

Emission spectroscopy of microplasma for the surface treatment of glass

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Introduction

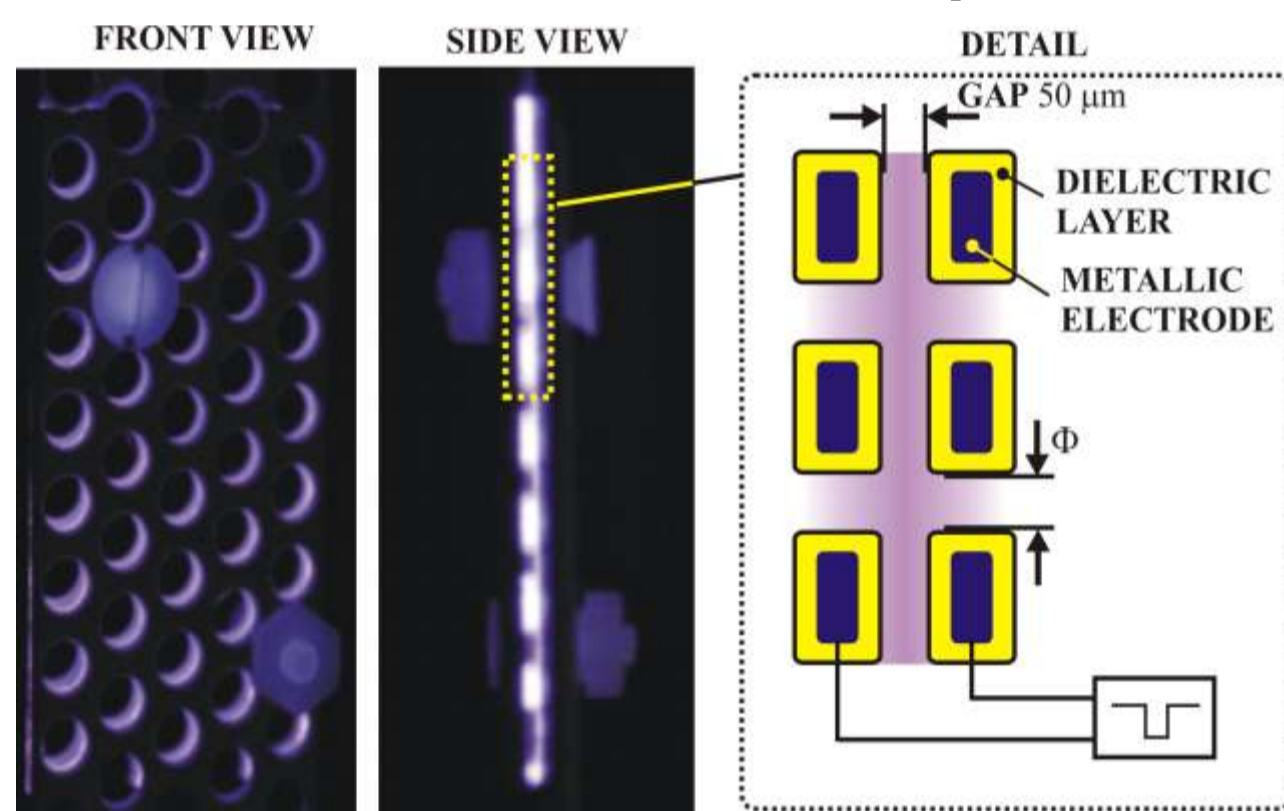
Microplasma can be found in many applications. In the last years, the technology was used in applications such as NO_x removal, surface treatment and sterilization or inactivation of bacteria. Emission spectroscopy is one of the methods to analyze plasma process. The emission spectrum will allow the calculation of microplasma's electron, vibrational and rotational temperatures which due to the particularities of microplasma such as small discharge gap, can be measured only by these non invasive technique.

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.

