Study of particle attachment on silicon wafers during rinsing

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Outline

1. Introduction
2. Experimental Method ①
3. Result & Discussion ①
4. Experimental Method ②
5. Result & Discussion ②
6. Conclusion

Introduction : Requirement for Ultrapure water quality

（ITRS2013　Yield Enhancement Table YE3）

	2013	2014	2015	2016	2017	2018	2019
Critical particle size[nm]	20	17.9	15.9	14.2	12.6	11.3	10
Number of particles[#/L]	1000	1000	1000	1000	1000	1000	1000

According to the ITRS, the number of particles should be reduced less than 1000 #/L for the size of at 10 nm particles by the year of 2019.

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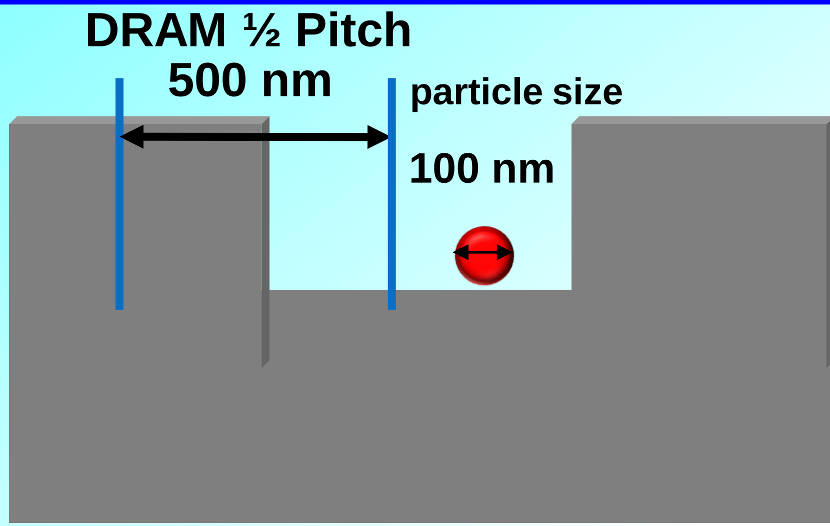
Introduction : Particle monitoring 1990s to 2019

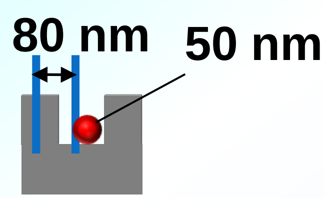
On-line monitor

【1990s】



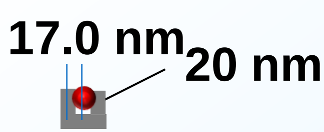
> φ 100 nm

【2000s】



> φ50 nm
(UDI-50)

【2019】



> φ20？ nm
(UDI-20)

It has been reaching the size detection limit of LPC

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Introduction : Requirement for wafer cleanliness by the ITRS

（ITRS2013　Front End Process Table FEP11）

	2013	2014	2015	2016	2017	2018	2019
Critical particle size[nm]	**14.2**	**12.0**	**11.3**	**10**	**8.9**	**8.0**	**7.1**
Number of particles[#/wafer]	**12.6**	**34.2**	**34.2**	**34.2**	**34.2**	**34.2**	**34.2**

According to the ITRS, the number of particles on the wafer should be controlled very severely.

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Introduction : Purpose of this study

<Needs for particle in UPW>

- **How should we detect the smaller particle ?**
- **How should we reduce the particle in UPW?**
- **What level should we remove particle in UPW to? ①**
- **What impurity increases particle adhesion on wafer ②**

Focus of this study

Purpose of this study

To clarify how the particle in UPW adsorb onto wafer surface

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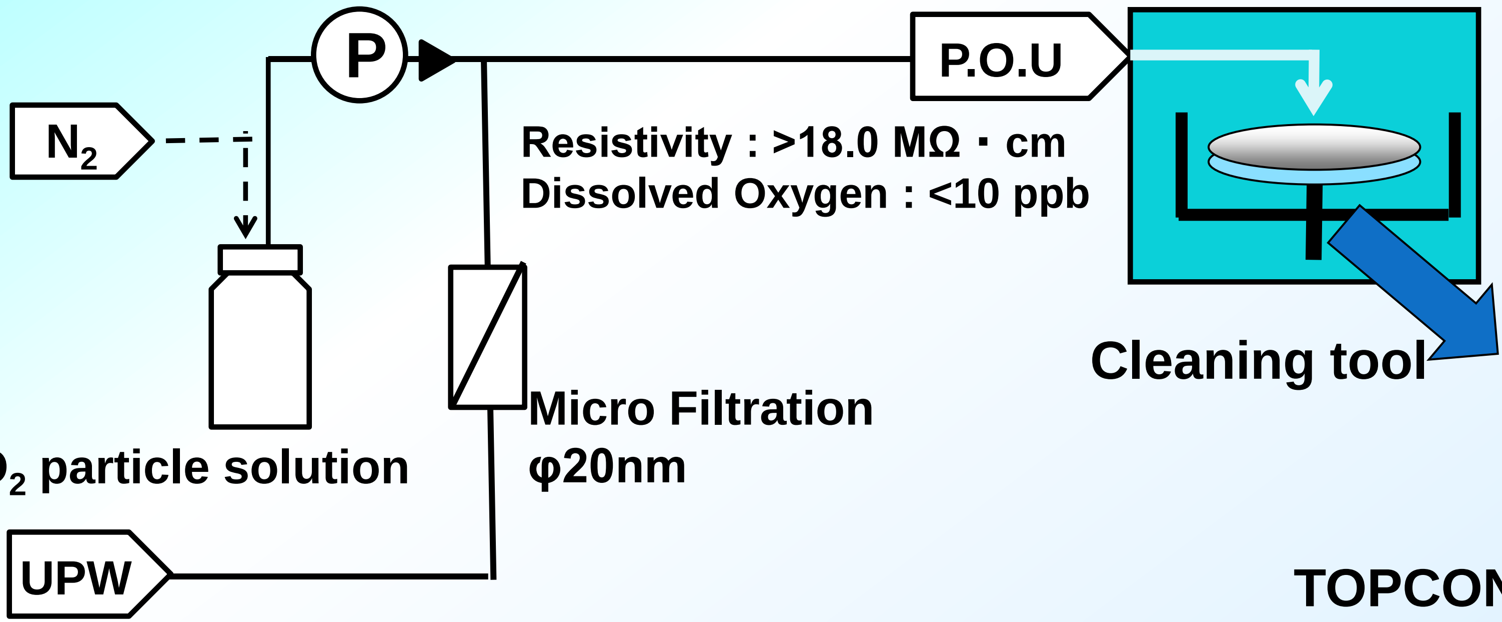
Experimental Method① : Experimental condition and flow

<Experimental condition>

- Wafer : 150 mm SiO_2/Si(100)
- Injected particle : SiO_2
- Injected particle size : around 100 nm
- Particle concentration in UPW : 20,000 #/mL
- Pre-cleaning : O_3 (30ppm) water rinse in 180 sec



TOPCON WM-1500

Detect particle size : >0.1 μm

Experimental Method ① : Rinsing recipe

< Rinsing recipe >

Operation No.	1	2	3	4	5	6
Rotation speed [rpm]	500	300	200	ω_1 (1000)	ω_2 (1000)	200
Time [sec]	2	5	5	t_1 (20)	t_2 (40)	5

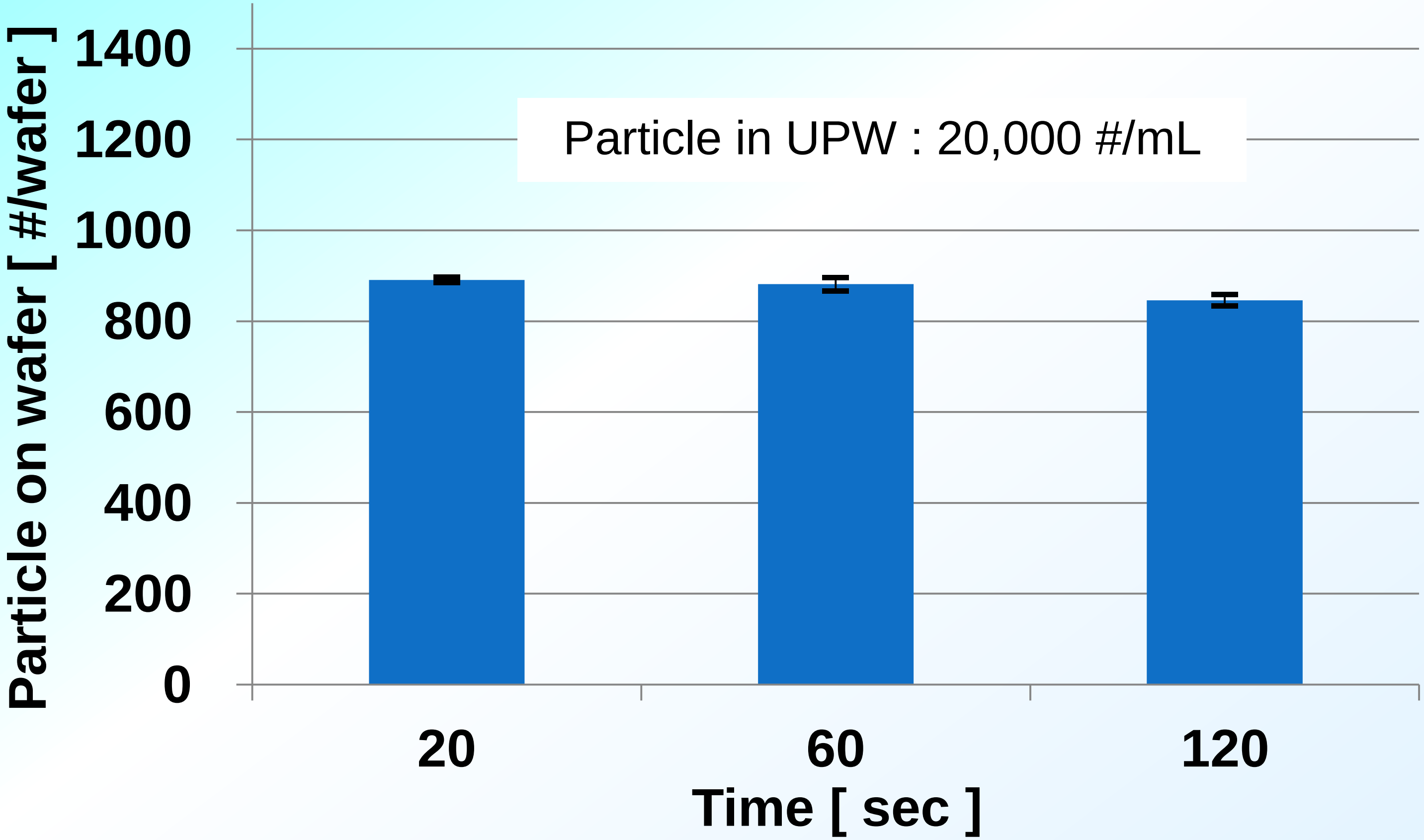
Rinsing process (Operations 2–4)

