NOx Removal Processes by Microplasma Generation in Multiple Electrode Configuration

M. Blajan, M. Kanamori, H. Mimura, K. Shimizu,

Innovation and Joint Research Center, Shizuoka University,

3-5-1 Jyouhoku, Hamamatsu, 432-8561, Japan

E-mail : blajanmarius@yahoo.com

Introduction

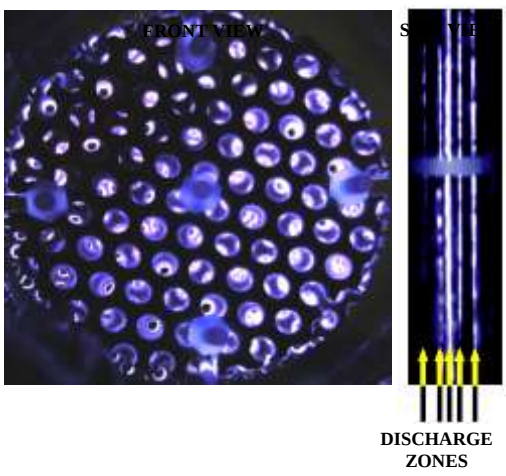
Nonthermal plasma was investigated in the decade as a solution to the environmental problems generated by the exhaust gases from factories, automobiles and other sources. High energy electrons and active species generated by non thermal plasma, could transform pollutants from exhaust gases in simpler compounds.

Microplasma is a nonthermal plasma at atmospheric pressure generated at very small discharge gaps and low discharge voltages. NOx removal from simulated exhaust gas is investigated by using microplasma.

Experimental Setup

(1)Microplasma Electrodes

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



Microplasma electrodes in multiple electrodes configuration

6 electrodes with Ø 42 mm faced together with a discharge gap of 0 μm ⇨ *5 discharge zones*.

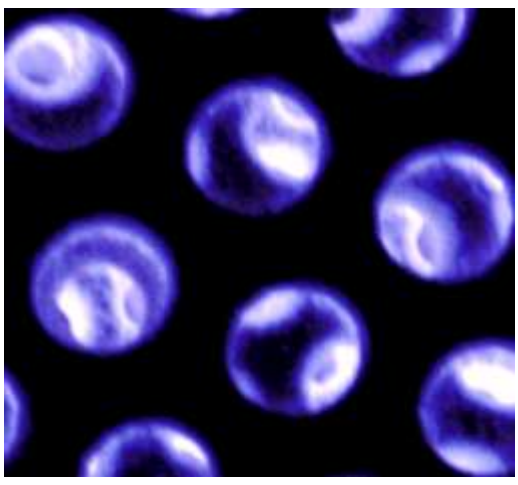
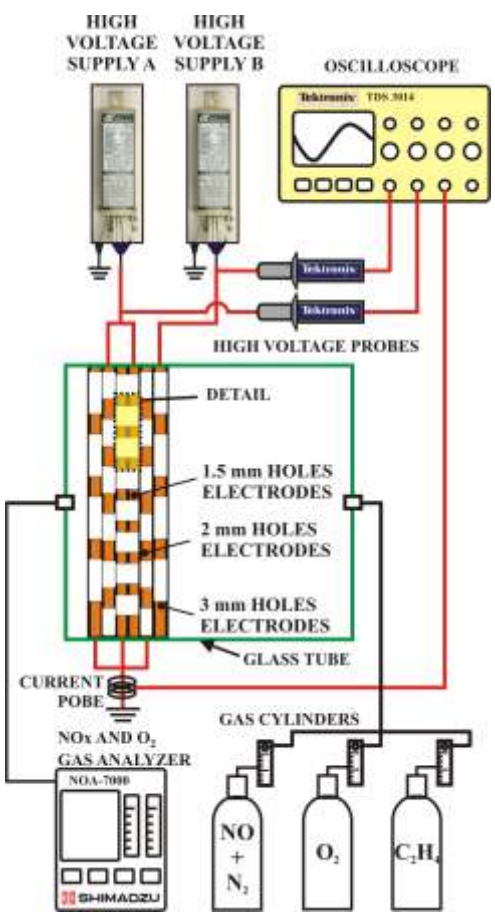


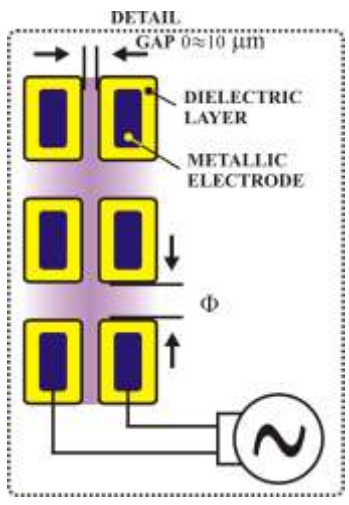
Photo of the microplasma discharge

(2) Experimental Setup

Three discharge zones are supplied with voltage from one power supply: *discharge voltage A*.
Two discharge zones are supplied from the second power supply: *discharge voltage B*.



Schematic view of microplasma electrodes and the supply circuit



Detail of microplasma electrodes

Two small size power supplies (LECIP, M-1H) to supply to the electrodes alternative voltages with frequencies around 25 kHz.

Discharge gas: NO 500 ppm, C_2H_4 3500 ppm, O_2 5% and N_2 balance.

Gas flow rate: 5 L/min.

