Electric Air Cleaner Composed of Non-thermal Plasma Reactor and Electrostatic Precipitator

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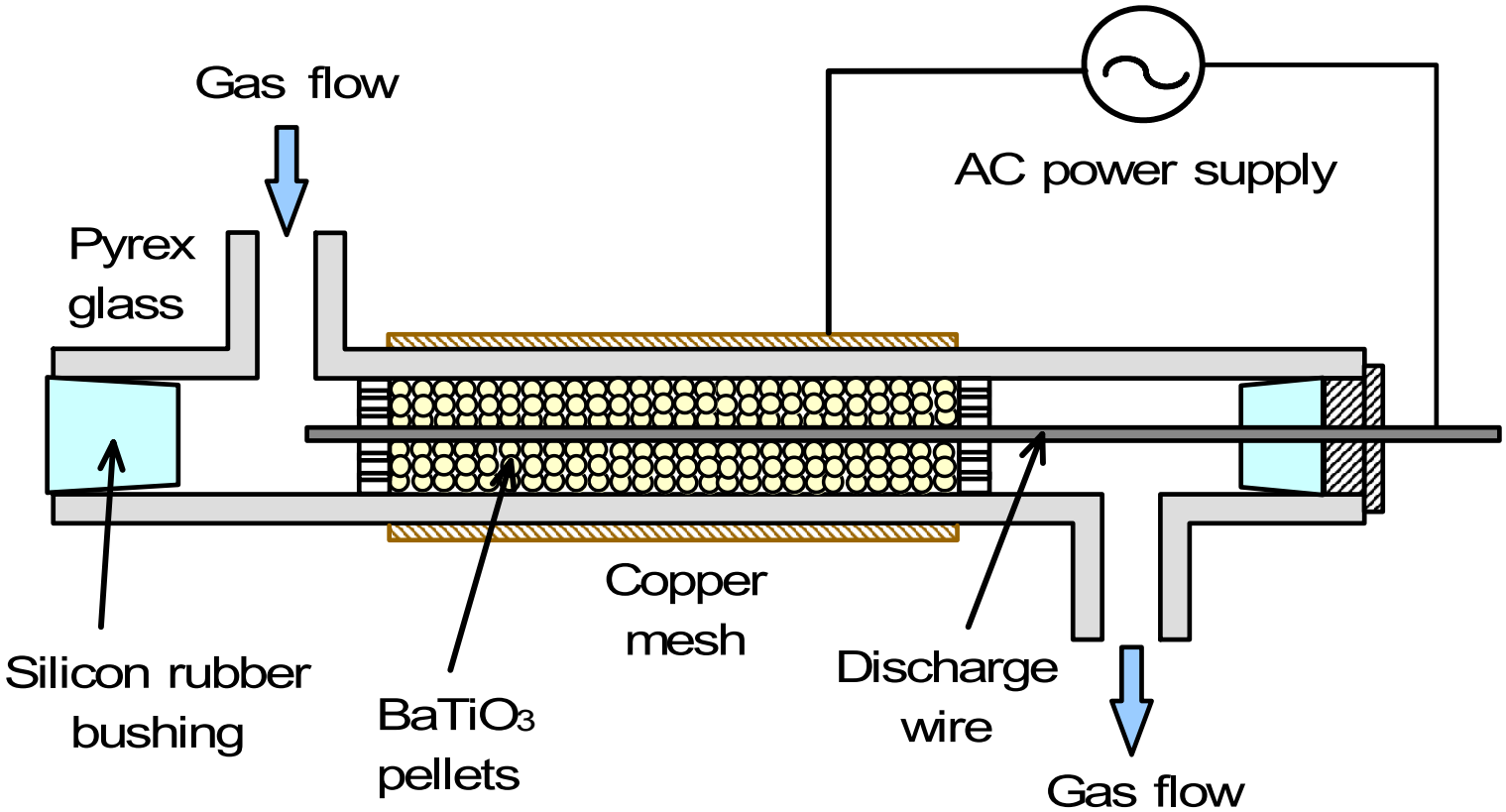
Introduction

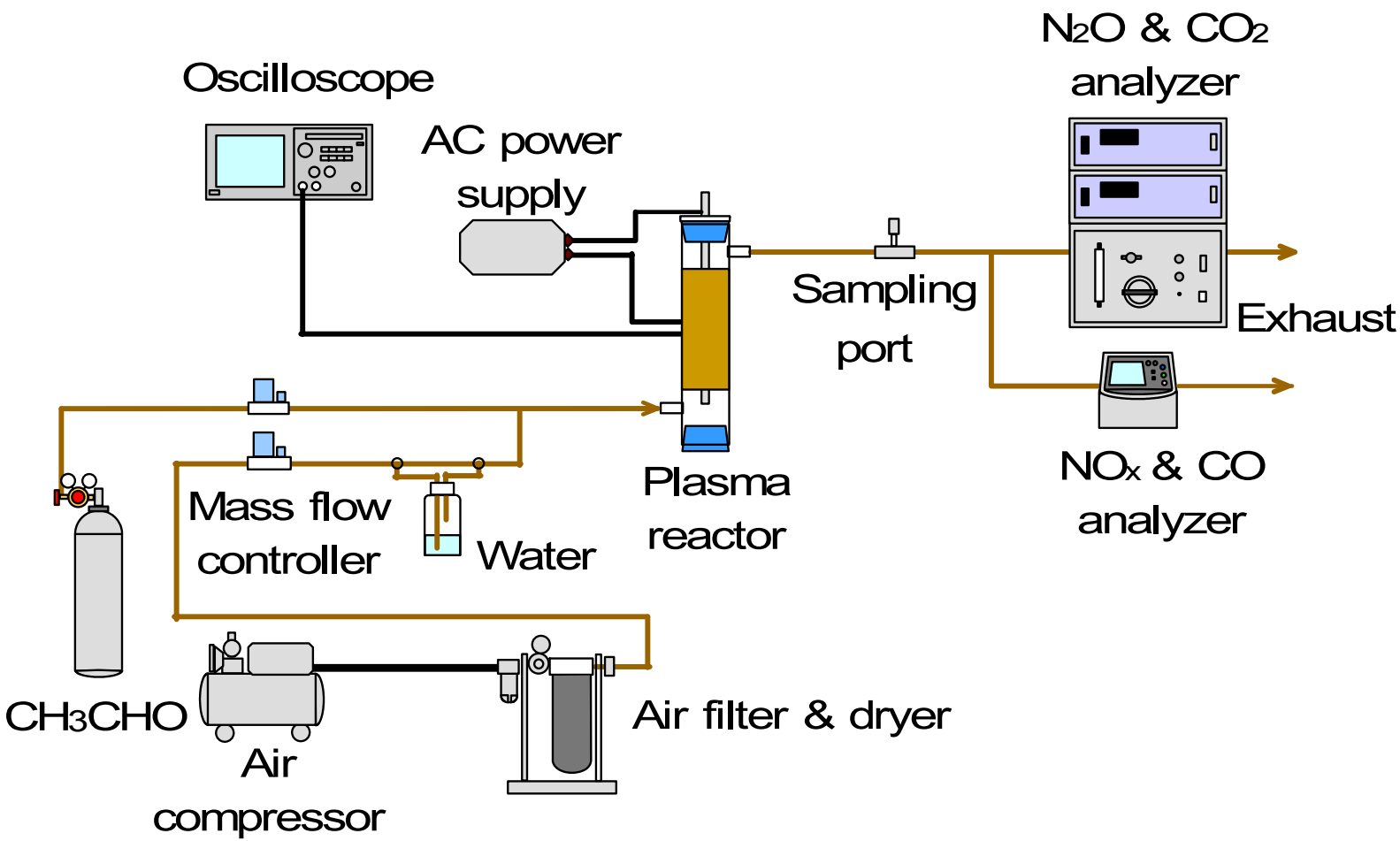
- A wide range of airborne particles can be collected effectively using an ordinary ESP as an indoor air cleaner. However, it is not possible to remove odors.
- In the present study, a new type of the electric air cleaner which realizes simultaneous removal of particles and odors was investigated.
- It is composed of a plasma reactor and a two-stage ESP.
  - The nonthermal plasma reactor decomposes the odors
  - The two-stage ESP collects the particles in the flow.
- The performances of these components were examined.
- In the experimental results, more than 90% of decomposition efficiency of acetaldehyde which causes the odor of tabacco smoke, and more than 99.7% collection efficiency of particles larger than 0.3μm were obtained in this system.

