Pulsed Power Microplasma Diagnostics for Glass' Surface Treatment

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Introduction

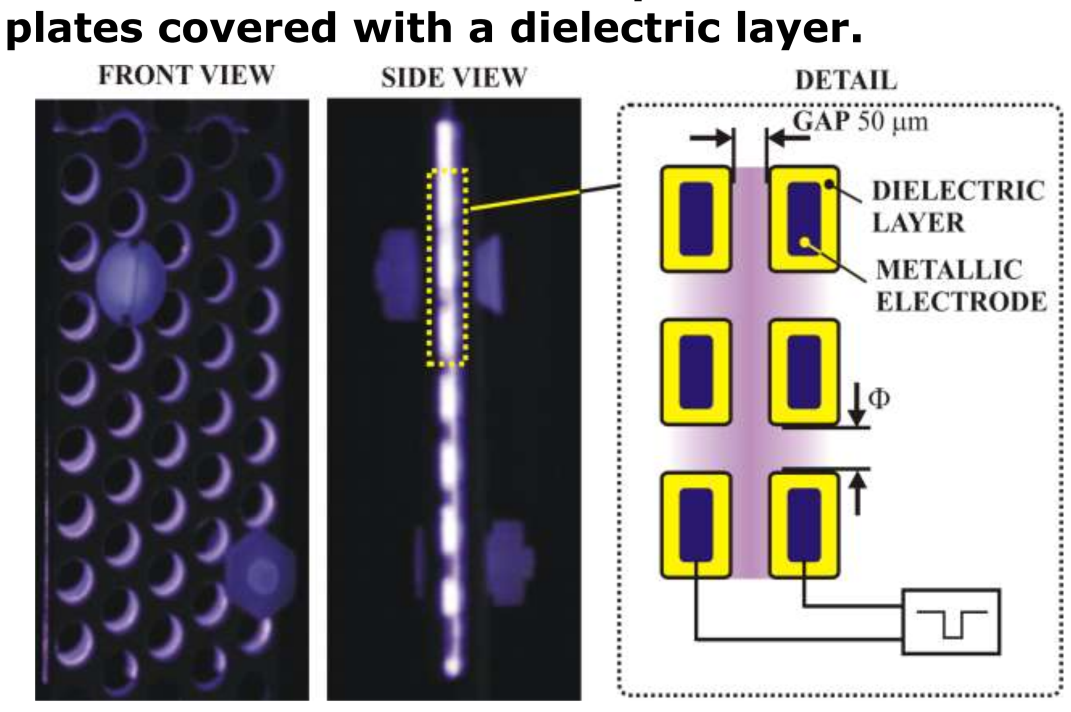
Microplasma can be found in many applications. In the last years, the technology was used in applications such as NOx removal, surface treatment and sterilization or inactivation of bacteria. Emission spectroscopy is one of the methods to analyze plasma process and will allow the calculation of microplasma's electron, vibrational and rotational temperatures.

The aim of this research is to analyze microplasma by emission spectroscopy for the process of glass surface treatment. Other research groups investigated nonthermal plasma for surface treatment with similar characteristics such as high electron, and low rotational temperatures which recommends that this technology could be applied for the surface modification due to its low gas temperature and molecular excitation ability. Our microplasma has this characteristics obtained at relatively low discharge voltages around 1 kV which can be advantageous in furthermore implementing the technology in industry. Moreover the surface potential after the microplasma treatment is low (about 20 V) comparing with plasma jet that charges the surface at more than 200 V.

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 for emission spectroscopy analysis. Discharge gap was set at 50 μm in this study.
Microplasma electrodes for surface treatment have 40 mm diameter .