Drying process (without N2 gas) (Operations 5–6)

The test conditions(ω and t) were changed in order to clarify the behavior of particle adsorption on wafer surface.

Result ① : Effect by the rinsing time on particle adsorption

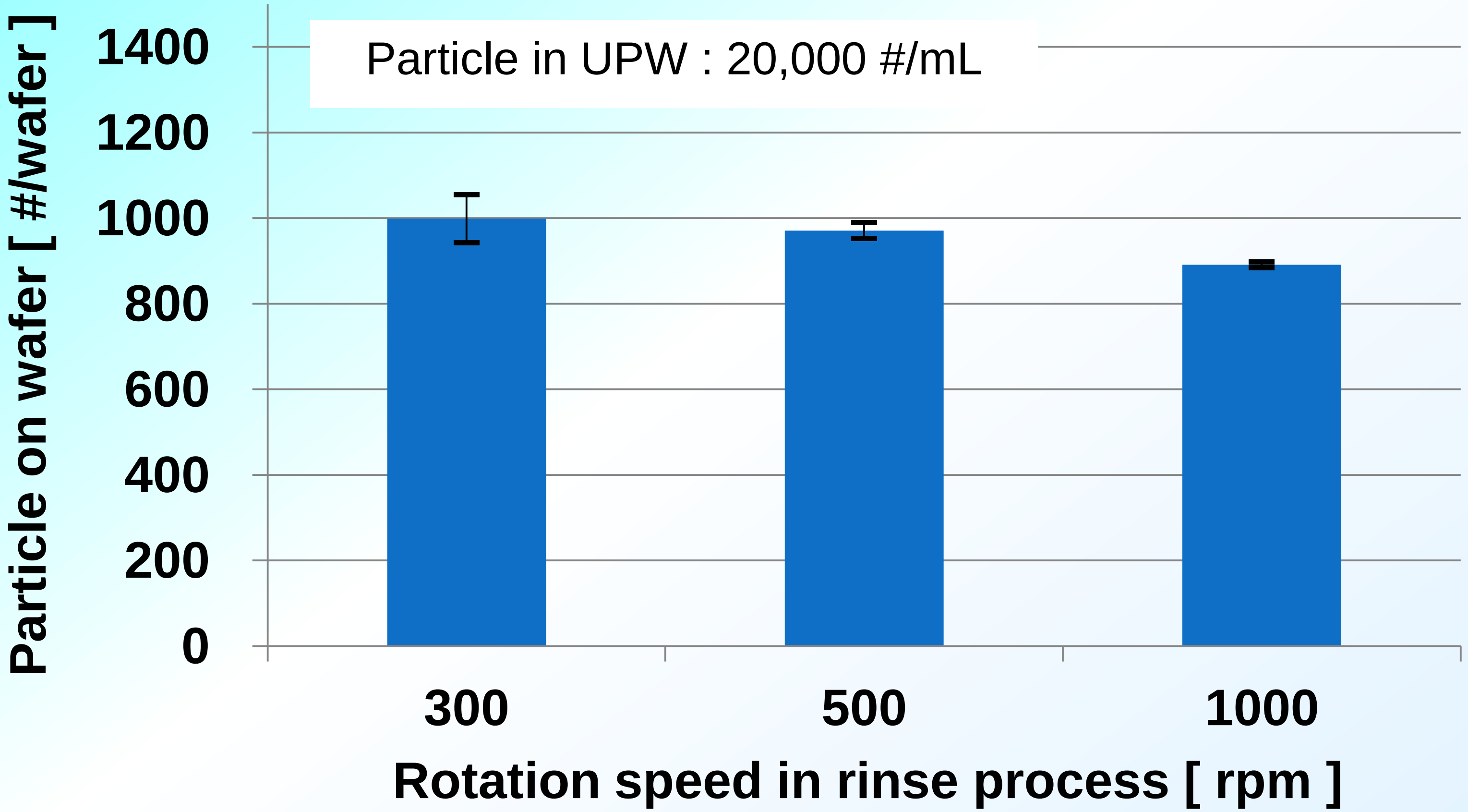
Operation No.	1	2	3	4	5	6
Rotation speed [rpm]	500	300	200	1000	1000	200
Time [sec]	2	5	5	t_1	40	5



Rinsing time does not affect the number of particle on wafer.

Result ① : Effect by the rotation speed in rinsing process on particle adsorption

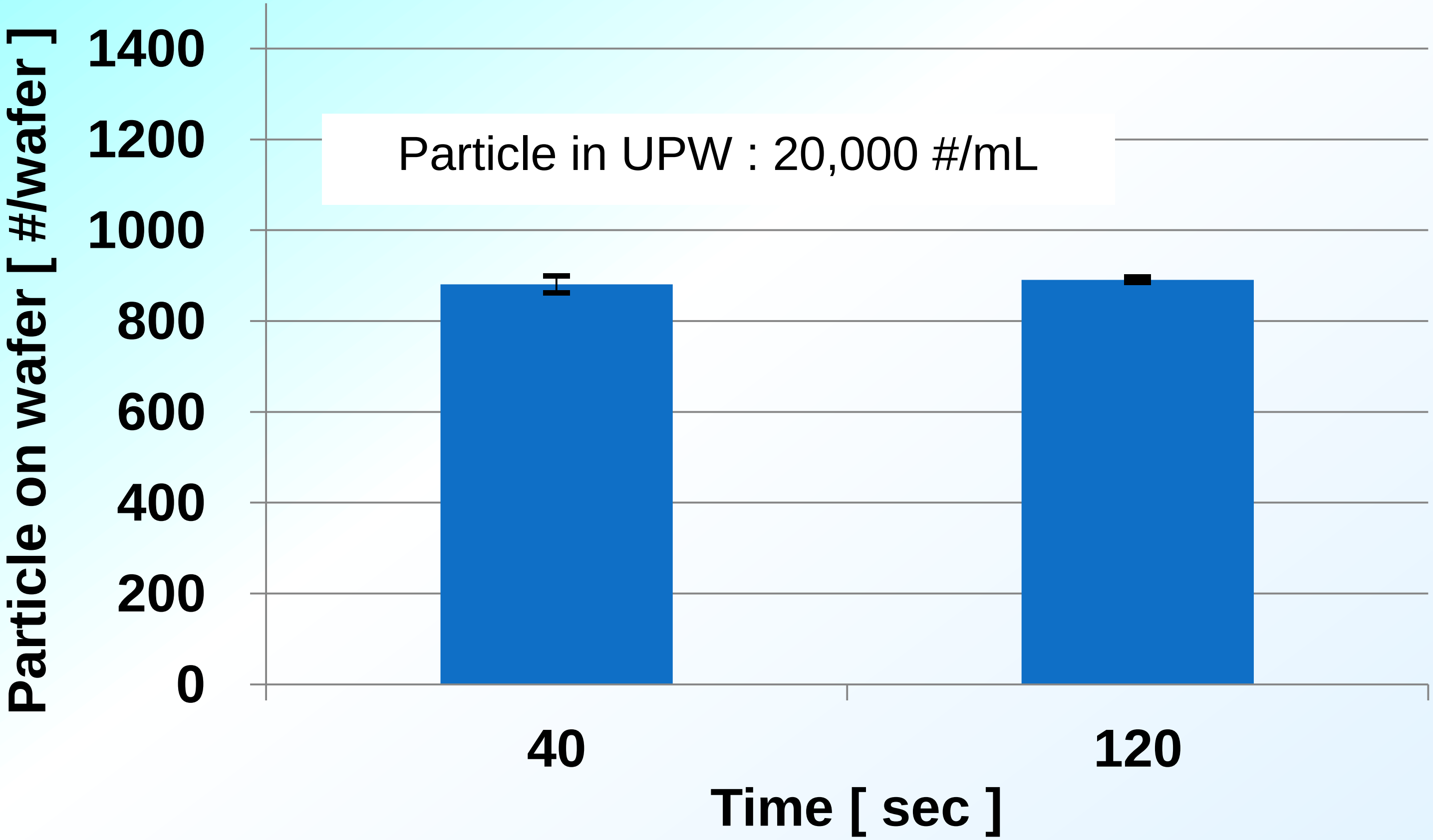
Operation No.	1	2	3	4	5	6
Rotation speed [rpm]	500	300	200	ω_1	1000	200
Time [sec]	2	5	5	20	40	5



Rotation speed in rinsing process does not affect the number of particle on wafer.

