Particle adsorption model on silicon wafer for clarifying required ultrapure water quality

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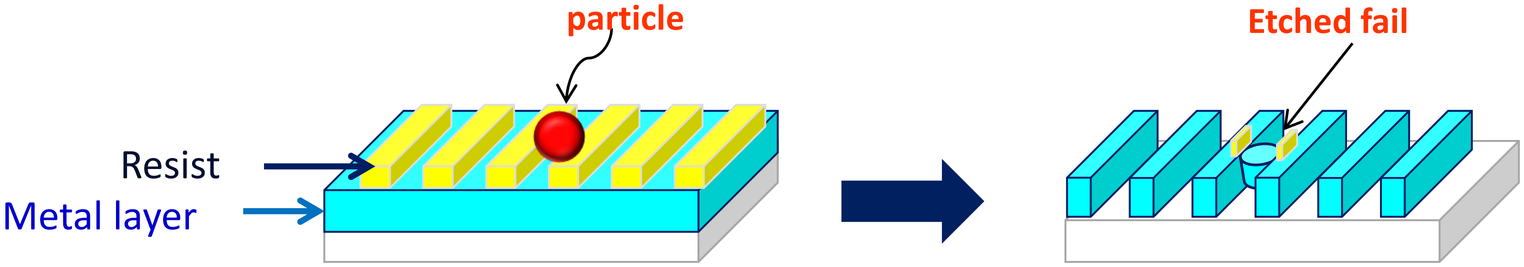
Introduction



Year of Production	2018	2019	2020	2021
Critical Metal [ppt]	＜1.0	＜1.0	＜1.0	＜1.0
Other ion [ppt]	＜50	＜50	＜50	＜50
Critical Particle size [nm] (Non electric active)	**18**	**14**	**14**	**12**
Number of Particles[pcs/L]	10,000	10,000	10,000	10,000

(IRDS 2017)

Proper control of the particles issue is important.
IRDS shows the critical particle sizes and the numbers.

Introduction

Previous study

① Particle adsorption between liquid and wafer (such as silicon, germanium and patterned wafer) has been studied.(1997～2015)

Concern

- Some studies are based on dip experiment
- Data are mostly on high concentration of particles
- No criteria for particle sizes and numbers for UPW have been shown

② Required UPW quality were suggested by relation between particles in UPW and silicon wafer.
(ex. *ECS* 2015)

Concern

- Data are mostly on high concentration of particles
- No prediction procedure for small particle sizes has been proposed

Introduction

To improve more ・・・ (Kurita idea)

Practical !

Approach to predict adsorption of small particles at low concentration is needed.

