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Emerging Applications of Plasma Science and Technology
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Recent Developments in Atmospheric Pressure Plasma for Gas Treatment

DUY TÂN UNIVERSITY

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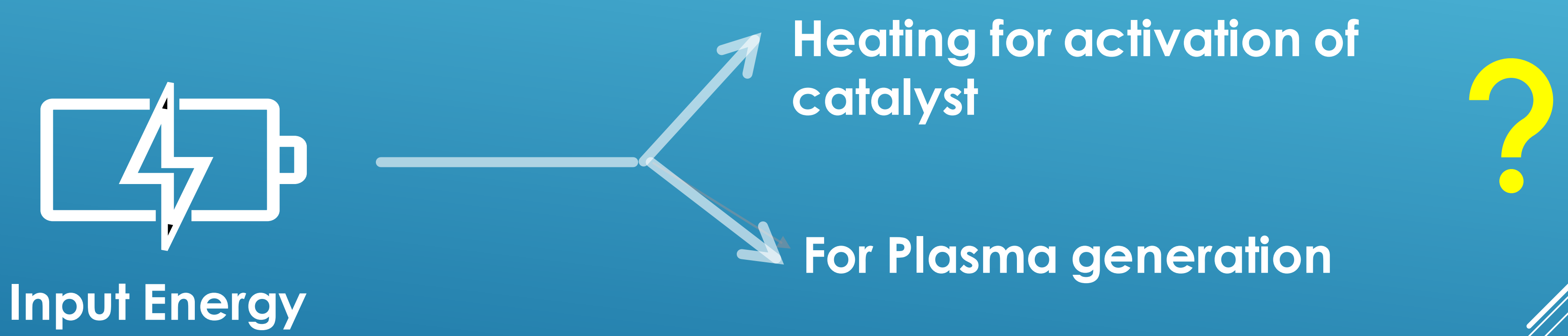
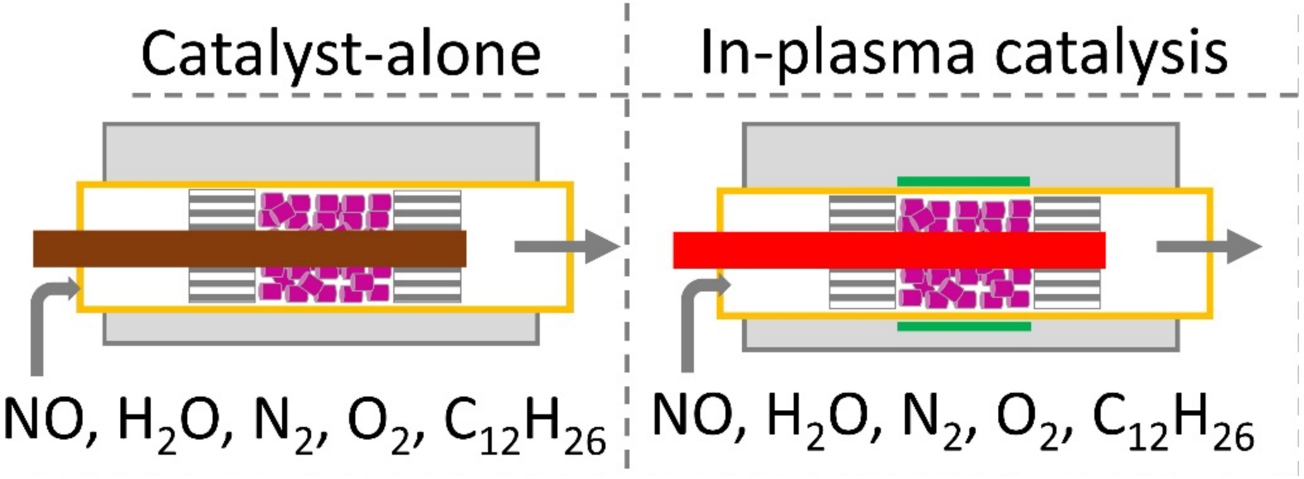
Outlines

- ❑ Synergetic plasma catalyst
- ❑ Enhancing dry reforming to syngas by liquid insulator
- ❑ Honeycomb plasma discharge with water vapor
- ❑ Application of Honeycomb Discharge for Environmental Applications
- ❑ Plasma Injection method for NO_x removal

1. Synergetic plasma catalyst



Synergetic plasma catalyst for NO_x removal



Input energy used to

Plasma generation

Heating gas from 200℃

Removal efficiency = f (Temperature; SEI)

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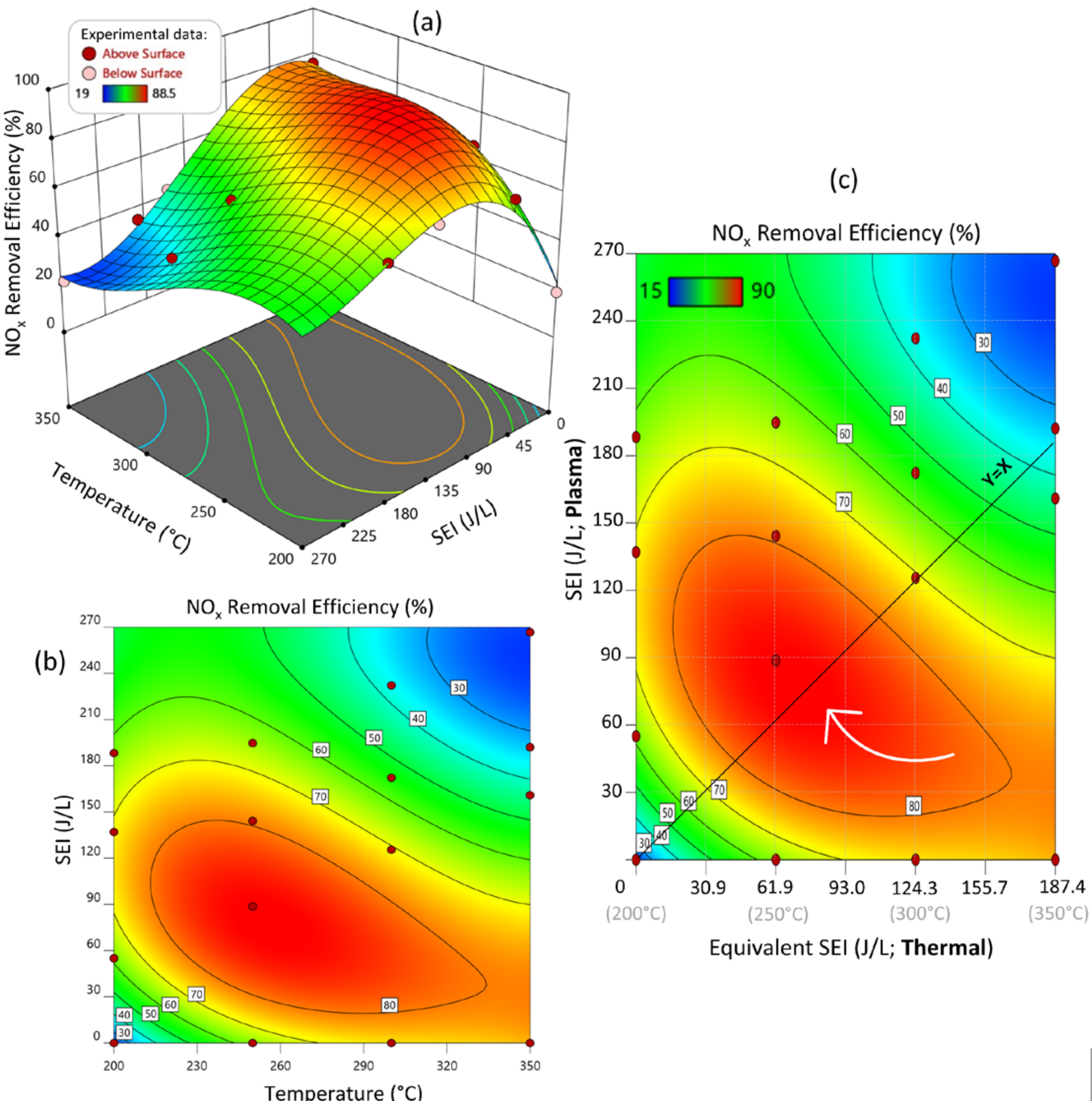
Synergetic plasma catalyst for NO_x removal

