# $CO_2$ Concentration Using Adsorption and Nonthermal Plasma Desorption

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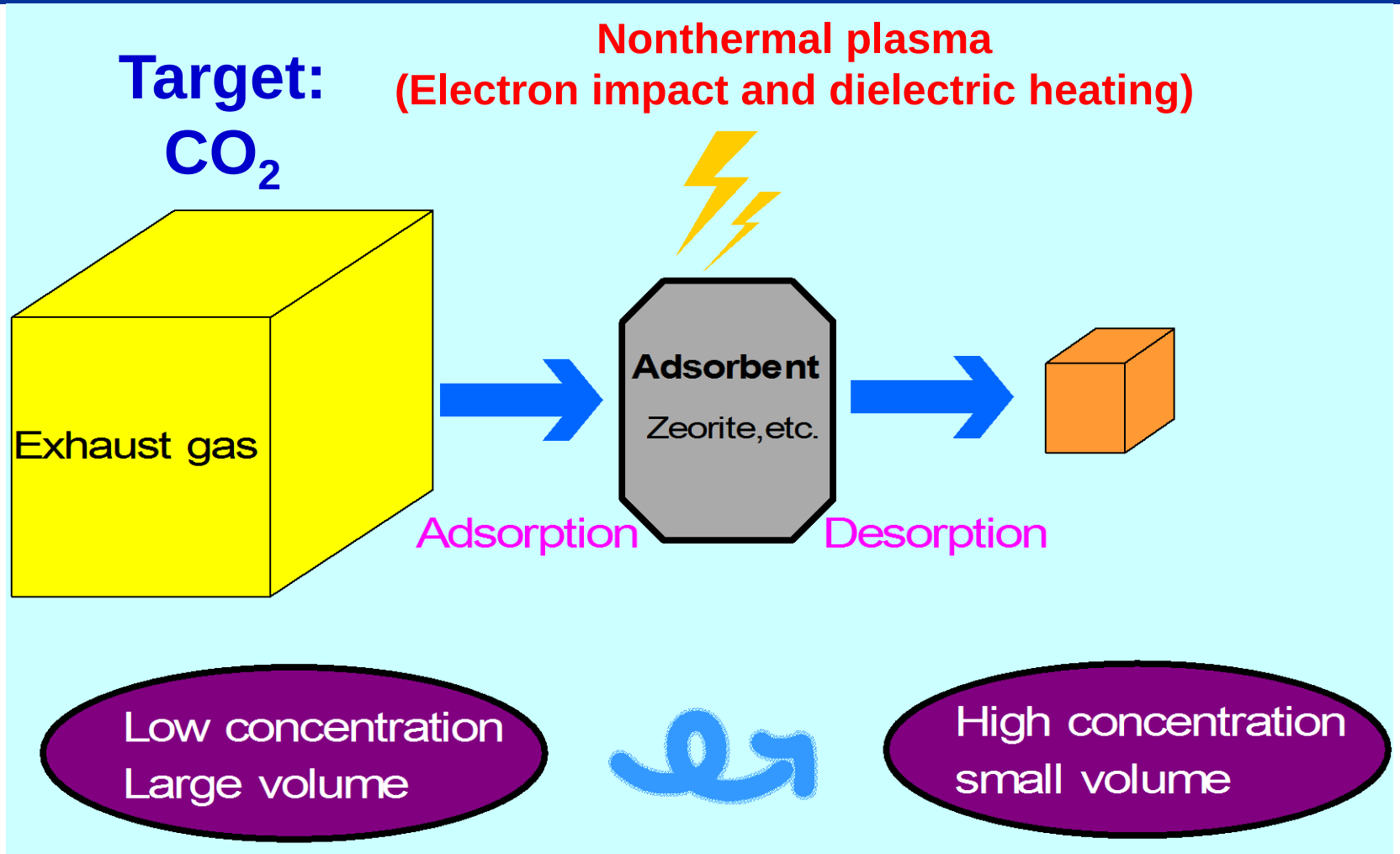
# Introduction



- The gas flow rates for flue gas or air pollutant emissions are generally large and their concentrations are low, in ppm or several % levels.
- When we try to treat directly the large flow rate and low concentration exhaust gas, the energy efficiency (g/kWh) becomes low and the size of the equipment becomes large, resulting in high operating cost.
- The objective of this study is to convert the flue gas with large flow rate and low concentration into the one with small flow rate and high concentration by desorbing the adsorbed gas from the adsorbent packed inside a nonthermal plasma (NTP) reactor by the application of NTP (Plasma desorption).

# Nonthermal plasma concentrating desorption






- High concentration $CO_2$ is obtained which can be converted to CO with higher energy efficiency.

