19th Surface Preparation and Cleaning Conference (SPCC)

Characterization of incoming PVA brush for 10nm below post CMP cleaning process

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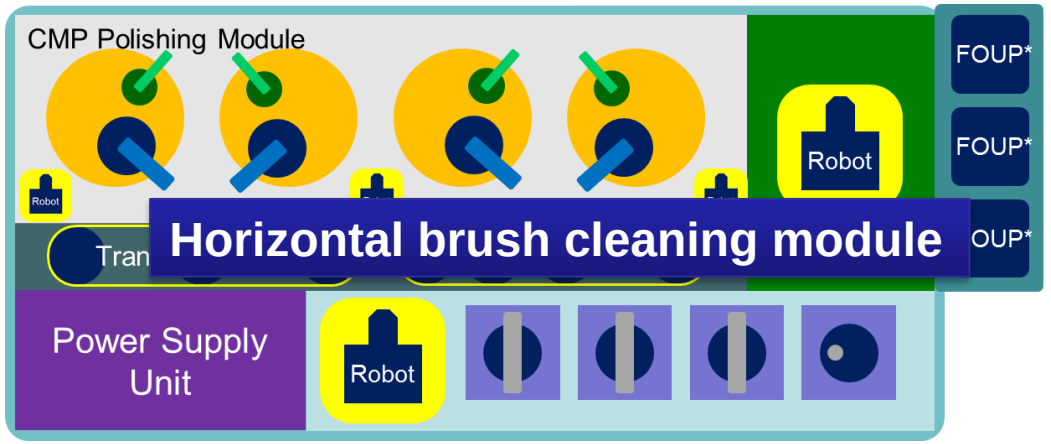
Post CMP Cleaning

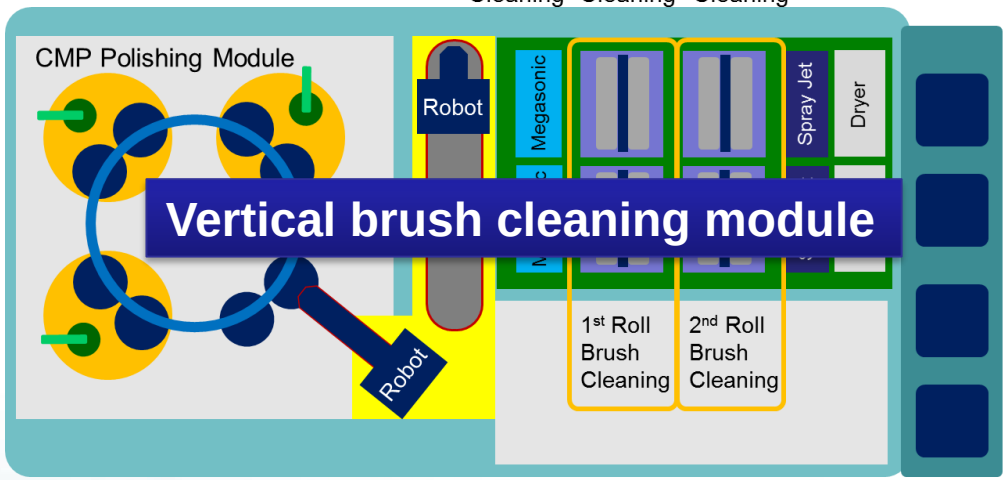
❖ Configurations of post CMP Cleaning Module

(*FOUP = Front Opening Unified Pod)



< "E" CMP & P-CMP Tool >

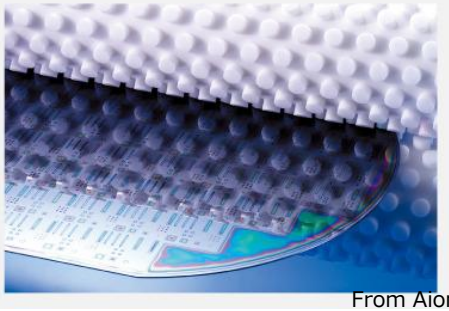
1st Roll Brush Cleaning | 2nd Roll Brush Cleaning | 3rd Roll Brush Cleaning | Pen Brush & Spin Dry



< "A" CMP & P-CMP Tool>

Cassette Line

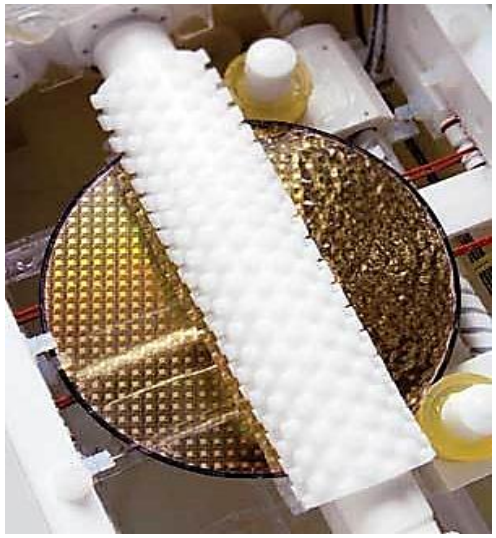
PVA Brushes!!