Energy use for:
Plasma generation > thermal catalyst

Fig. Removal Efficiency of NO_x with in-plasma catalysis process under various temperature and SEI (a) surface response and (b) contour, and (c) a correlative energy consumption between plasma and thermal catalyst process on the NO_x removal efficiency



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Synergetic plasma catalyst for acetaldehyde removal

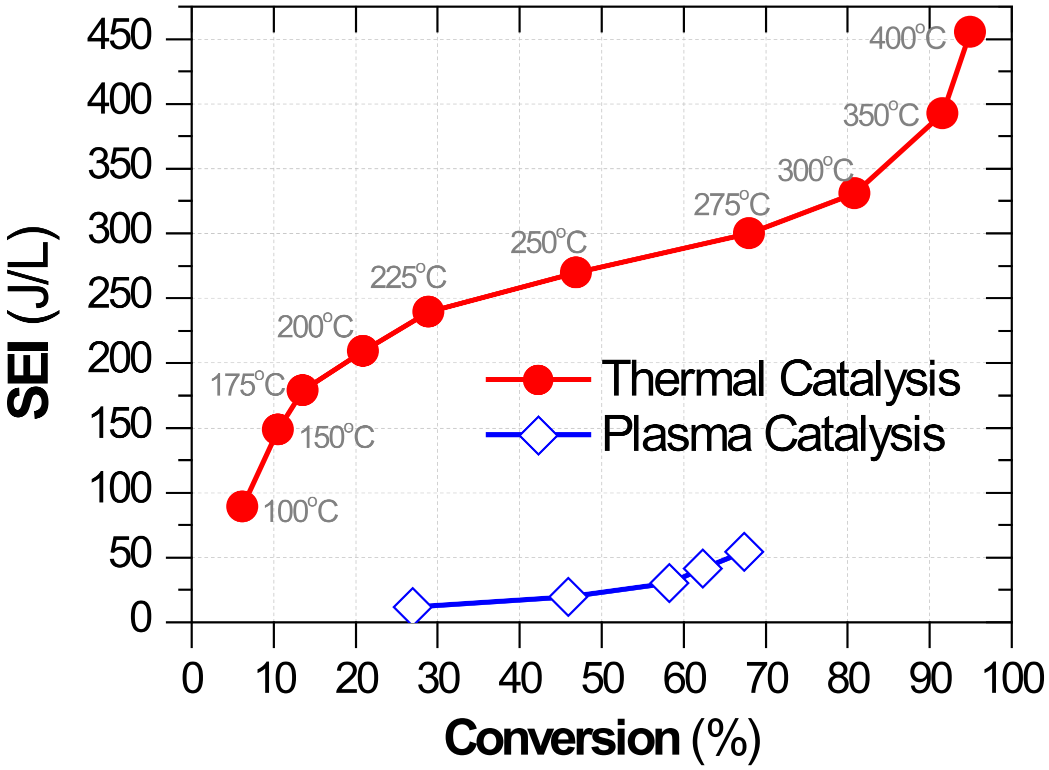

Fig. A Comparison between thermal catalytic activity and plasma for acetaldehyde conversion based SEI consumption (GHSV = 10,600 h^{-1}; water amount =2.5%; C_2H_4O inlet = 5 ppm).

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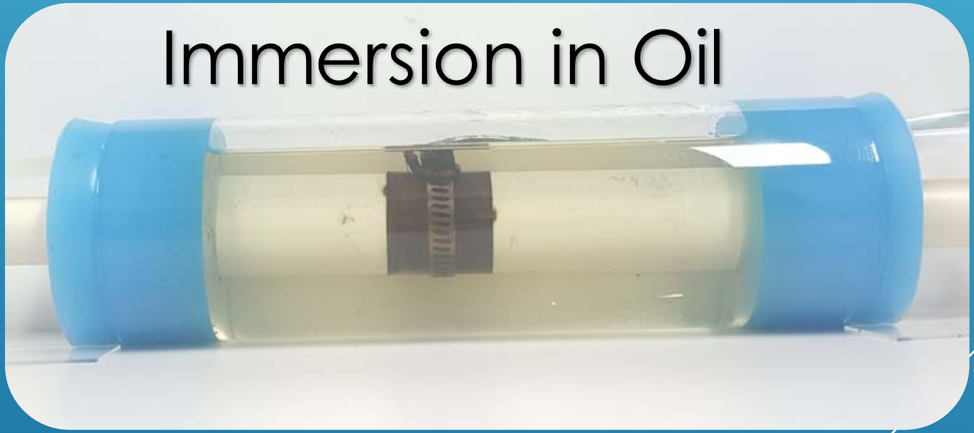
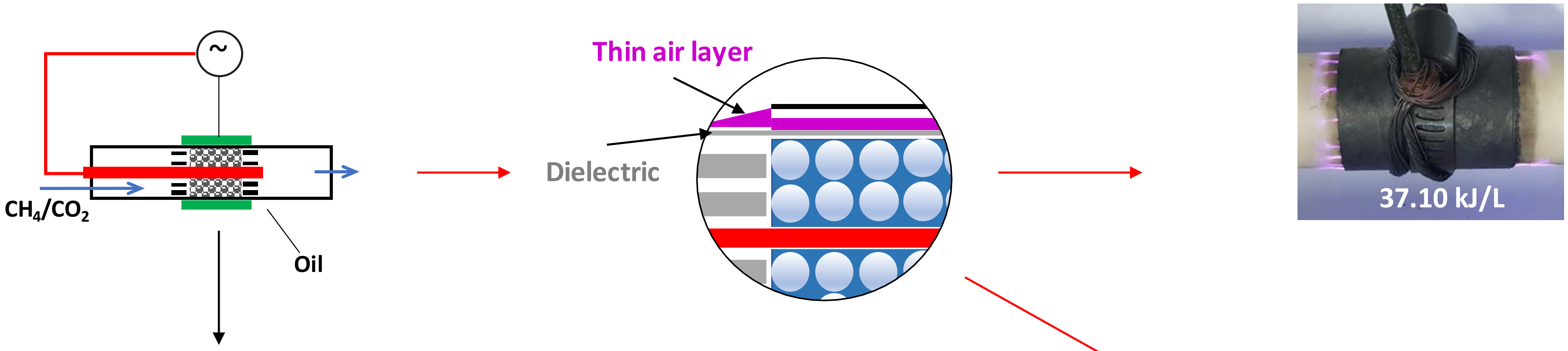
2. Enhancing dry reforming to syngas by liquid insulator