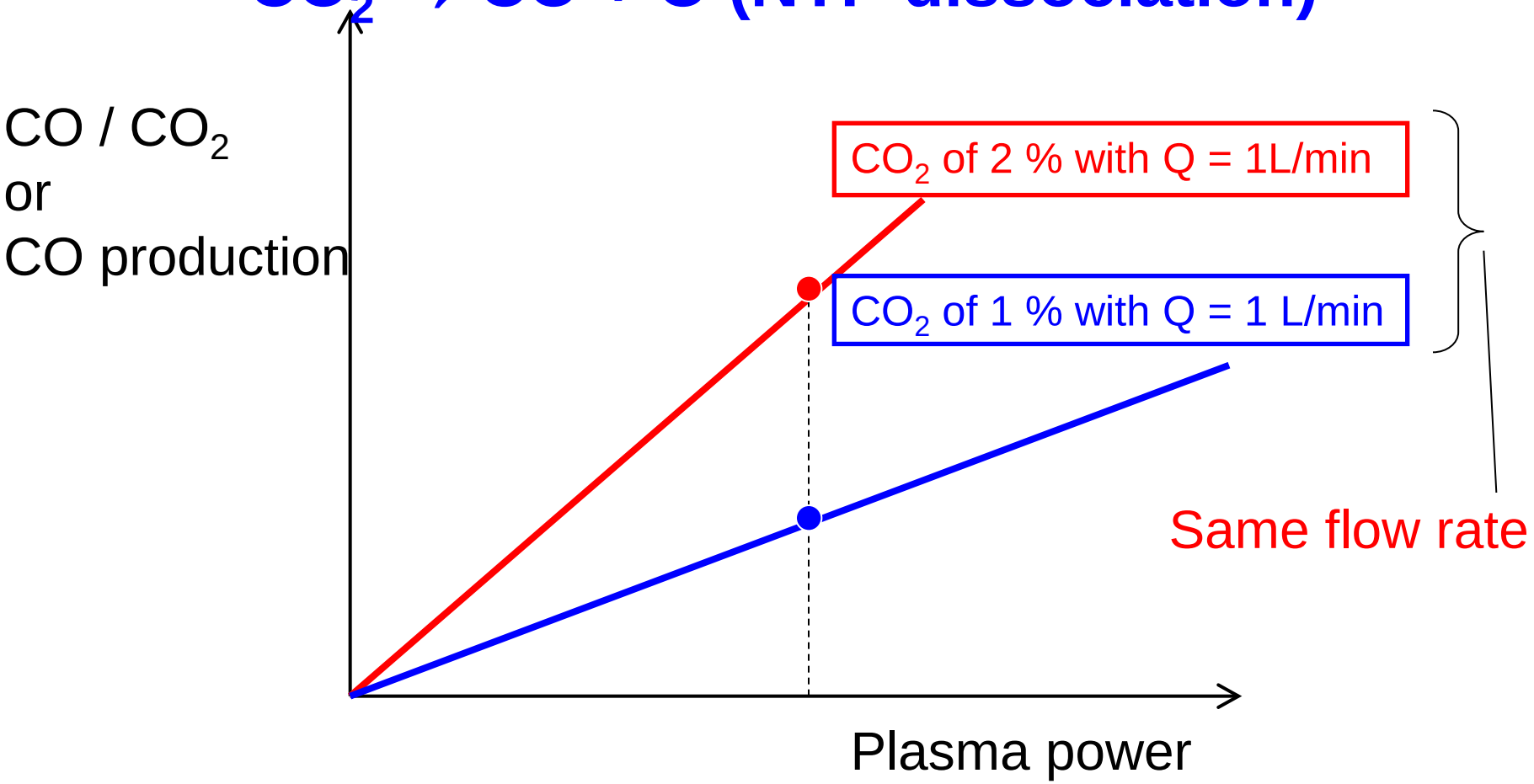
# Previous papers



- In our previous papers, we have reported the results concerning on $NO_x$ and $H_2O$ concentrations using this technique, NTP desorption.
  - M. Okubo et al., *Plasma Chem. P. P.*, **28,** 2008, 173.
  - M. Okubo et al., *Appl. Phys. Let.*, **90**, 131501. 2007.
  - M. Okubo et al., *J. Electrostat.*, **65**, 4, 2007, 221.
- In this study, we mainly focused on the more difficulties to treat carbon dioxide ($CO_2$).
- The plasma desorption is carried out by applying the nanosecond positive pulse high voltage.
- Generally, it is known that $CO_2$ is reduced to CO by NTP, but efficiency is not so high ~1 g/kWh.