Result ① : Effect by the drying time on particle adsorption

Operation No.	1	2	3	4	5	6
Rotation speed [rpm]	500	300	200	1000	1000	200
Time [sec]	2	5	5	20	t_2	5



Drying time does not affect the number of particles on wafer.

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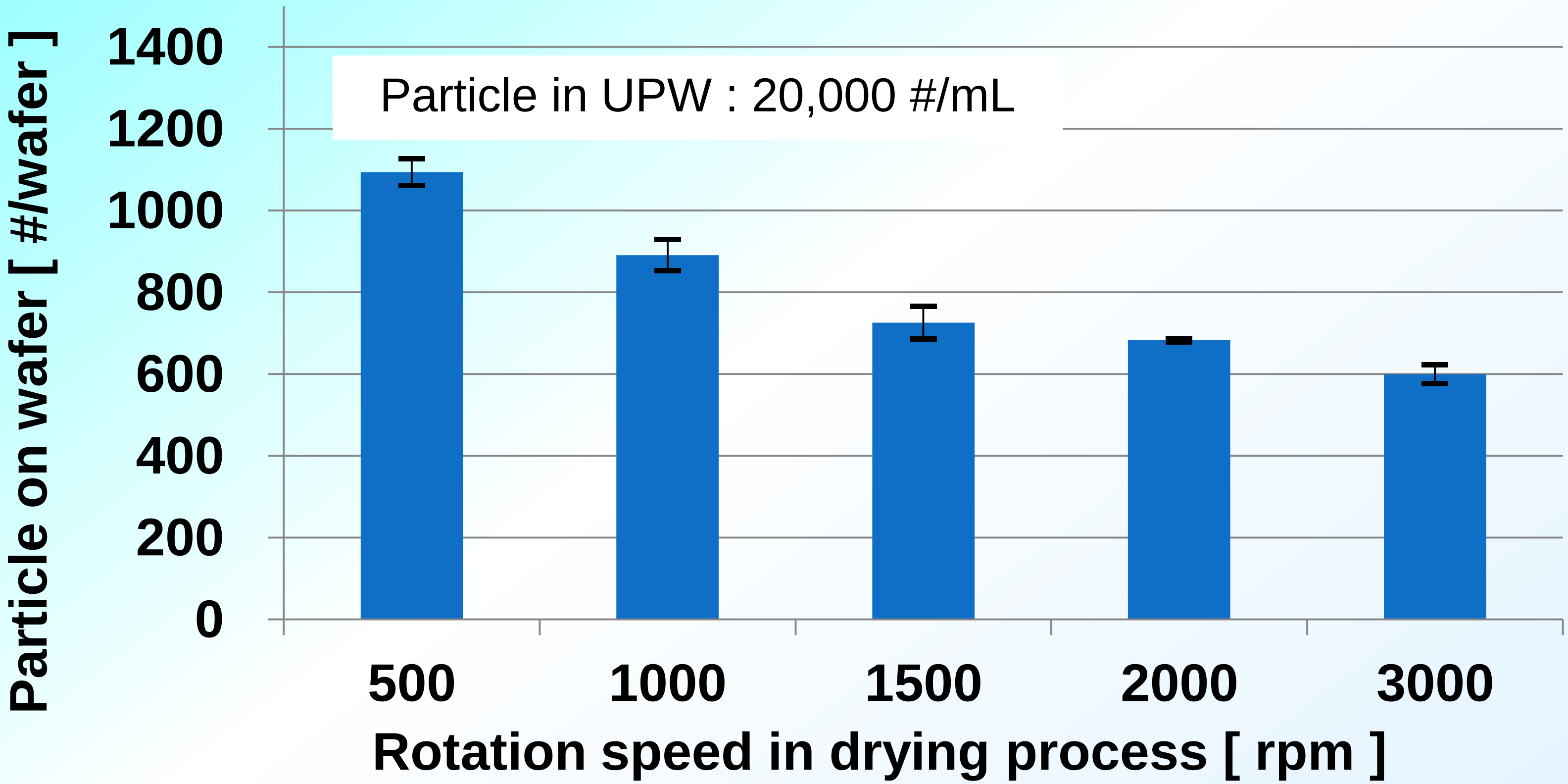
Result ① : Effect by the rotation speed in drying process on particle adsorption

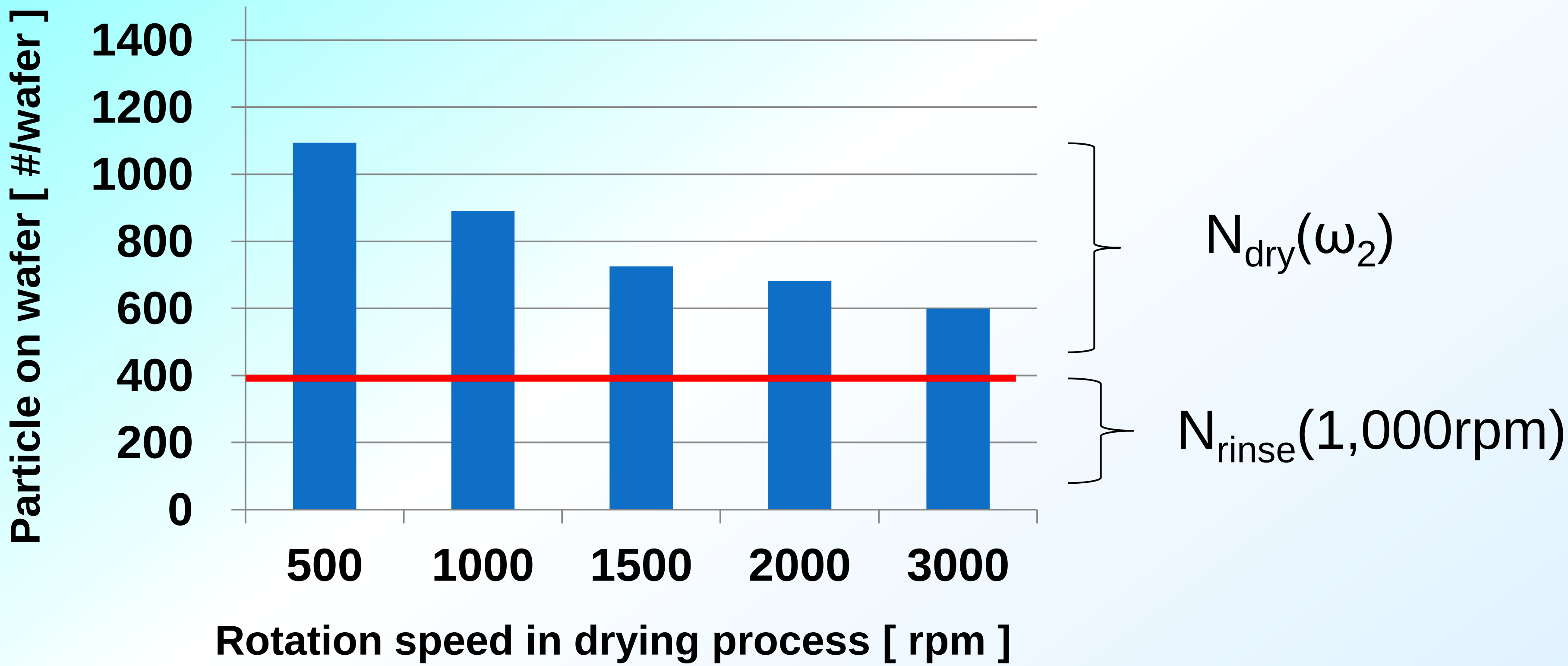
Operation No.	1	2	3	4	5	6
Rotation speed [rpm]	500	300	200	1000	ω 2	200
Time [sec]	2	5	5	20	40	5



Particle on wafer decreases as rotation speed in drying process increases.