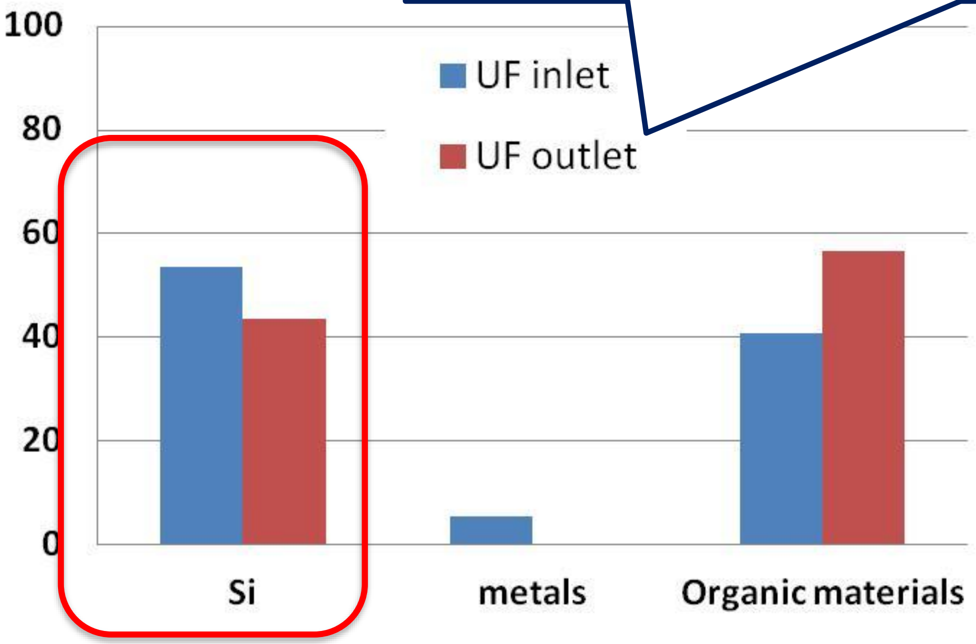
In this research,

①Model equation was derived based on the relation between the number of particles in UPW and the number of particles on the silicon wafer **focused on the low particle concentration** in UPW.

②**Requirements for** water quality in terms of particles especially of **smaller sizes were predicted.**

Introduction

Kurita possesses the method of detecting the number of 10 nm particles and it's composing elements in UPW.



(Y. Tanaka UPW micro 2015)

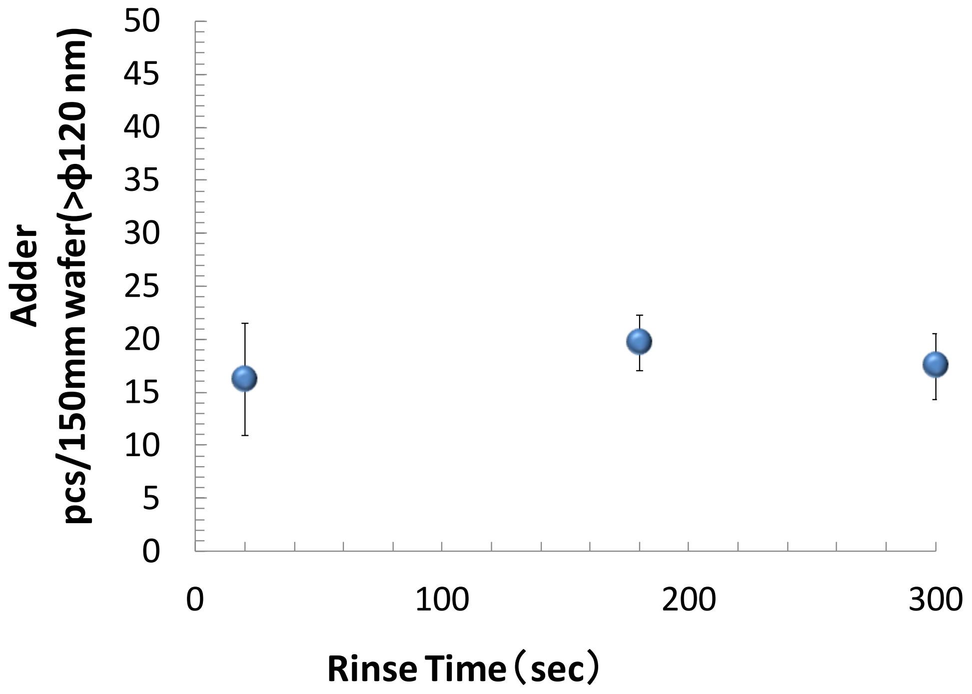
Behavior of SiO_2 particle is selected as 1st priority to research.

Si and organic matter are observed at both Inlet and outlet of UF.

Step 1: Correlation between particle in UPW and added defects

Method：

6 inch (150mm) wafer
Particle; 120 nm SiO_2 particles, 100 pcs/mL
Pretreatment; 30ppm O_3 last
Procedure; With Particle 20～300 sec（1000rpm）→ Dry 30sec (500rpm).