# Higher-efficiency $CO_2$ dissociation using concentration

**$CO_2 \rightarrow CO + O$ (NTP dissociation)**

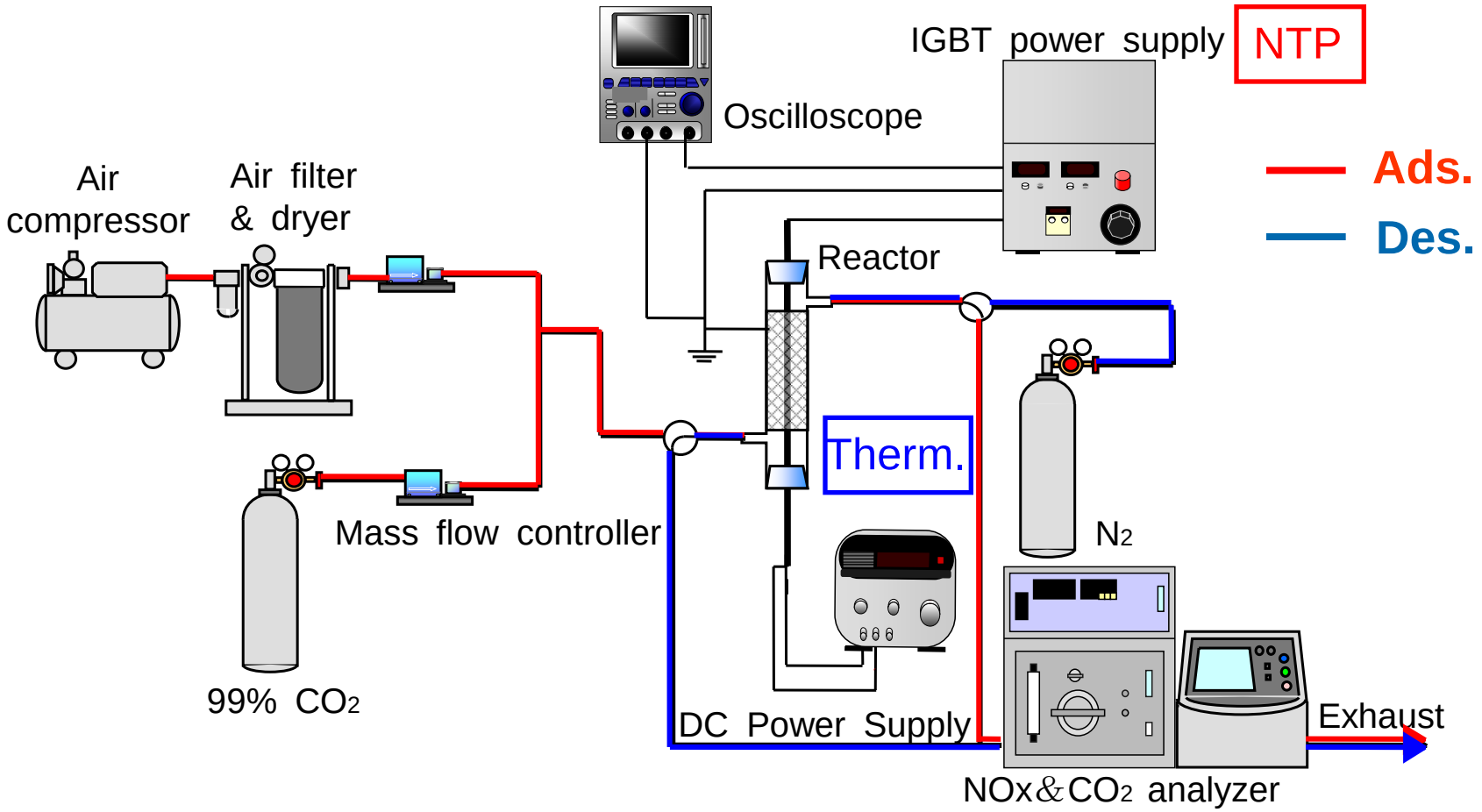



- **CO production efficiency (g / kWh) increases with increases in the concentration of $CO_2$.**

# *Experiments*

# Experimental apparatus

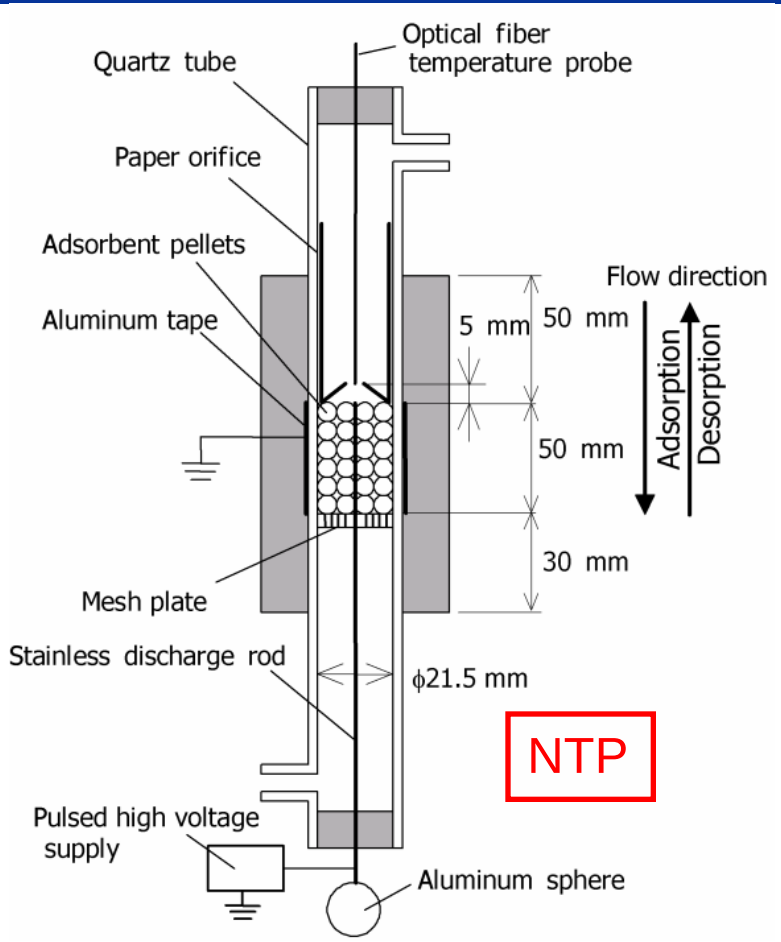


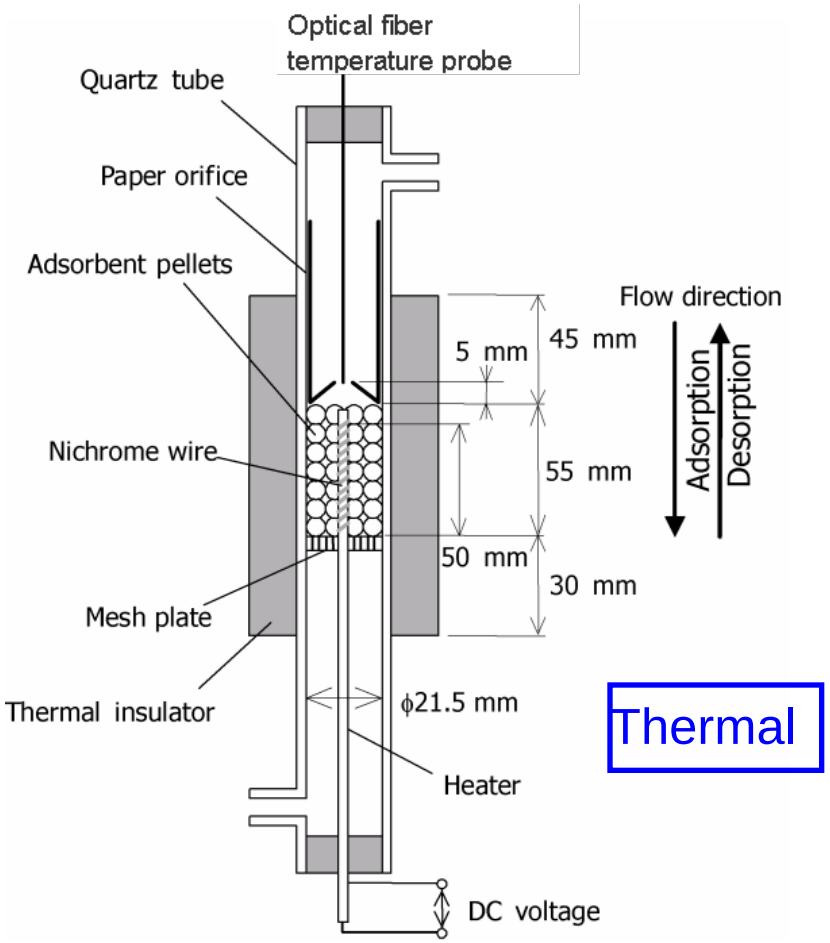



**Adsorption:** MS-13X (2mm, 12 g), $CO_2$ = 2.75%, $Q$ = 4.0 L/min, $t$ = 10 min
**Desorption:** flow rate = 0.5 L/min, $t$ = 7 min,
Input power = 8.4 W (NTP: IGBT $f$ = 210 Hz or thermal heater )