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

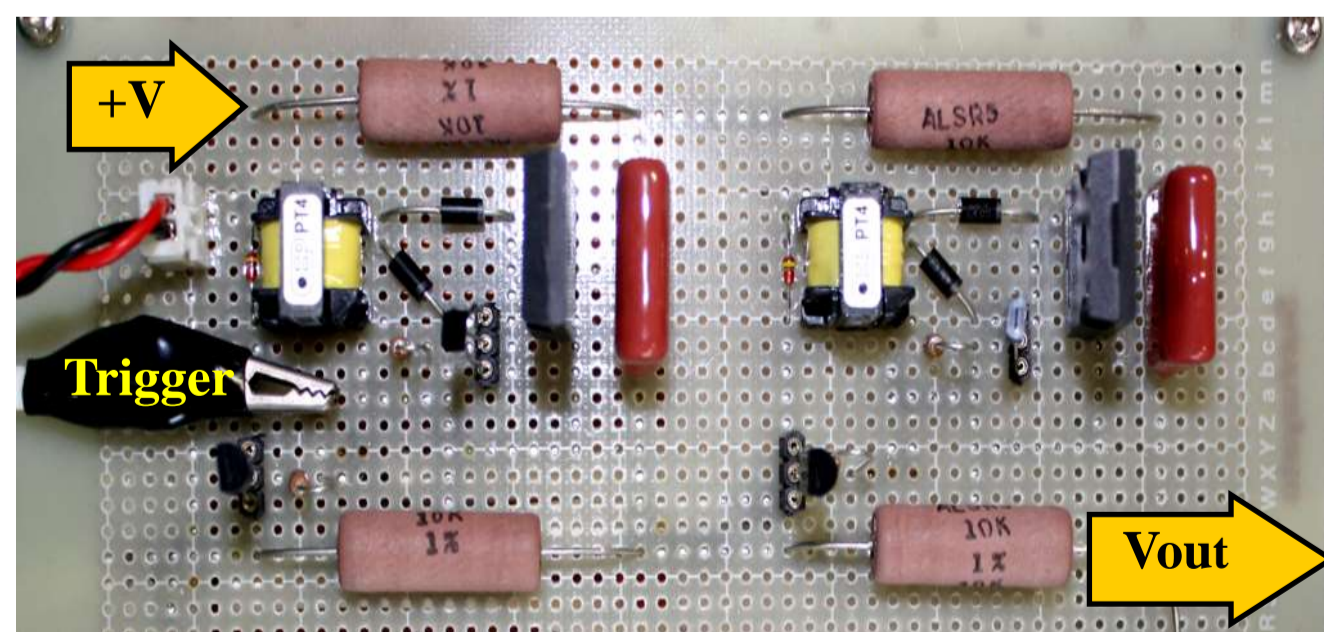


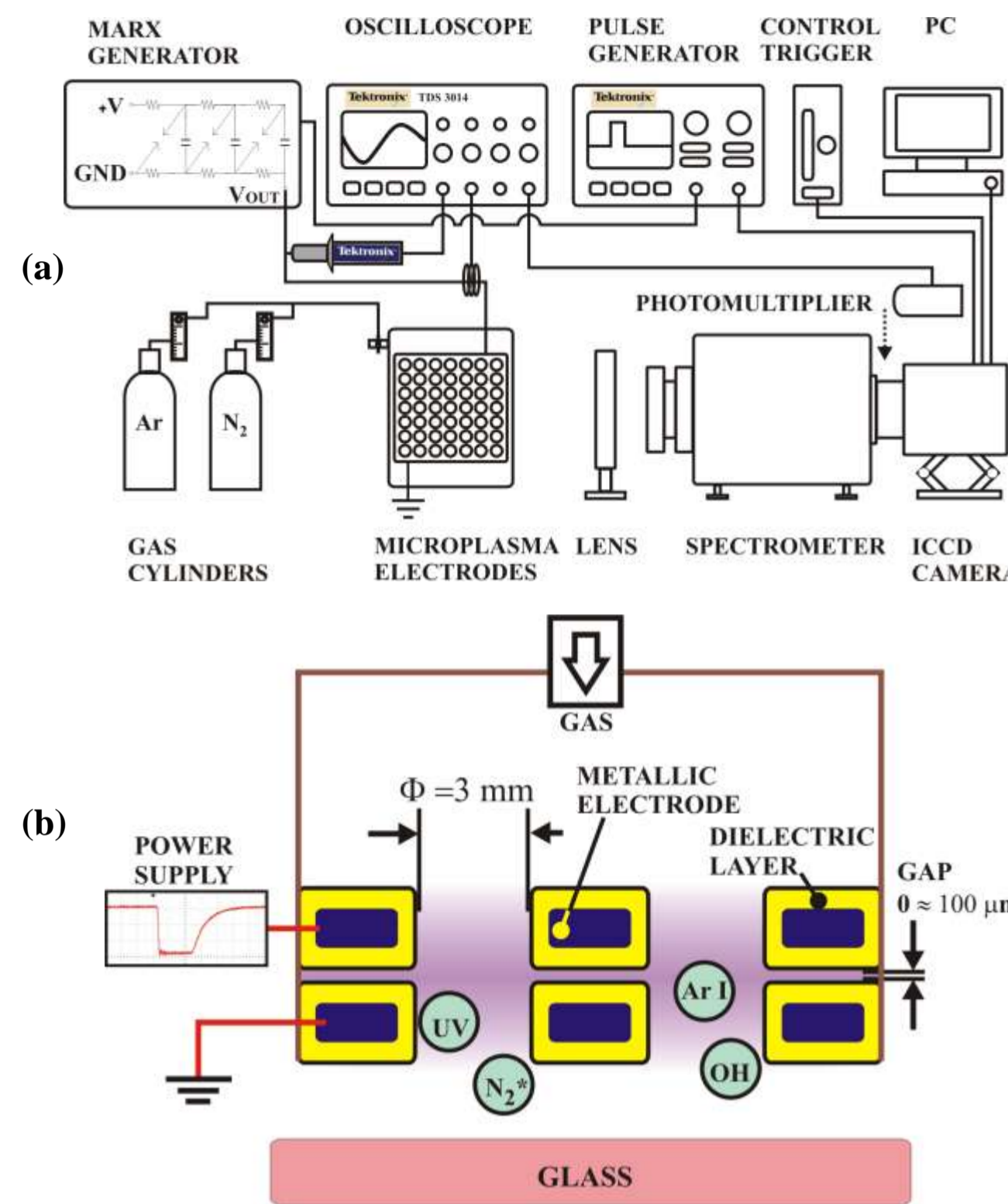
Photo of negative pulse Marx Generator.