Issues with conventional DBD

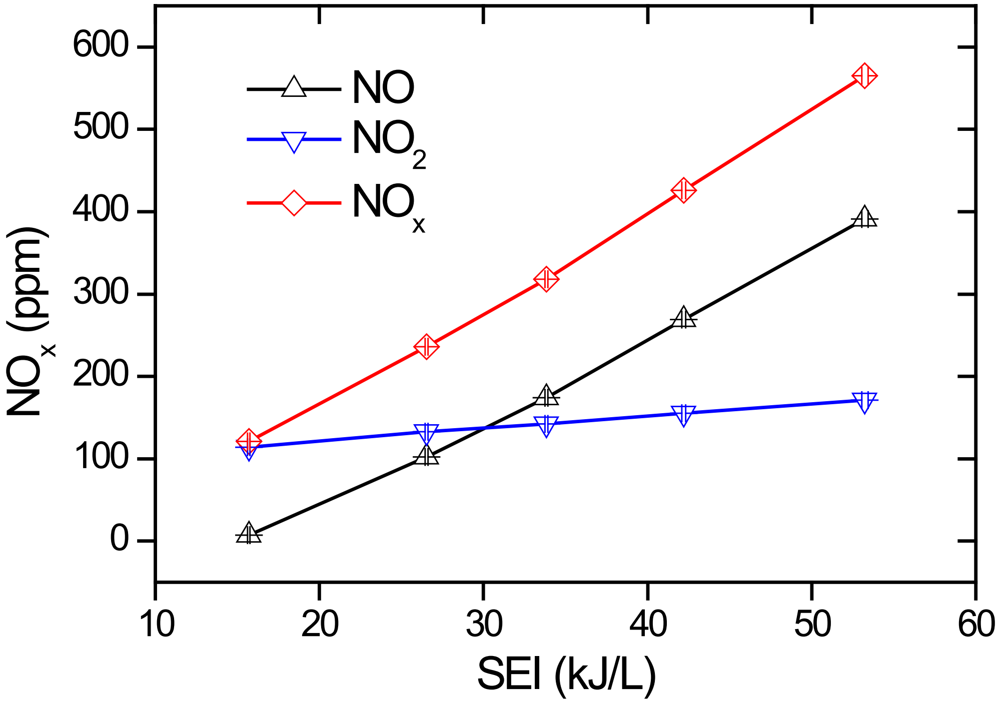


Ground electrode materials

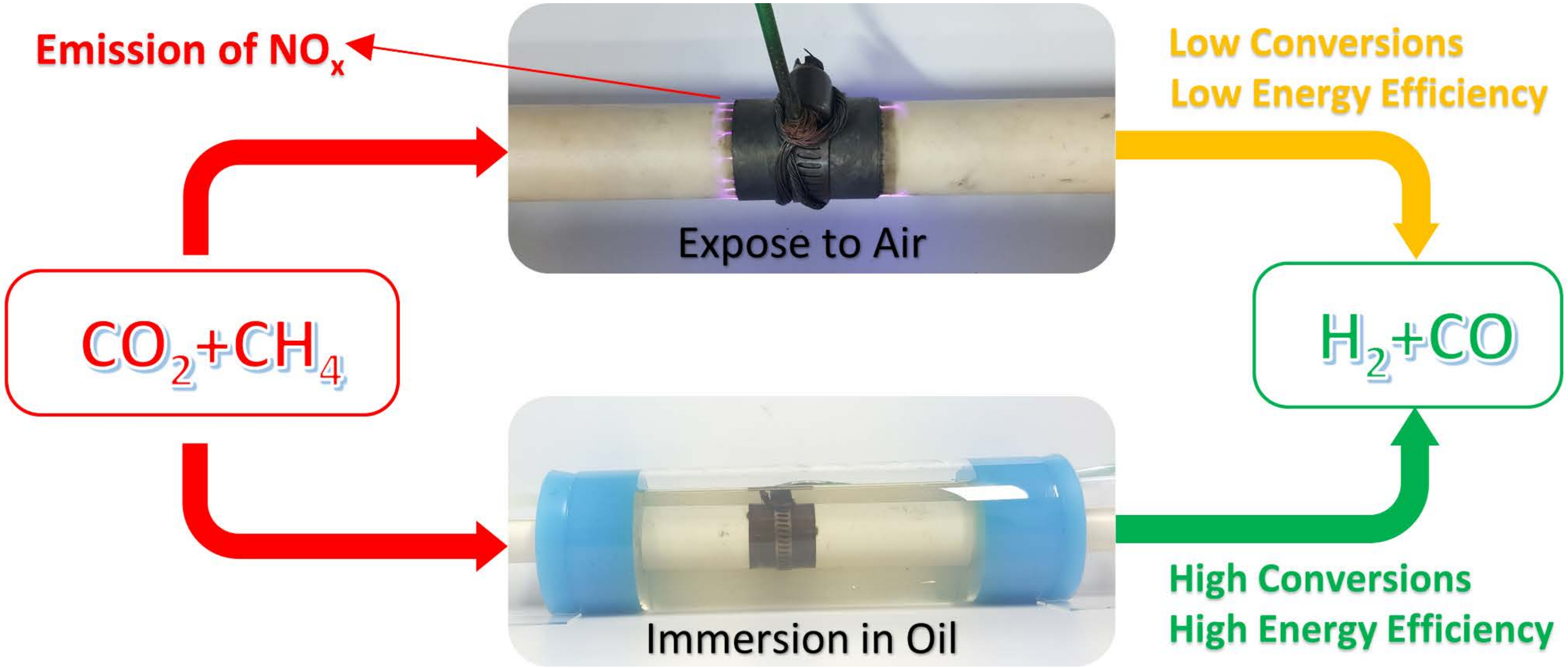
Metal sheet Mesh sheet Metal wire

Emission of NO_x and O_3

Fig. Generation of nitrogen oxides (NO and NO_2) by micro-discharge surrounding ground electrode and its pictures under various SEI (frequency = 30 kHz; duty cycle = 20%; total flow rate = 100 mL/min; CH_4/CO_2 = 1/1; gas pump for NO_x analyzer = 1.5 L/min).