Discussion ① : The model of particle adsorption onto wafer surface

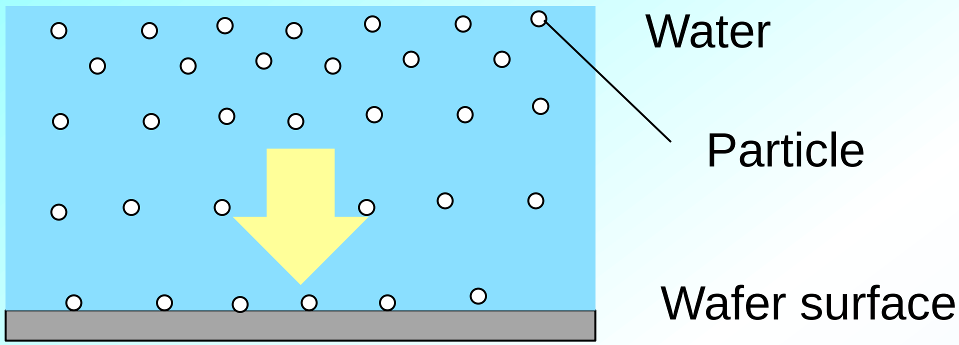
We divided two process of particle adsorption onto wafer surface.
One is rinsing process and another is drying process.
We evaluated each of effect.



$$N = N_{rinse}(\omega_1) + N_{dry}(\omega_2)$$

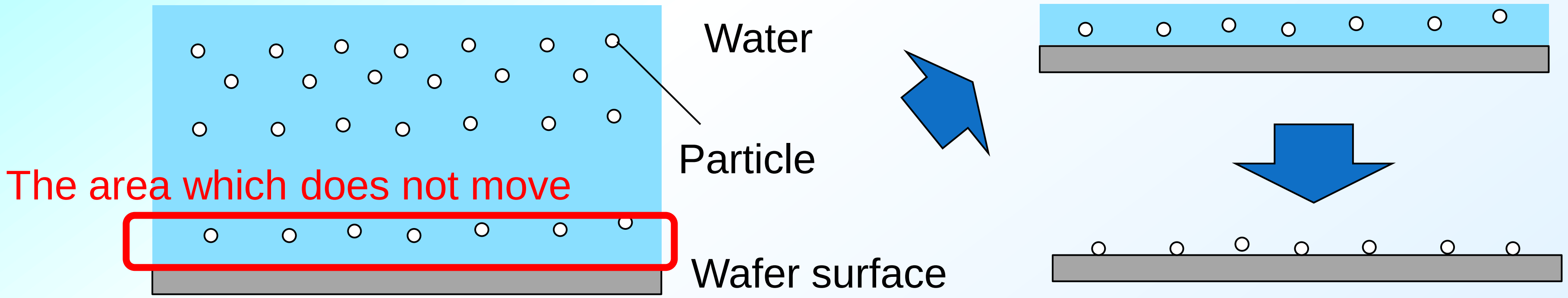
Discussion ① : The model of particle adsorption onto wafer surface

1.In the rinsing process



➢Particle adsorption to wafer surface by equilibrium reaction

2.In the drying process



➢Particles in the boundary layer accumulate on the wafer surface by water evaporation.

Discussion ① : How to calculate water property

The water thickness and the average velocity of water are shown as the equation (1) and (2).

$$h = e\frac{r}{(r+l)}\frac{v_0}{v_{av}} \qquad (1)$$

$$v_{av} = \sqrt{\frac{2(\mathrm{E}-\rho g e)}{\rho}} \qquad (2)$$

↓

The boundary thickness (3) can be calculated by the results of equation (1) and (2).

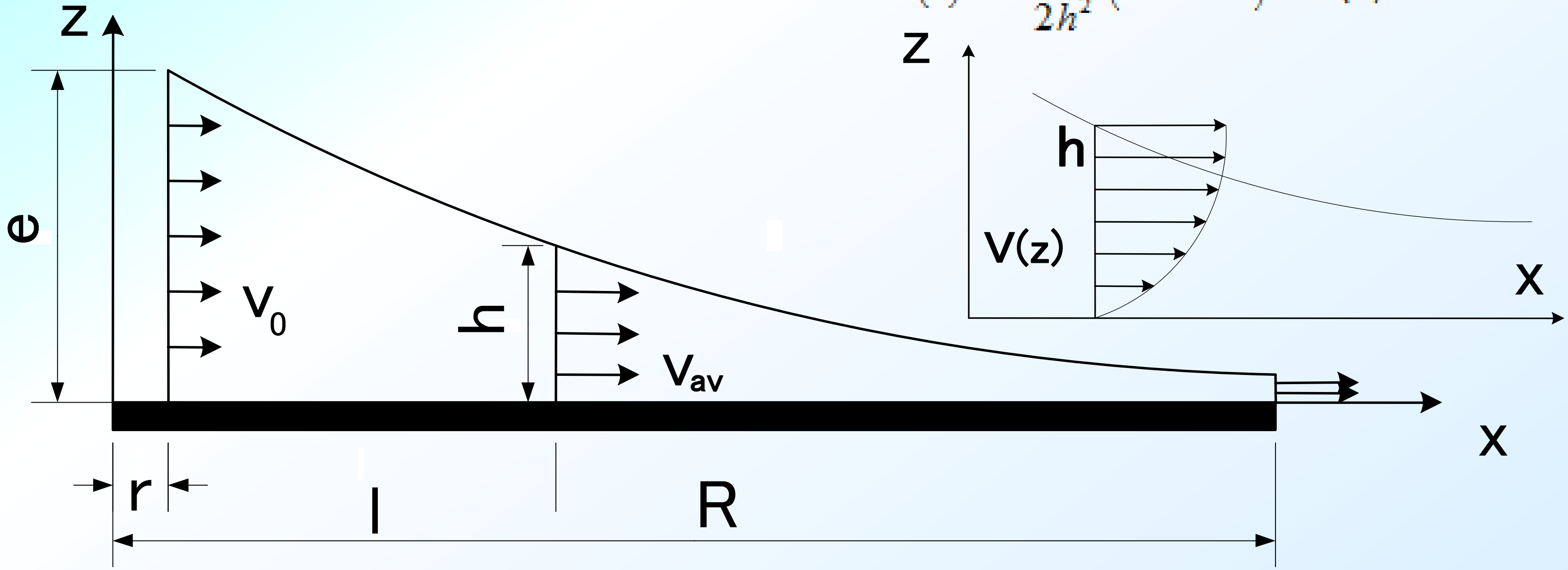
$$E = \frac{1}{2}\rho v_{av}^{2} + \rho g e = \frac{1}{2}\rho v_0^{2} + \rho g e + \int_{r}^{r+l} d\mathrm{E}$$

$$d\mathrm{E} = (C_f - F_f)dl = \left(\rho(r+l)\omega^2 - \frac{3\mu v_{av}}{h^2}\right)dl$$

