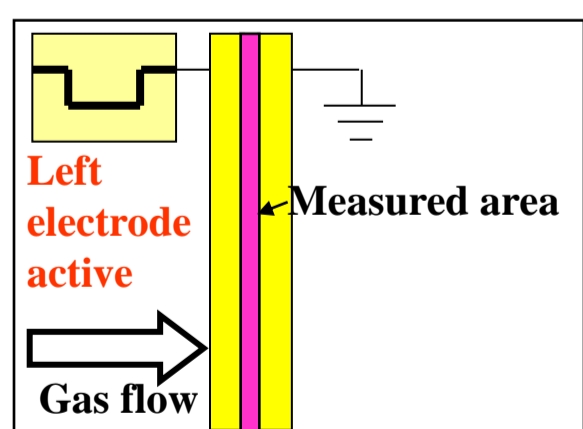


Fig. 3 Measured area of emission spectra.

### (3) Microdischarges

Very small discharge gaps and relatively low discharge voltages (about 1 kV). A high intensity electric field (10<sup>7</sup>-10<sup>8</sup> V/m) assures the formation of microplasma.

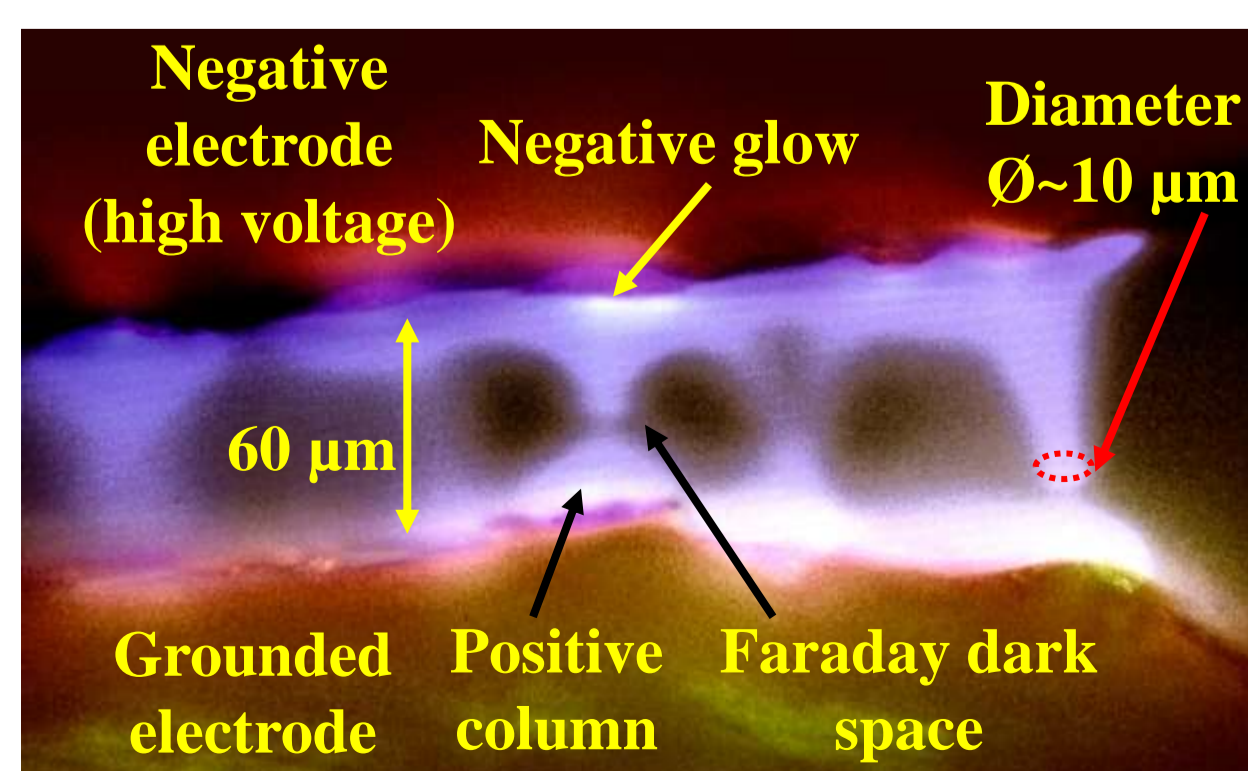


Fig. 4 Phenomena of microdischarges.