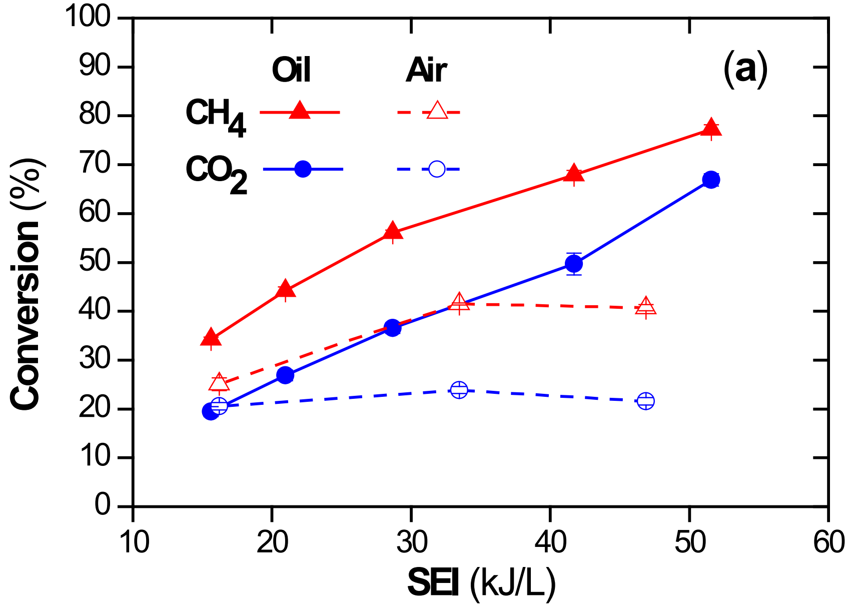


Plasma reactor immersed in oil

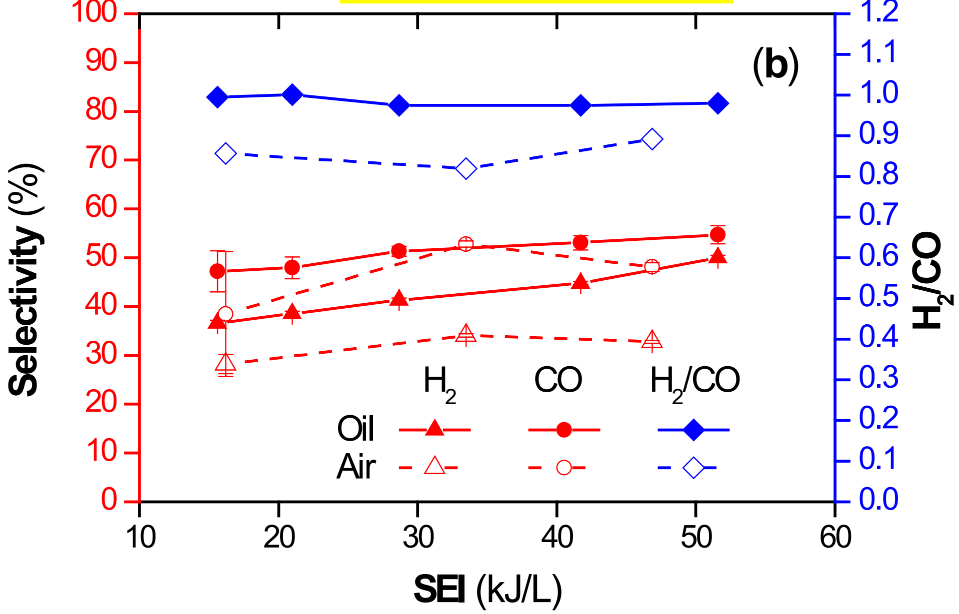


Enhancing plasma catalyst reaction

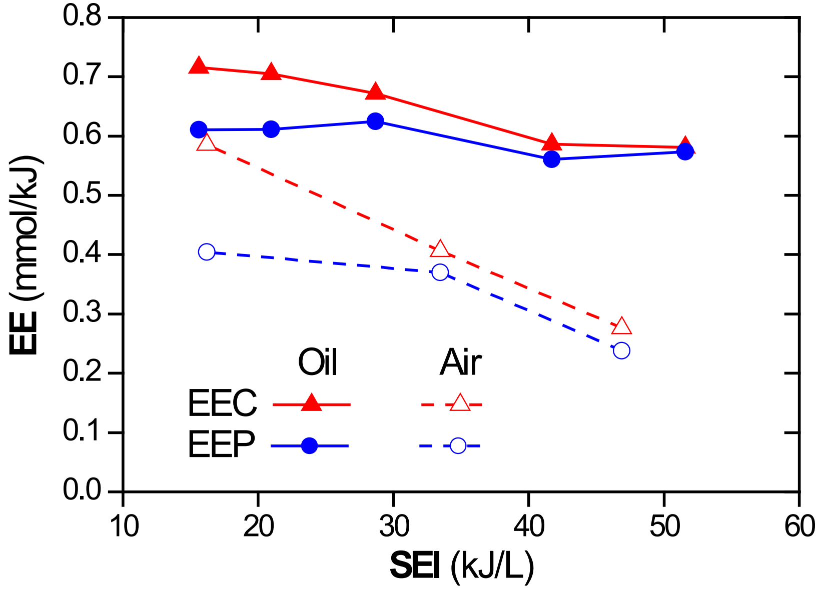
Conversion



Products selectivity



Energy efficiency



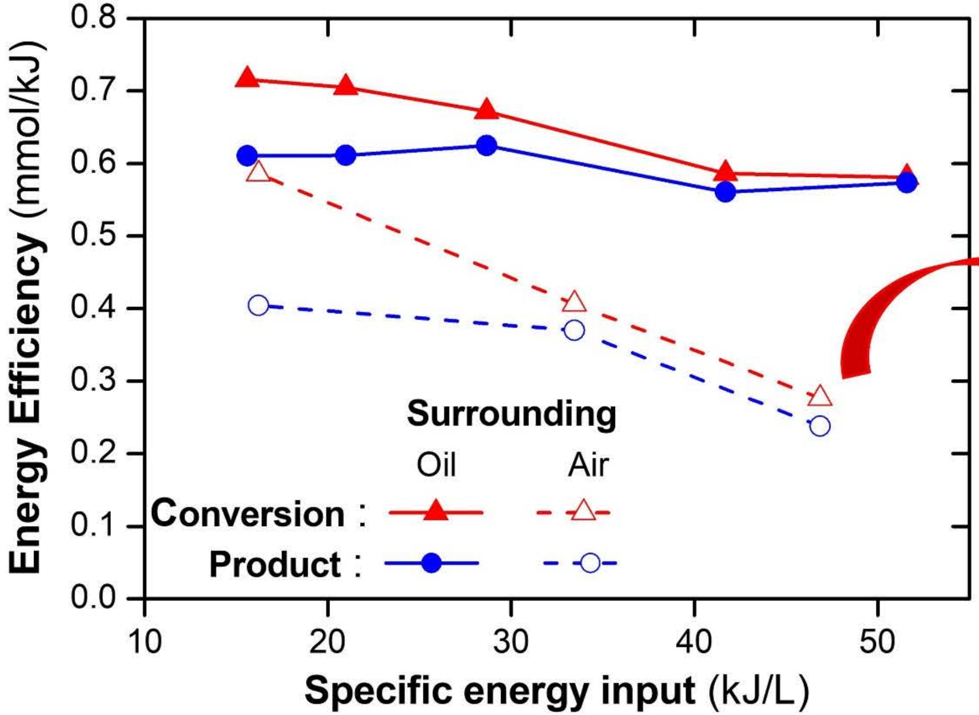
Comparison

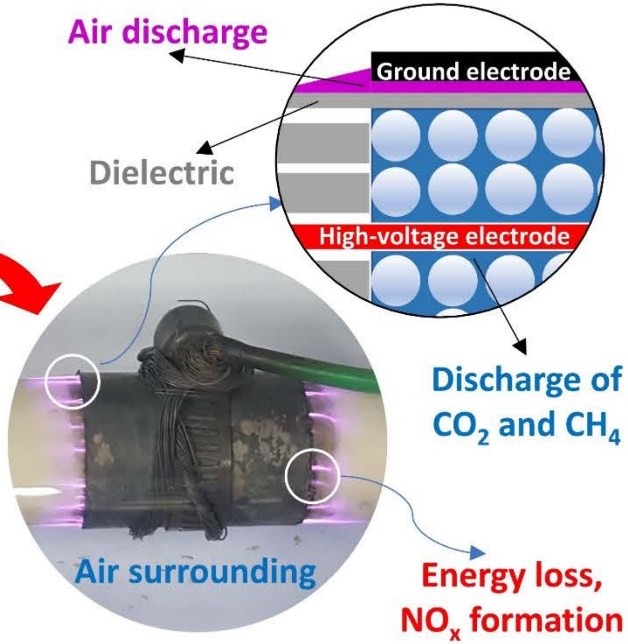
Table . Comparison of conversion and energy efficiency of plasma/plasma-catalytic reforming of CH_4 with CO_2

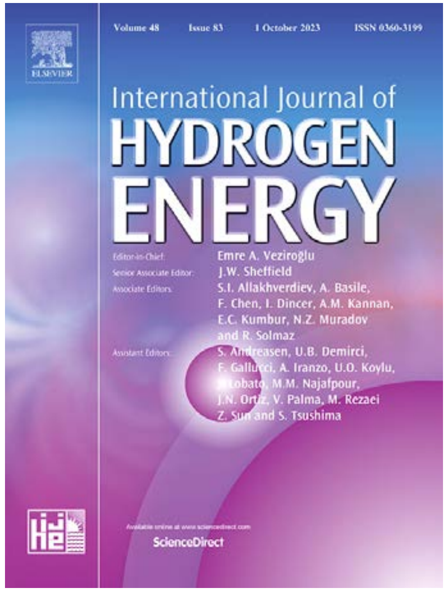
Ref.	Conditions			SEI	Flow rate	Conv. (%)		EEC (mmol/kJ)	Carrier gas
	Catalyst	Ambient	Voltage waveform	(kJ/L)	(mL/min)	CH_4	CO_2		
[44]	Ni/γ-Al_2O_3	Air	Sinusoidal	3.3	250	12	10	0.22	83.68% Ar
[45]	Non	Air	Sinusoidal	176	30	70	30	0.12	Non
[20]	Non	Air	Sinusoidal	18	100	15	6	0.19	Non
	Non	Air	Sinusoidal	144	25	50	30	0.10	Non
	10 wt% Ni/γ-Al_2O_3	Air	Sinusoidal	60	50	56.4	30.2	0.33	Non
[26]	Non	Air	Quasi-pulse	29	40	66	47	0.81	Non
	$BaFe_{0.5}Nb_{0.5}O_3$	Air	Quasi-pulse	34	40	70	51	0.72	Non
[29]	Non	Air	Sinusoidal	36	25	35		0.20	Non
[46]	Non	Air	Sinusoidal	192	50	50	40	0.10	Non
	Non	Air	Sinusoidal	96	100	30	30	0.13	Non
	$LaNiO_3/SiO_2$	Air	Sinusoidal	96	100	50	45	0.21	Non
	$LaNiO_3/SiO_2$	Air	Sinusoidal	192	50	70	60	0.14	Non
[42]	Non	Air	Sinusoidal	370	24	74	68	0.08	Non
[21]	Glass	Air	Sinusoidal	6	20	10.5	7.5	0.16	50% He
[28]	Non	Air	Sinusoidal	1.4	120	15	7	0.20	93.75% Ar
[22]	Non	Oil	Pulse	219	80	69	47	0.11	Non
This work	5 wt% Ni/α-Al_2O_3	Oil	Pulse	52	100	77	67	0.58	Non

Note: Several conversion values estimated from figures in the reference and used to calculate EEC; CH_4/CO_2 in feed of 1/1.