Barrier-type packed-bed plasma reactor

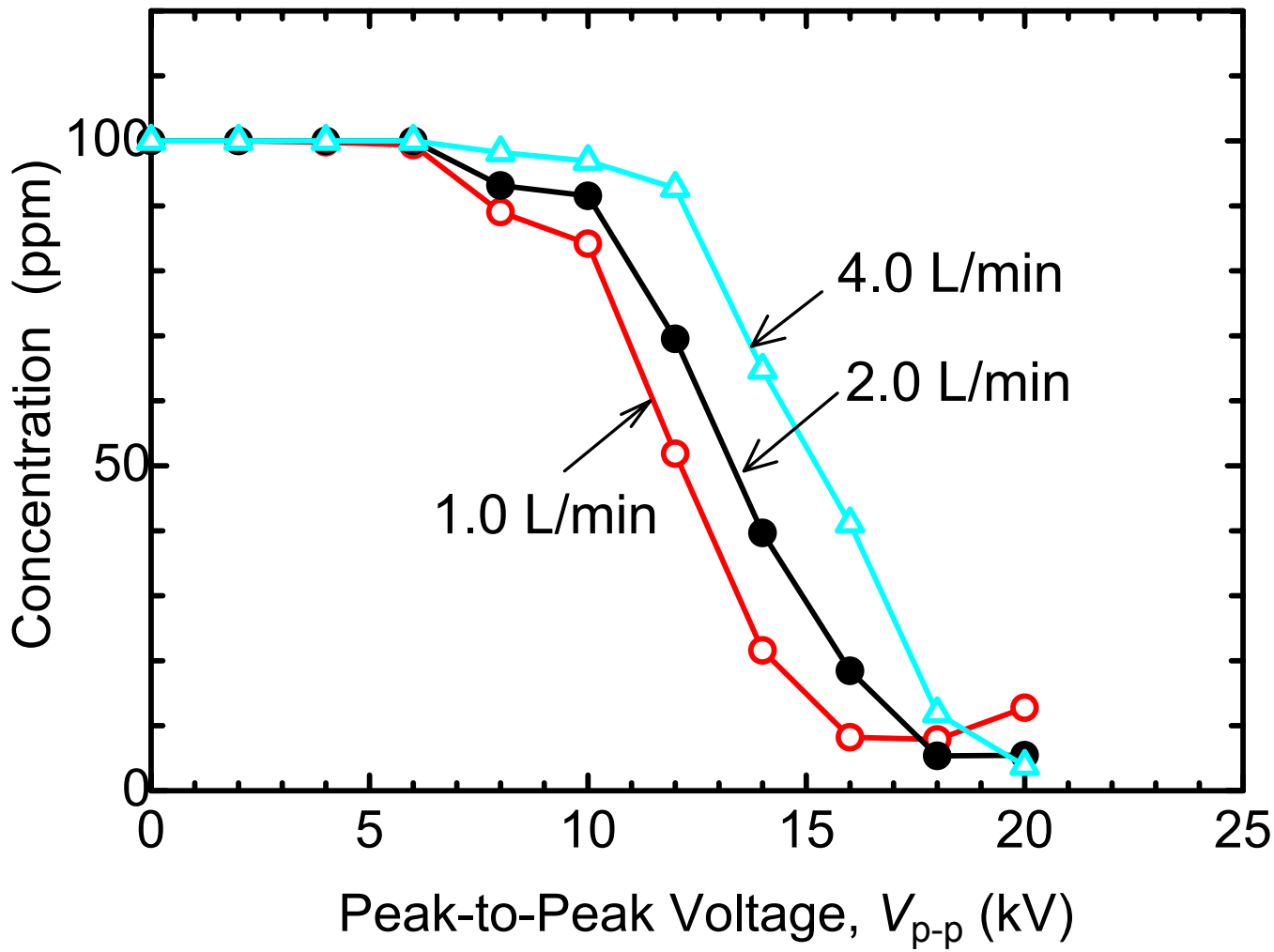


- Effective reactor length=200 mm
- $BaTiO_3$ pellets: d=1.7～2.0 mm, ε =10000
- AC high voltage (Max. 20kV) of 60Hz was applied to the reactor.

Experimental set-up for decomposition of CH_3CHO

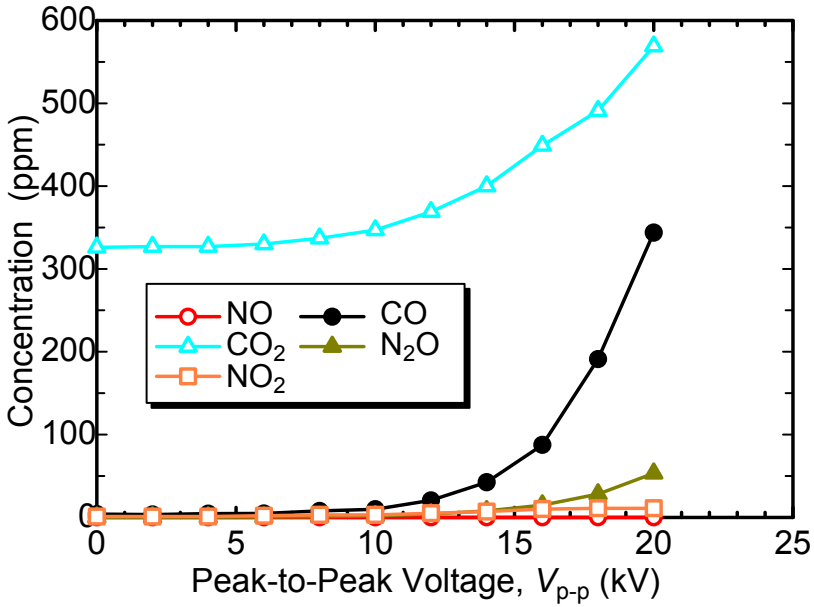


Decomposition efficiency of CH_3CHO using the plasma reactor (dry condition)