(2) Power Supplies

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

Neon transformer
- **Output voltage: up to 2 kV AC**
- **Frequency 24 kHz**

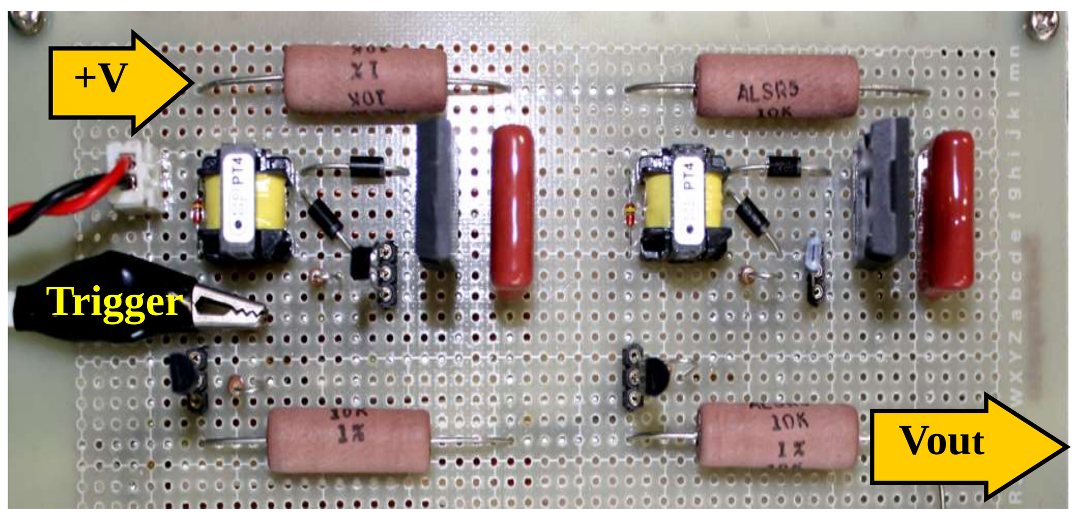


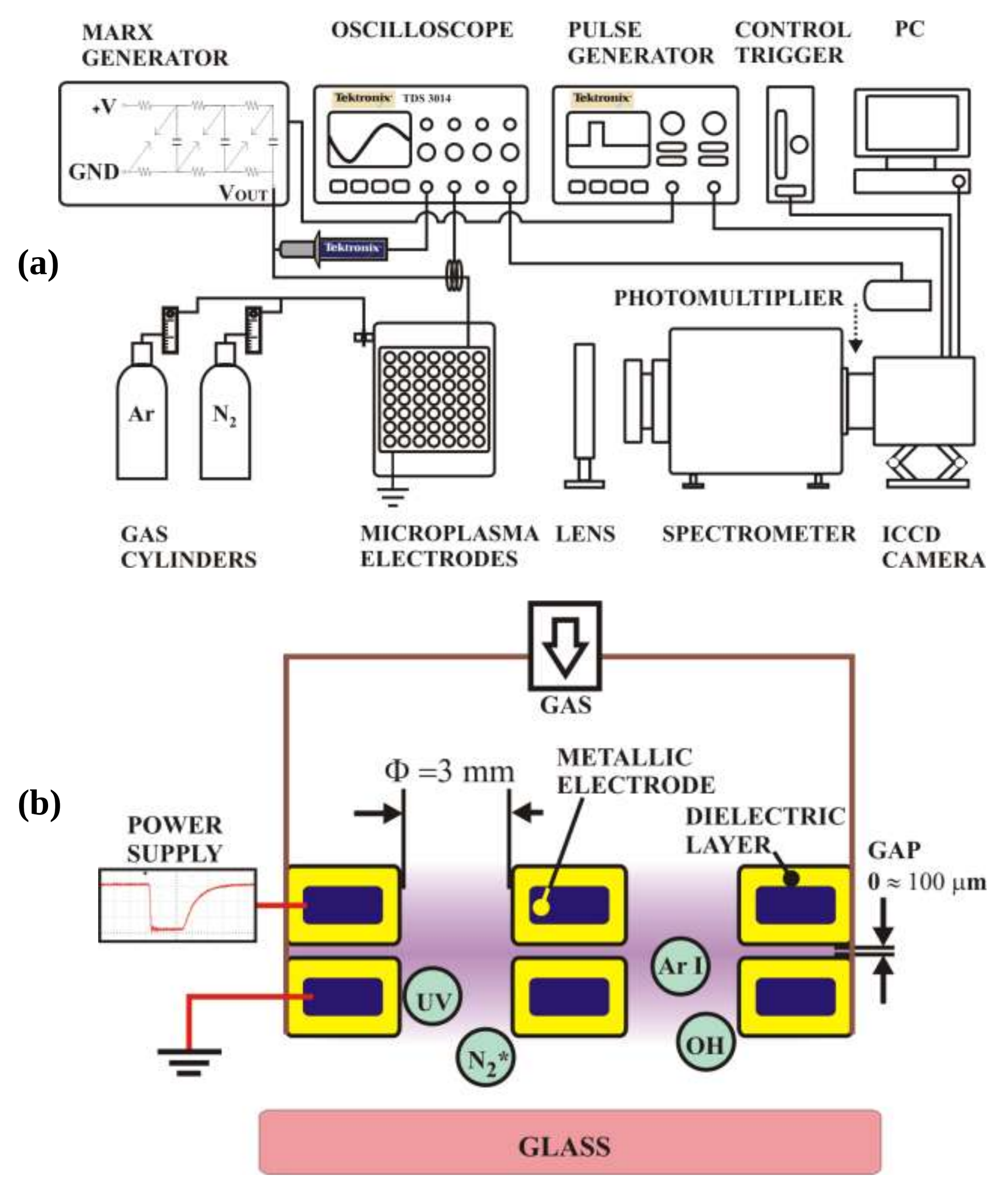
Photo of negative pulse Marx Generator.