Enhancing plasma/plasma catalyst process by the immersion oil

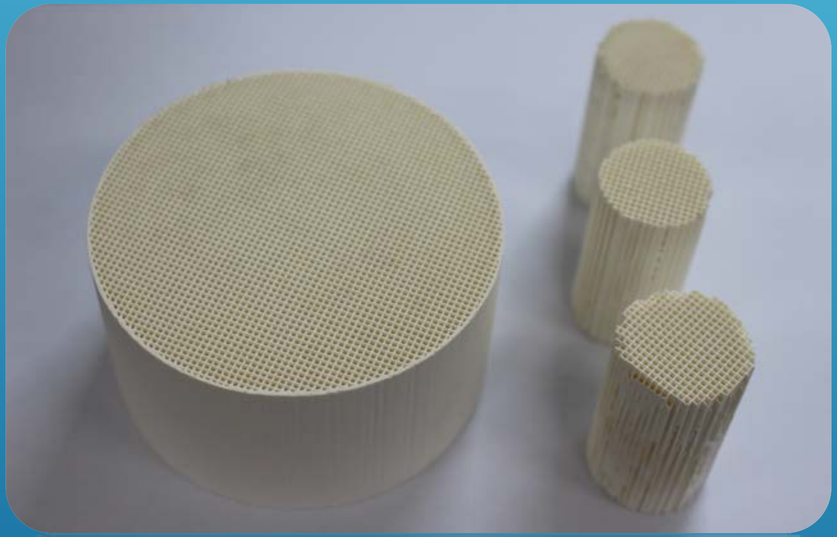


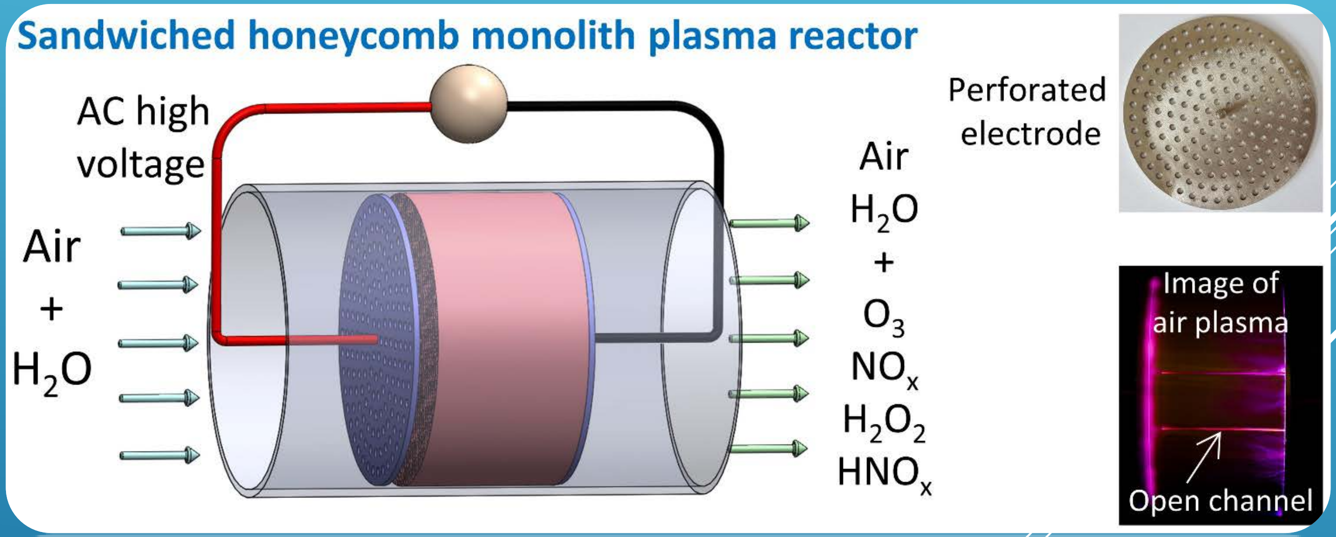




Int. J. Hydrogen Energy
45 (2020) 18519-18532

III. Honeycomb plasma discharge with water vapor





Challenges in indoor and diesel exhaust gas treatment

- ❖ Large volume gas requires treatment
- ❖ Contents water vapor

Atmospheric conditions

Diesel exhaust gas

Role of honeycomb monolith for plasma generation

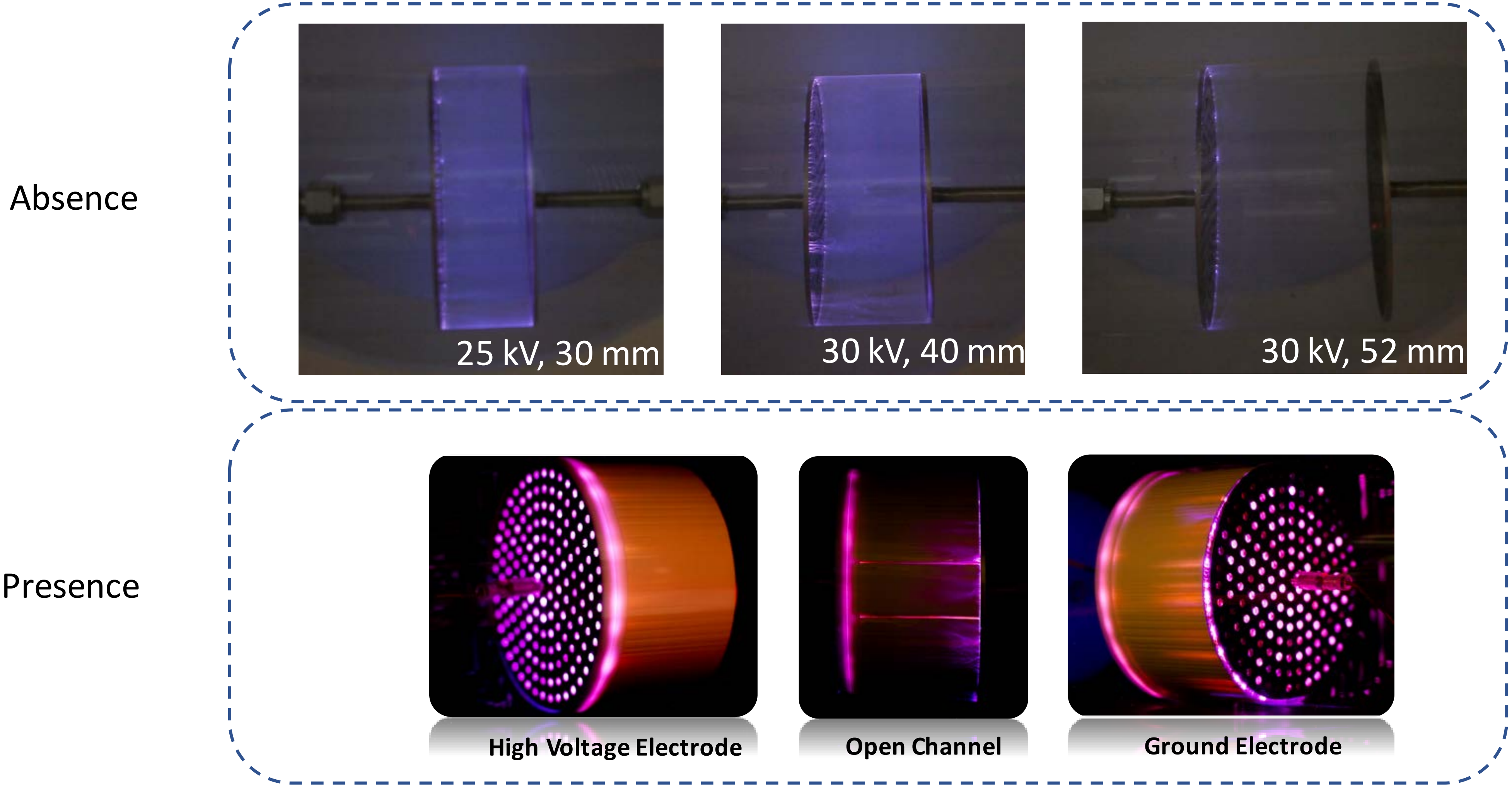


Fig. Images of plasma discharge with the absence/presence of honeycomb monolith

Role of water content

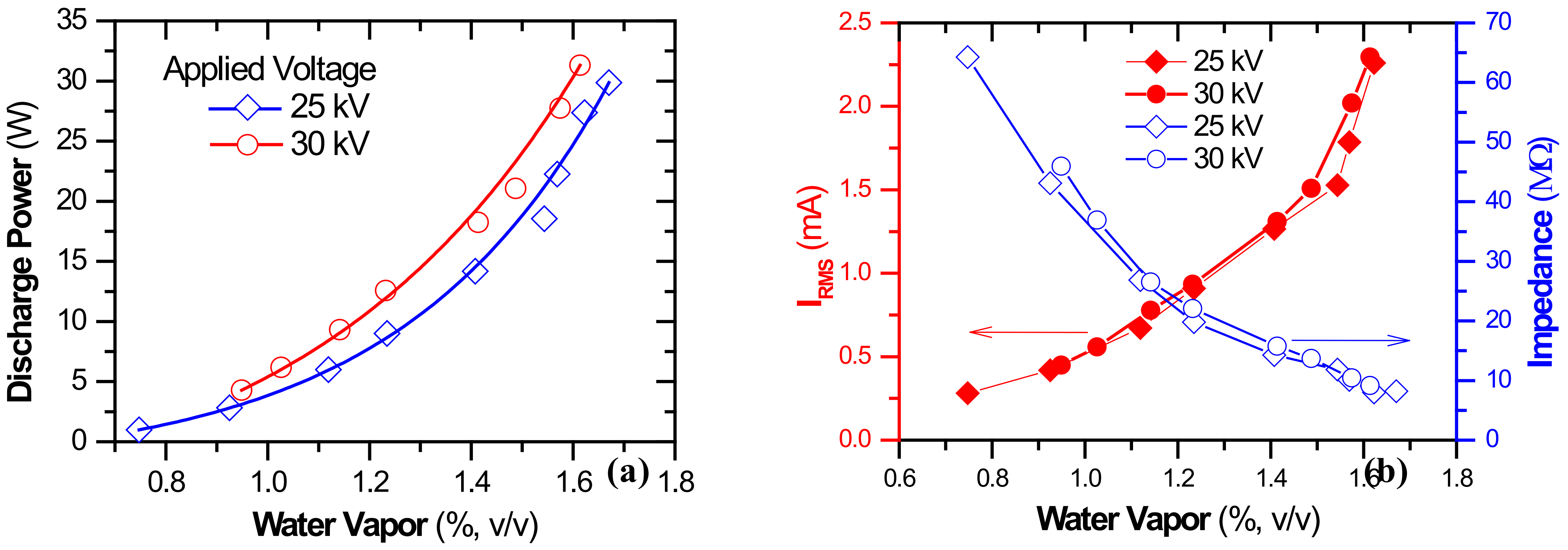


Fig. Effects of water content in air on (a) discharge power (b) current and impedance. (Feed gas 75 slm air, Electrode gap from monolith: 2mm (high voltage), 0mm (ground electrode), diameter of perforated holes:3 mm)

Honeycomb Plasma Discharge

- Initial state
- Input parameter : Voltage, flow rate, water content
- Reactor configuration, d_g , d_g, electrodes
- Monolith
- Temperature