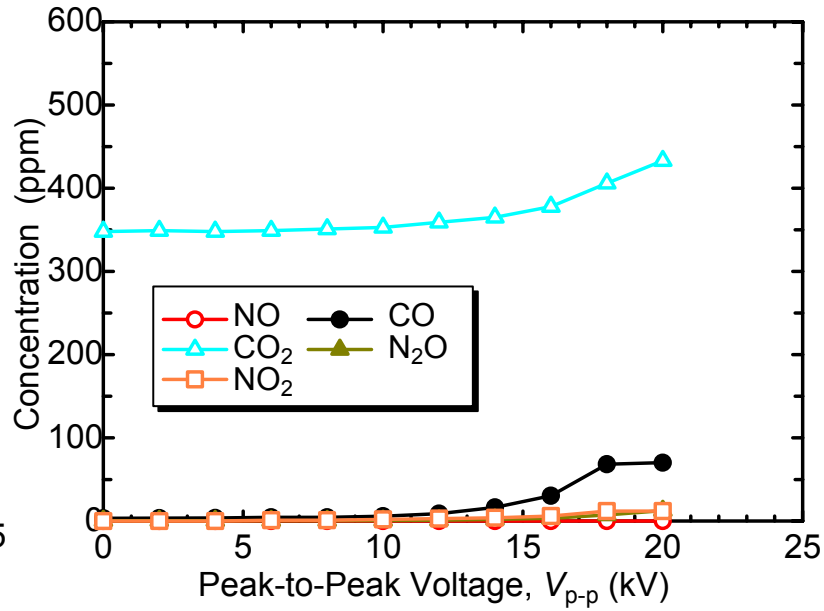


- More than 90% decomposition efficiencies were obtained when the applied voltage became the optimum values

Byproducts concentrations (dry condition)



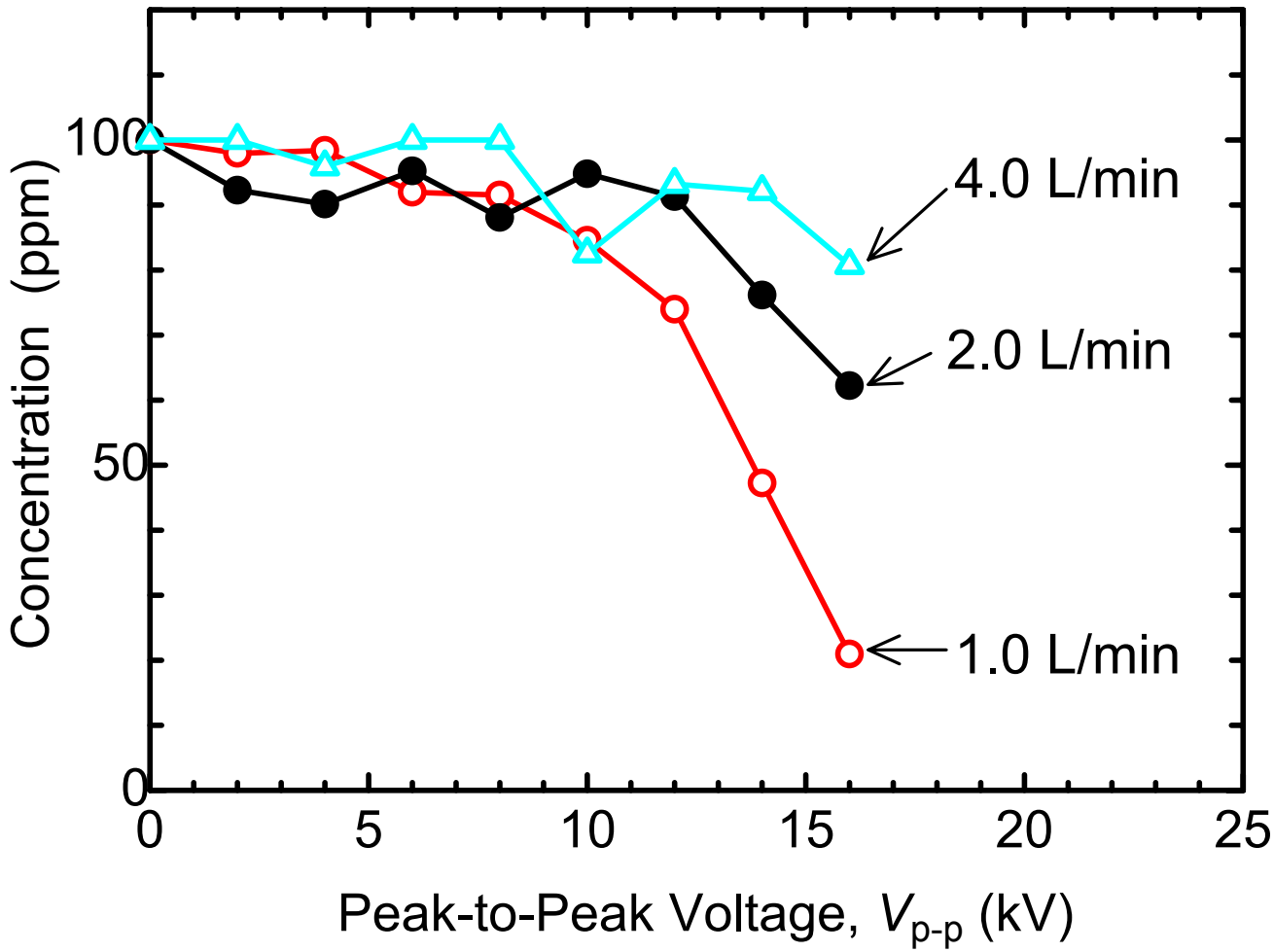
• Flow rate = 1.0 L/min



• Flow rate = 4.0 L/min

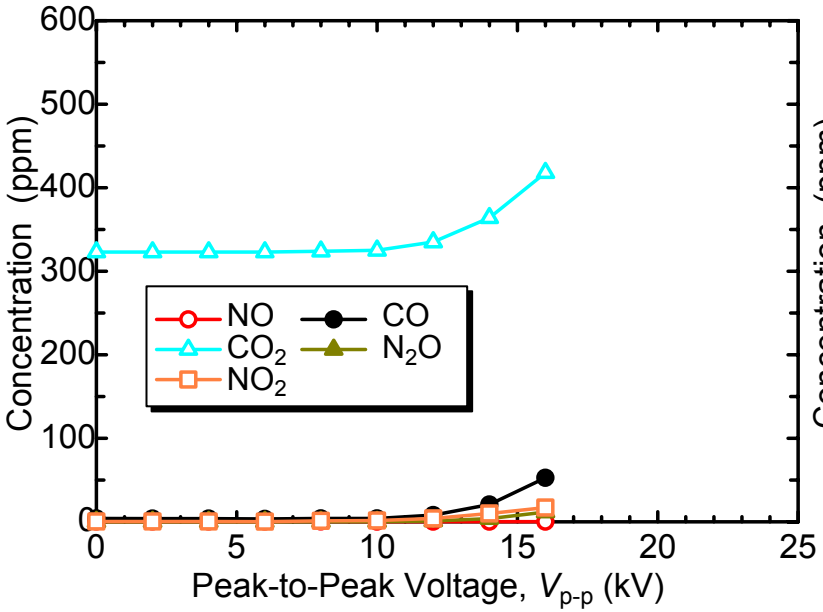
- Considering the carbon balance, acetaldehyde was converted to CO, CO_2 and the other hydrocarbons by the nonthermal plasma

Decomposition efficiency of CH_3CHO using the plasma reactor (humidified condition)