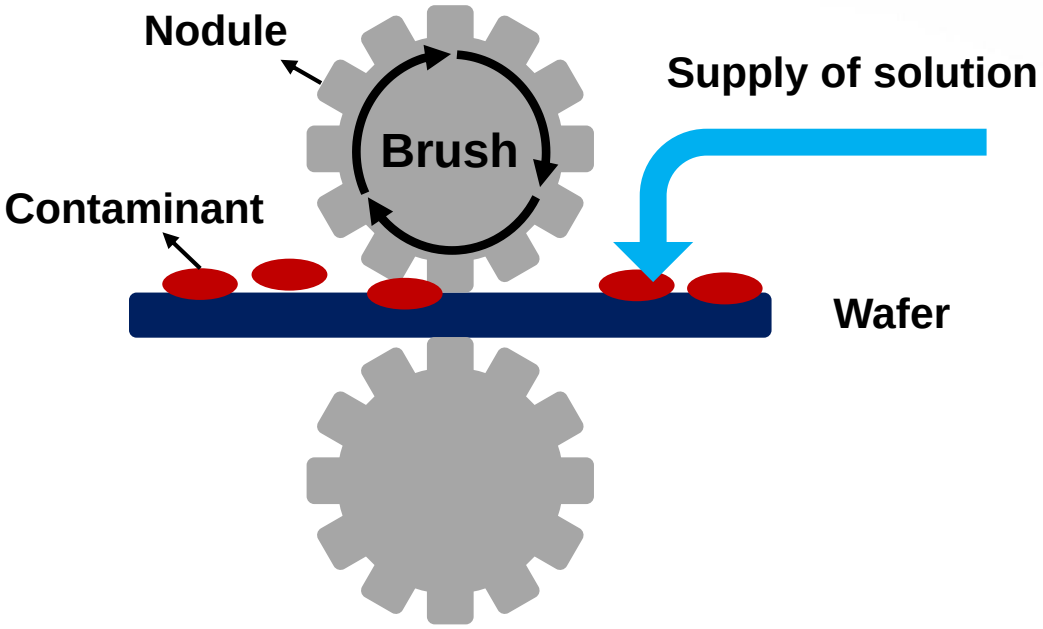
From Aion

PVA Brush Cleaning Process

❖ **Brush Cleaning Module**



❖ **Schematic diagram of Brush Cleaning Module**

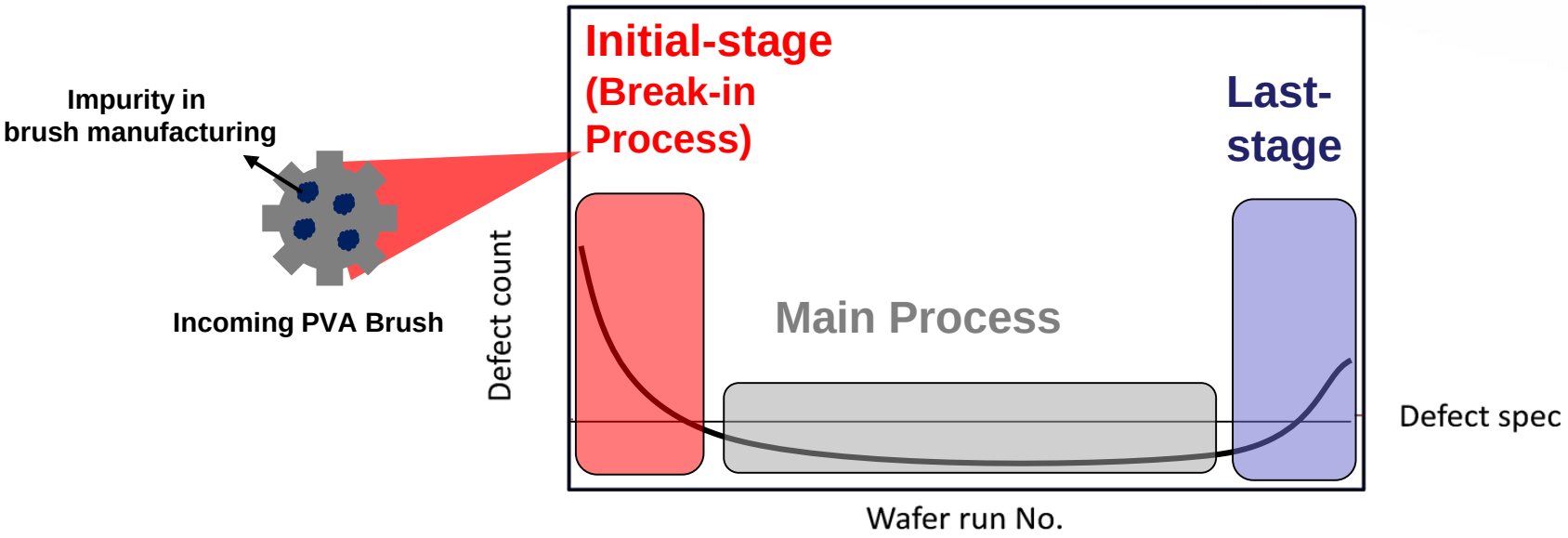


❖ **Advantages of Brush Cleaning**

- **High cleaning efficiency** due to its physical force by direct contact between brush and wafer surface.
- **Effective low cost of ownership (COO)**
- **Process flexibility with various solutions**

Defects from PVA Brush as a function of process time

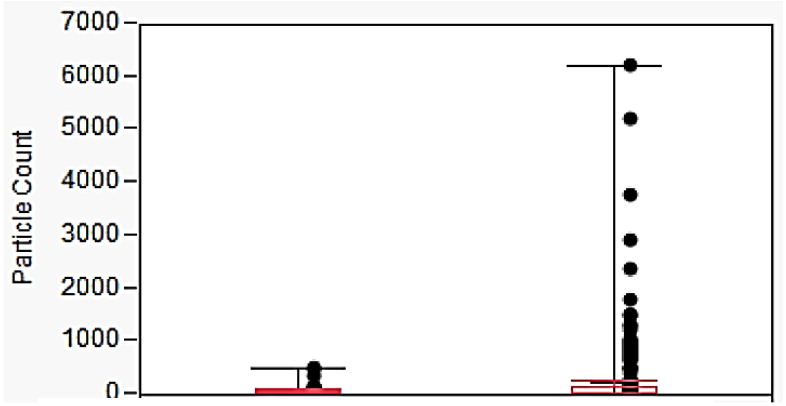
❖ **Defect Count Vs. Wafer Run No.**



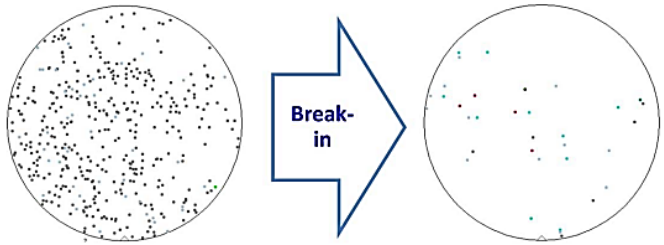
- **Defect Level: Initial-stage > Last-stage >> Main Process**
- **An incoming brush shows higher defect level at initial-stage due to the presence of residual impurities inside the brush.**
- **Pre-treatment process (break-in process) for the removal of impurities from incoming brush is necessary before using.**