Result：

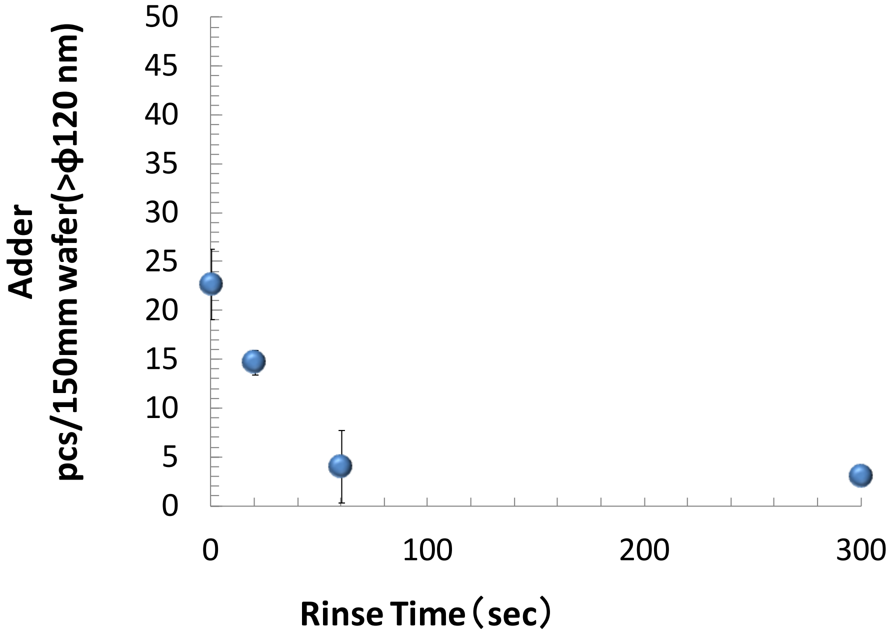
Adsorption on the wafer seems saturated as the rinse time gets longer.

It seems like an equilibrium adsorption

Step 1: Correlation between particle in UPW and added defects

Method:

6 inch (150mm) wafer
Pretreatment; 30ppm O_3 last
Procedure; With Particle SiO_2 500pcs/mL 20 sec（1000rpm）→ UPW Rinse
(Rinse time 0 sec, 20 sec, 60 sec, 300 sec）1000rpm→ Dry 30sec (500rpm).



Result:

① Adsorption on the wafer gets decreased as the rinse time of UPW gets longer.

② Finally, the adsorption level reaches as low as treated with the UPW only.

It seems like an equilibrium adsorption

What type ??