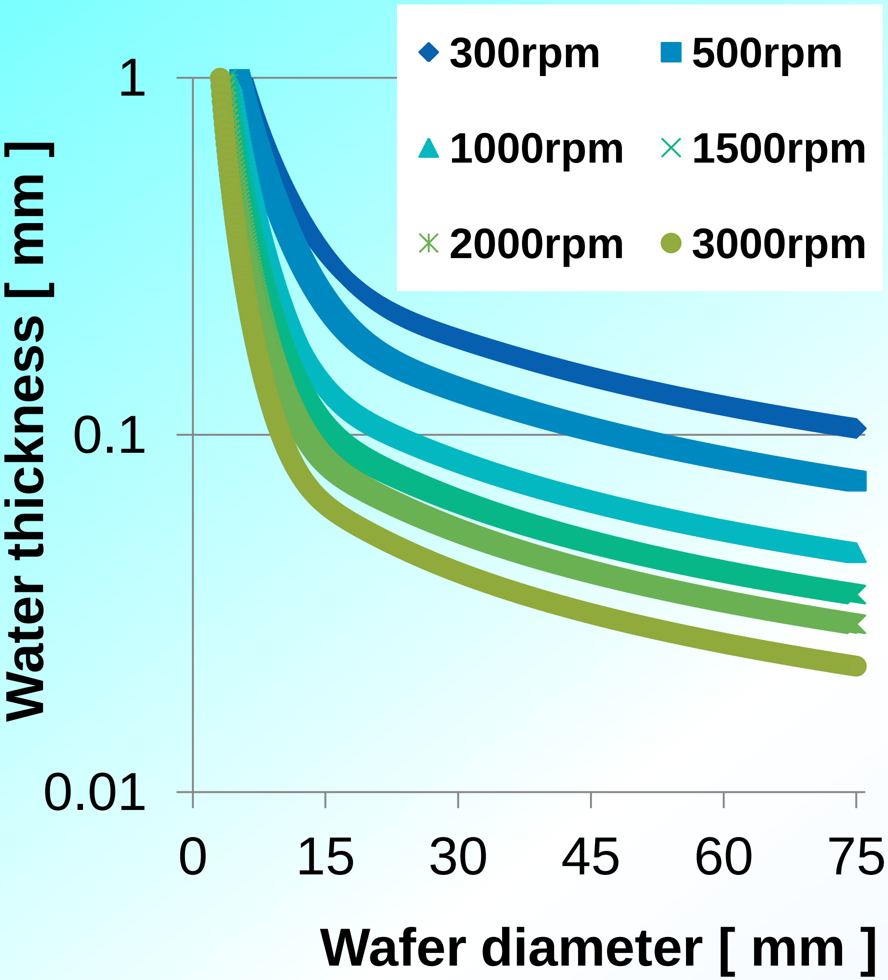
↓

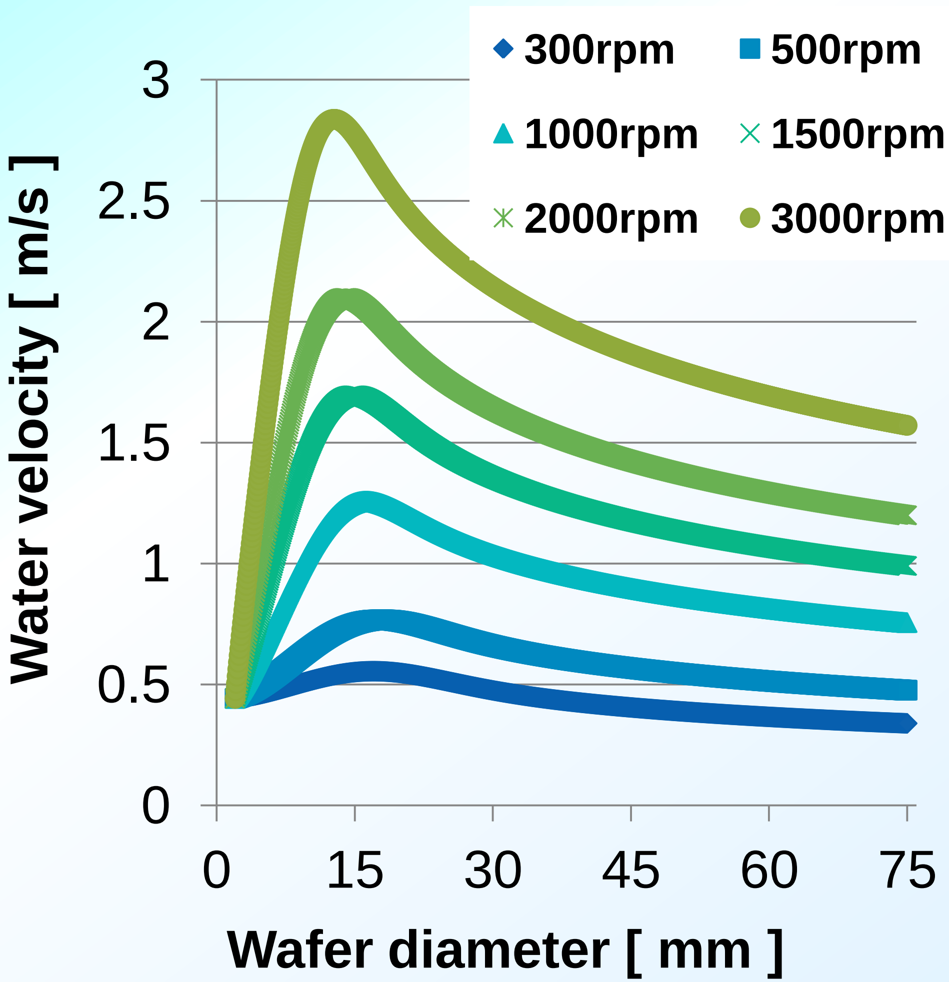
$$v(z) = -\frac{3v_{av}}{2h^2}\left(z^2 - 2hz\right) \qquad (3)$$

The number of particles adsorbed on the wafer is calculated.



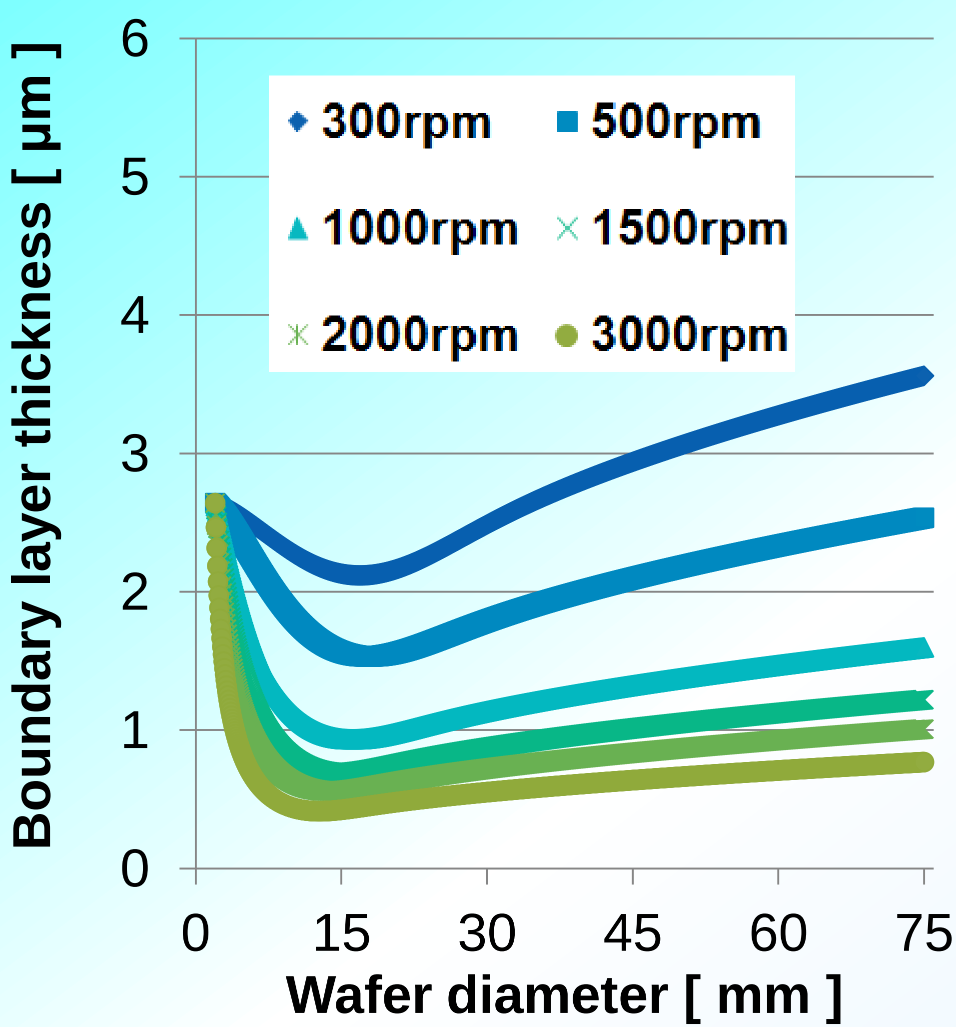
Discussion ① : Model calculation of spin cleaning

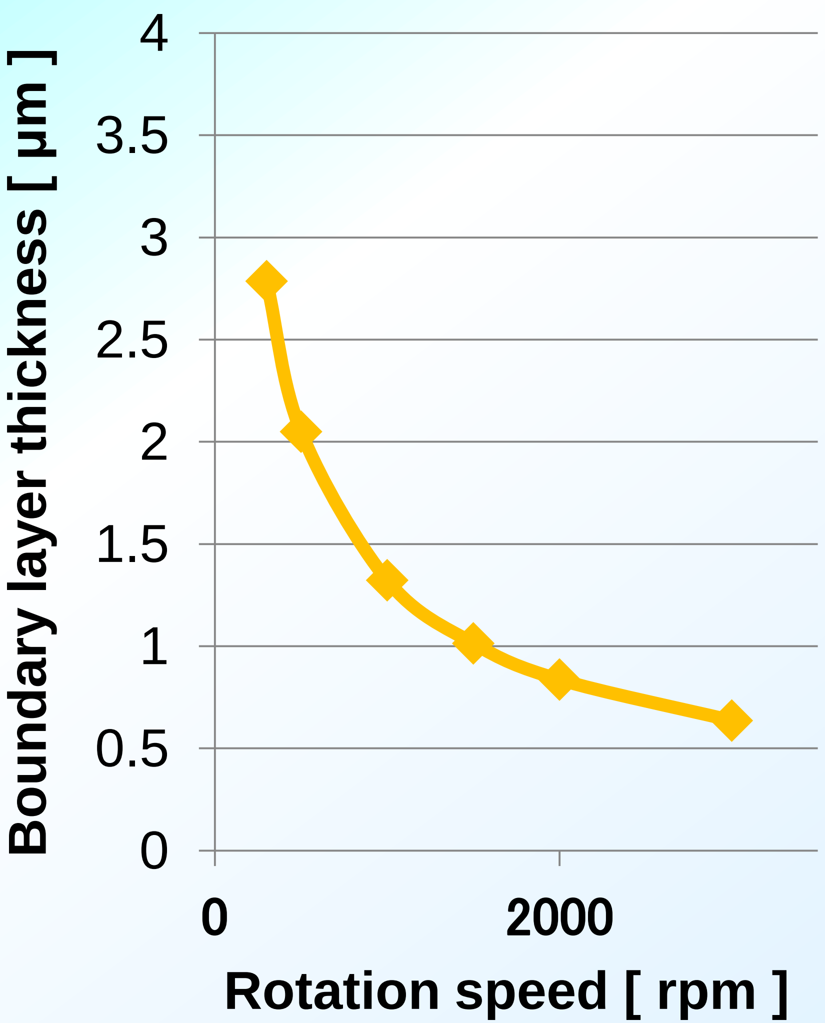




Water thickness and water velocity were calculated as functions of distance from the center of wafer.

Discussion ① : Boundary layer calculation





Boundary layer was calculated as a function of distance from the center of wafer.