## Emission Spectroscopy

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

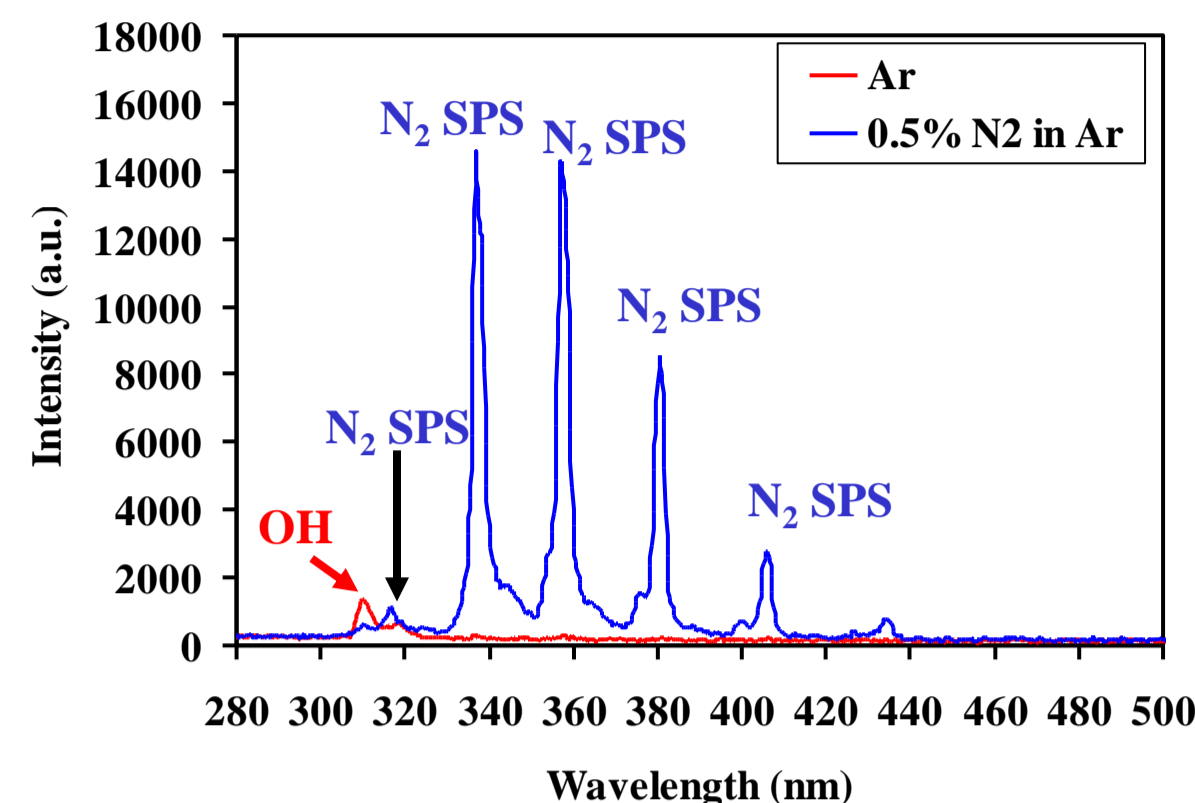
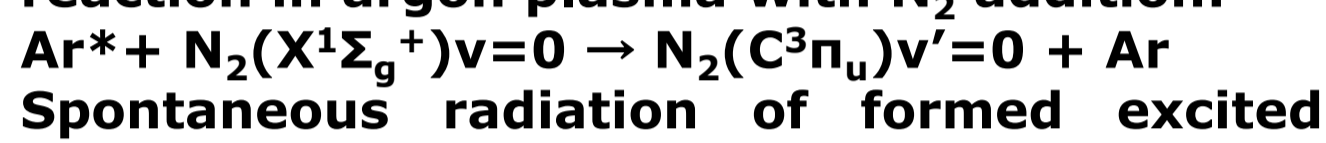
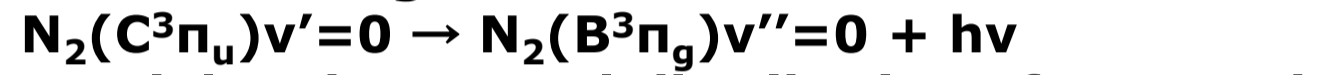


Fig. 5 Emission spectrum of microplasma in N<sub>2</sub>/Ar at -1.2 kV.