Chem. Eng. J.
401(2020)125970

PSST
29(2021)25016

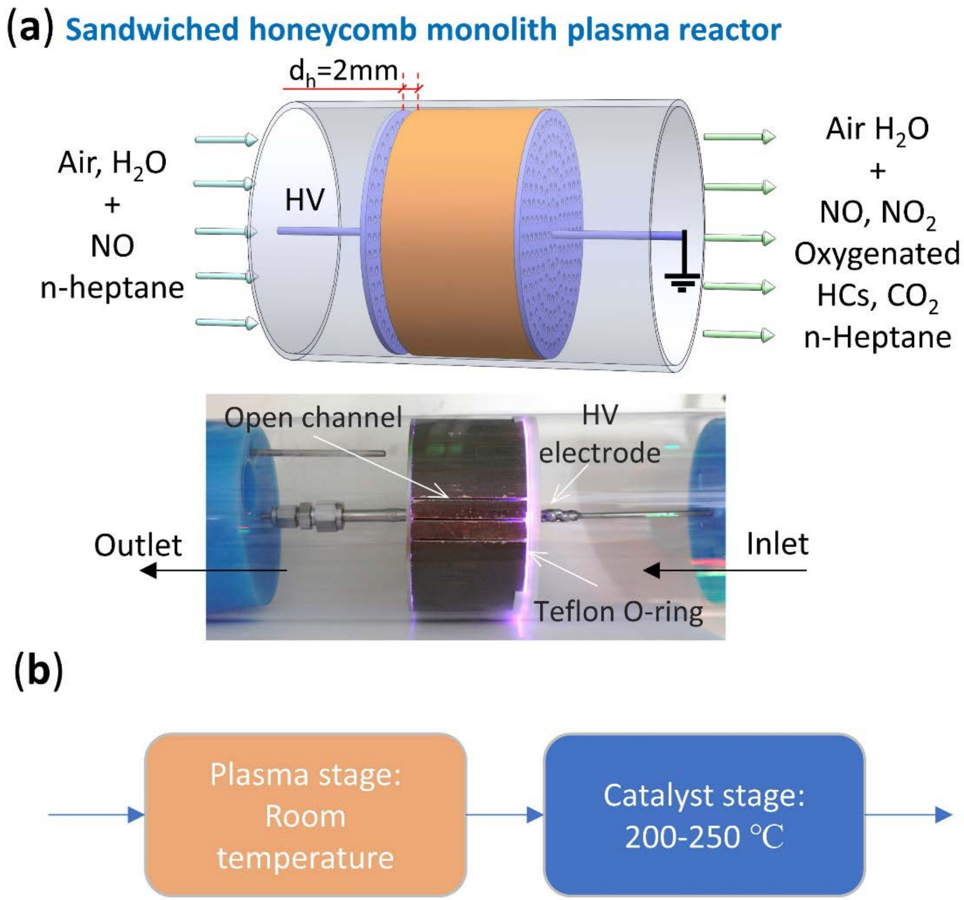
J. Hazard. Mater.
404(2021)124024

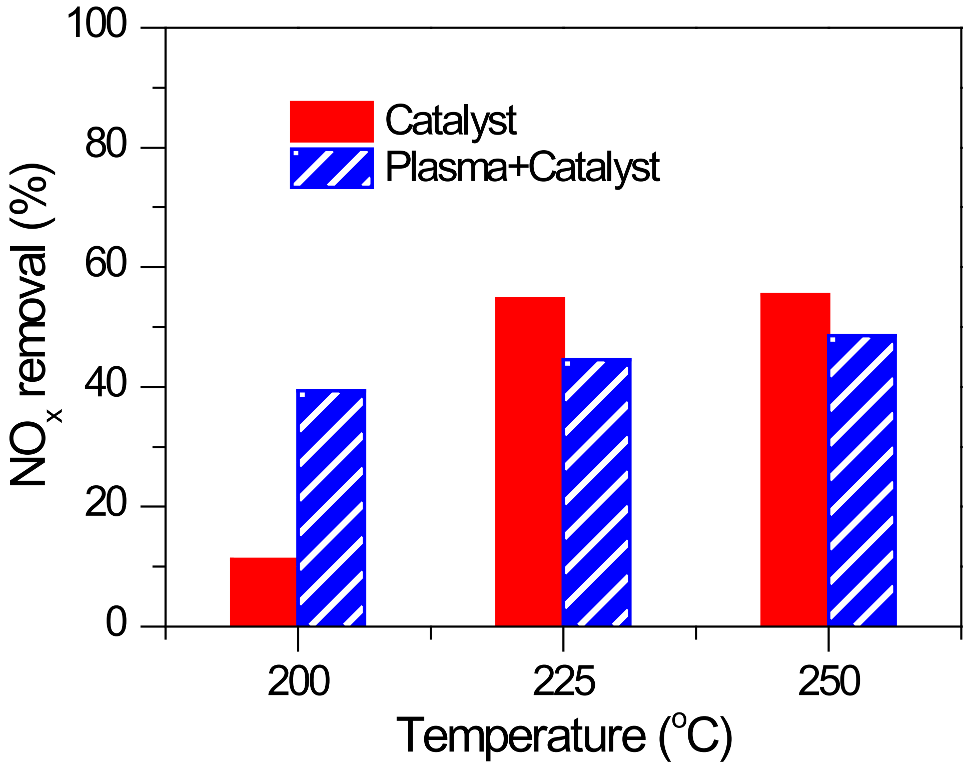
IV. Application of Honeycomb Discharge for Environmental Applications

❖NO_x removal

❖VOCs removal

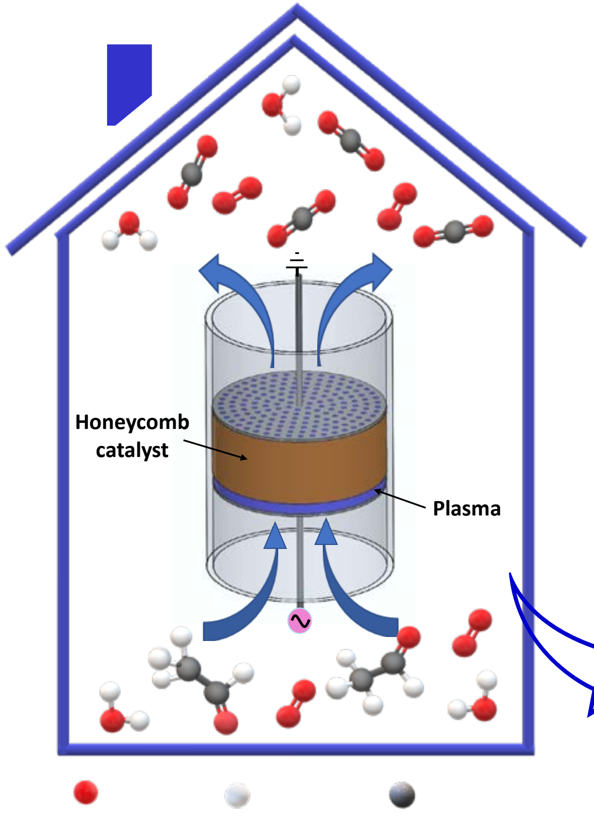