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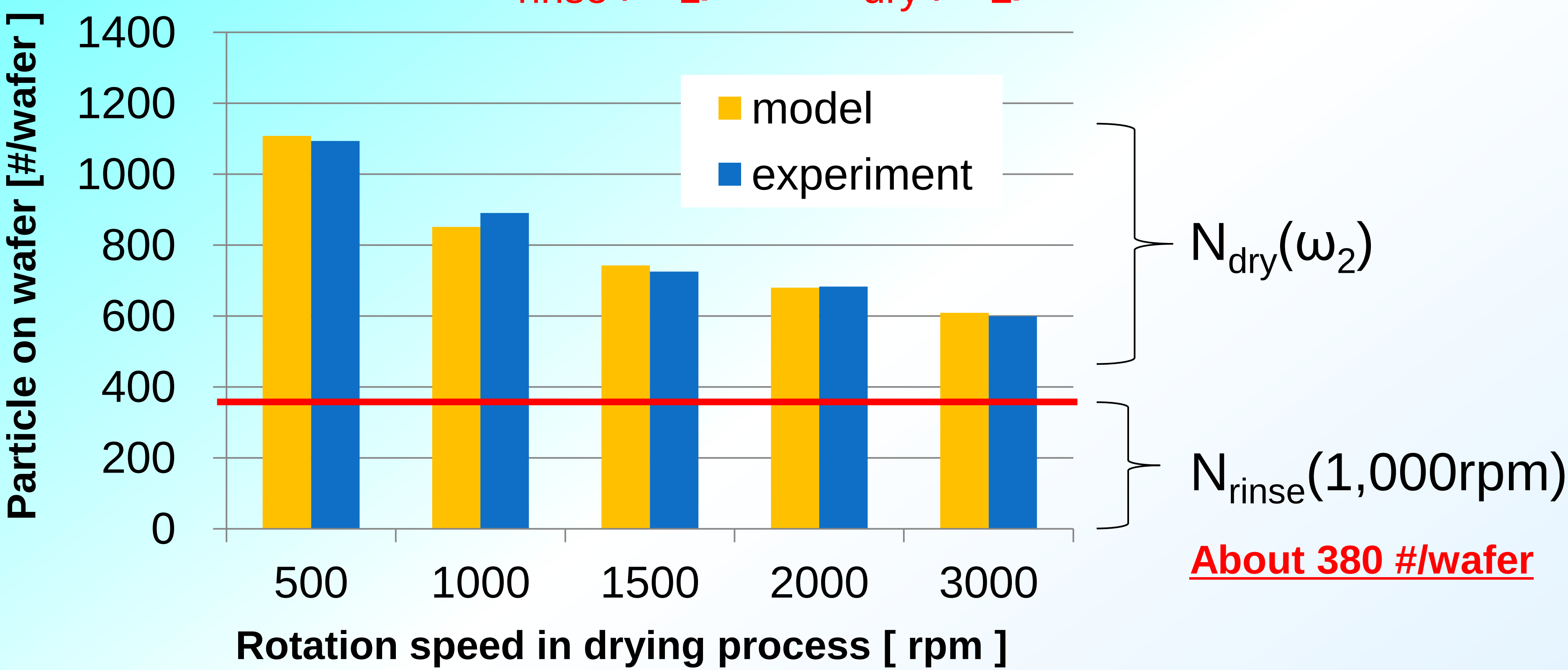
Discussion ① : Comparison between the model and experimental result

$$N = N_{rinse}(\omega_1) + N_{dry}(\omega_2)$$



- The calculation result well fitted with experimental result.
- The impact of rinsing process is roughly the same degree as that of drying process and cannot be ignored.

⇒ To avoid adhering particles to wafer on UPW cleaning process, the number of particle in UPW should be decreased.

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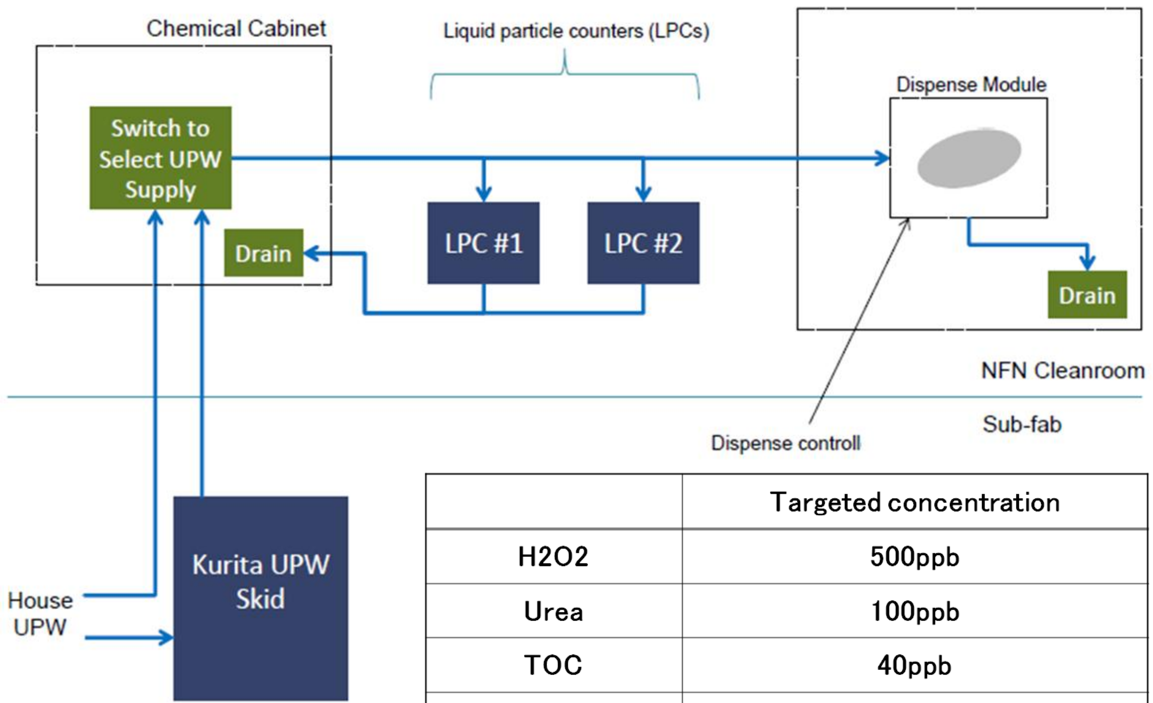
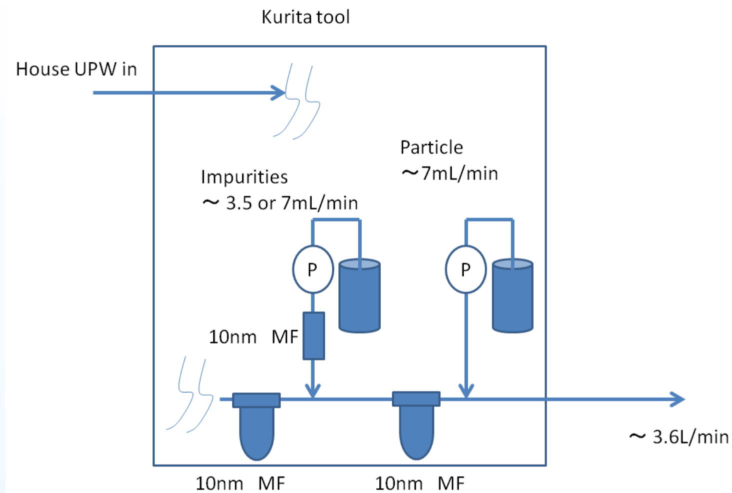
Experimental Method ②: Experimental condition and flow

<Experimental condition>

- Wafer : 300 mm SiO_2/Si and SiGe(Ge:50%)/Si
- Injected particle : SiO_2
- Injected particle size : 50 nm (for SiO_2/Si), 150 nm (for SiGe/Si)



	Targeted concentration
H2O2	500ppb
Urea	100ppb
TOC	40ppb
CO2	0.26mS/m (pH=5.1)
O2	900ppb



Kurita's water quality control unit

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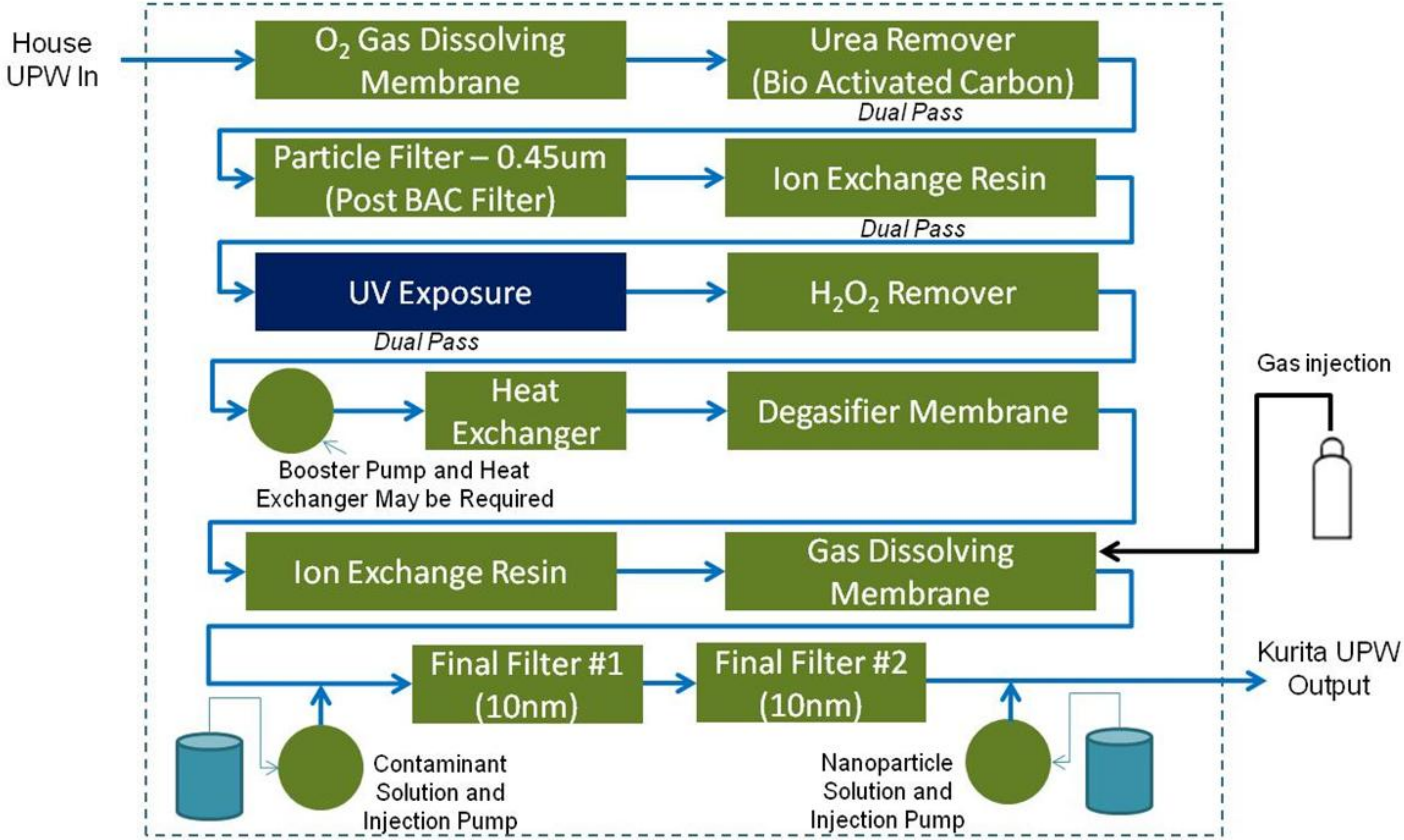
Experimental Method ② : Kurita's water quality control unit