N<sub>2</sub> molecules excited argon neutrals and reaction in argon plasma with N<sub>2</sub> addition:



Spontaneous radiation of formed excited state of nitrogen:



Spatial and temporal distribution of Ar I peak at 696.5 nm and N<sub>2</sub> SPS peak at 337.1 nm shows higher intensity towards anode up to 20 ns and after that shifted to cathode.

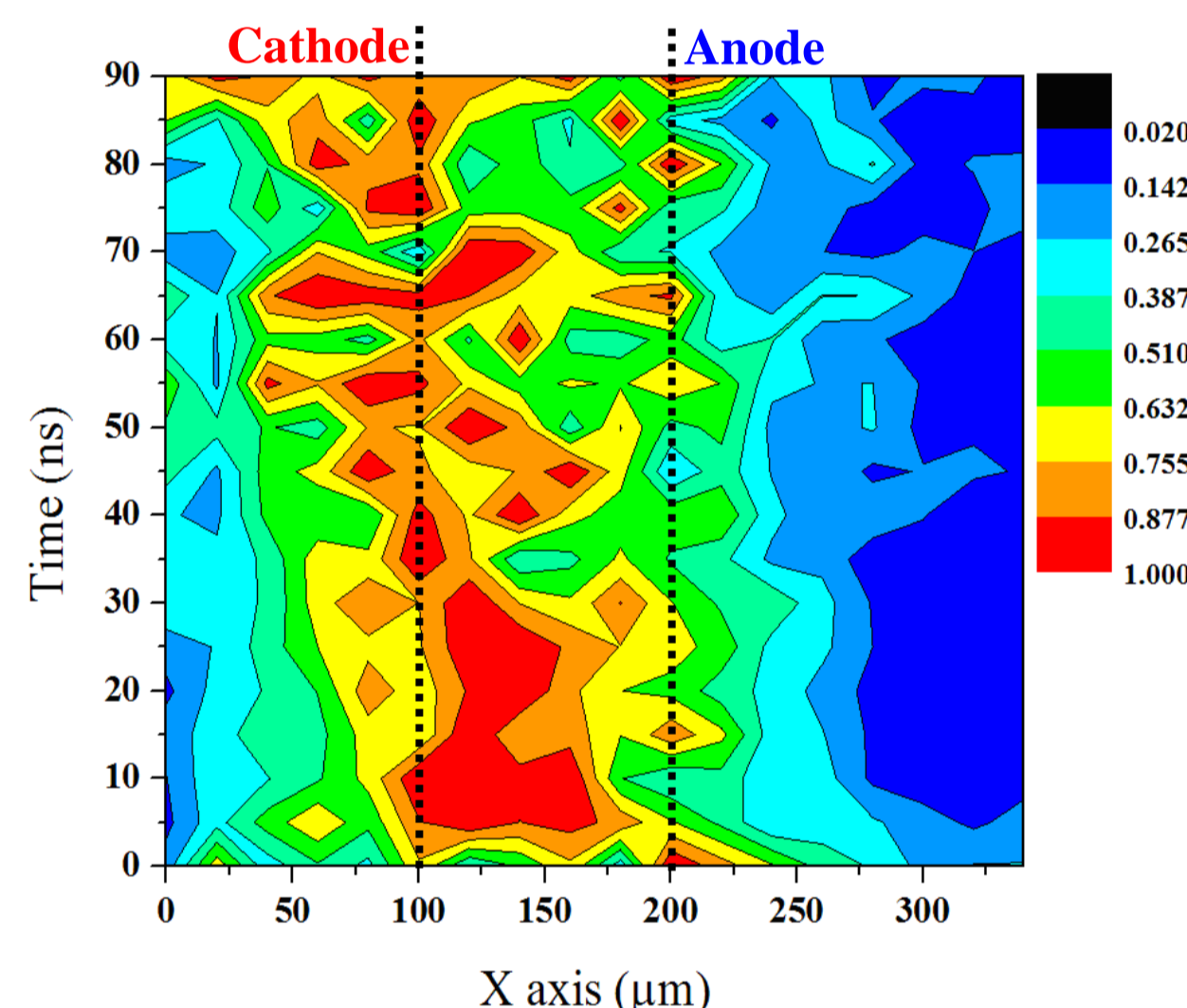


Fig. 6 Spatial and temporal evolution of the relative intensity of Ar I peak at 696.5 nm for microplasma discharge in Ar at 1 kV.