Break-in Process of Incoming Brush

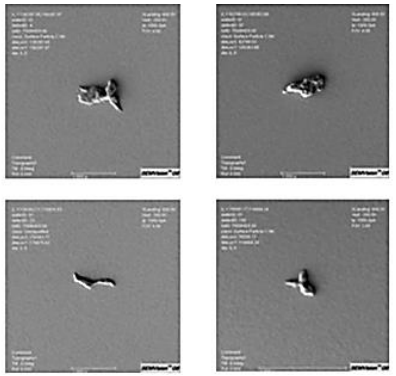
❖ **Effect of Brush Break-in Process**



(a) With Break-in, (b) Without Break-in



(a) Defect map before and after Break-in



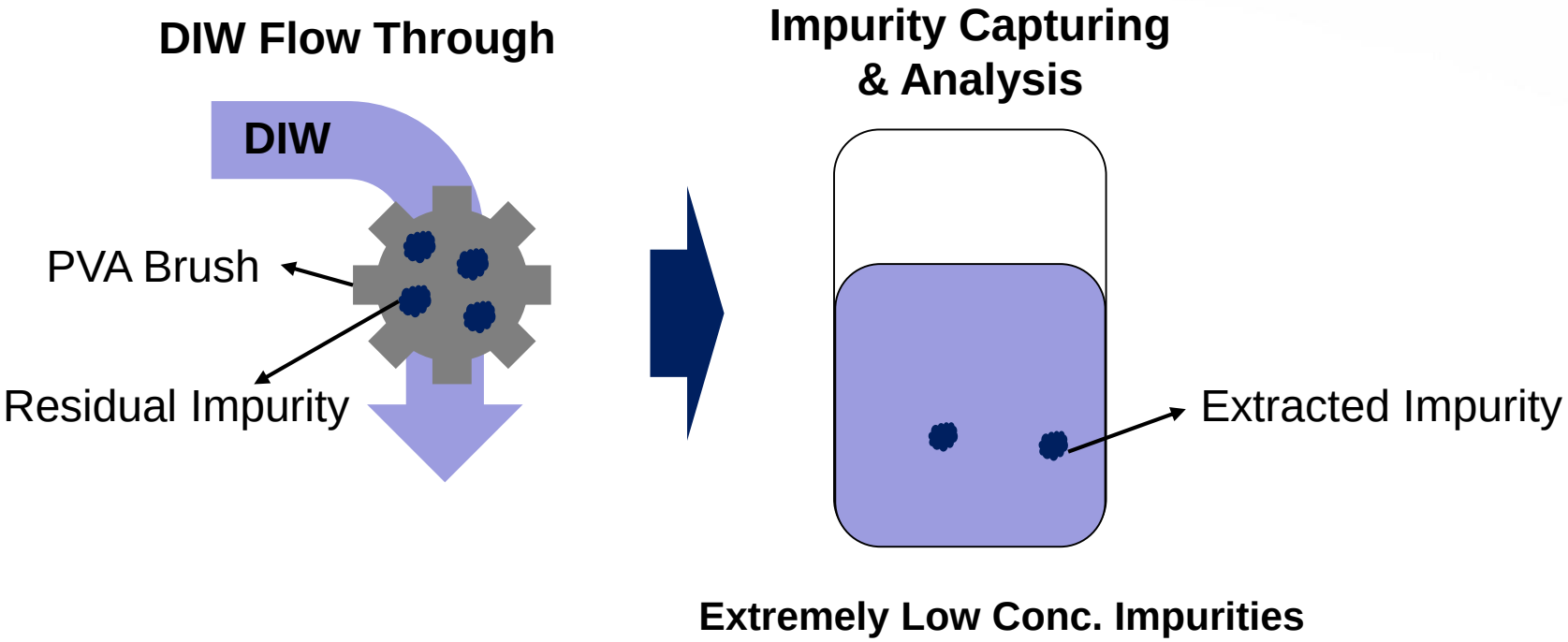
(b) SEM images of organic residue defect

- Conventional break-in process applies **DIW flow through** method and **scrubbing** on dummy wafer to **remove impurities from incoming brush**.
- Break-in process significantly reduces impurities of new brush and increases efficiency of post CMP cleaning.

***Ref: Hong Jin Kim, Korea Cleaning UGM 2016**

Conventional Analysis Methods of Impurities

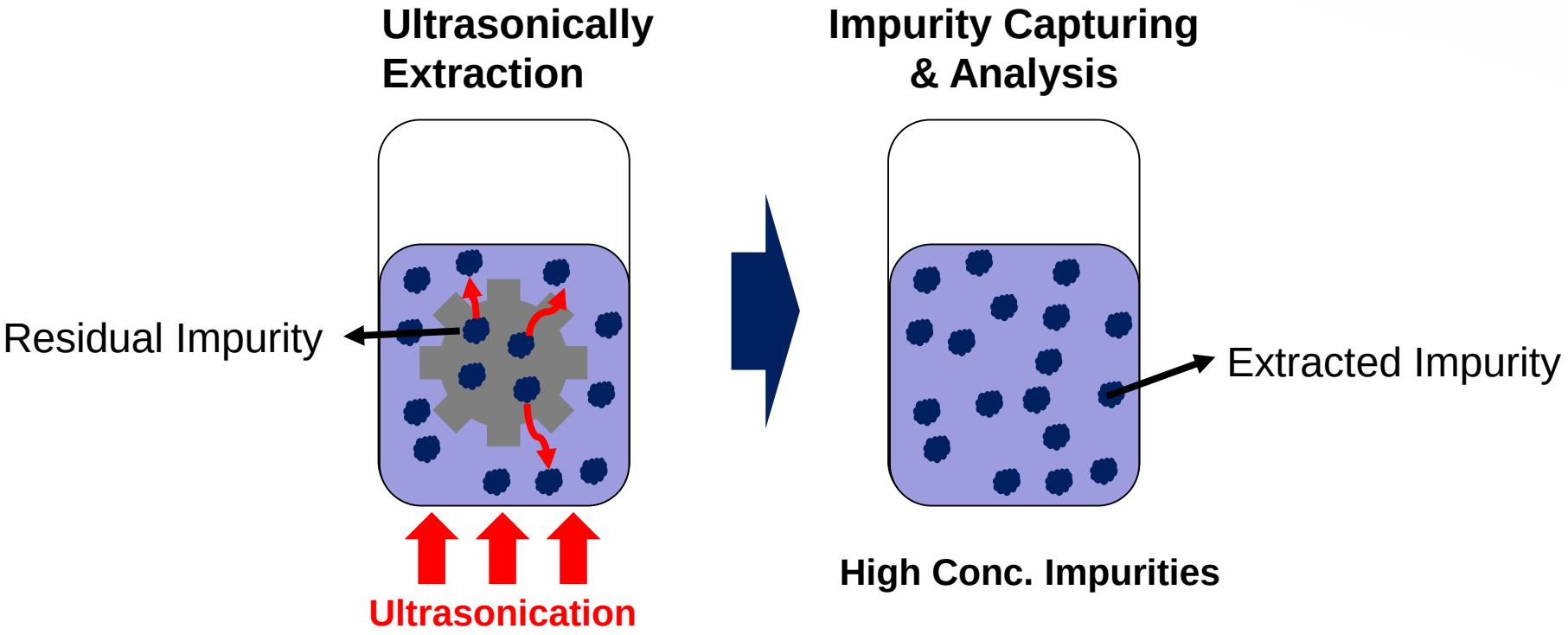
❖ **Analysis of brush Impurities after DIW Flow Through Break-in**



➢ **Composition of impurities** from incoming brush was not studied due to **extremely low concentration of impurities in conventional break-in method**.