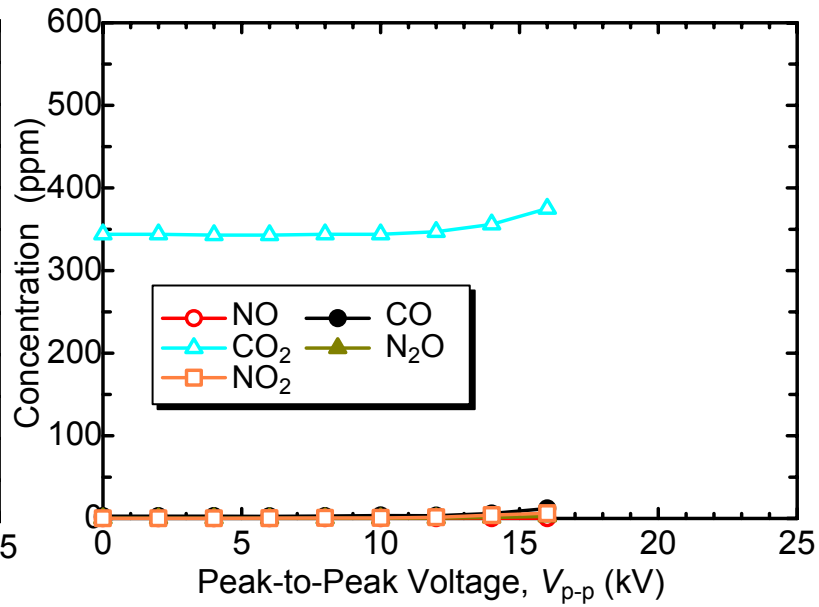


- Compared with the previous result under dry condition, decomposition efficiencies decrease under humidified condition

Byproducts concentrations (humidified condition)



