Spatial and Temporal Analysis of Microplasma Light Emission for the Surface Treatment Processes

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Introduction

Microplasma can be found in many applications. Technology was used in for NOx removal, surface treatment and sterilization or inactivation of bacteria.

The development and optimization of microplasma technologies depend on the clarification of microplasma physics. Our microplasma is a dielectric barrier discharge at atmospheric pressure.

L-lactic acid surface was treated by microplasma.

Experimental Setup

(1)Microplasma Electrodes

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

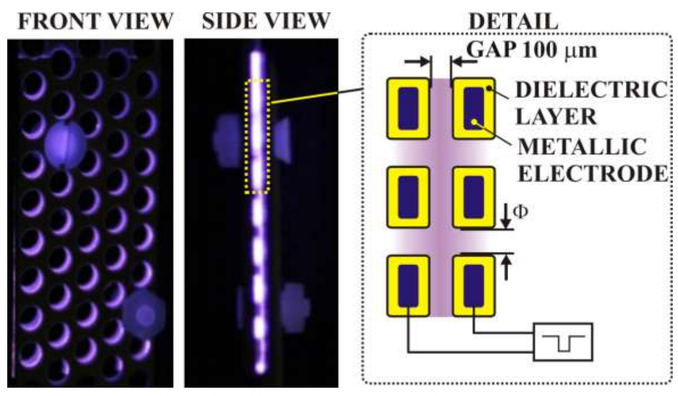

Fig. 1 Microplasma electrodes

Electrode size was 20 mm versus 40 mm for emission spectroscopy analysis. Discharge gap was set from 30 µm to 100 µm in this study.
A *Marx Generator* with MOSFET switches as pulse power supply:
- Output Voltage: -2 kV negative
- Rise time: 100 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, N_2/Ar and O_2/Ar at 10 L/min.

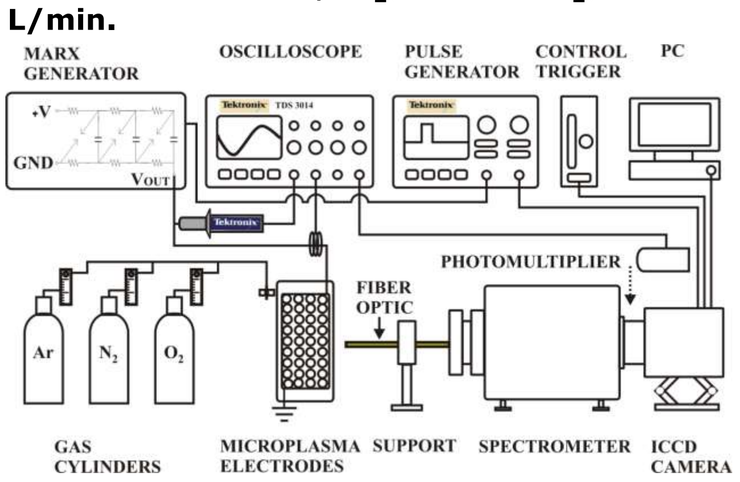

Fig. 2 Experimental setup for emission spectroscopy.

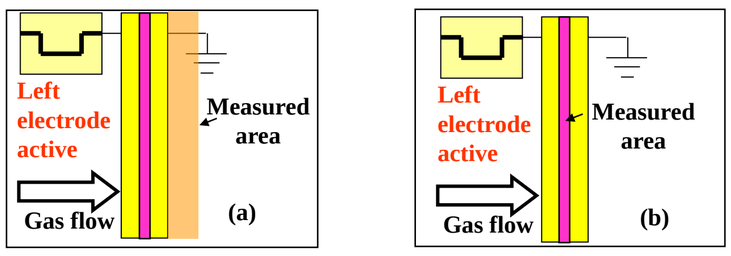

Fig. 3 Measured area of emission spectra: (a) outside the electrode: (b) in discharge gap.

(3) Polymer film treatment

L-lactic acid ($C_3H_6O_3$) polymer film was treated by remote microplasma process.