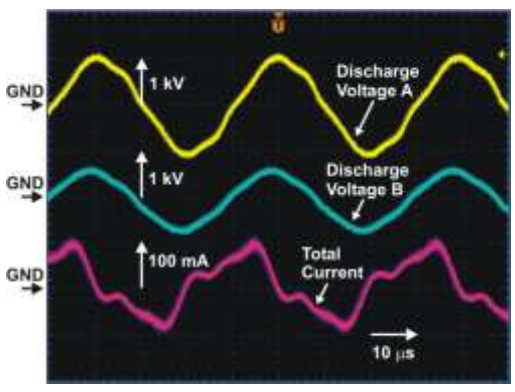
Aperture of electrodes:
•Middle pair1.5 mm holes
•Intermediate pair 2 mm holes
•Extremities 3 mm holes
⇨honeycomb like structure

The treated gas was analyzed by a NOx and O_2 gas analyzer (Shimadzu NOA-7000).

NOx Removal Processes

(1) 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 voltages and discharge current

(2) NOx Removal

The highest values were obtained at *1.2 kV discharge voltage A* and *1.2 kV discharge voltage B*:
•NOx removal 51 ppm
•NO removal 218 ppm
•Generated NO_2 171 ppm

NOx removal concentration, NO removal concentration and generated NO_2 concentration for different values of the discharge voltages

Discharge Voltage A (kV)	Discharge Voltage B (kV)	NO Removal Concentration (ppm)	NOx Removal Concentration (ppm)	NO_2 Concentration (ppm)
0.7	0.7	45	9	42
0.7	1.2	113	21	102
0.7	0.8	53	17	47
0.7	0.9	61	19	52
0.7	1	79	21	73
0.7	1.1	94	26	81
0.9	0.9	120	34	101
0.9	0.9	135	28	111
0.9	0.9	133	35	110
0.9	1.2	155	35	136
0.95	0.95	160	39	126
0.95	0.95	167	47	140
0.95	0.95	169	44	132
1.1	0.7	147	43	124
1.1	1.1	171	51	136
1.1	1.2	195	48	158
1.2	0.7	181	48	141
1.2	1.2	218	51	171

The dissociation energy for N_2 is 9 eV and for O_2 is 5-6 eV
⇨ with the increase of discharge voltage the NOx removal concentration will be higher:

$$e + N_2 \rightarrow e + N(^4S) + N(^2D)$$
$$NO + N(^2D) \rightarrow N_2 + O$$
$$e + O_2 \rightarrow e + O(^3P) + O(^1D)$$
$$O + O_2 + M \rightarrow O_3 + M$$
$$NO + O_3 \rightarrow NO_2 + O_2$$

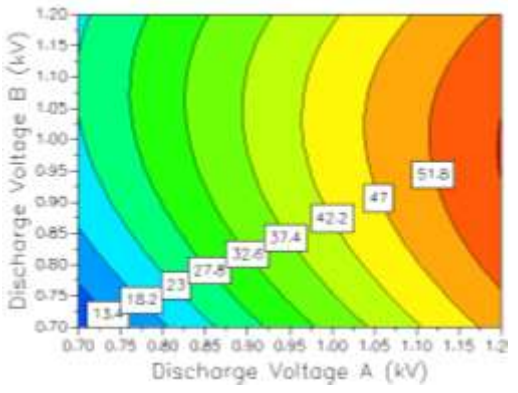
(3) Design of Experiments

The methodology of design of experiments proposes a *factorial experimentation* in which the factors

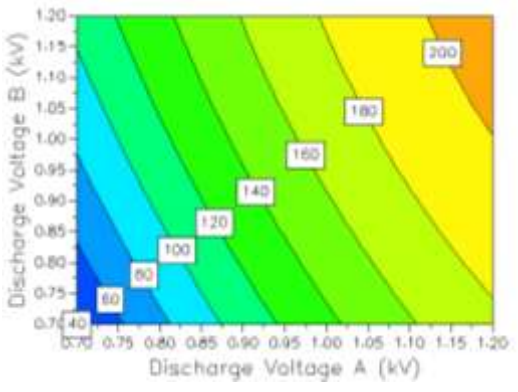
•Discharge voltage A

•Discharge voltage B

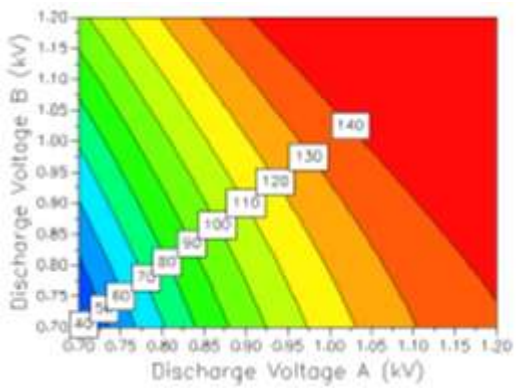
vary simultaneously.



Contour plot of the predicted response of NOx removal concentration



Contour plot of the predicted response of NO removal concentration



Contour plot of the predicted response of generated NO_2 concentration

Using MODDE 5.0 software the data were analyzed.

Larger microplasma area powered by high voltage power supply A:

⇨optimal predicted value of *NOx removal concentration*: *1.2 kV for discharge voltage A* and *1 kV for discharge voltage B*.

⇨optimal predicted value of *NO removal concentration*: *1.2 kV for discharge voltage A* and *1.2 kV for discharge voltage B*.

⇨optimal predicted value of *generated NO_2 concentration: 1.2 kV for discharge voltage A* and *0.95 kV to 1.2 kV for discharge voltage B*.

Conclusions

•As the *discharge voltages were increased* the *NOx removal* concentration, *NO removal* concentration and *generated NO_2* concentration *increased*.

•Design of experiments software analysis shows that with the *increase of both discharge voltages higher values of the NOx and NO removal* concentrations and *generated NO_2* concentration are *obtained*.