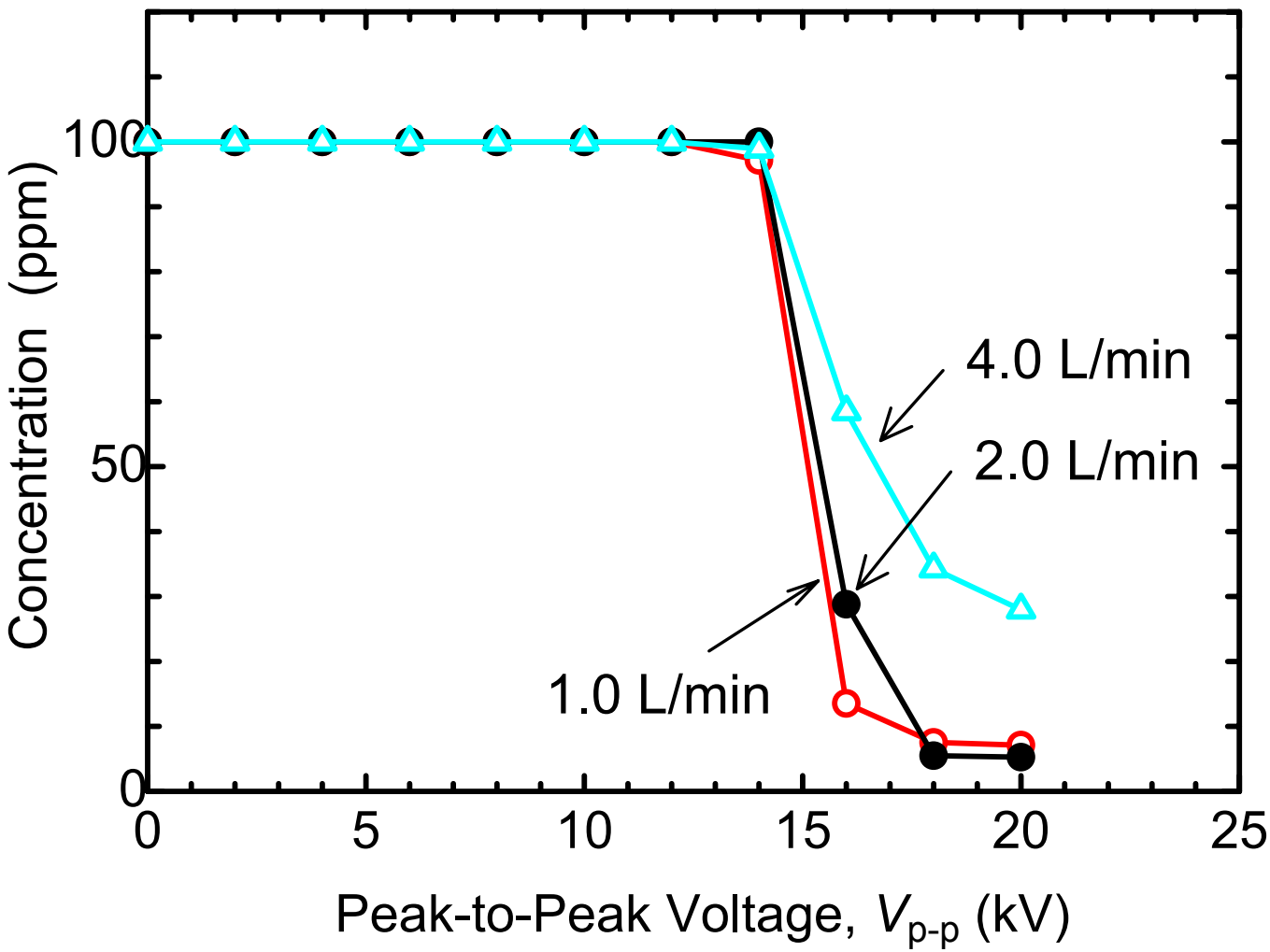
• Flow rate = 1.0 L/min



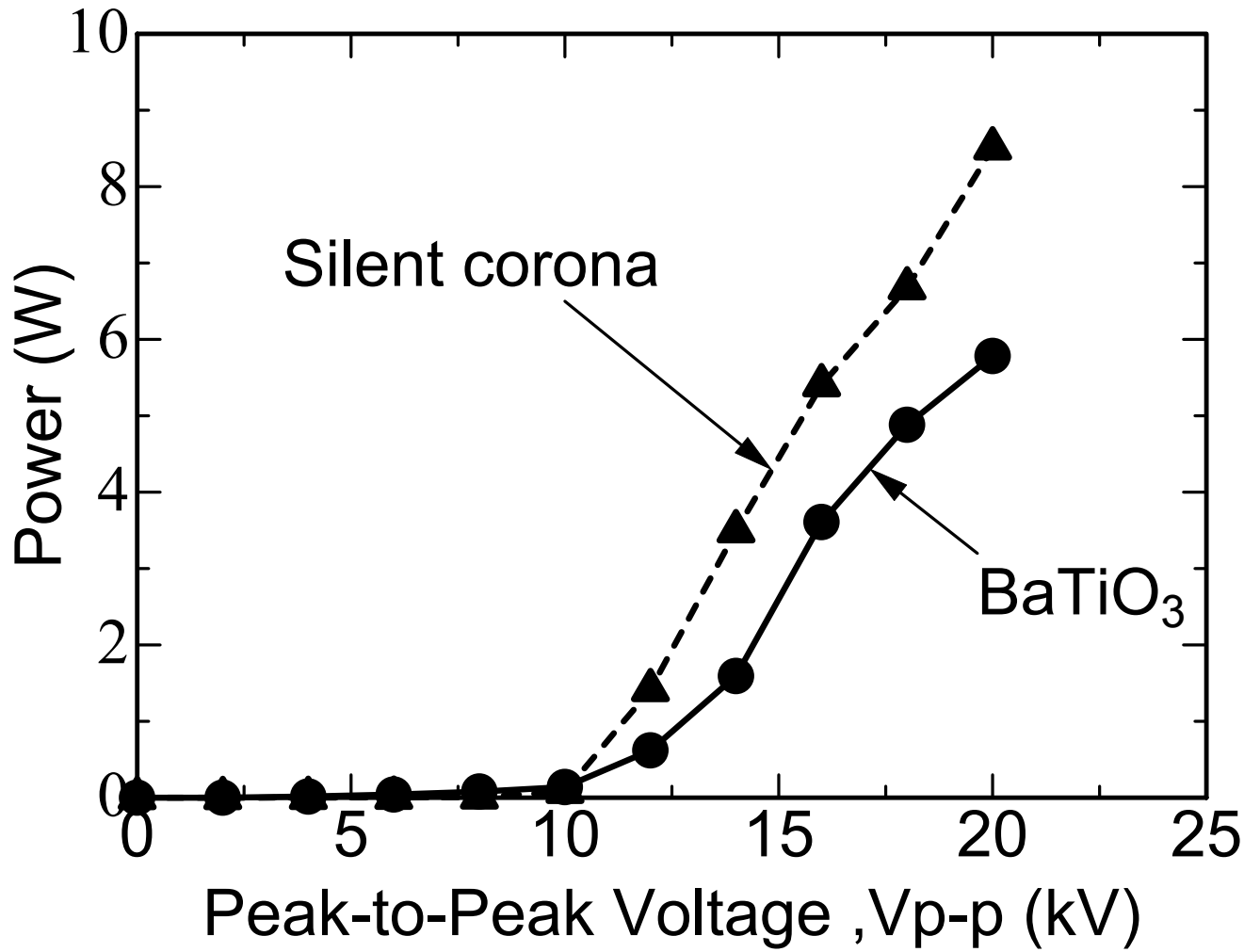
• Flow rate = 4.0 L/min

- The results are similar to those on dry condition, but the concentrations of CO and CO_2 were lower because the decomposition efficiency was lower.

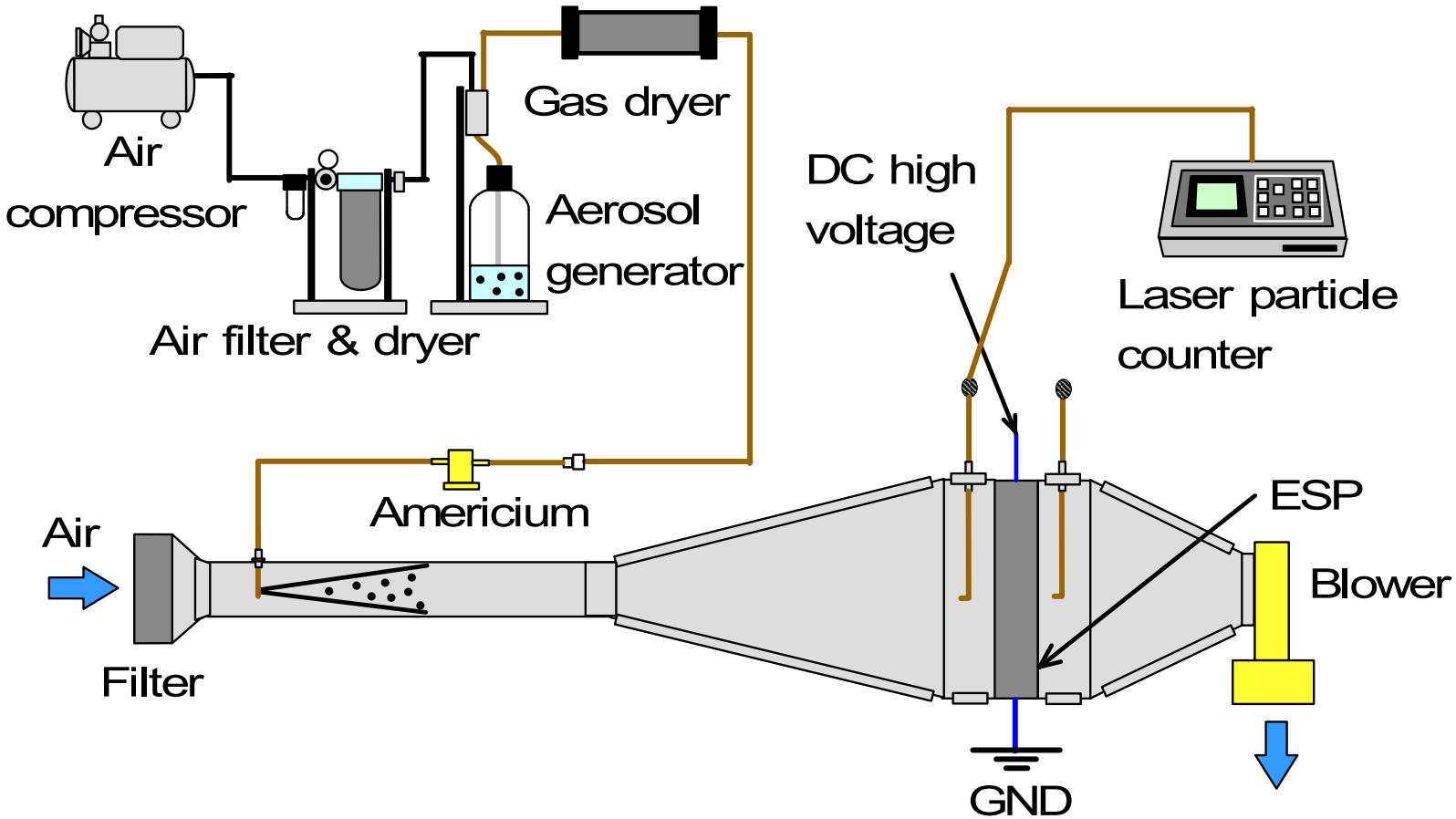
Decomposition efficiency of CH_3CHO using the silent discharge reactor (dry)