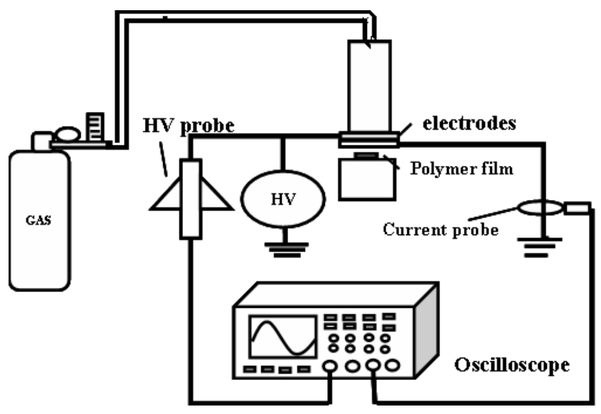

Fig. 4 Experimental setup for surface treatment of polymer film.

A high intensity electric field (10^7-10^8 V/m) assures the formation of microplasma and a corresponding discharge current.

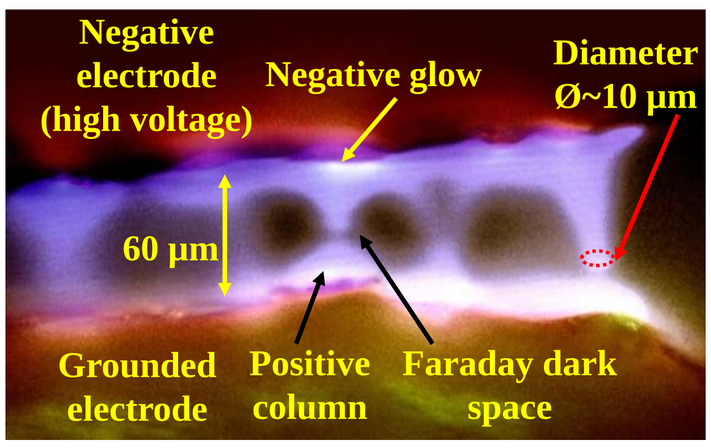

Fig. 5 Phenomena of microdischarges.