NO_x removal

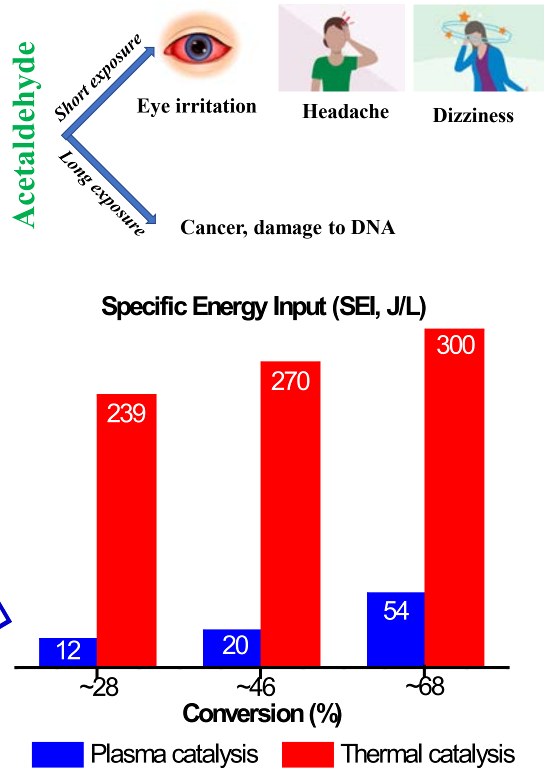




Environ. Sci. Technol.
55 (2021) 6386-6396

Acetaldehyde Removal





5-20 ppm Acetaldehyde

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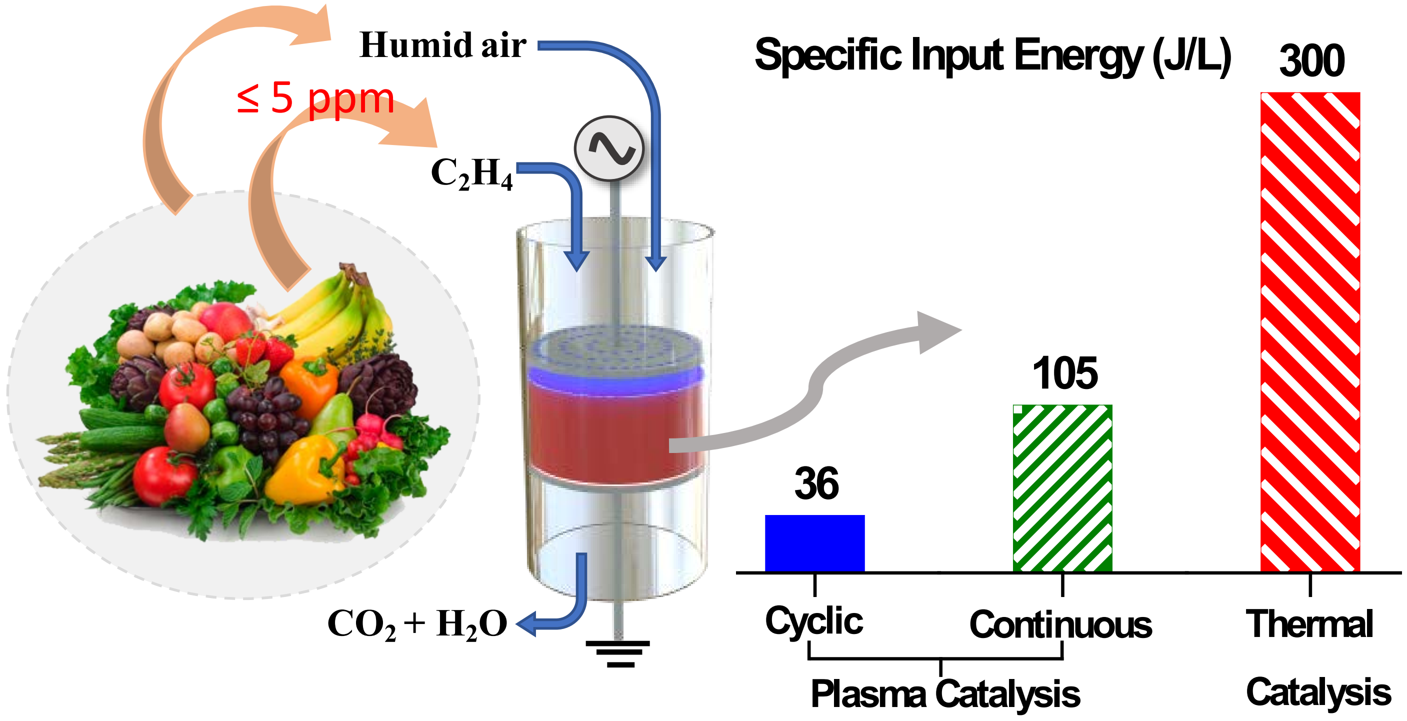
Diluted Ethylene Removal