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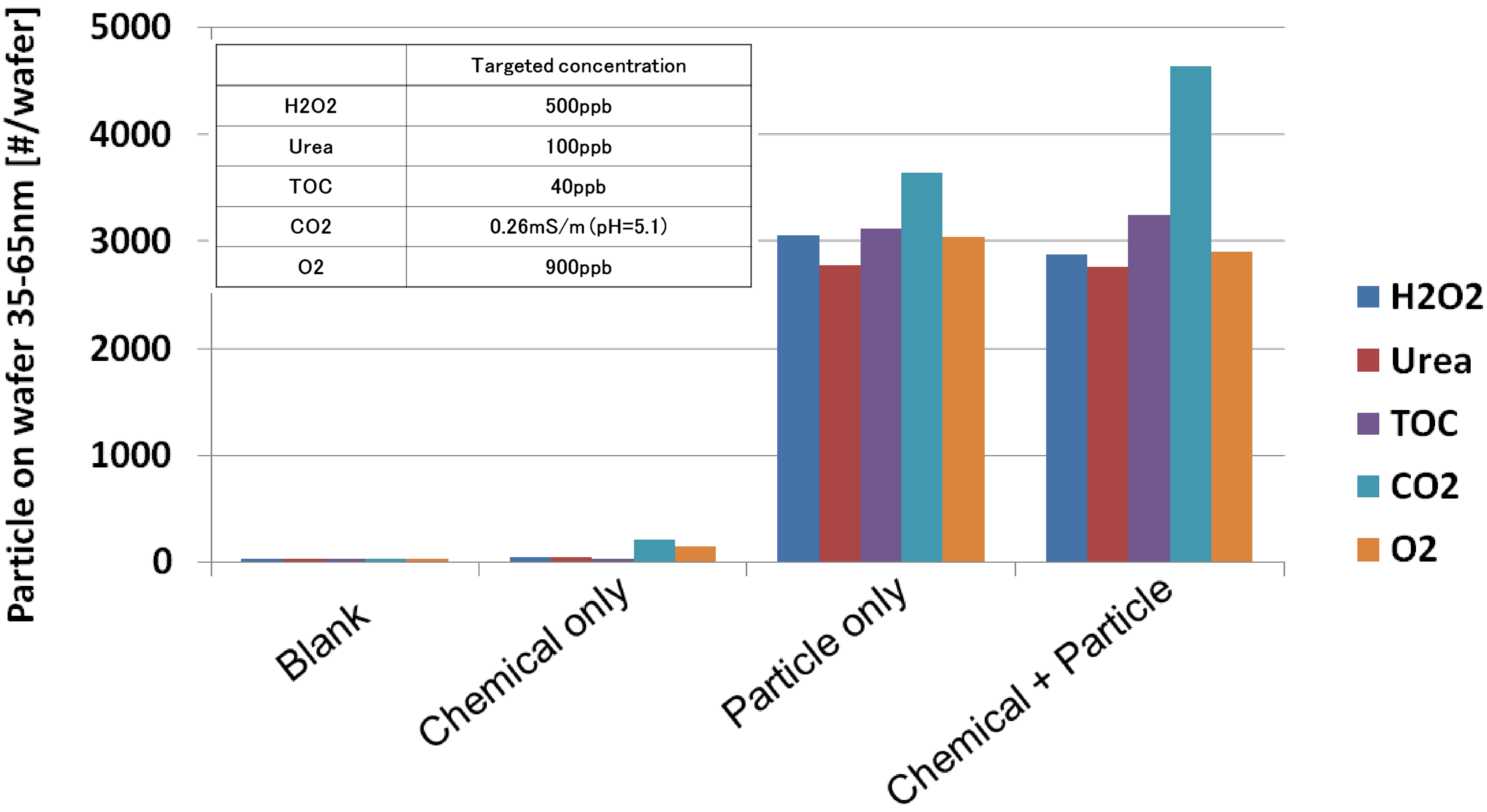
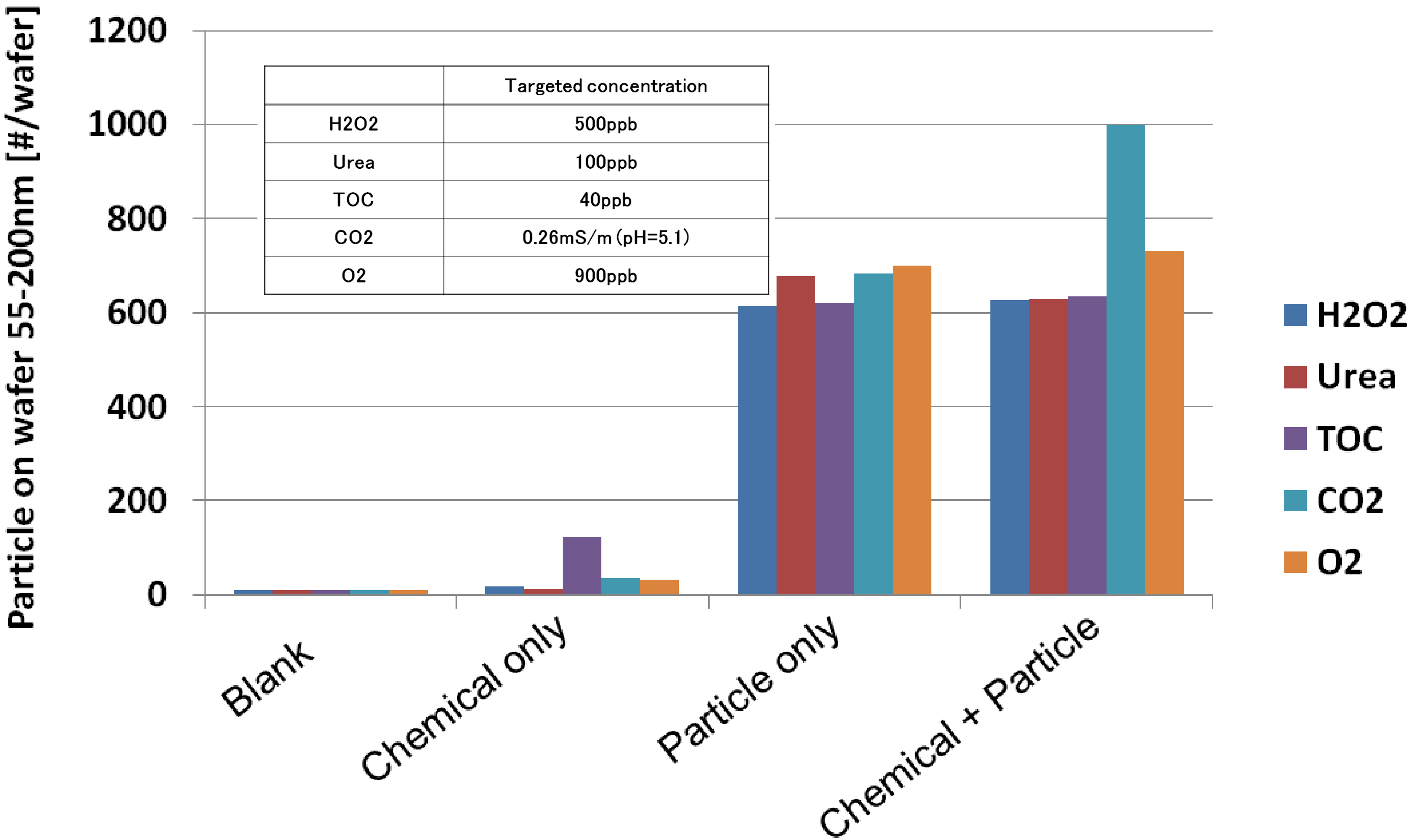
Result & Discussion ②: Effect of chemicals on SiO_2 /Si wafer and SiO_2 particle



	Targeted concentration
H2O2	500ppb
Urea	100ppb
TOC	40ppb
CO2	0.26mS/m (pH=5.1)
O2	900ppb

CO_2 has the influence on particle adhesion to SiO_2 surface.