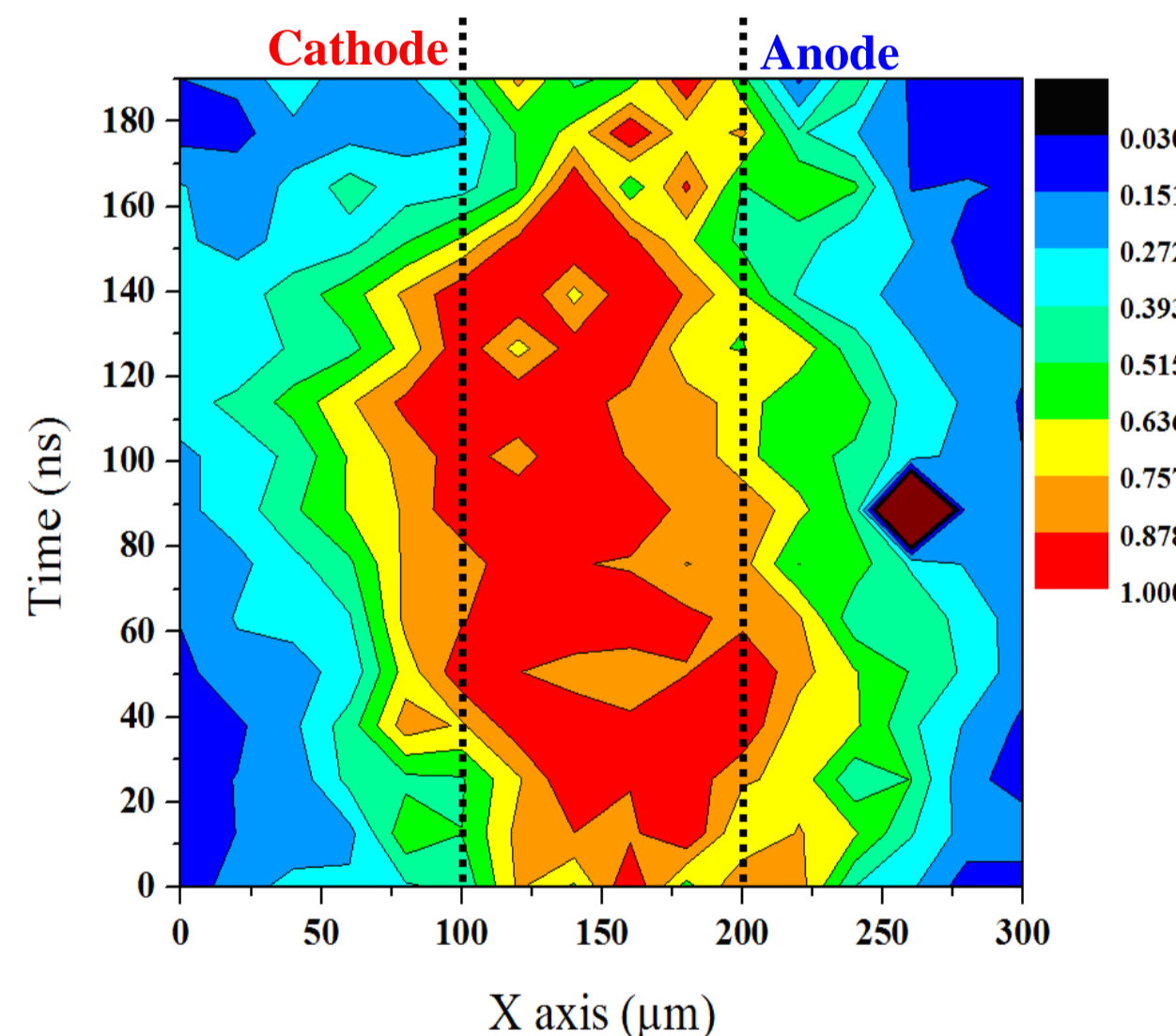


Fig. 7 Spatial and temporal evolution of the relative intensity of N<sub>2</sub> SPS peak at 337.1 nm for microplasma discharge in 1% N<sub>2</sub> in Ar at 1 kV.