Honeycomb Plasma Reactor for Ethylene Removal



≥ 95% removal efficiency

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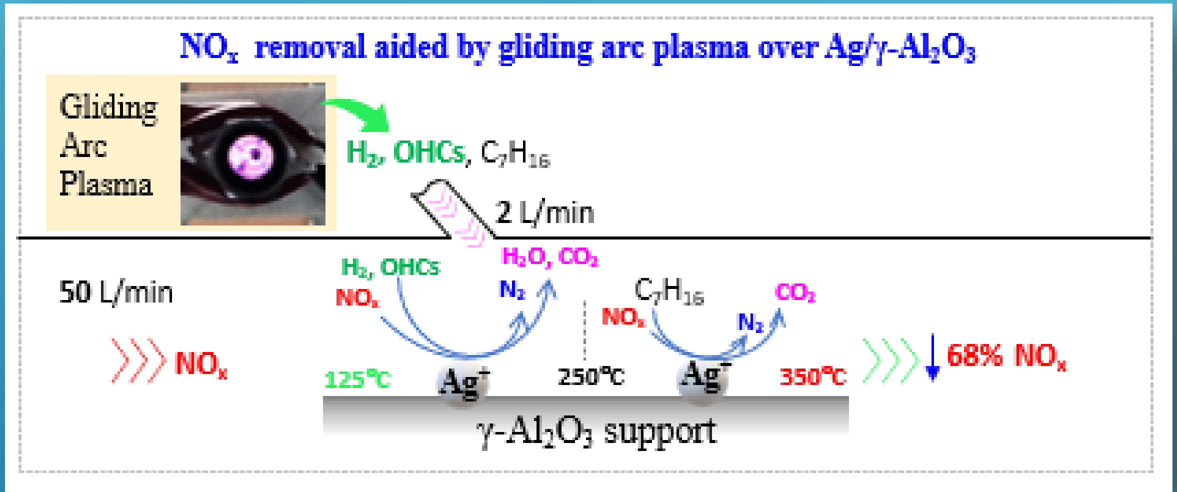
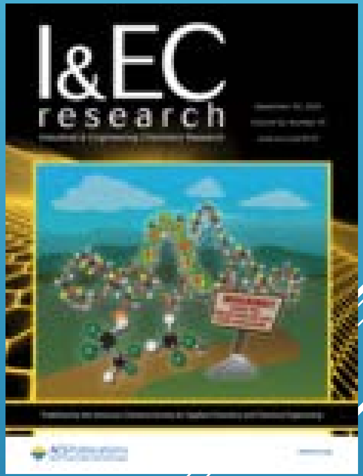
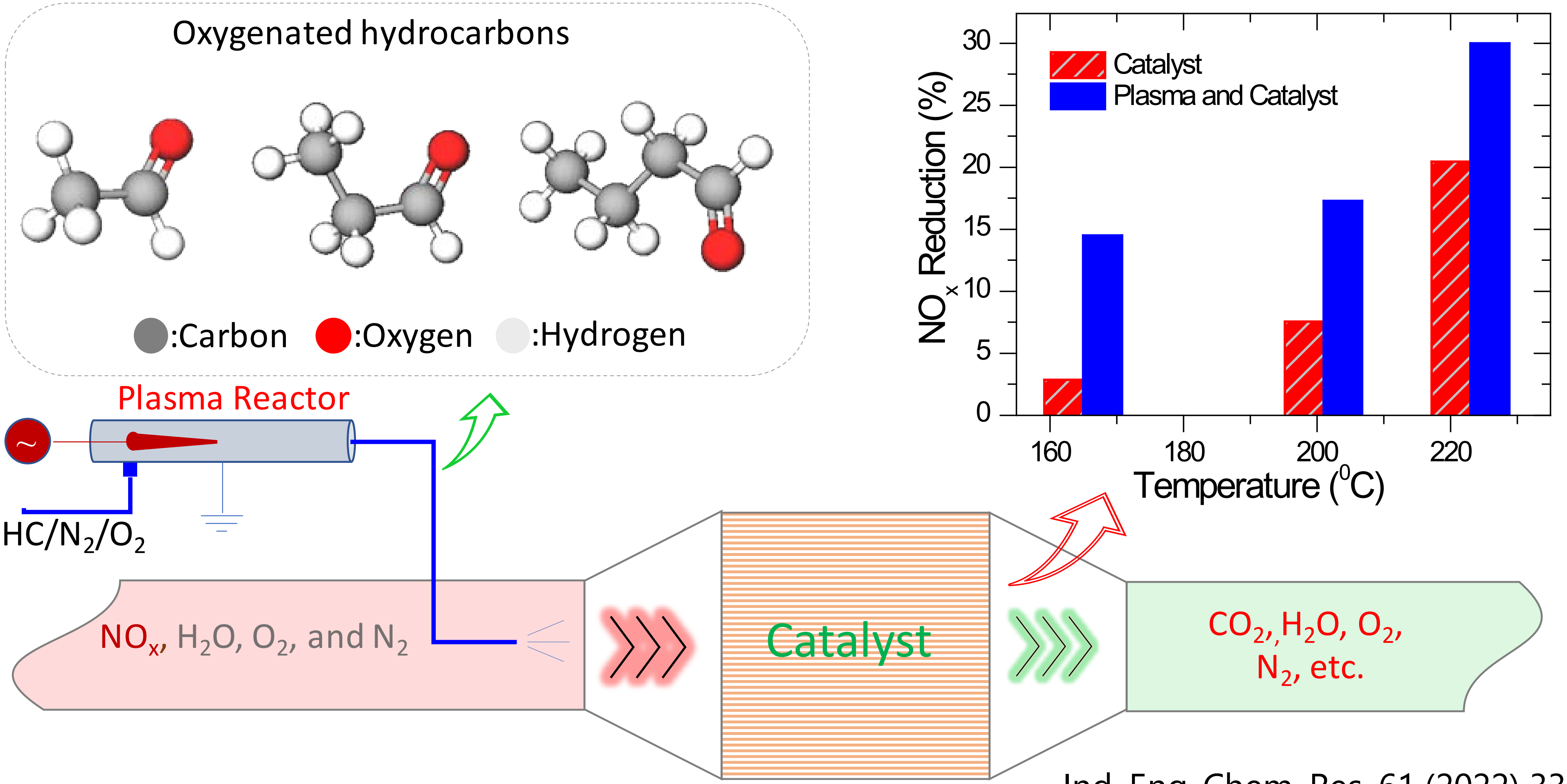
V. Injection method for NO_x removal





Ind. Eng. Chem. Res.
61 (2022) 3365-3373
62 (2023) 9595-9606

Gliding arc plasma assisted NOx removal at low temperature



Ind. Eng. Chem. Res. 61 (2022) 3365-3373

Summary Results

1. Using energy for plasma potential better than for heating catalyst
2. Immersion of ground electrodes in the liquid insulator enhanced plasma-catalyst performance
3. Large atmospheric pressure plasma can be working with honeycomb plasma discharge configuration
4. Honeycomb plasma discharge is potential application for indoor treatment
5. Injected plasma-catalyst reduced energy consumption for NO_x removal

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Thank you for your attention!