# Detail of the reactors



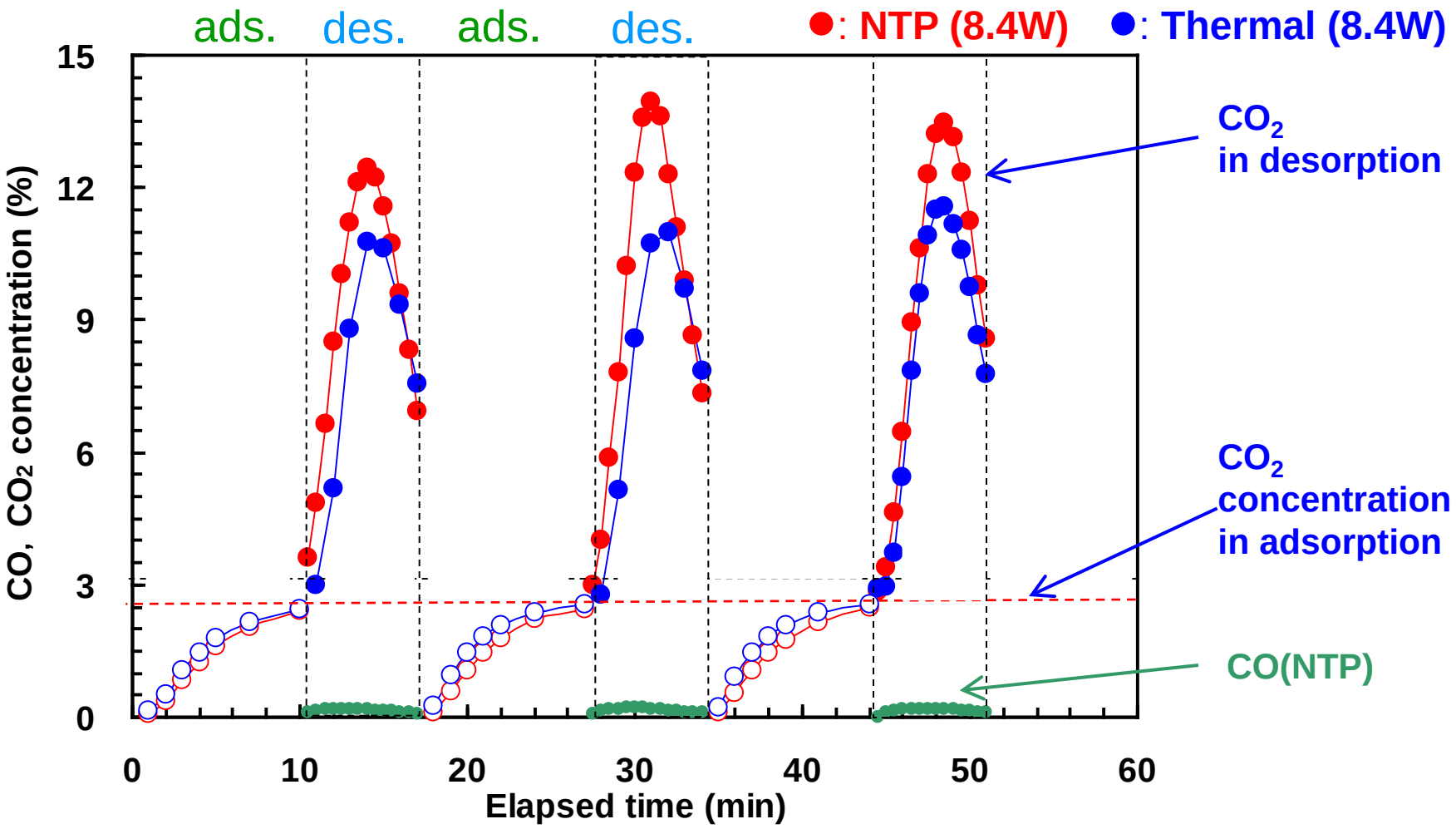



- Coaxial quartz reactors (effective $L$ = 50 mm) with centered wire or heater
- Different flow directions in adsorption/desorption
- NTP: $V_p$ = 35 kV, pulse $f$ = 210 Hz, width = 600 ns, $O_2$ = 18%, $H_2O$ = 1%