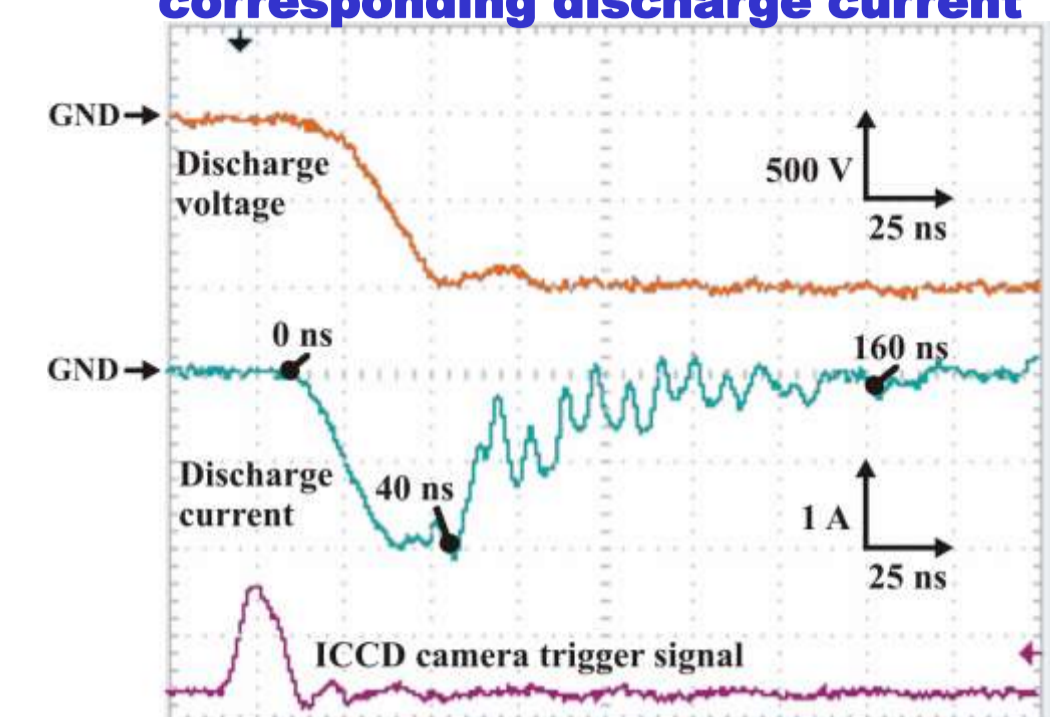
## Spatial and Temporal Evolution of Microplasma

The observation of microdischarge by ICCD camera shows the streamer formation phenomena and the correlation of the microdischarge evolution with the discharge current.

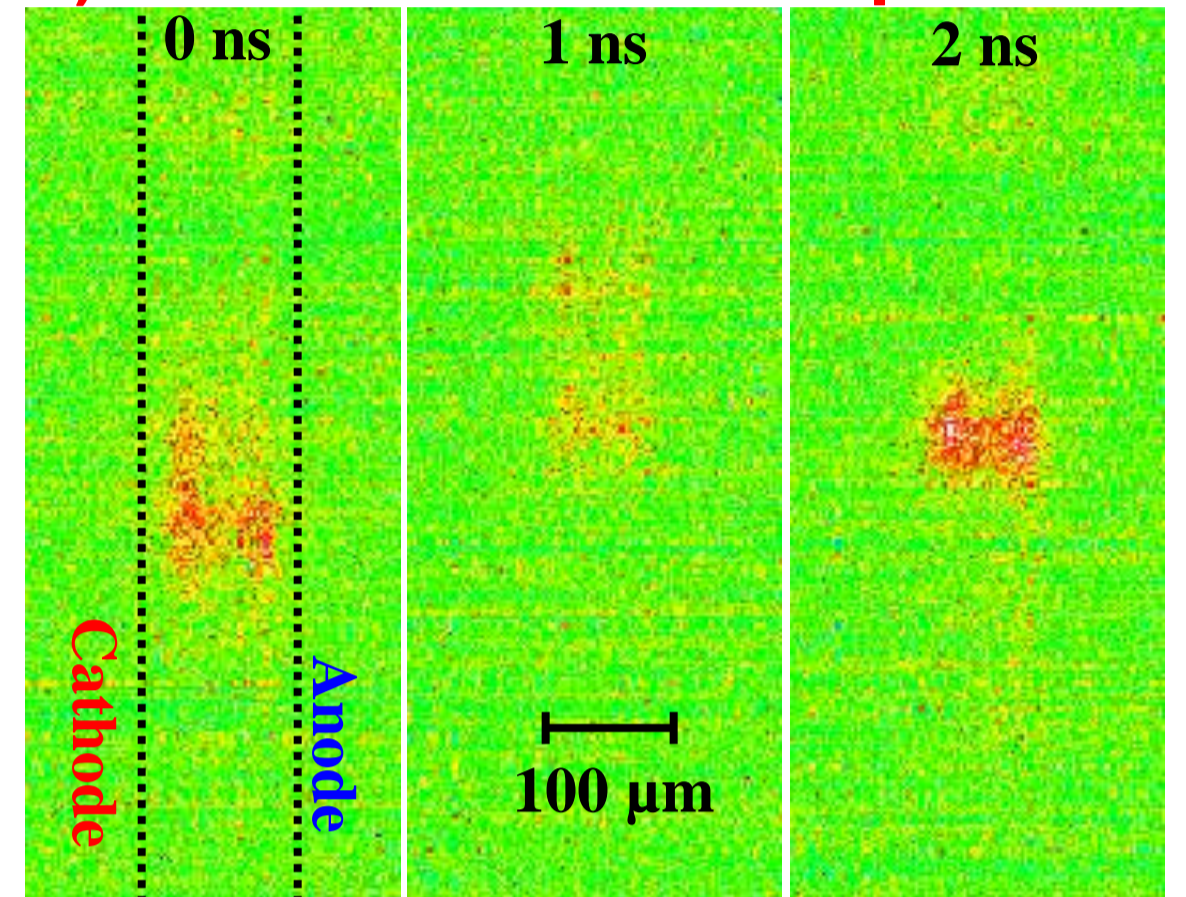
Microdischarges phenomena was well correlated with the discharge current value.