(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 N₂/Ar at 10 L/min.

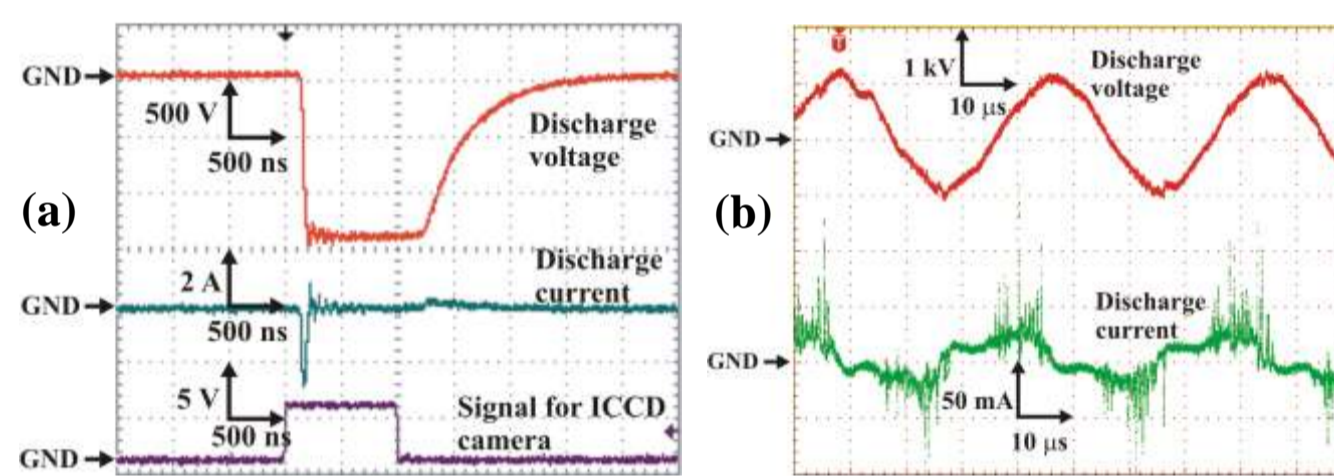


Experimental setup: (a) emission spectroscopy; (b) surface treatment.

(4) Electrical Characteristics

Very small discharge gaps and relatively **low discharge voltages** (about 1 kV)