Emission Spectroscopy

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

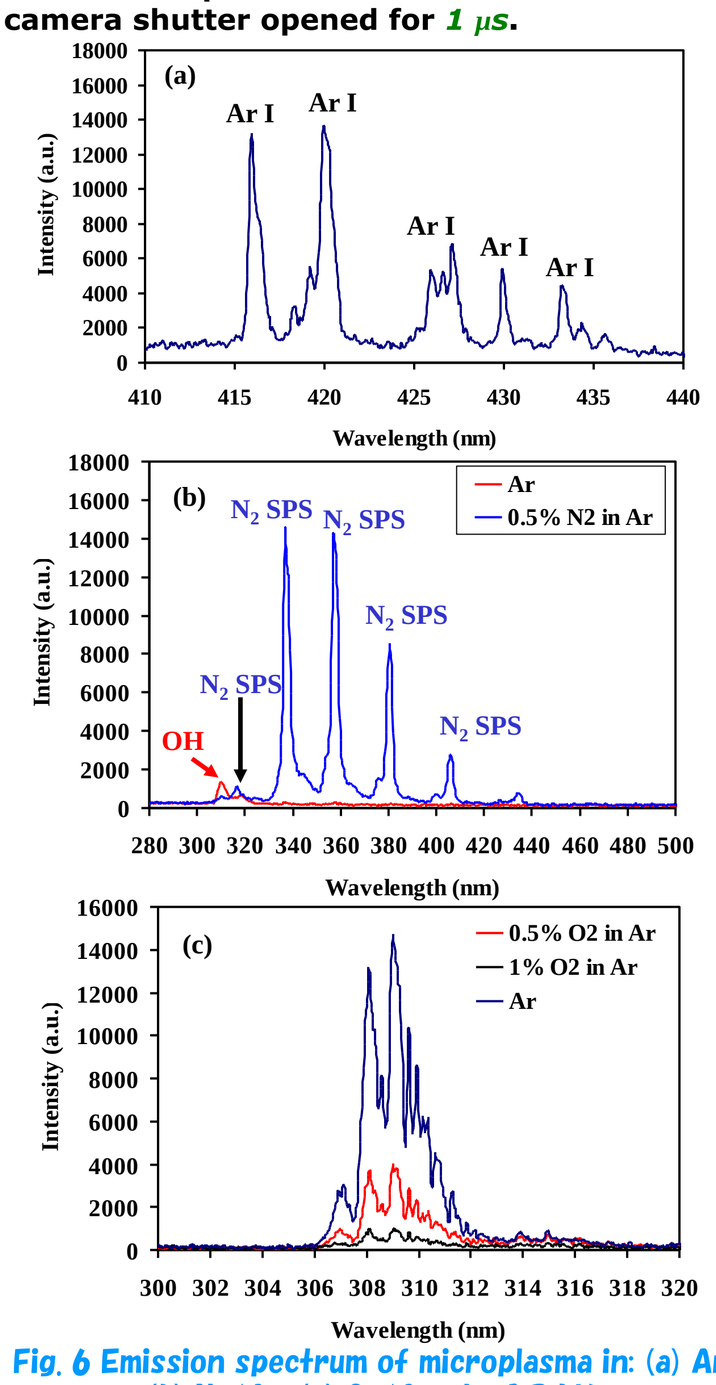

Fig. 6 Emission spectrum of microplasma in: (a) Ar: (b) N_2/Ar: (c) O_2/Ar at -1.2 kV.

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.

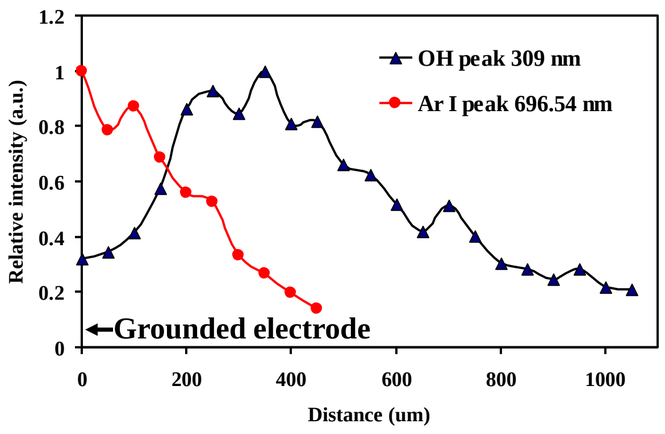

Fig. 7 Spatial distribution of OH radical and Ar I at the outside of grounded electrode for electrode arrangement shown in Fig. 3 (a).

The streamer diameter was proportionally with the discharge gap and thinner than previously reported.

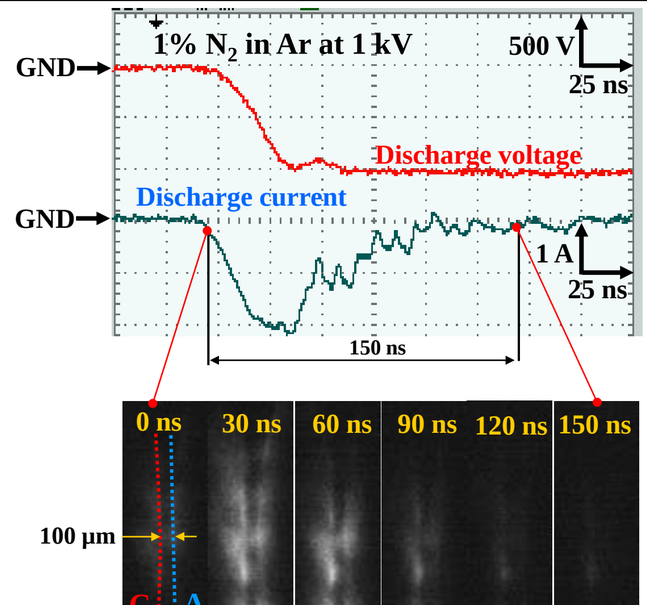

Fig. 8 Temporal evolution of microplasma discharge. Gating of ICCD camera was set at 3 ns.