# Adsorption/desorption ($CO_2$ =2.75%)

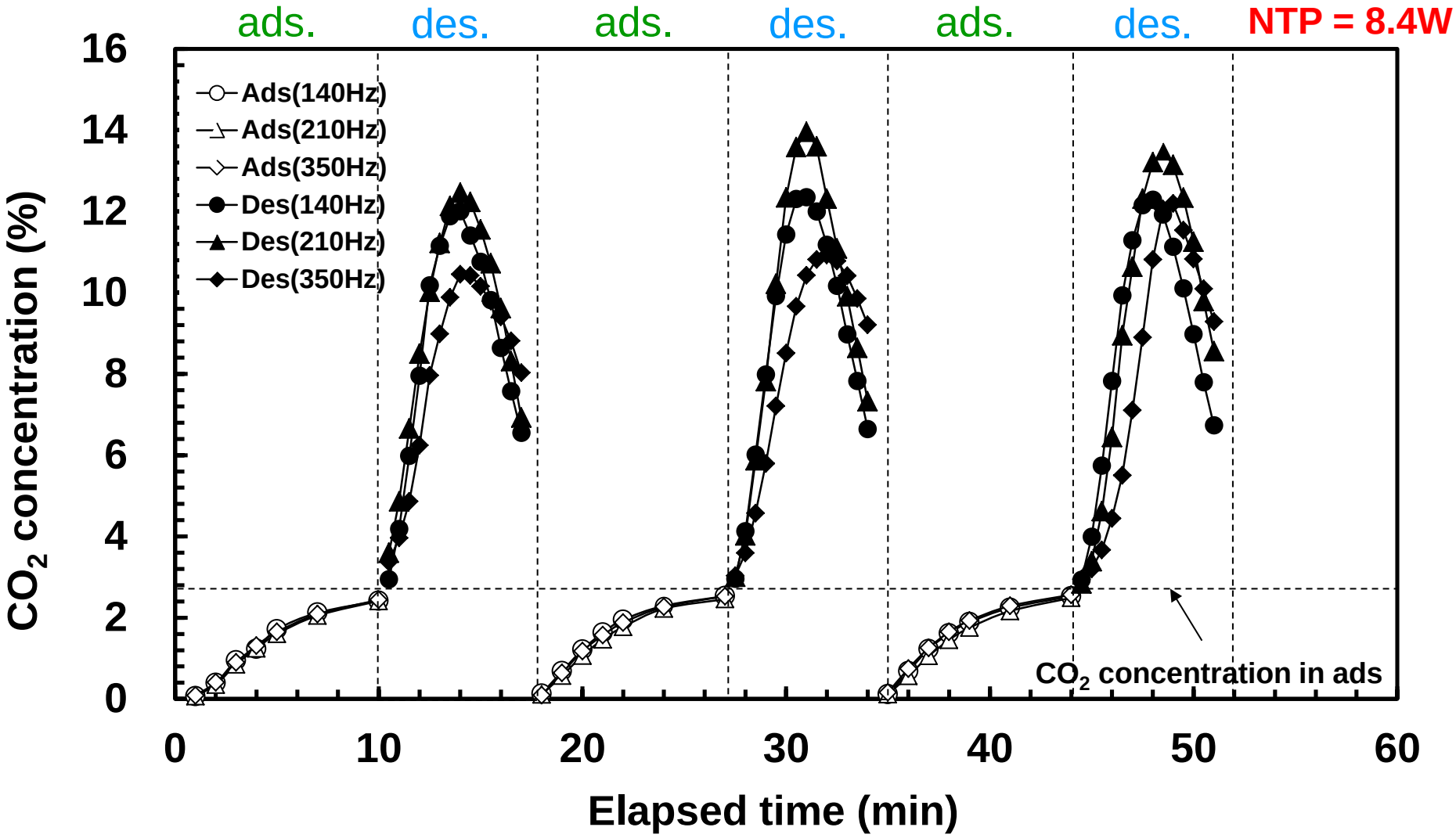





- NTP desorption has higher performance for the same power

# Adsorption/desorption (Effect of frequency)

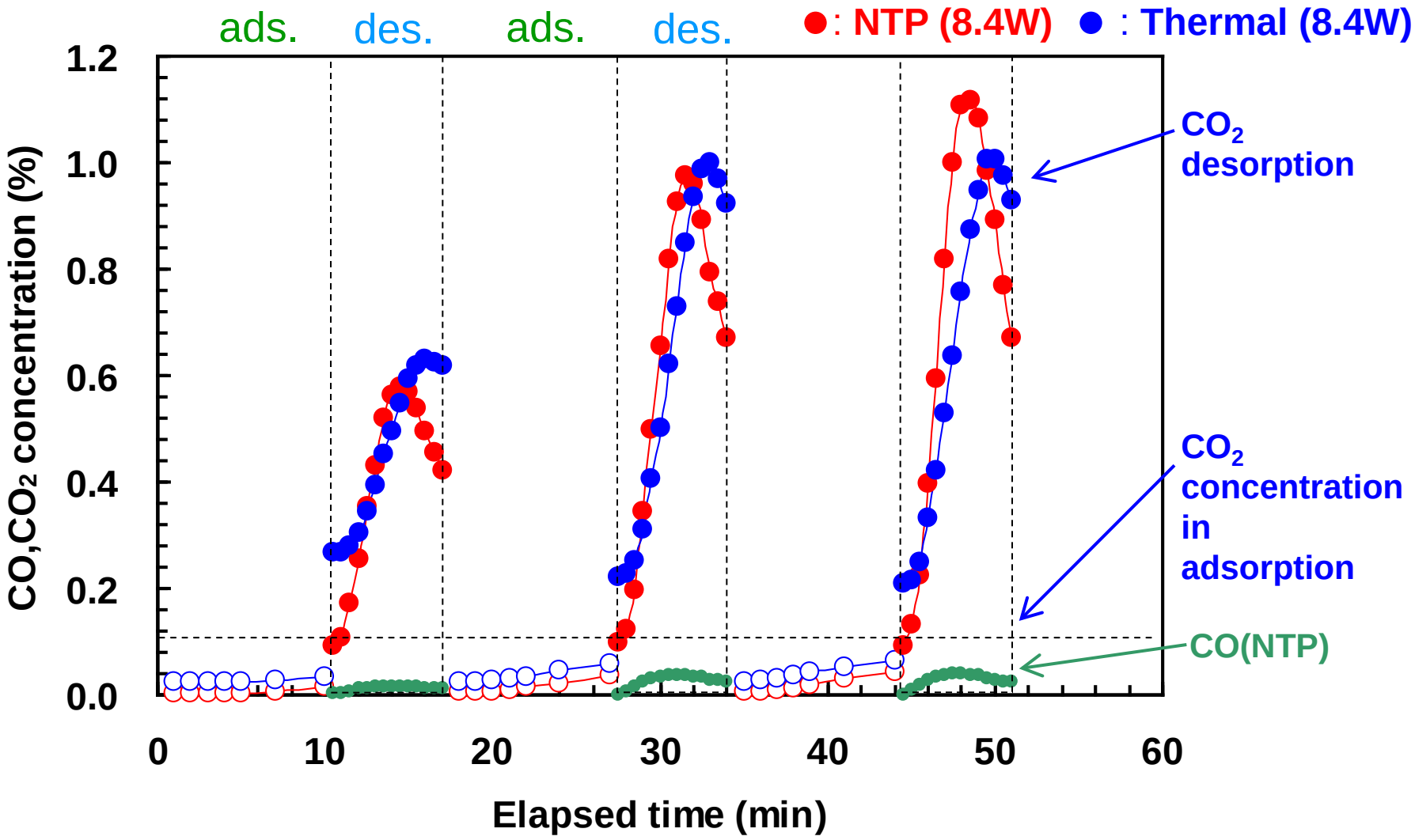