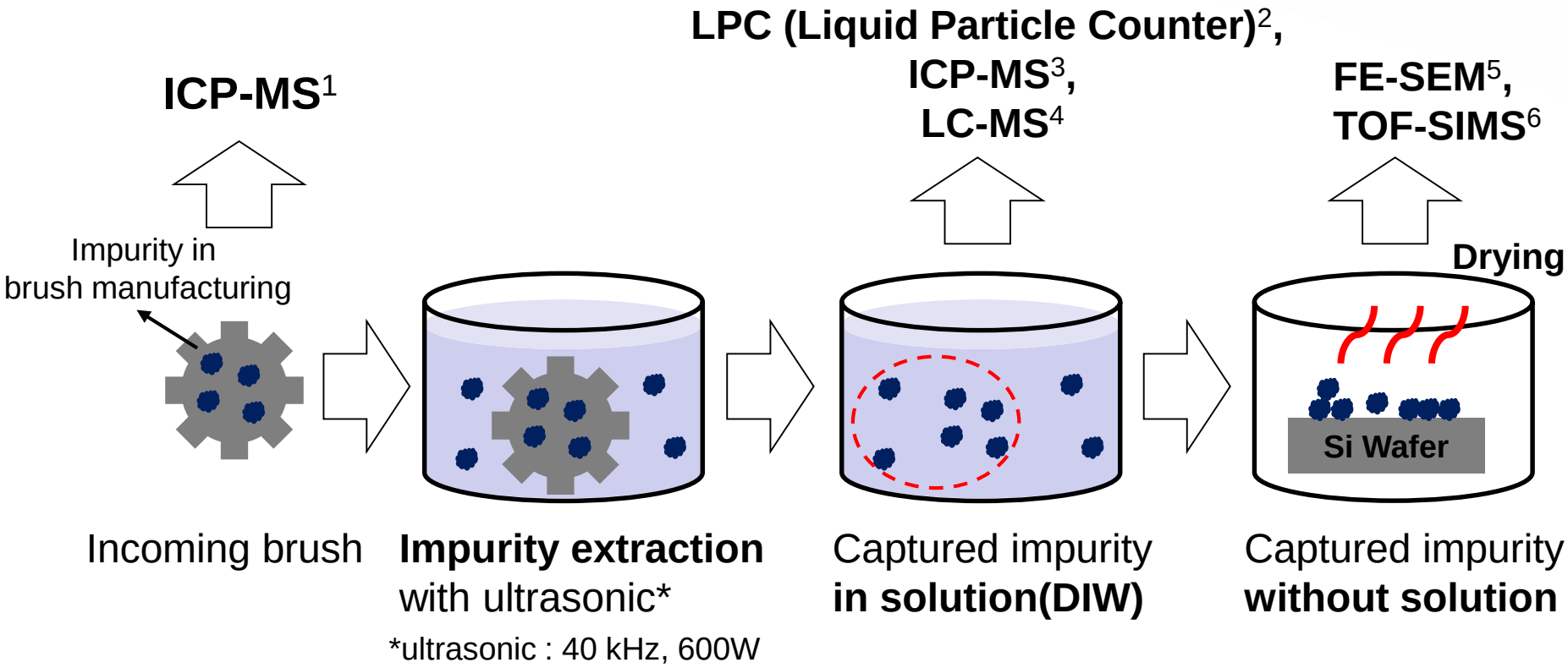
Developed Analysis Methods of Impurities

❖ **Analysis of brush Impurities after Ultrasonication process**



➢ Developed characterization method using **ultrasonication** **can extract impurities at higher concentration and make it possible to analyze the impurities.**

Characterization Procedure and Equipment



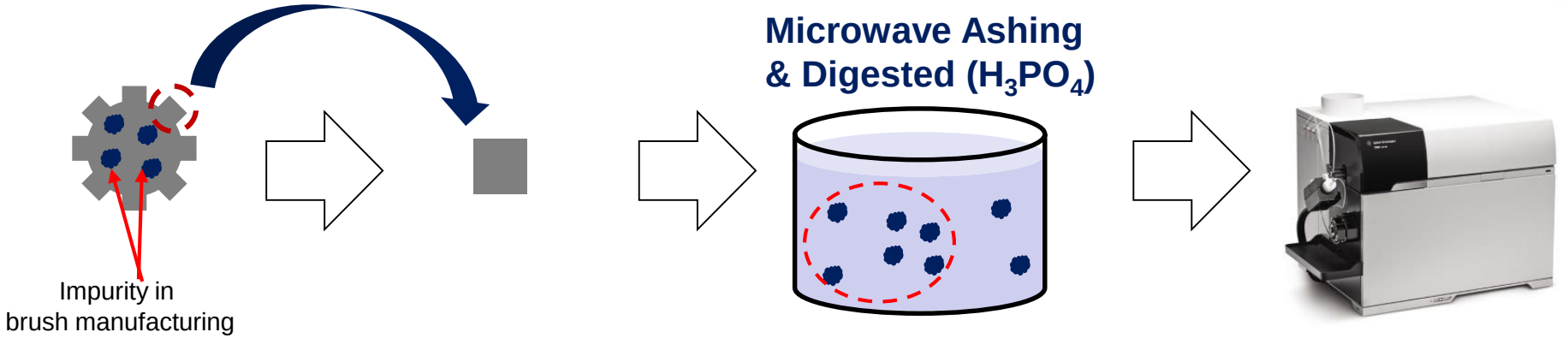
Characterization Procedure and Equipment

Status	Equipment	Analysis
Wet	Liquid Particle Counter[2]	Number of particulate impurity
	ICP-MS[1, 3]	Type of Impurity (Inorganic)
	LC-MS[4]	Type of Impurity (organic)
Dry	FE-SEM[5]	Shape, Size
	TOF-SIMS[6]	Type of Impurity (organic)

Wet: Measurement of impurities in solution
Dry: Measurement of impurities after drying process

1. ICP-MS Analysis of Incoming Brush without Extraction

❖ **Analysis Procedure of Inorganic Impurity from Brush (Without Extraction)**



* ICP-MS: Inductively coupled plasma mass spectrometry

➢ **Inorganic impurities in brush w/o extraction process was analyzed by using ICP-MS analysis.**