$J = 5.2 \text{ A/cm}^2$  for  $\text{Ø}30 \text{ μm}$  microdischarge  
 $n_e = J / (E\mu_e e)$  - electron density  
 $v_d$  - electron drift velocity =  $2 \times 10^5 \text{ m/s}$   
 $E$  - intensity of electric field =  $1 \text{ kV} / 100 \text{ μm}$   
 $\mu_e = v_d / E$  - electron mobility =  $200 \text{ cm}^2 / (\text{V s})$   
 $\Rightarrow n_e = 1.6 \times 10^{12} \text{ cm}^{-3}$

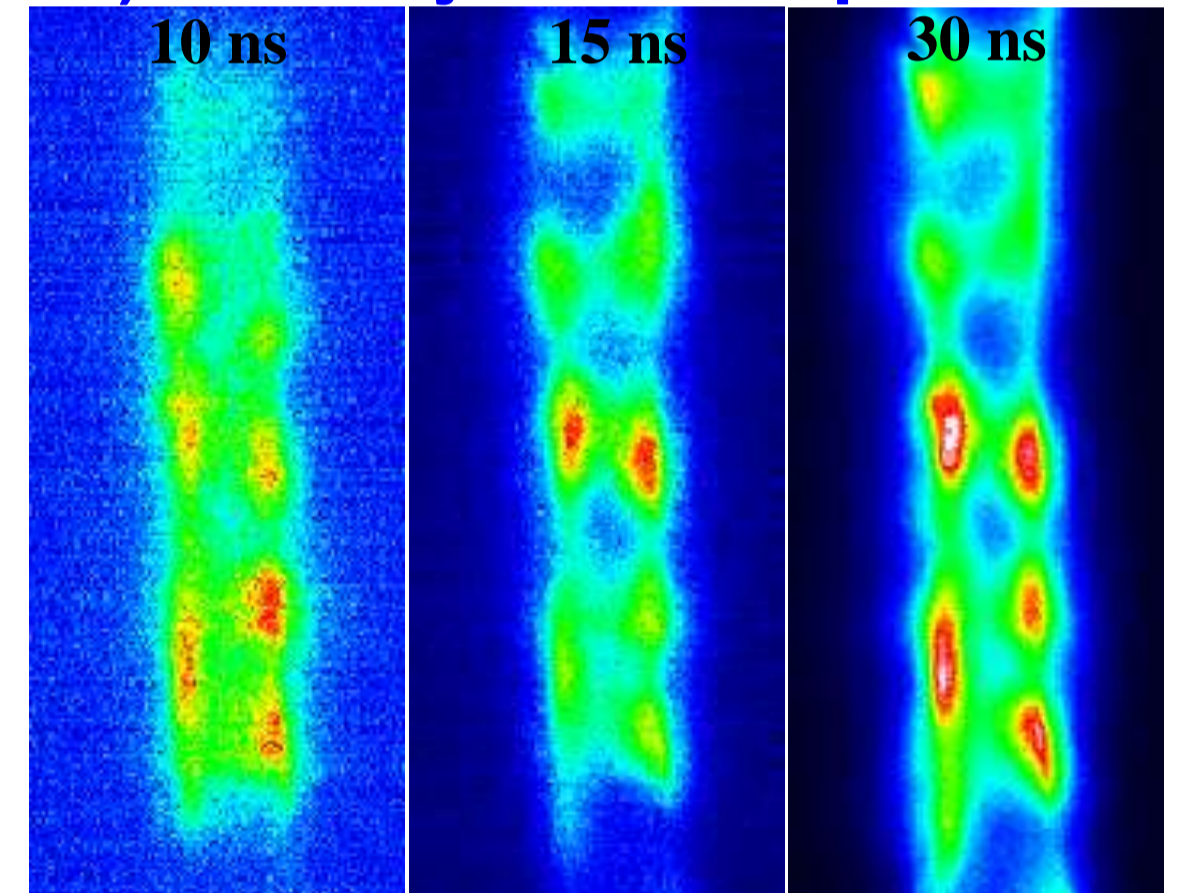
## Discharge voltage and corresponding discharge current