- $CO_2$ desorption increases with increase in the frequency.

# Adsorption/desorption ($CO_2$=1000 ppm)

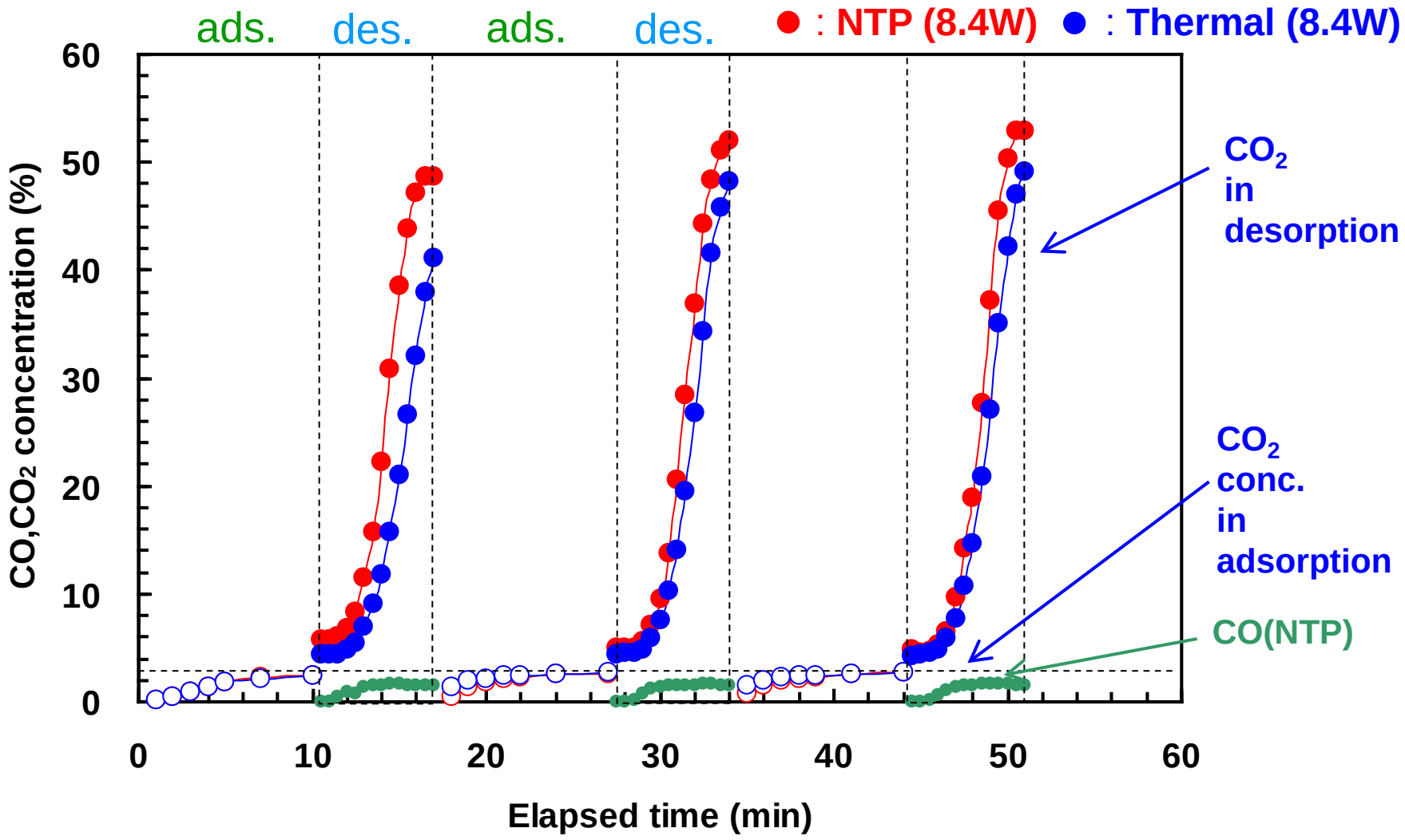





- For $CO_2$ of 1000 ppm, the performance of NTP is higher.