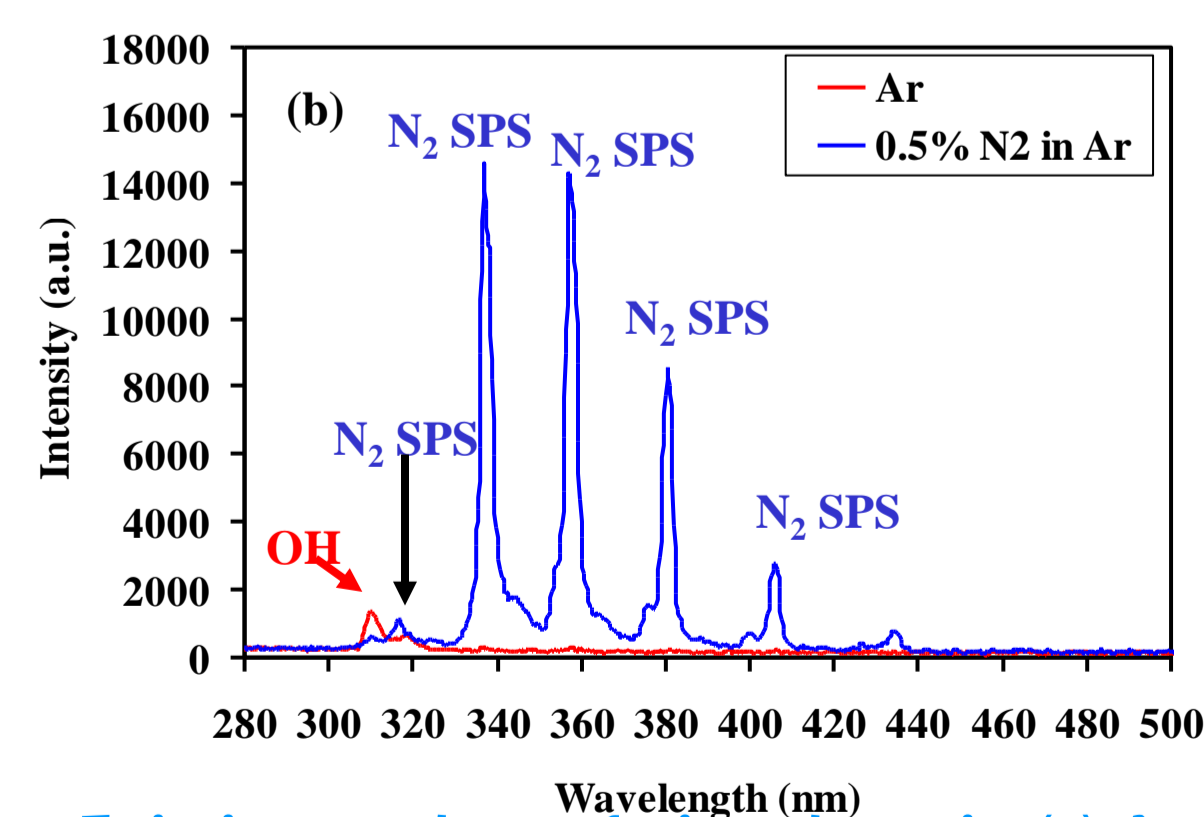
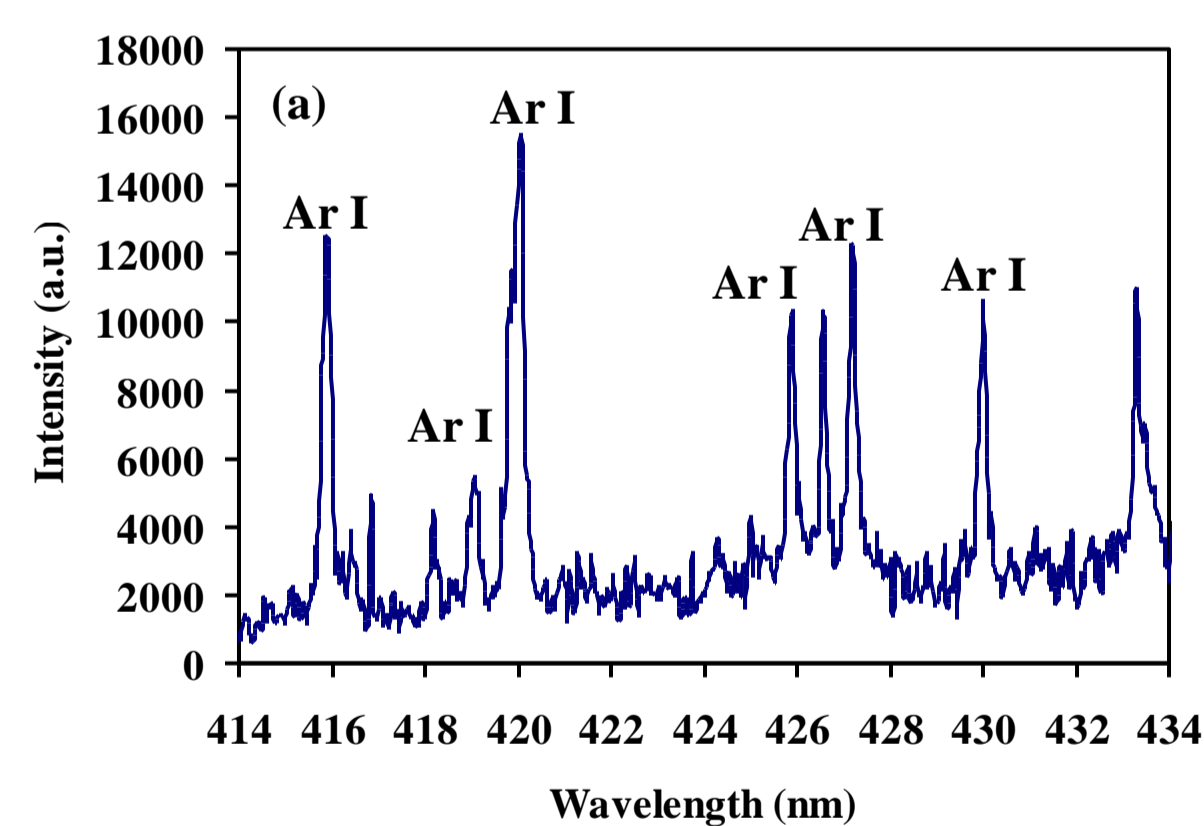
⇒ A **high intensity electric field** (10^7 - 10^8 V/m) assures the formation of microplasma and a corresponding discharge current.