(3) Experimental setup

Emission spectrum was measured by a spectrometer, an ICCD camera and a photomultiplier tube.

A microplasma enclosed reactor was used for surface treatment of glass. A contact angle meter was used to measure the contact angle of a water droplet at the surface of glass.

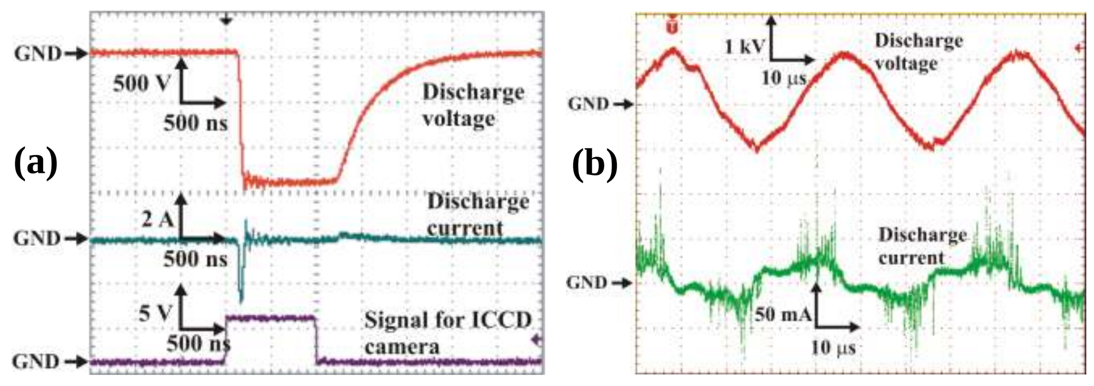
Gas flow rate: Ar and N_2/Ar at 10 L/min.



Experimental setup: (a) emission spectroscopy; (b) surface treatment.