# Adsorption/desorption (desorption $Q$ = 0.1L/min)

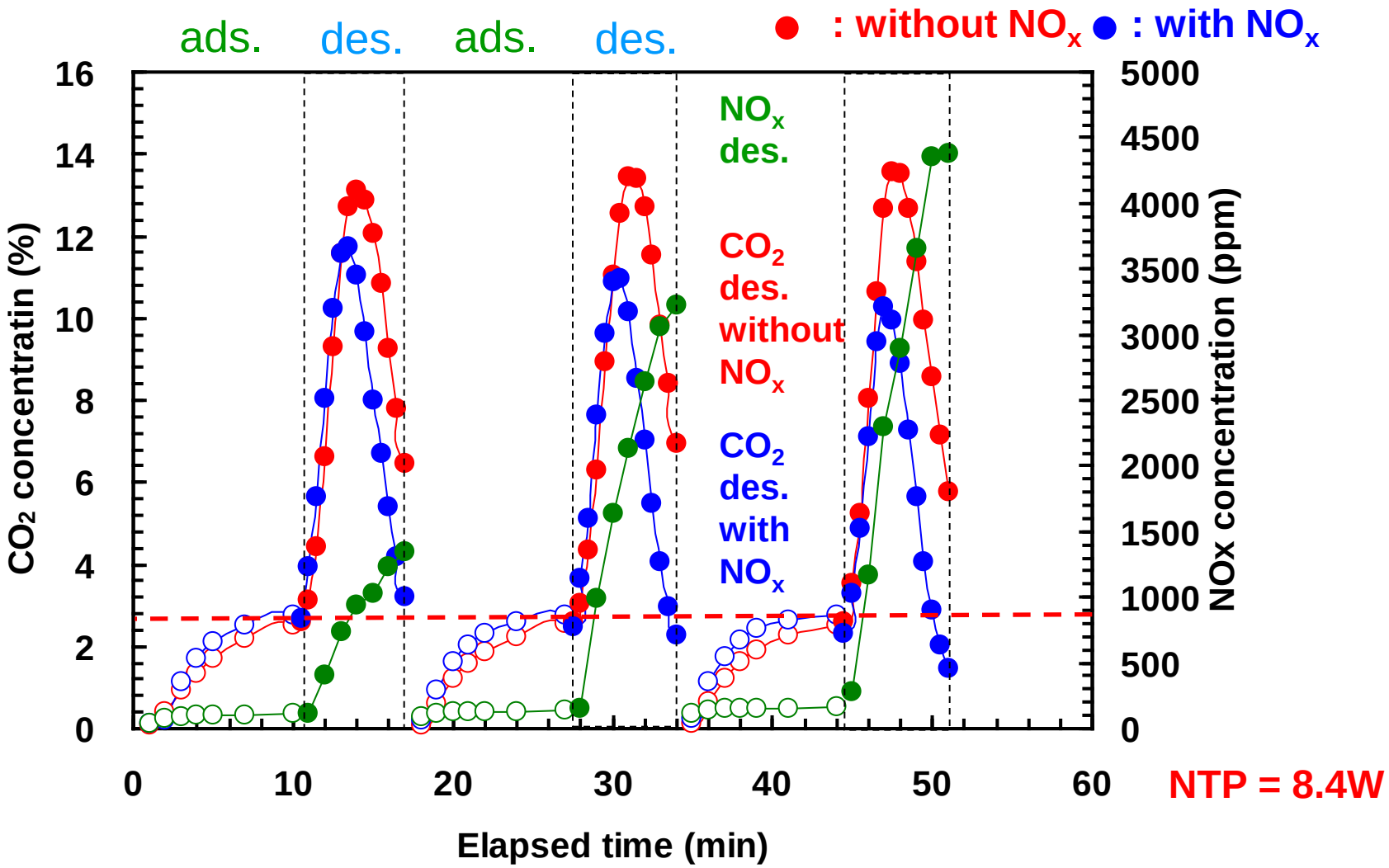





- High concentration near 50% is achieved, but difference is small.