Step 1: Correlation between particle in UPW and added defects

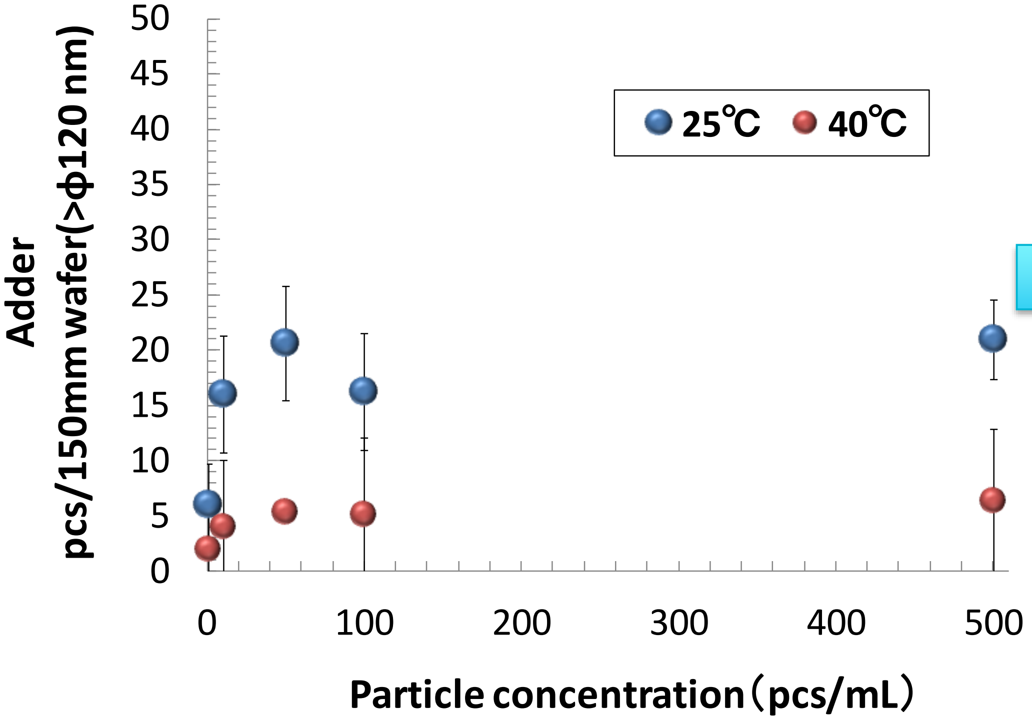
Method：

6 inch wafer

Particle; 120 nm SiO_2 particles, 0〜500 pcs/mL

Pretreatment; 30ppm O_3 last

Procedure; With Particle 20 sec（1000rpm）→ Dry 30sec (500rpm).



Result：

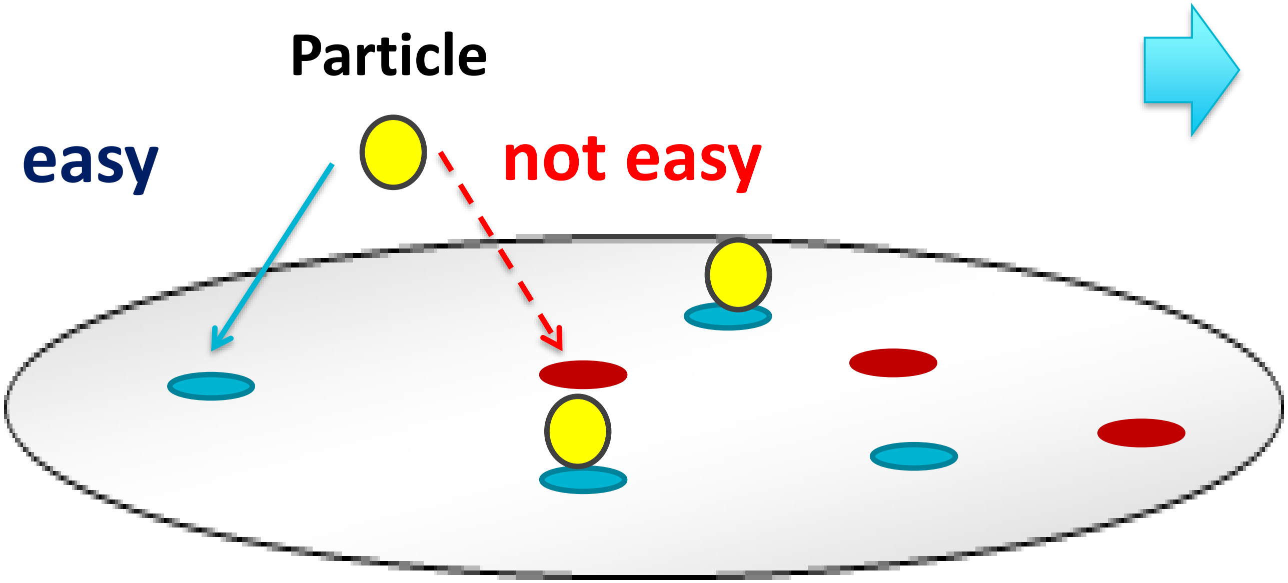
Maximum adsorption on wafers changes as the temperature changes

It is not a Langmuir type, and the results indicate that all adsorption sites are not homogeneous.