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**.

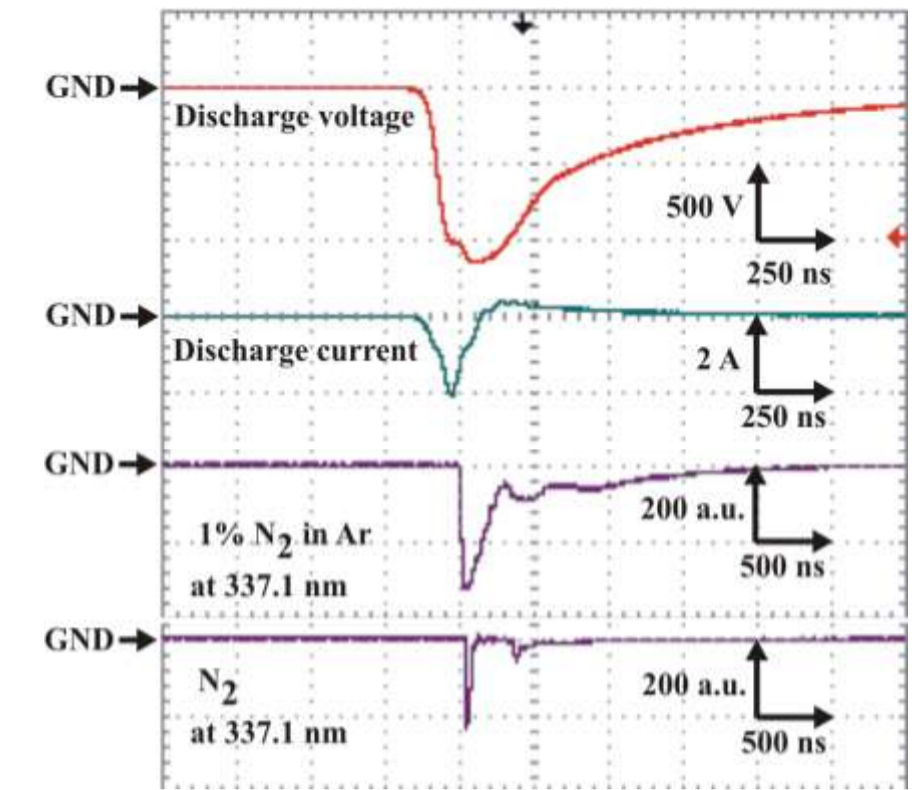
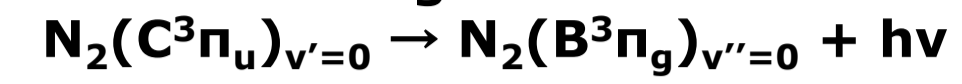


Emission spectrum of microplasma in: (a) Ar; (b) N₂/Ar at -1.2 kV.

Emission spectrum in Ar and Ar/N₂ shows:

- N₂ second positive band system peaks at 315.9, 337.1, 357.7, 380.4, 400 and 405 nm.
- N₂⁺ 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.