1. ICP-MS Analysis of Incoming Brush without Extraction

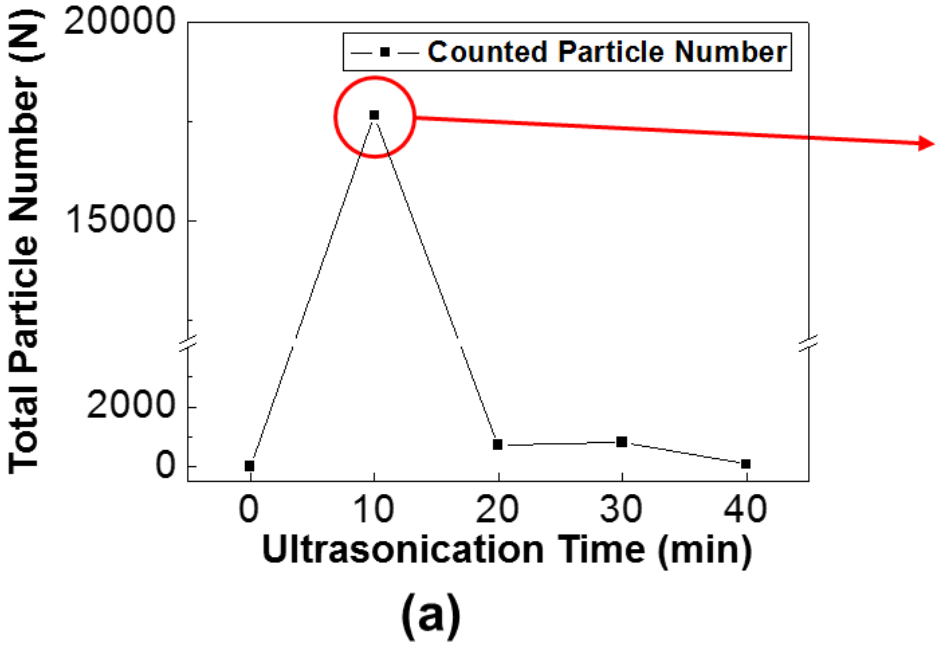
❖ **Analyzed Inorganic Impurities from Brush**

Element	Concentration (ug/g, ppm)	SD (Standard Deviation)	Relative SD (%)	Composition (%)	Total Amount (ug/g, ppm)
Si	**4278.596**	**157.878**	**3.690**	**88.650**	4,826
Ti	523.721	25.080	4.789	10.851	
W	0.036	0.002	4.162	0.001	
Cu	14.118	0.672	4.764	0.293	
Fe	9.916	0.751	7.575	0.205	

- **ICP-MS analysis shows the presence of Si residues in an incoming brush.**
- **An incoming brush contains high level of Si based impurity.**

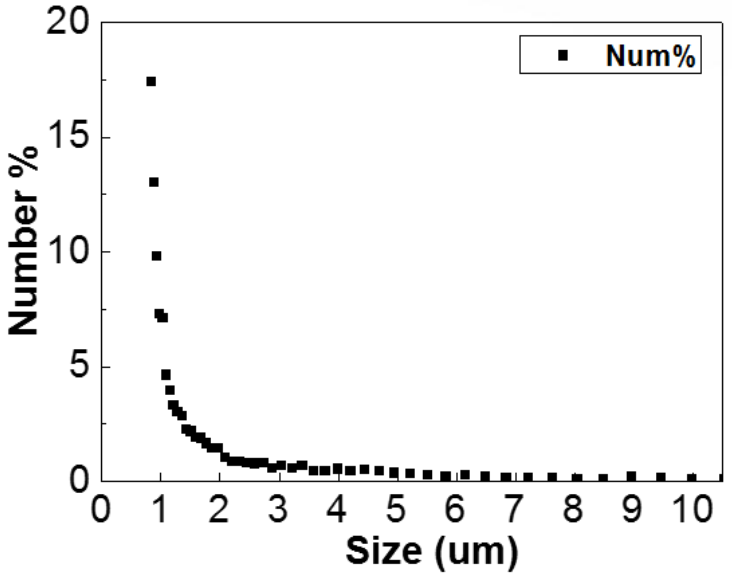
2. Liquid Particle Analysis of Extracted Solution

❖ # of Particle Vs. Ultrasonication Time



(a)

❖ Particle Size Distribution

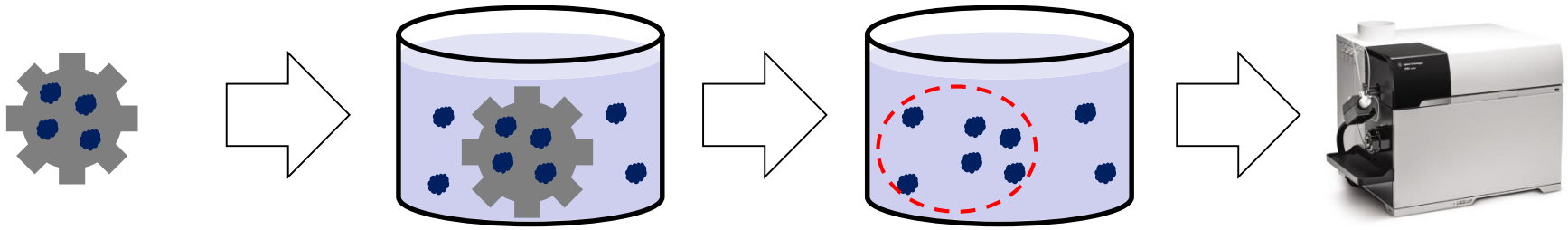


(b)

- **Most of the particulate contaminants were extracted completely within 10 min.**
- Particle size range: X nm ~ 4 um
- **Ultrasonication is very effective and fast process to capture the impurities from the brush.**

3. ICP-MS Analysis of Extracted Solution

❖ **Analysis Procedure of Inorganic Impurities from Extracted Solution**



Incoming brush

Impurity extraction
with ultrasonic

Captured impurity
in solution(DIW)

ICP-MS
Measurement

7900 ICP-MS, Agilent (USA)

➢ **Inorganic impurities w/ ultrasonically extraction process was analyzed by using ICP-MS analysis.**