Step1: Model image

Image of model

⇒ Easily adsorbable sites are occupied first.



$$v = a\ln\left(K_A C\right)$$

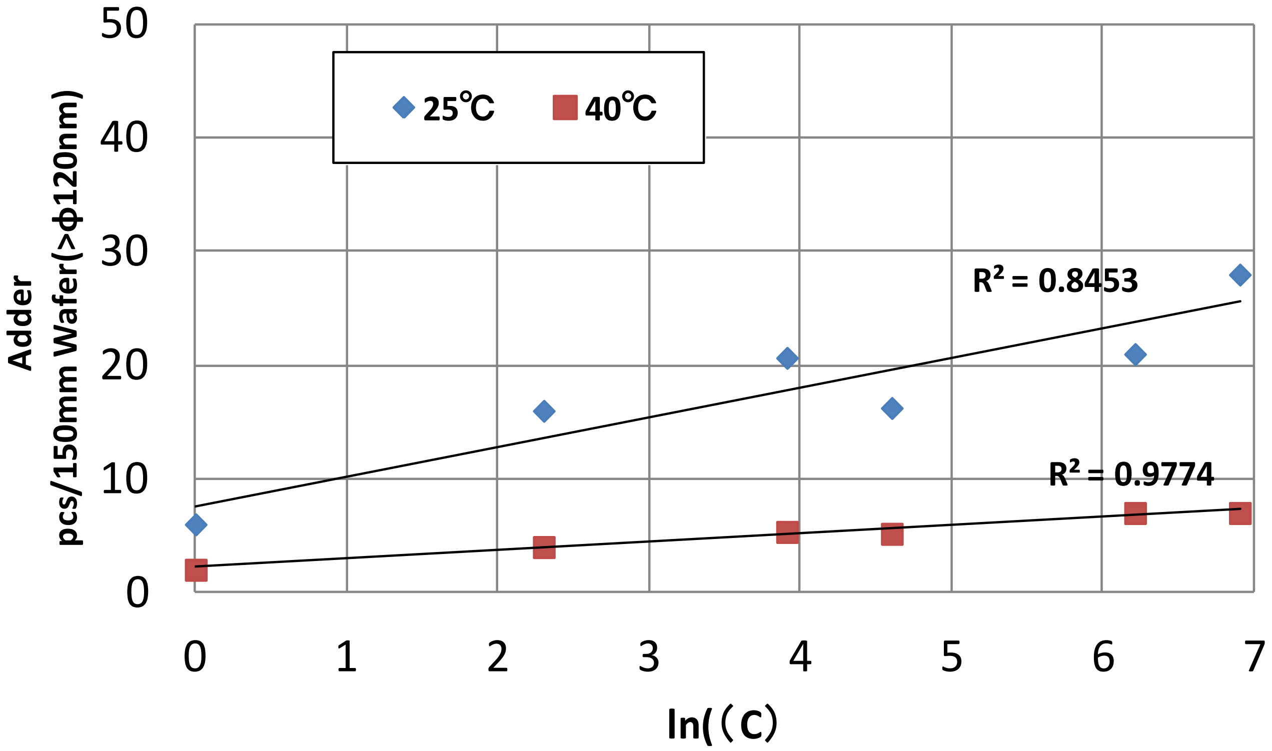
🟦 **Easily adsorbable site**

🟥 **Not easily adsorbable site**

Step 1: Verification of the model

Verification of the model

V=a ln(C)＋a ln(Ka)



Linearity was obtained for different temperatures, which verifies the equation.