(4) Electrical Characteristics

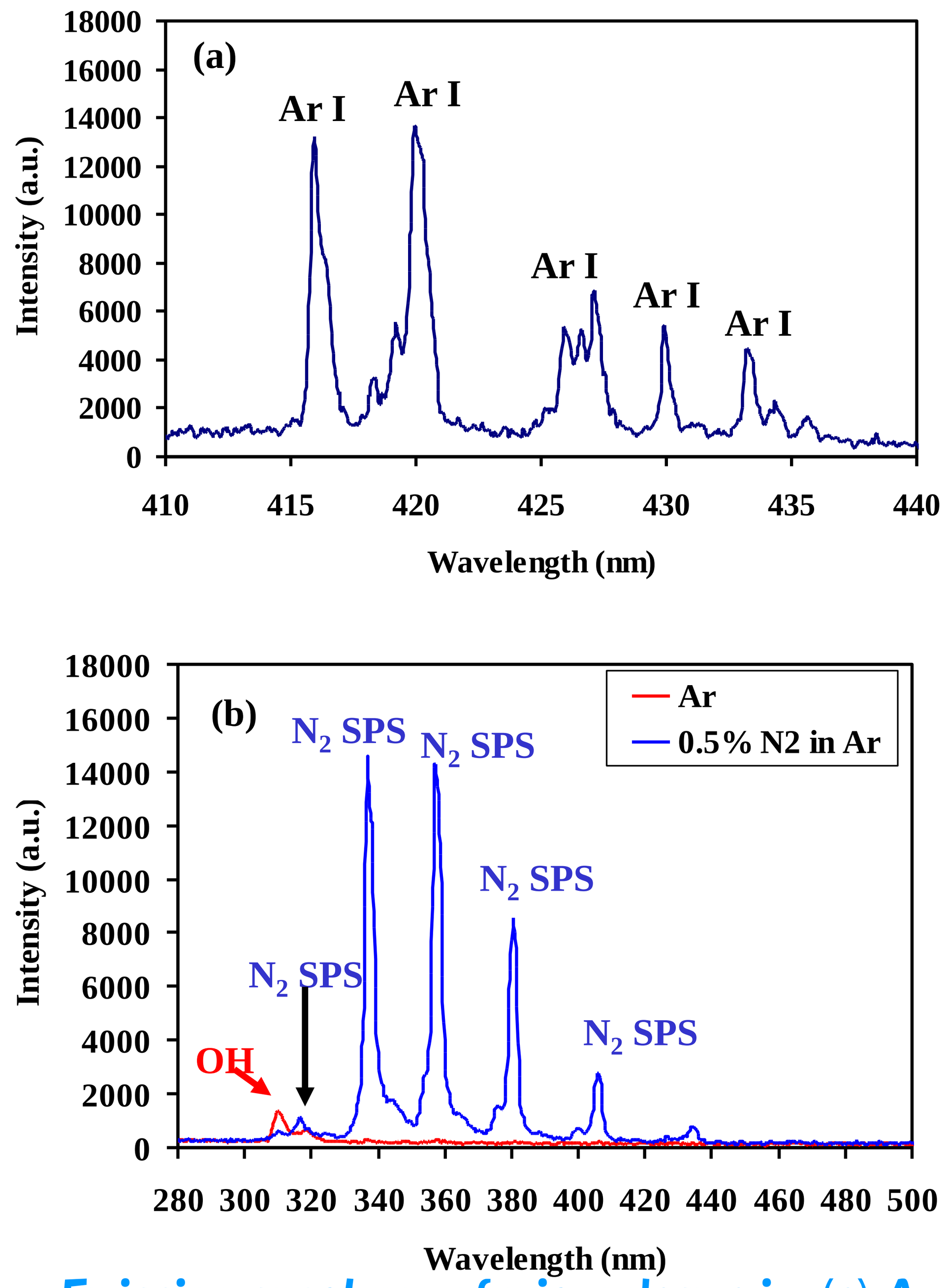
Very small discharge gaps and relatively *low discharge voltages* (about 1 kV)
⇨A *high intensity electric field* (10^7-10^8 V/m) assures the formation of microplasma and a corresponding discharge current.



Waveforms of the discharge voltage, corresponding discharge current and gate signal for ICCD camera: (a) Marx Generator; (b) Neon transformer.

Emission Spectroscopy

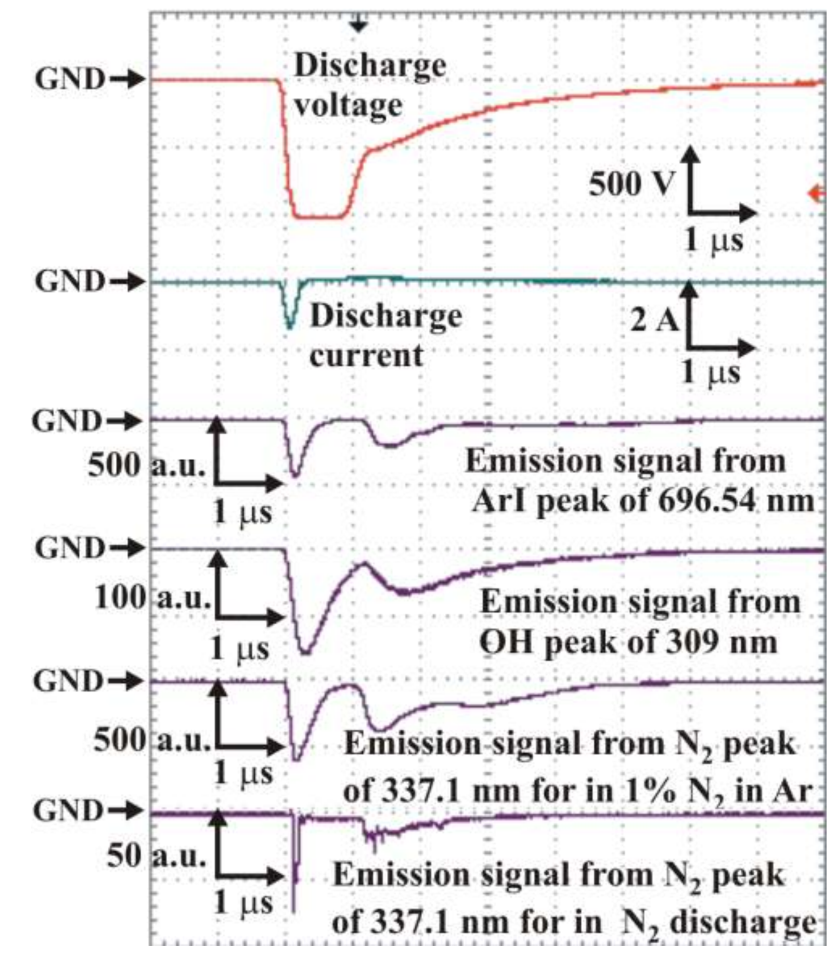
Emission spectrum was measured with camera shutter opened for *1 μs*.