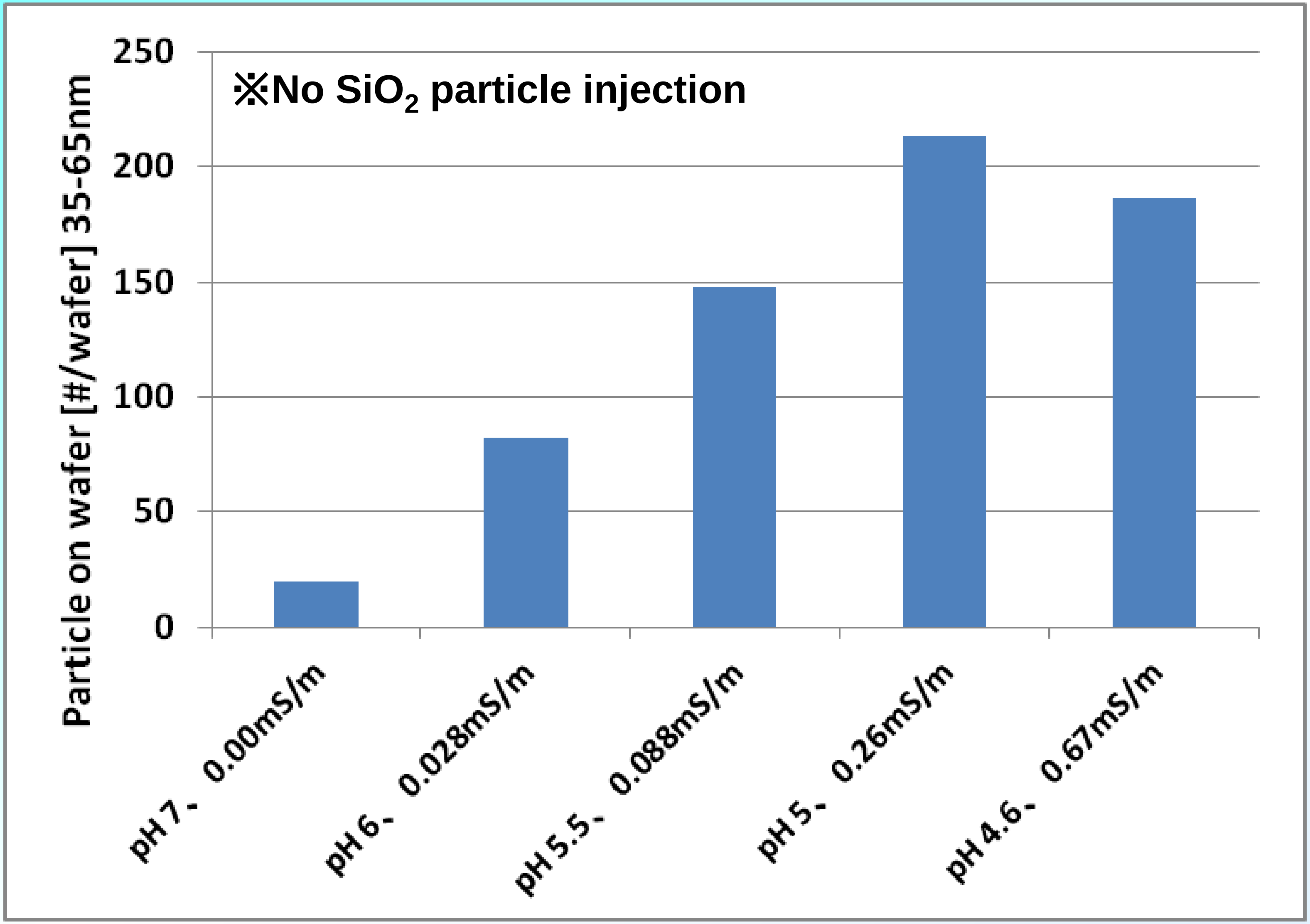
Result & Discussion ②: Effect of chemicals on SiGe /Si wafer and SiO_2 particle



	Targeted concentration
H2O2	500ppb
Urea	100ppb
TOC	40ppb
CO2	0.26mS/m (pH=5.1)
O2	900ppb

CO_2 has the influence on particle adhesion to SiGe surface.

Result & Discussion ②: Effect of CO_2 water on SiO_2/Si wafer



CO_2 has a strong influence on the number of particle on wafer.

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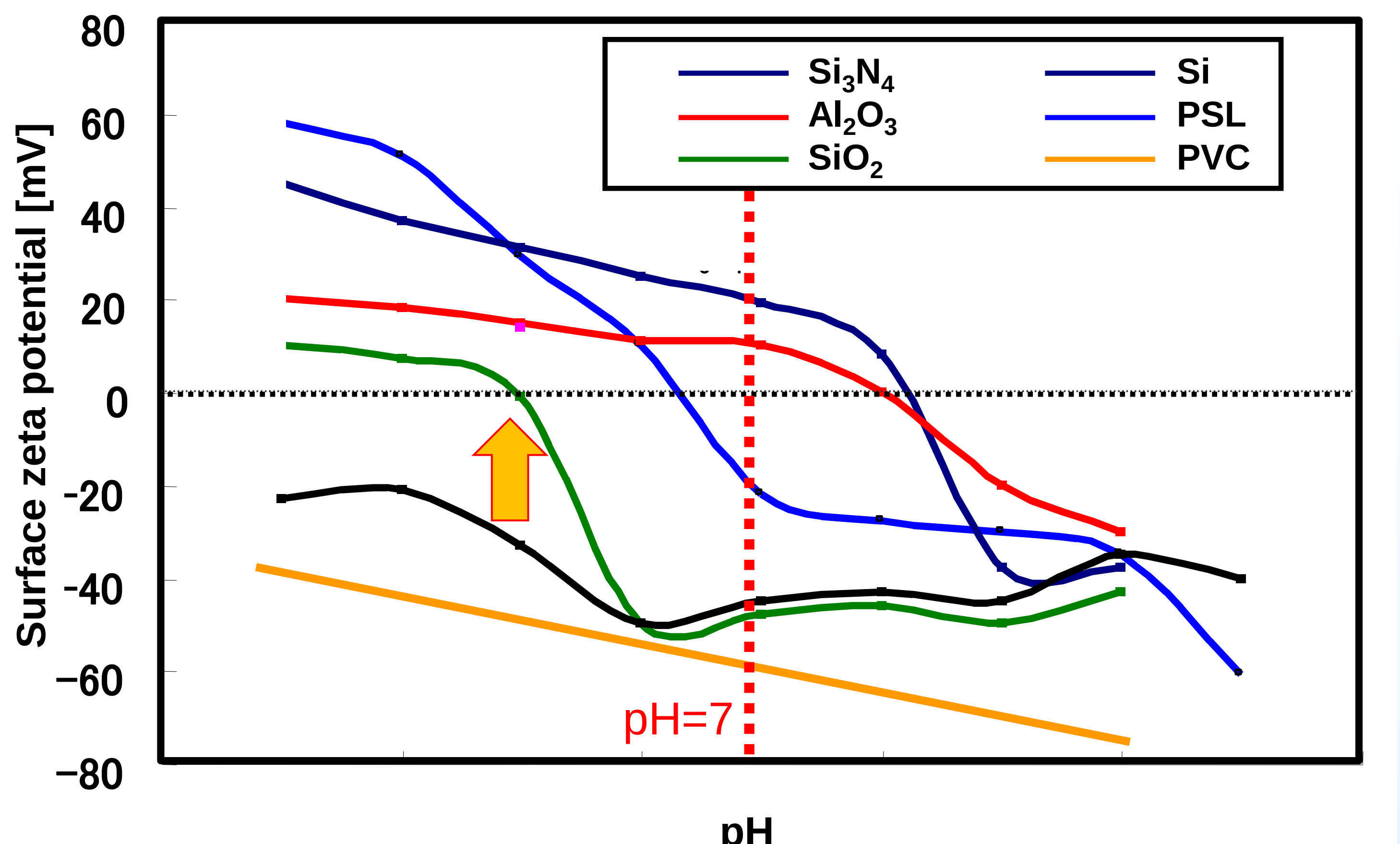
Result &Discussion②: Relationship between zeta potential and pH



In CO_2 water, the zeta potential of SiO_2 approaches zero , resulting in the drop of the repulsive force between the wafer and particles.

⇒ We would like to discuss the effect of the surface charge by changing particle species in the next study.

Conclusion

We studied about the particle adhesion to wafer and the impact of impurity.

(1) The rotation speed of drying process is one of the most effective parameters in the particle adsorption.

(2) The number of particles adsorbed at the rinsing process is large and almost constant.

(3) CO_2 has the influence on particle adhesion to SiGe and SiO_2 surface to wafer.

Next, we would like to investigate the effect of the surface charge and the particle size in detail.

We can support quality stabilization of a semiconductor products.

Not just water, Creativity

Thank you for your attention

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