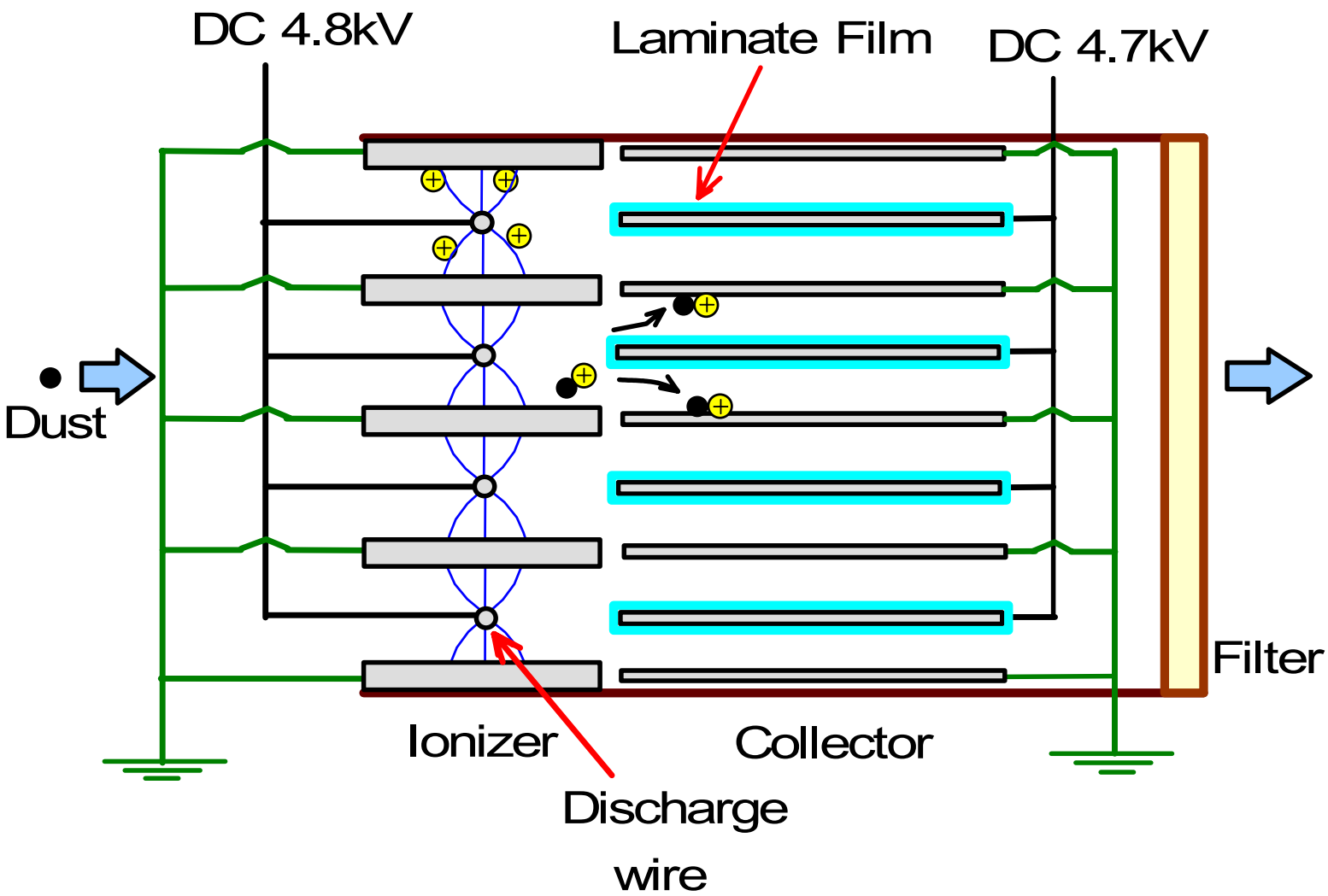
Power vs. voltage



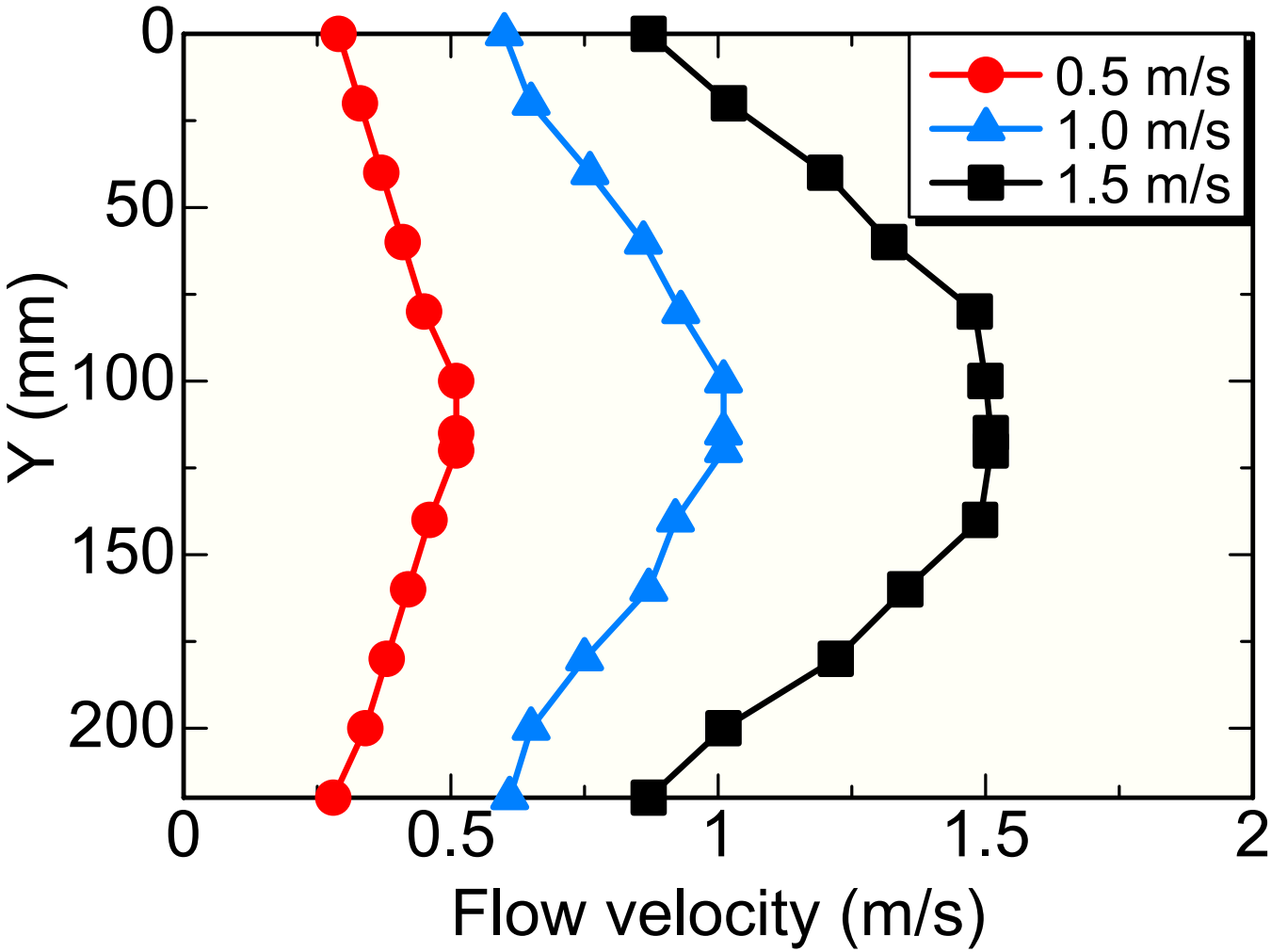
Experimental set-up for evaluation of the ESP