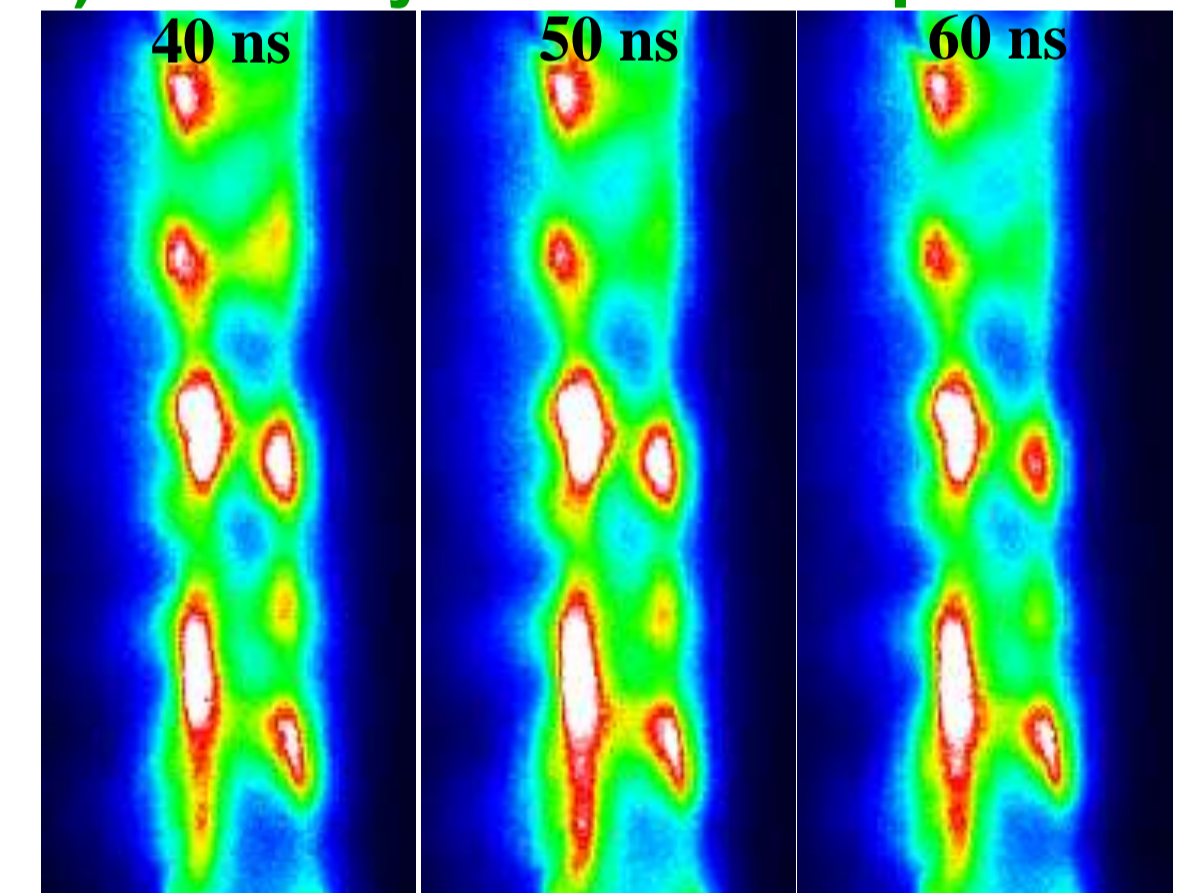
### 1) Streamer reaches cathode up to 1 ns