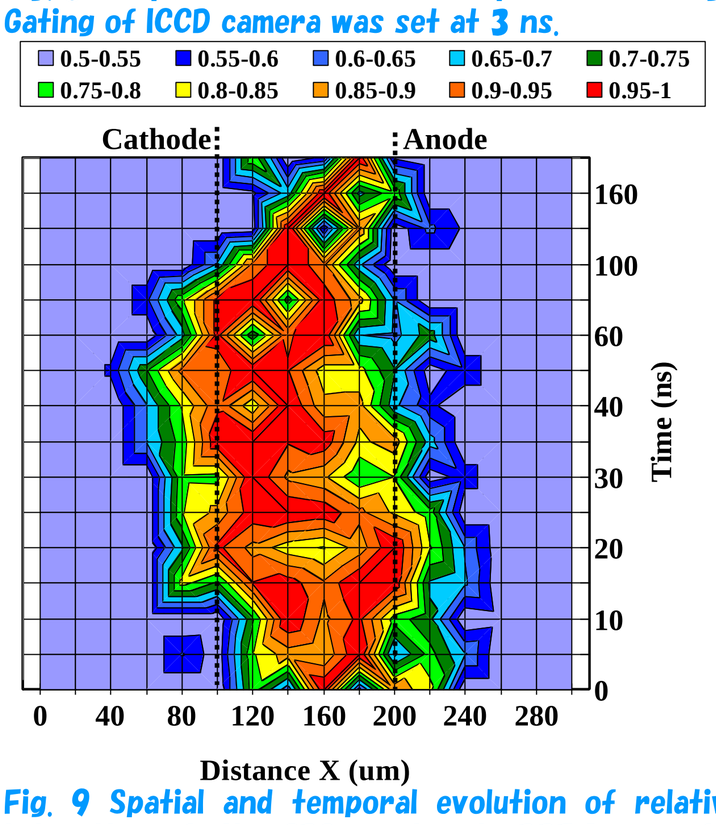

Fig. 9 Spatial and temporal evolution of relative intensity of N_2 SPS peak at 337.1 nm for microplasma in 1% N_2 in Ar. Gating of ICCD camera was set at 3 ns.

Spatial and temporal distribution for the N_2 SPS peak at 337.1 nm inside the discharge gap shown a maximum intensity towards the anode for the 25 ns corresponding to the rise time of discharge current and it shifted after towards cathode.

Surface Treatment of L-lactic acid

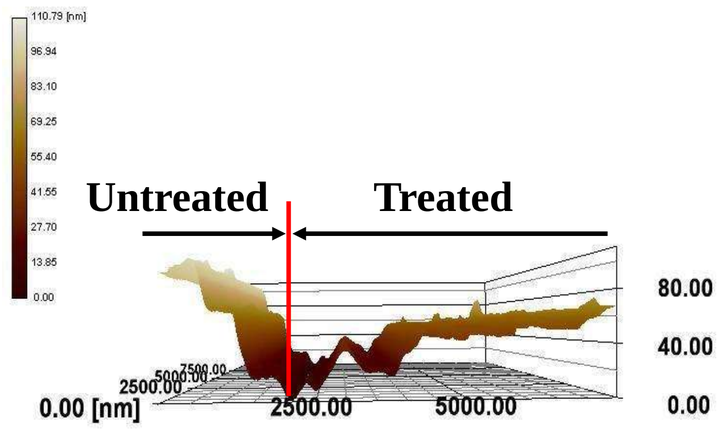

Fig. 10 AFM analysis of the polymer surface before (left side) and after (right side) microplasma treatment with Ar.

Conclusions

- Streamer diameter was proportionally with the discharge gap.
- 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.
- Light near the cathode was preceded by the waves of light intensity that started directly from the anode and propagated towards the cathode.
- Polymer's surface hydrophilicity was improved by microplasma treatment. AFM analysis showed modifications at the surface of polymer.