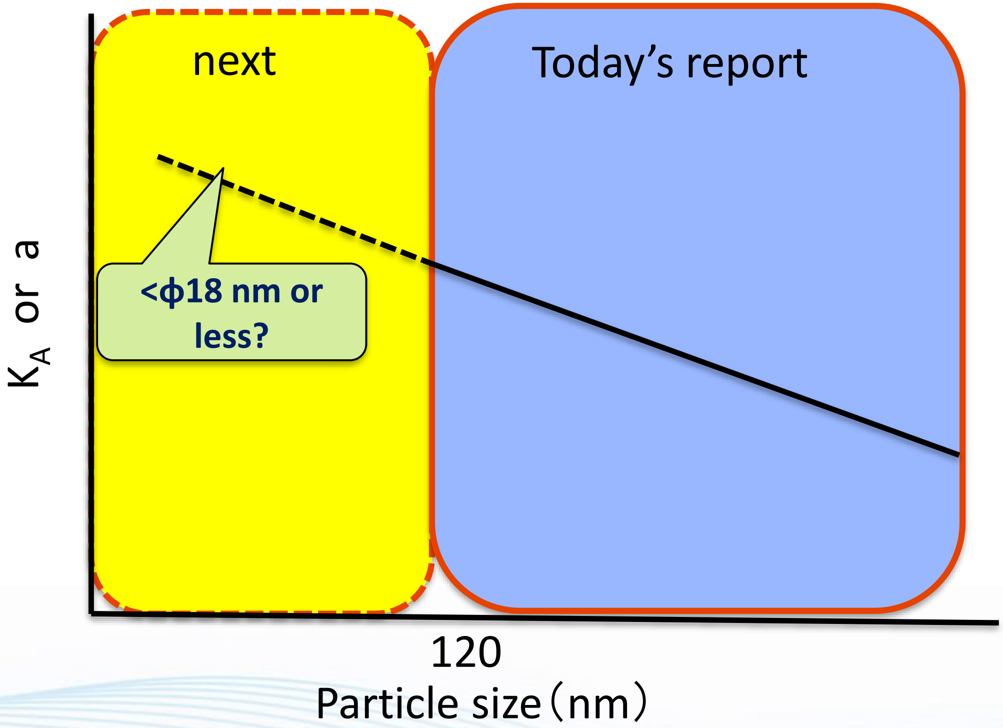
Approach

STEP 1

Determine the formula of particle adsorption on wafer

$$v = a \ln(K_A C)$$

V; Required criteria of particle number on wafer
C; Required UPW quality for particle number
K_A; Equilibrium constant
a; Coefficient



STEP 2

Extrapolate from experimental data to forecast parameters for small particle sizes

STEP3

Calculate required UPW quality for particles using the formula and parameters

STEP 2: Experiments for prediction

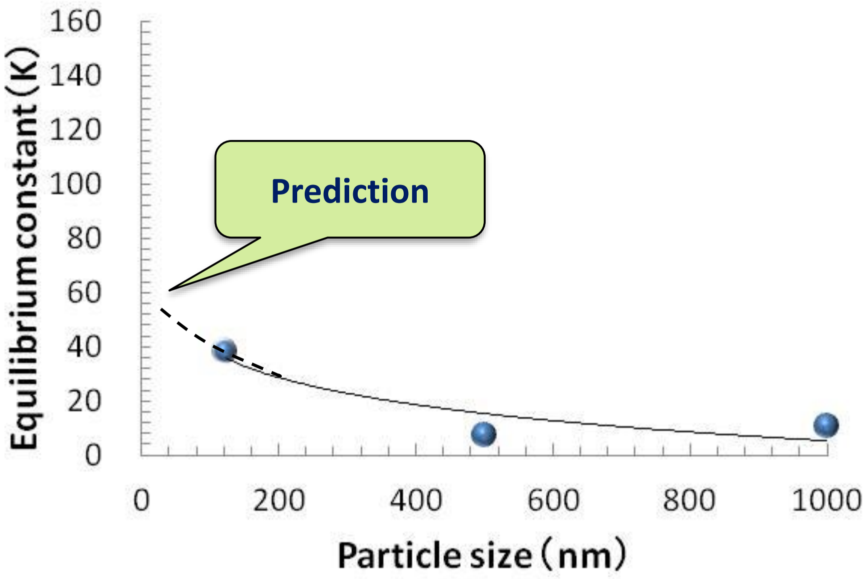
Method:

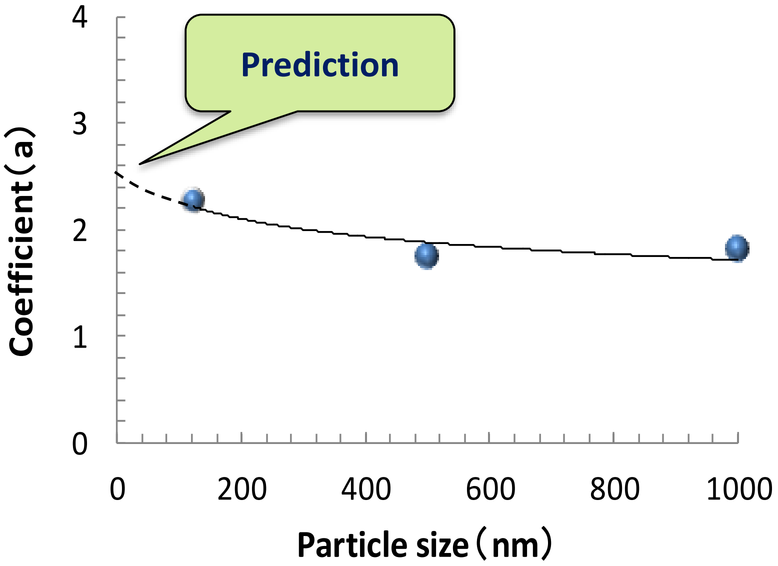
6 inch wafer

Particle; SiO_2 particles (120 nm, 500 nm, 1000nm）

Pretreatment; 30ppm O_3 last

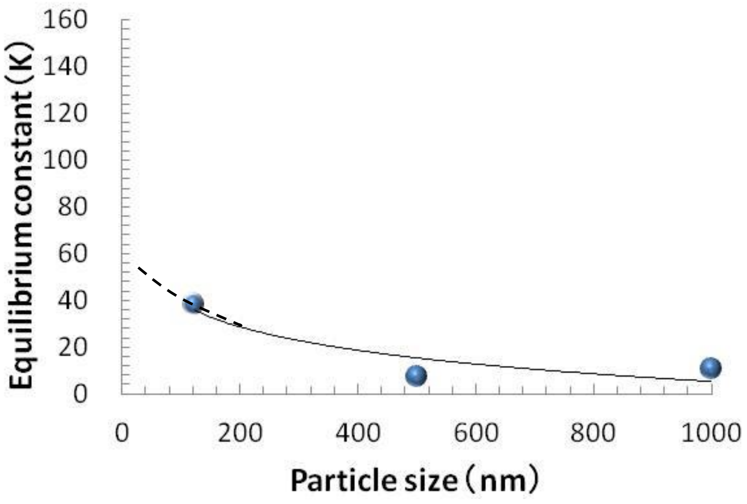
Procedure; With Particle 20 sec（1000rpm）→ Dry 30sec (500rpm).