Schematic of the two-stage ESP



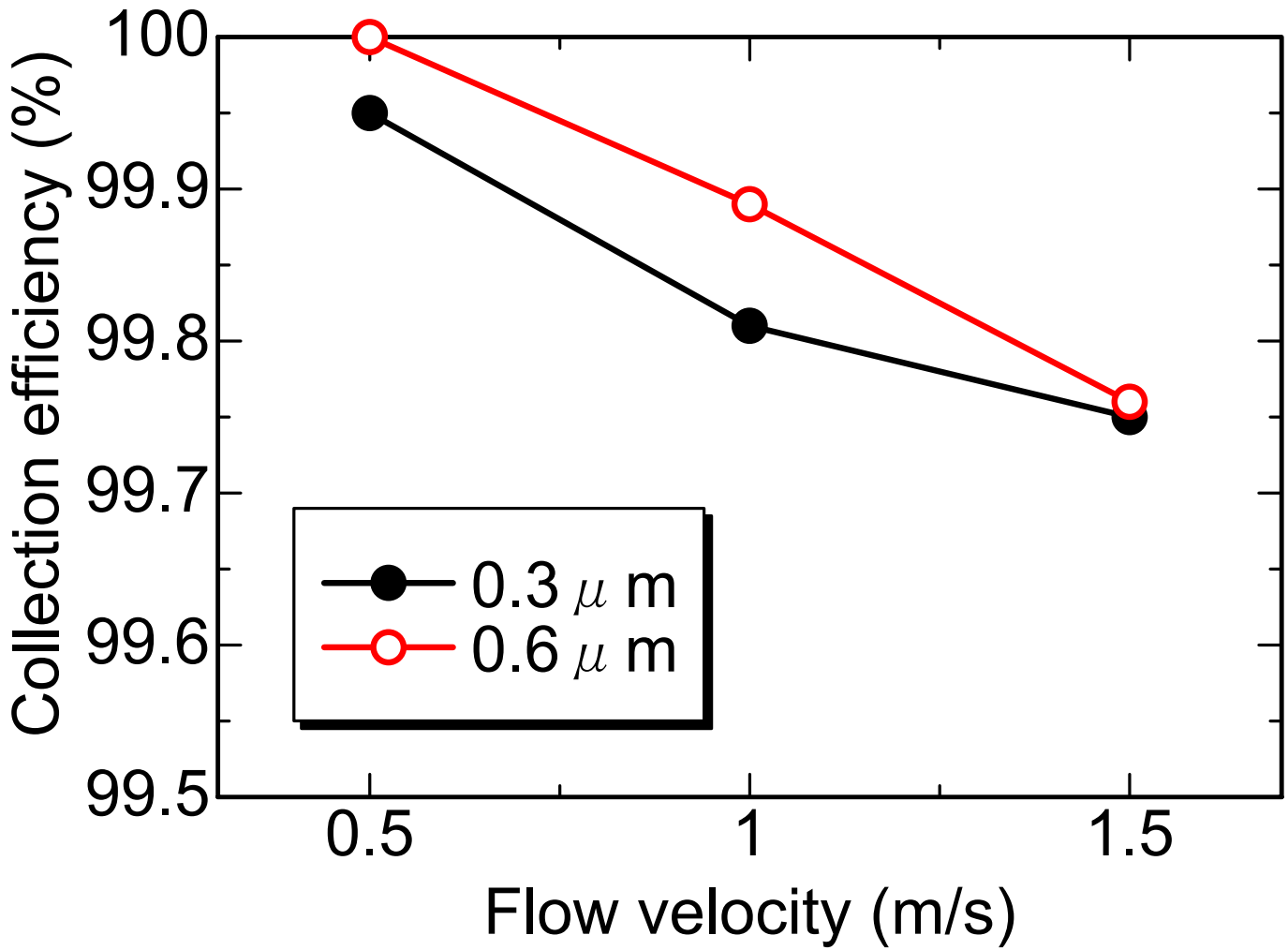
Velocity distributions in the wind tunnel



Size dependent collection efficiencies for indoor air flow

Velocity m/s	Particle Size μm	The number of particles in 1 L		Collection efficiency %
		before ESP	after ESP	
0.5	0.3 ~ 0.5	135997	4	99.997
	0.5 ~ 1.0	11155	0	100
	1.0 ~ 3.0	1527	0	100
	3.0 ~ 5.0	24	0	100
	5.0 ~	4	0	100
1	0.3 ~ 0.5	131498	57	99.96
	0.5 ~ 1.0	10646	4	99.96
	1.0 ~ 3.0	1536	0	100
	3.0 ~ 5.0	40	0	100
	5.0 ~	8	0	100
1.5	0.3 ~ 0.5	72703	157	99.78
	0.5 ~ 1.0	5574	13	99.77
	1.0 ~ 3.0	832	0	100
	3.0 ~ 5.0	18	0	100
	5.0 ~	6	0	100

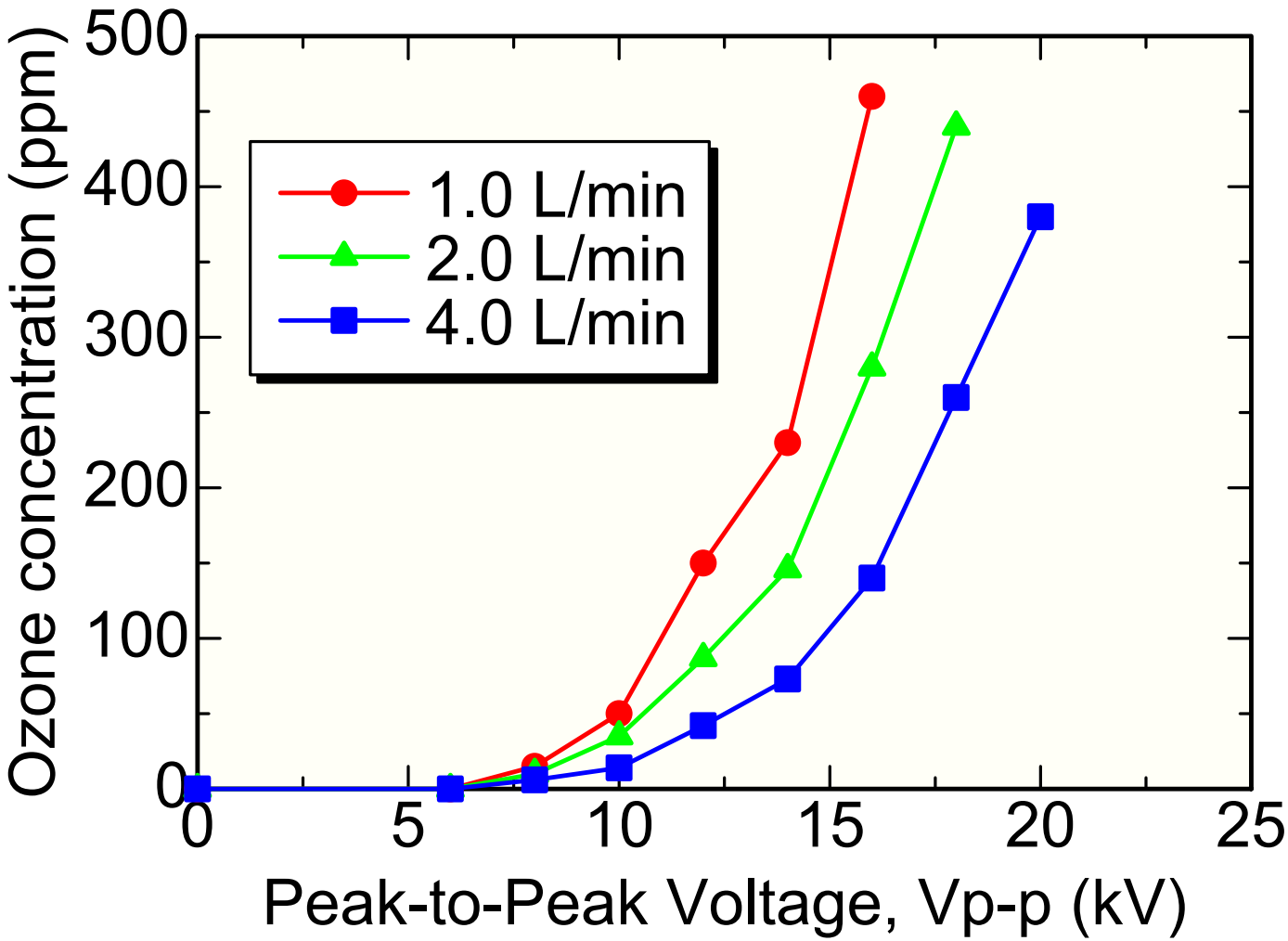
Collection efficiency for monodispersed aerosol vs. flow velocity