N₂ molecules excited argon neutrals and reaction in argon plasma with N₂ addition: Ar* + N₂(X¹Σ_g⁺)_{v=0} → N₂(C³Π_u)_{v'=0} + Ar Spontaneous radiation of formed excited state of nitrogen:



Waveform of the discharge voltage, discharge current and emission signal of microplasma discharge (337.1 nm) in 1% N₂ in Ar and in N₂.

Lifetime emission signal of N₂ SPS peak at 337.1 nm increased from 40 ns to 260 ns when 1% N₂ was added in Ar.

Vibrational quantum number difference Δv=v'-v''=-2 was chosen to determine the vibrational temperature of N₂(C). The value of vibrational temperature was Tvib=3160 K.

Electron temperature was calculated using line to continuum ratio of Ar I peak at 430 nm: Te = 23000 K.

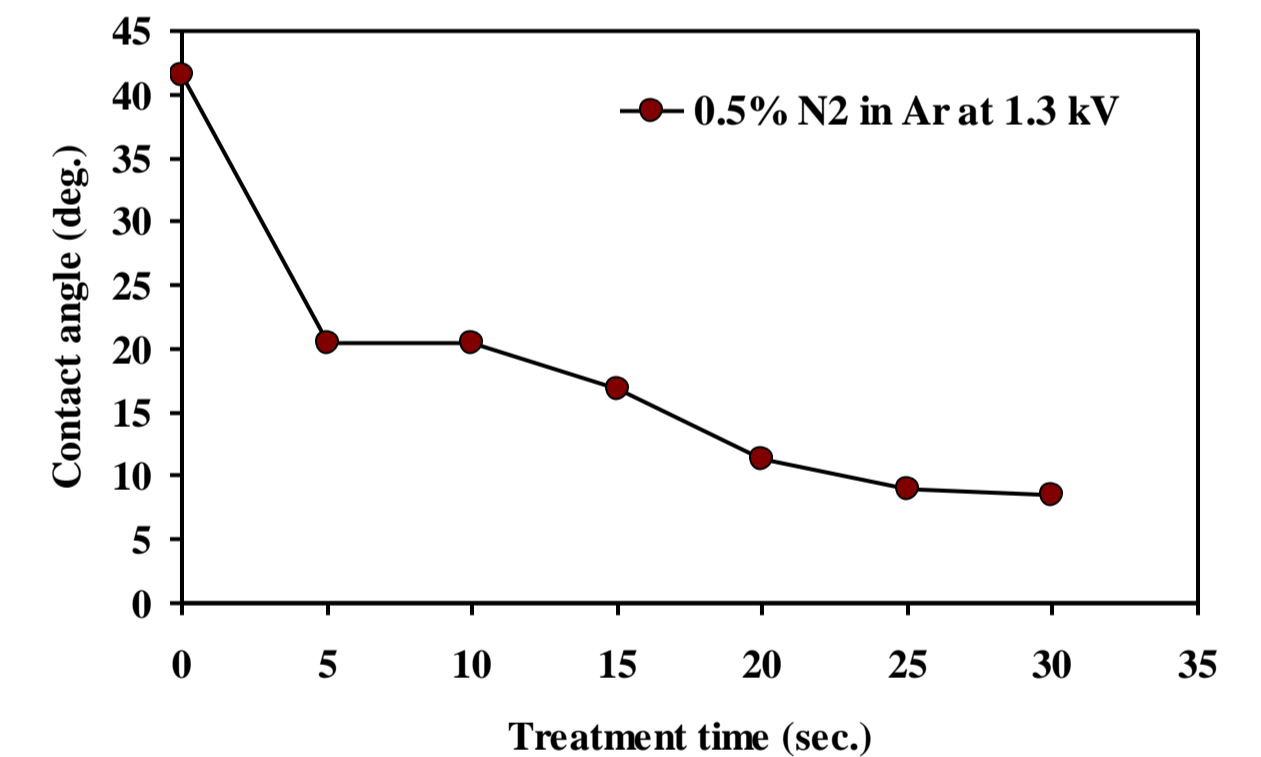
LIFBASE software was used for the calculation of the rotational temperature.

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% N₂ 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 N₂ SPS and N₂⁺ FNS, OH and Ar I.

•Lifetime emission signal peak of the 337.1 nm N₂ SPS peak for microplasma in N₂ was 40 ns and 260 ns when 1% N₂ 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 in electronic industry.