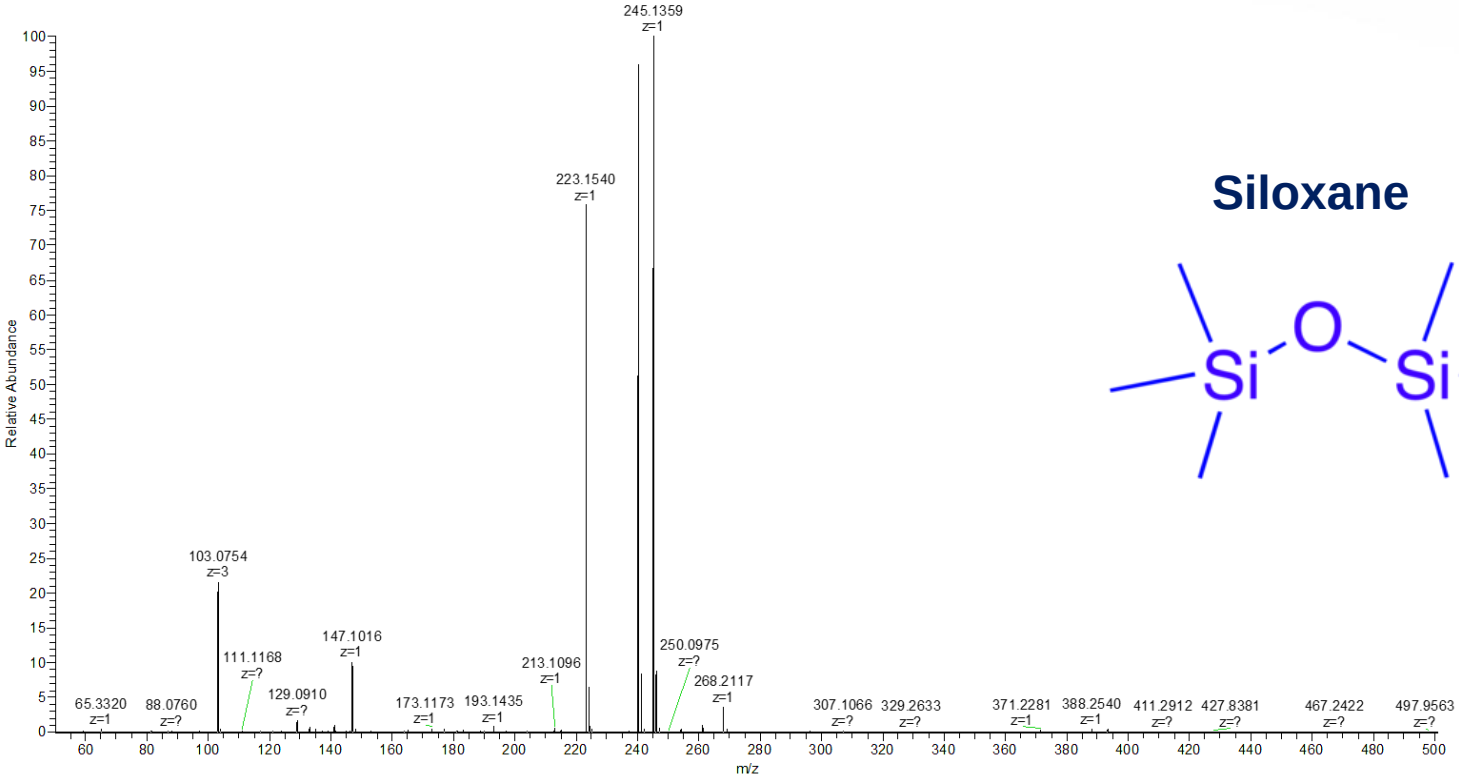
3. ICP-MS Analysis of Extracted Solution

❖ **ICP-MS results of Extracted Solution from Brush**

Element	Concentration (ng/mL, ppb)	Relative SD (%)	Composition (%)	Total Amount (ng/mL, ppb)
Si	**35.355**	**2.8**	**74.11**	47.703
Ti	3.422	4.3	7.17	
W	2.403	2.3	3.36	
Cu	4.924	1.8	10.32	
Fe	1.602	2.4	5.04	

➢ **ICP-MS analysis confirms the presence of Si impurities in ultrasonically extracted solution of incoming brush.**

4. LC-MS Analysis of Extracted Solution

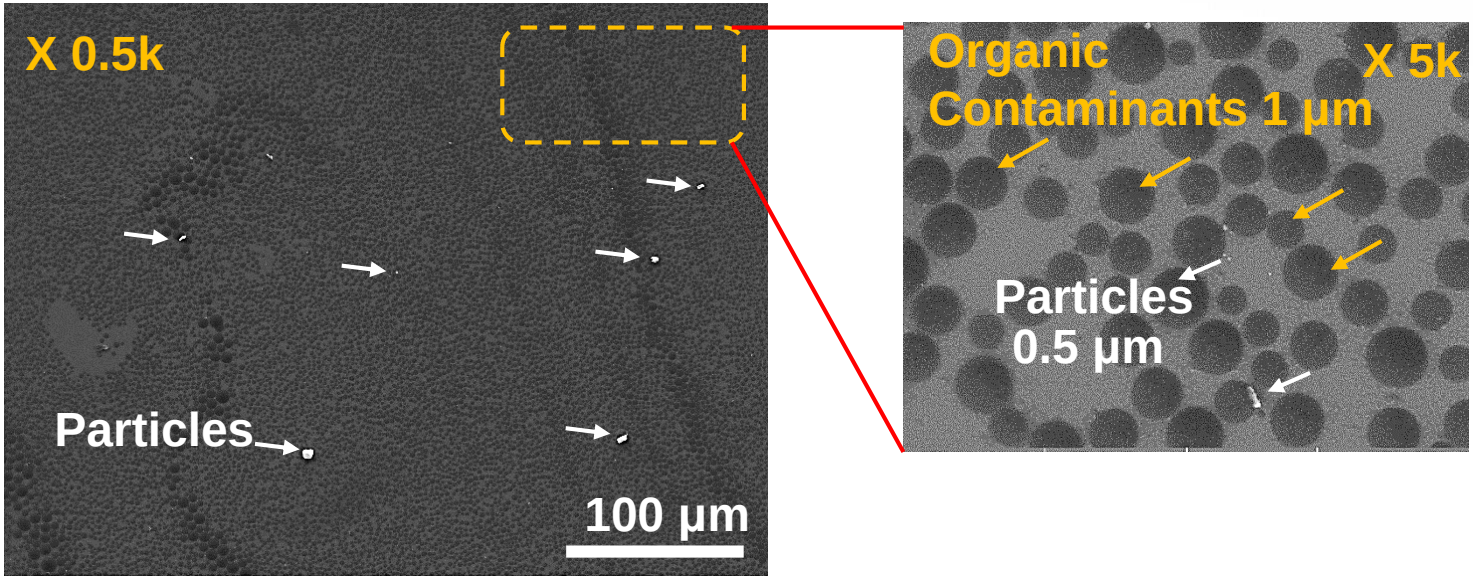


Siloxane

- **Siloxane peaks were observed from extracted solution.**
- This LC-MS result is well matched with ICP-MS results.