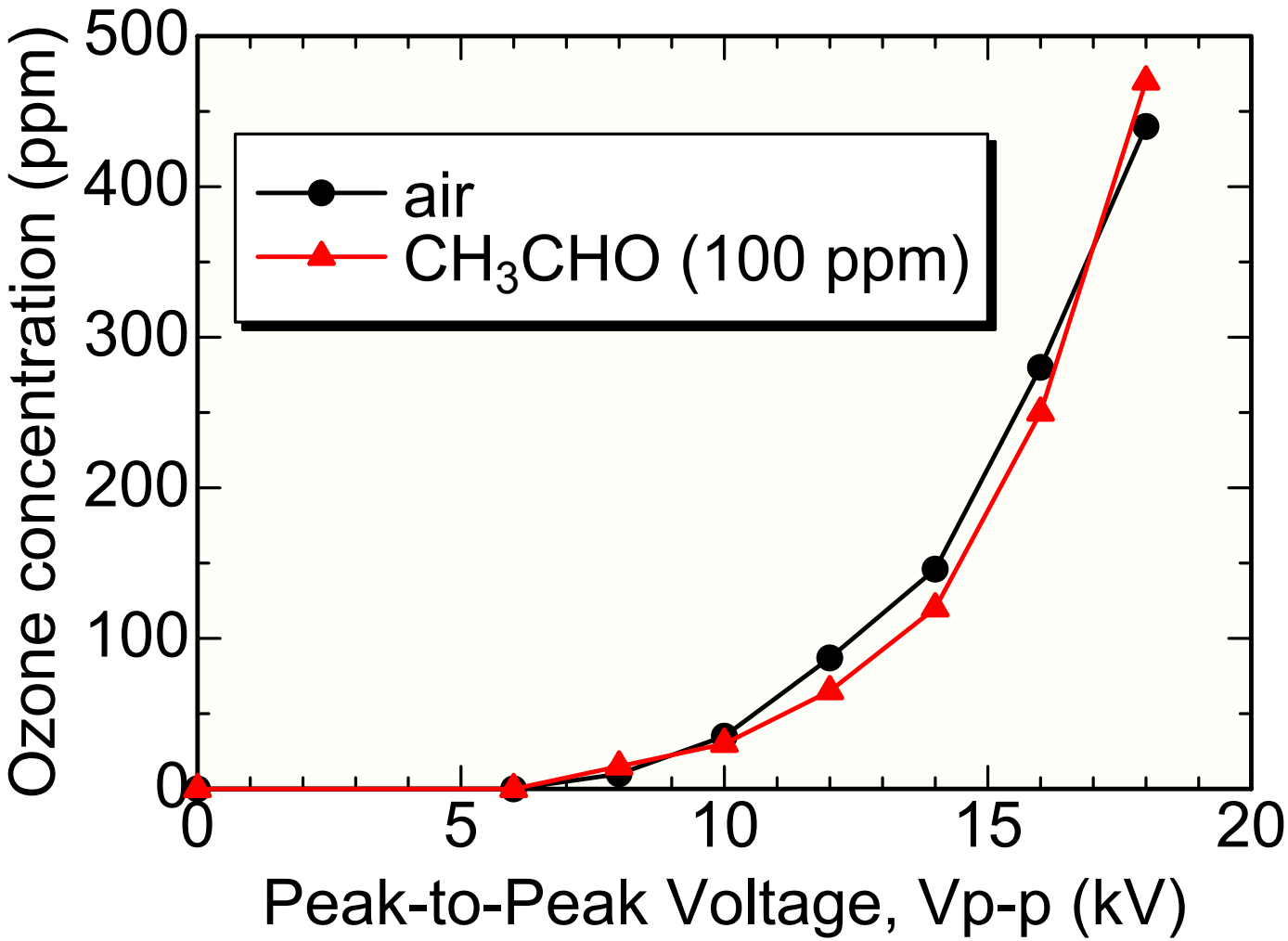
Conclusions

- **Performance of the plasma reactor**
  - Under dry condition, CH_3CHO decomposition more than 90% was obtained. The optimum voltage increased with increase in the flow rate.
  - The byproducts concentrations of CO and CO_2 were higher, the concentrations of NO_x and N_2O were lower. CH_3CHO was converted to CO, CO_2 and the other hydrocarbons.
  - Under humidified condition, the decomposition efficiency became lower.
- **Performance of the two-stage ESP**
  - More than 99.7% collection efficiencies were obtained for particles greater than 0.3μm in indoor air.
  - The collection efficiency for monodispersed aerosols was determined. It decreases with increase in the flow velocity and increases in the diameter of a particle.

Ozone concentration (dry condition)



Ozone concentration for air and CH_3CHO flows



Measurement results for air flow with 0.3 μ m aerosol

Velocity m/s	Particle Size μm	The number of particles in 1 L			
		Air before ESP	Air after ESP	Air+PSL before ESP	Air+PSL after ESP
0.5	0.3 ~ 0.5	276	9.67	6510	13.0
	0.5 ~ 1.0	9.67	0.67	69.3	0.33
	1.0 ~ 3.0	1.0	0	4.33	0
	3.0 ~ 5.0	0	0	0	0
	5.0 ~	0	0	0	0
1	0.3 ~ 0.5	1180	8.0	3879	13.0
	0.5 ~ 1.0	81.0	0	90.3	0.67
	1.0 ~ 3.0	3.0	0	3.7	0
	3.0 ~ 5.0	0	0	0	0
	5.0 ~	0	0	0	0
1.5	0.3 ~ 0.5	539	4.0	2778	9.67
	0.5 ~ 1.0	33.0	0.67	53.0	1.0
	1.0 ~ 3.0	2.0	0	1.67	0
	3.0 ~ 5.0	1.0	0	0	0
	5.0 ~	0	0	0	0

Measurement results for air flow with 0.6 μm aerosol

Velocity m/s	Particle Size μm	The number of particles in 1 L			
		Air before ESP	Air after ESP	Air+PSL before ESP	Air+PSL after ESP
0.5	0.3 ~ 0.5	759	14.3	718	10.7
	0.5 ~ 1.0	40.3	0	875	0
	1.0 ~ 3.0	2.67	0	3.67	0
	3.0 ~ 5.0	0	0	0	0
	5.0 ~	0	0	0	0
1	0.3 ~ 0.5	869	7.0	1017	11.7
	0.5 ~ 1.0	47.3	0	647	0.67
	1.0 ~ 3.0	5.33	0	9.33	0
	3.0 ~ 5.0	0.67	0	0	0
	5.0 ~	0	0	0	0
1.5	0.3 ~ 0.5	867	6.0	978	6.33
	0.5 ~ 1.0	42.7	0	324	0.67
	1.0 ~ 3.0	3.67	0	4.33	0
	3.0 ~ 5.0	0	0	0	0
	5.0 ~	0	0	0	0