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.**
- ***N_2^+ first negative band system peak*** **at 391.4 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:
$N_2(C^3\Pi_u)_{v'=0} \rightarrow N_2(B^3\Pi_g)_{v''=0} + h\nu$



Waveform of the discharge voltage, discharge current and emission signal of microplasma discharge in 1% N_2 in Ar and in N_2.

Lifetime emission signal of *N_2 SPS* peak at 337.1 nm increased *from 60 ns to about 500 ns* when 1% N_2 was added in Ar.

Vibrational temperature was Tvib=3160 K.

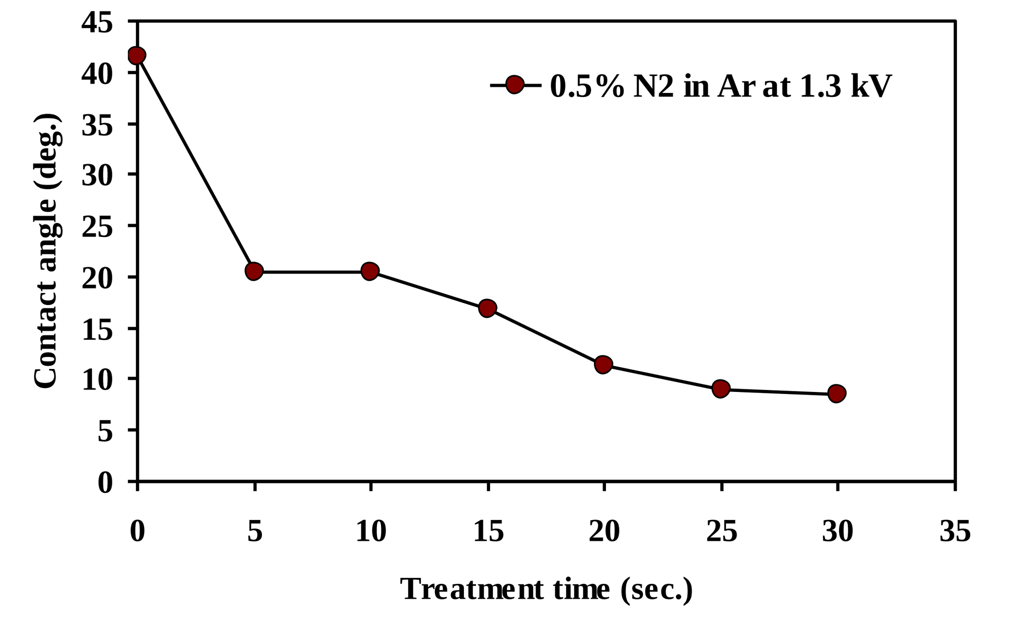
Electron temperature was Te = 23000 K.

Rotational temperature Tgas = Trot = 300 K.

⇨*Microplasma=Nonthermal plasma*

Surface Treatment of Glass

A neon transformer was used to energize the electrodes at *1.3 kV*. With the increase of treatment time the contact angle is decreasing from *41.5°* without treatment to *8.5°* after 30 seconds.



Contact angle of a water droplet at the surface of glass versus treatment time by microplasma discharge in 0.5 % N_2 in Ar.

Contact angle of a water droplet at the surface of glass before and after microplasma treatment..

Conclusions

- **Emission spectrum of microplasma shown intensity peaks of *N_2 SPS and N_2^+ FNS, OH and ArI*.**
- **Lifetime emission signal peak of the 337.1 nm N_2 SPS peak for microplasma in N_2 was *60 ns and about 500 ns* when 1% N_2 was added in Ar.**
- **Temperatures of microplasma: *Trot = 300 K; Tvib = 3160 K; Te = 23000 K* ⇨ this technology could be applied for the surface modification due to its low gas temperature and molecular excitation ability obtained at about 1 kV.**
- **The contact angle of a water droplet at a surface of the glass panel decreased after microplasma treatment from *41.5°* to *8.5°* after 30 seconds. This recommends microplasma as a solution for the surface treatment of glass panels used in electronic industry.**