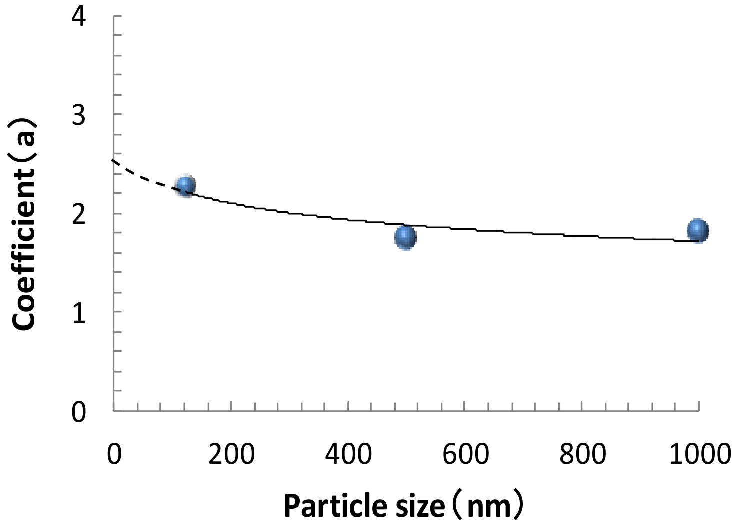




Predict the value of each factor for small particle sizes

STEP 3: Predict the UPW quality





ex) If we need to control

IRDS

adder 30pcs/ 300 mm wafer@18 nm up

$$v = a \ln\left(K_A C\right)$$

<u>Number of particles of</u>
<u>ϕ18 nm or under in the</u>
<u>UPW should be controlled</u>
<u>below 1,000 pcs/L</u>

***We need to check whether the same equilibrium adsorption will be applied at small particle size.**

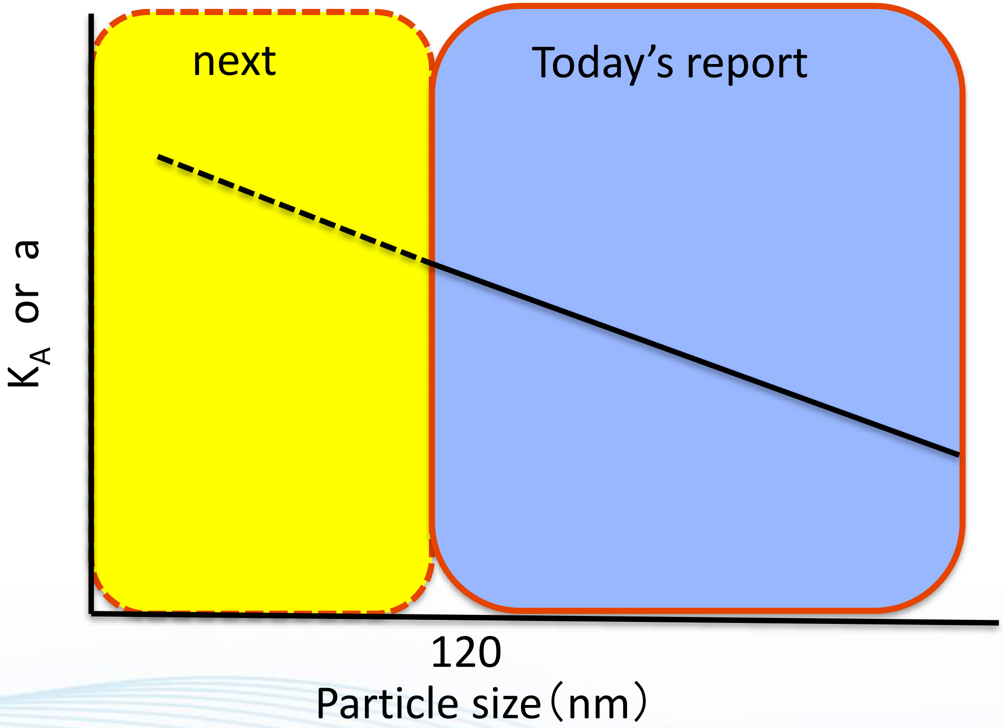
Approach

STEP 1

Determine the formula of particle adsorption on wafer

$$v = a \ln(K_A C)$$

V; Required criteria of particle number on wafer
C; Required UPW quality for particle number
K_A ; Equilibrium constant
a; Coefficient



STEP 2

Extrapolate from experiment to forecast parameter for small particle size

STEP3

Required UPW quality for particle number is calculated by parameter and formula

Summary

- Equilibrium model was obtained for particle adsorption

- Kurita suggests an approach to predict the required UPW quality.

- To control adder 30 pcs/300mm wafer of 18 nm or larger, particles in the UPW should be controlled less than 1,000 pcs/L at 18 nm.

- Further research is needed to improve the accuracy of prediction for small particle sizes.

Thank you for your attention.

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