# 1000ppm NO mixing (NTP desorption)

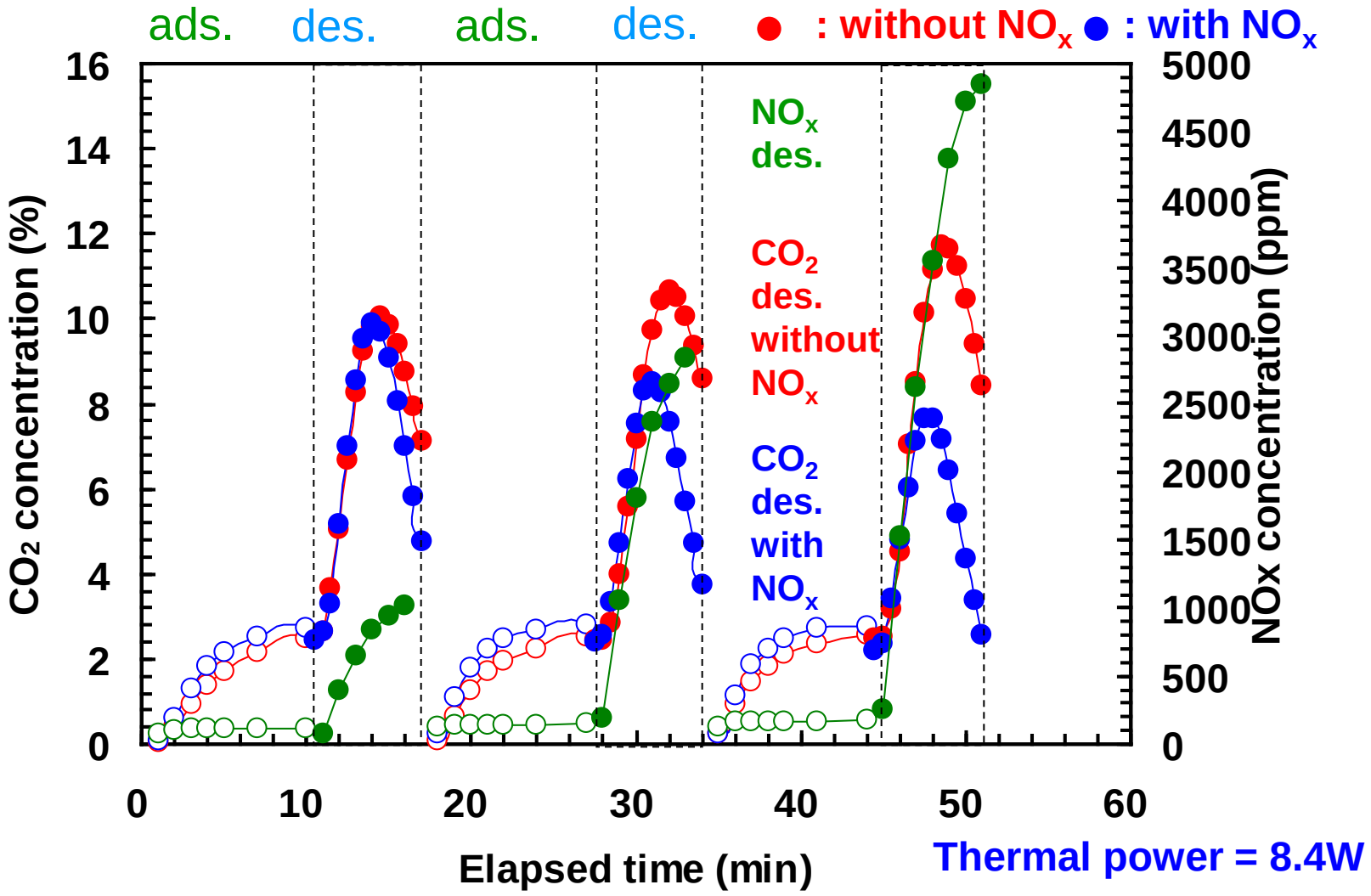





● $CO_2$ desorption decreases by the energy consumption of $NO_x$

# 1000ppm NO mixing (thermal desorption)



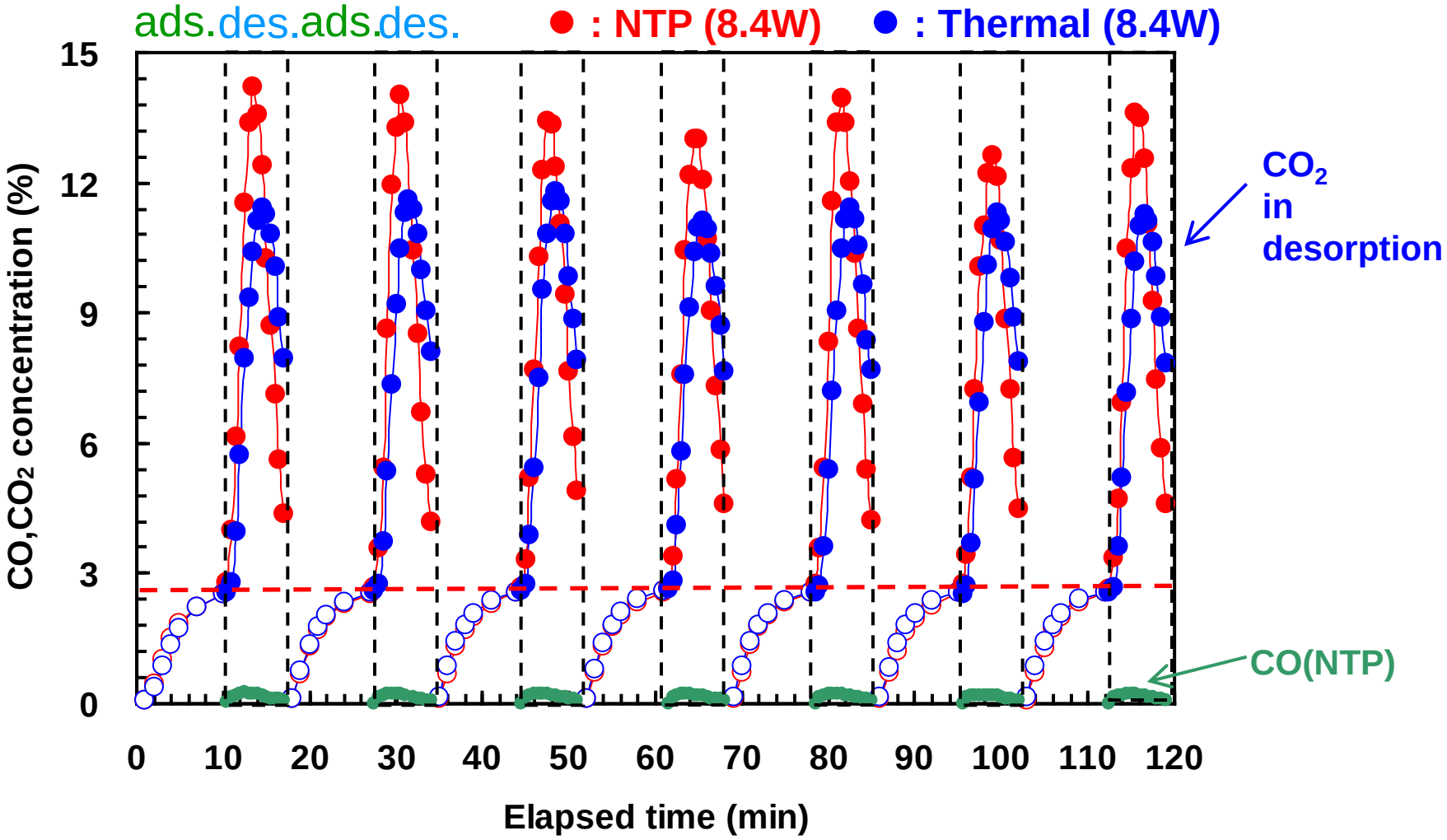



● $CO_2$ desorption greatly decreases in thermal desorption with $NO_x$

*Repeated adsorption/desorption*

# Repeated adsorption/desorption






- After 7 repeated adsorption/desorption, they reach the steady state.
- A little CO is induced by NTP desorption
- The peak concentration in NTP desorption is higher than that of the thermal one.

# Conclusions



- Higher-efficiency NTP $CO_2$ reduction could be possible with NTP concentrating desorption with lower power.
- When $CO_2$ concentration is 2.75%, NTP desorption is more effective with **20% higher peak** than the thermal.
- When $CO_2$ concentration is 1,000ppm, NTP is more effective with **10% higher peak** than the thermal.
- When NO is mixed, the performance of $CO_2$ concentration decreases.
- Approx. **20 times $CO_2$ concentration** is achieved.
- After 7 repeated adsorption/desorption, they reach the steady state. The peak concentration in NTP desorption is always higher than that of the thermal.

# *Thank you for your attention !*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