5. FE-SEM Measurement of Dried Sample

❖ **FE-SEM Images of Impurities after Drying Process**

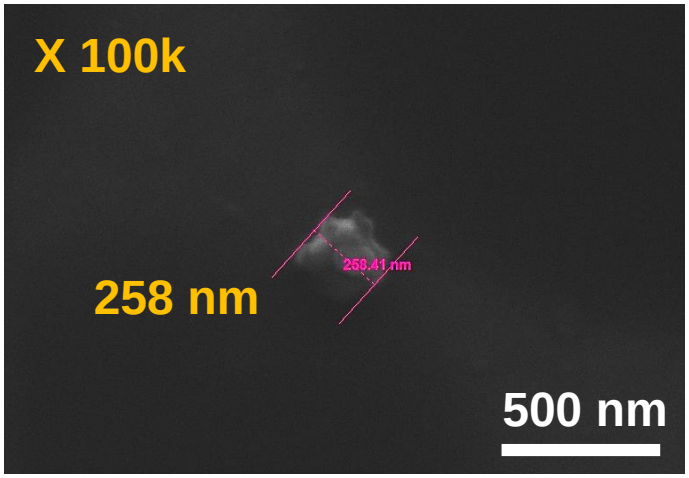


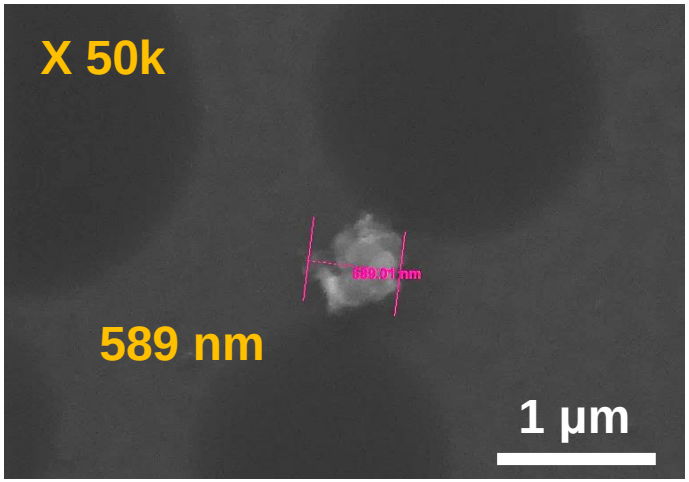
(a) X 0.5K **(b) X 5K**

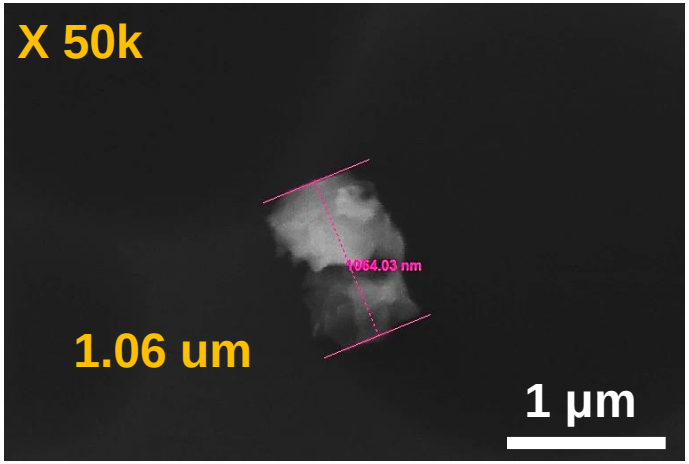
- **Organic contaminants and particles were observed.**
- **Density : organic contaminants >> particles**

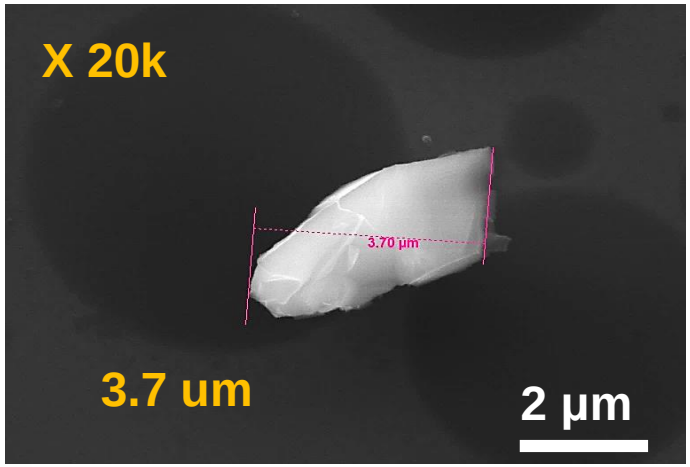
5. FE-SEM Measurement of Particles

❖ **FE-SEM Images of Particulate Impurities**





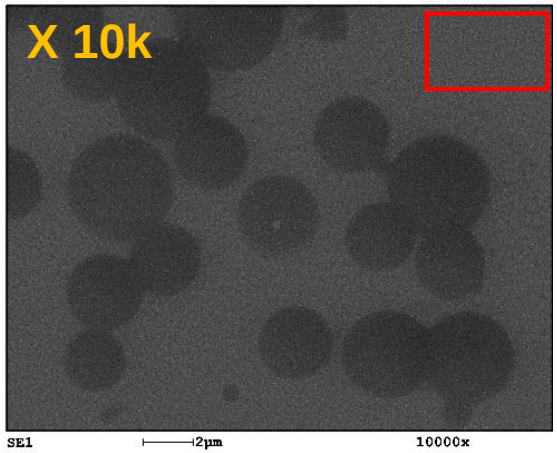




- **Particle size range: 200 nm ~ 4 um**
- These FE-SEM results are well matched with LPC results.