### 2) Cathode layer formation up to 30 ns



### 3) Cathode layer enhancement up to 70 ns



### 4) Cathode layer decay up to 270 ns

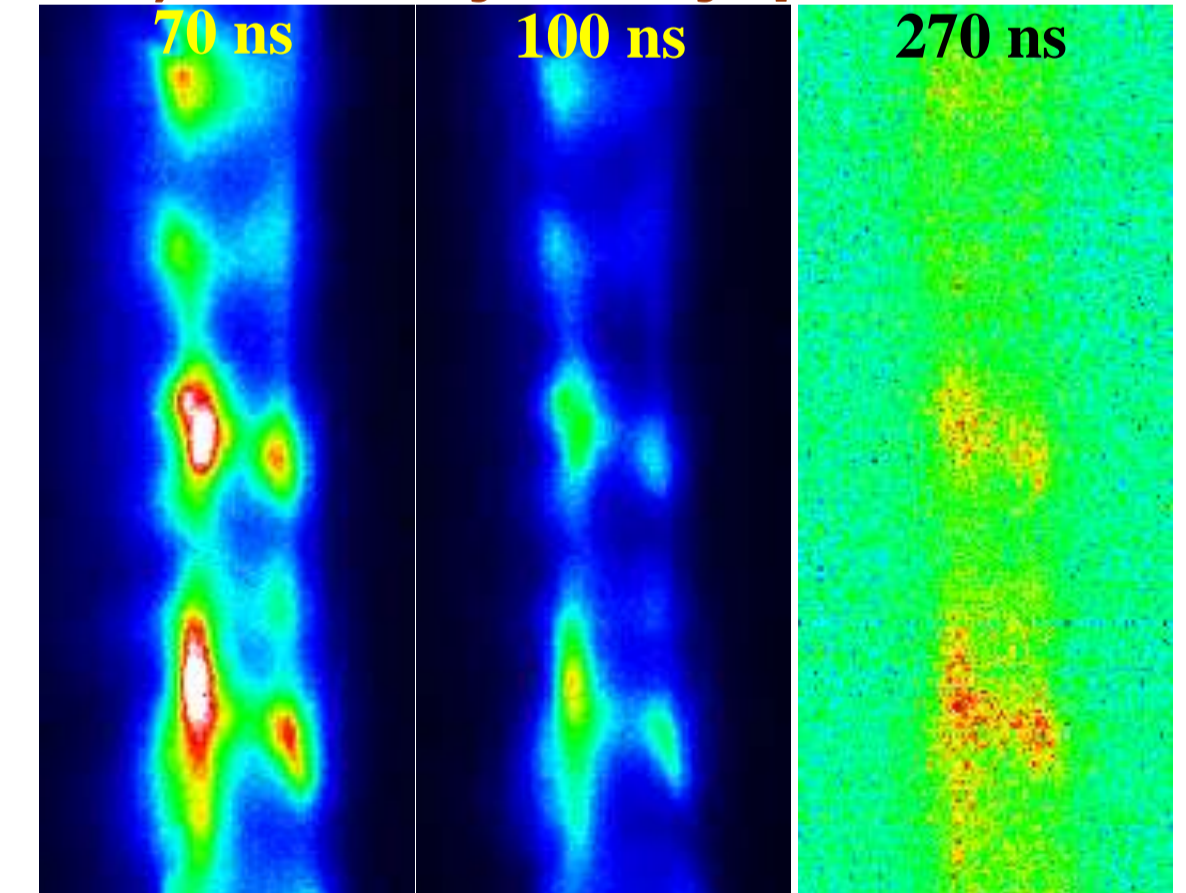


Fig. 8 Spatial and temporal evolution of microplasma discharge in 3% N<sub>2</sub> in Ar at 1 kV. ICCD camera shutter was opened for 2 ns.

## Conclusions

• Emission spectrum of microplasma shown intensity peaks of N<sub>2</sub> SPS, OH and ArI.

• Spatial and temporal evolution of the relative intensities of ArI peak at 696.54 nm and N<sub>2</sub> SPS peak at 337.1 nm showed higher intensity towards anode up to 20 ns and after it shifted towards cathode.

• ICCD camera images showed the evolution of microdischarges from the phase when streamer reaches anode to cathode layer formation, cathode layer enhancement and finally cathode layer decay.