5. EDX Analysis of Contaminants

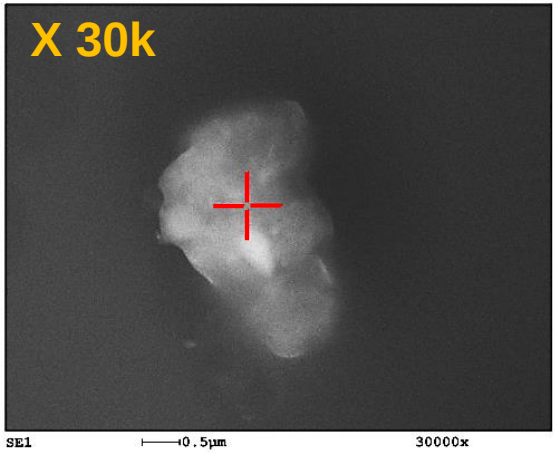
❖ Uncontaminated Area



EDS Quantitative Results

Element	Wt%	At%
SiK	100.00	100.00

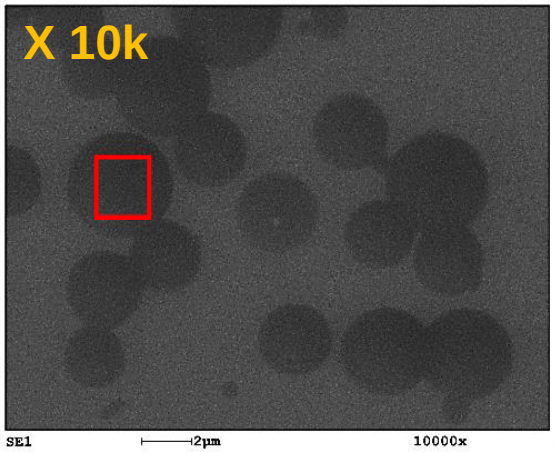
❖ Contaminated particle



EDS Quantitative Results

Element	Wt%	At%
CK	**61.60**	**73.30**
OK	18.62	16.64
SiK	19.78	10.07

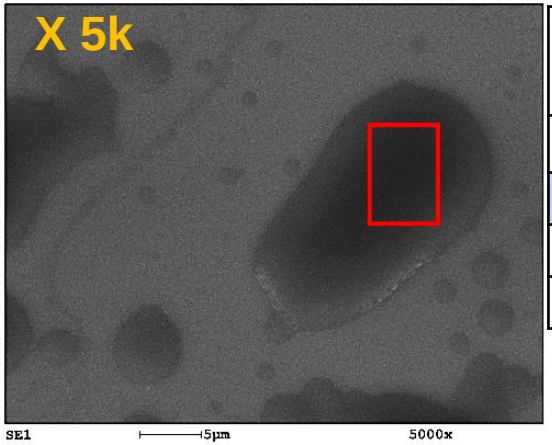
❖ Contaminated Area



EDS Quantitative Results

Element	Wt%	At%
CK	**43.34**	**64.14**
SiK	56.66	35.86

❖ Contaminated Area

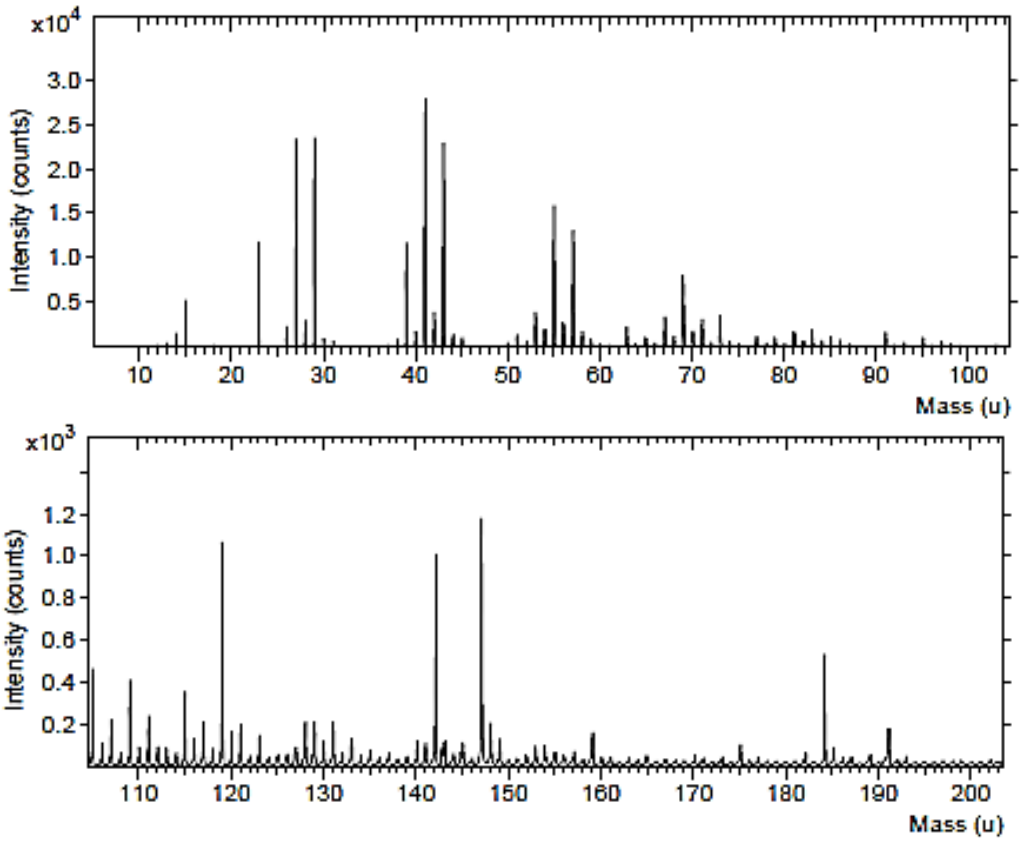


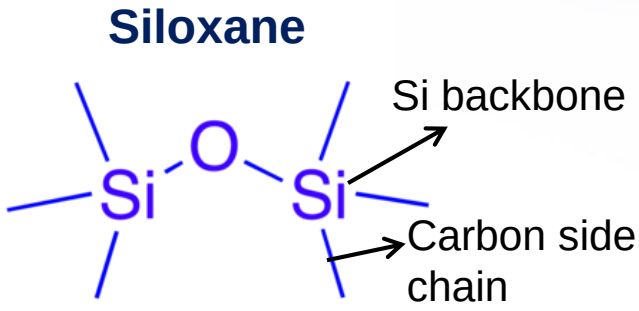
EDS Quantitative Results

Element	Wt%	At%
CK	**61.38**	**74.60**
OK	13.57	12.38
SiK	25.06	13.02

➢ **Organic contaminants and particles show carbon peak.**

6. TOF-SIMS Analysis of Dried Sample



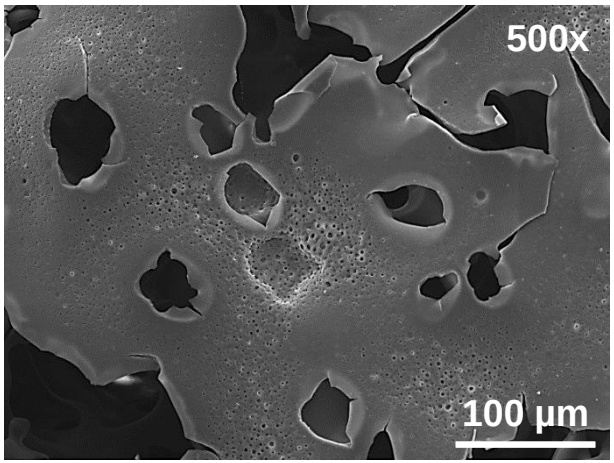


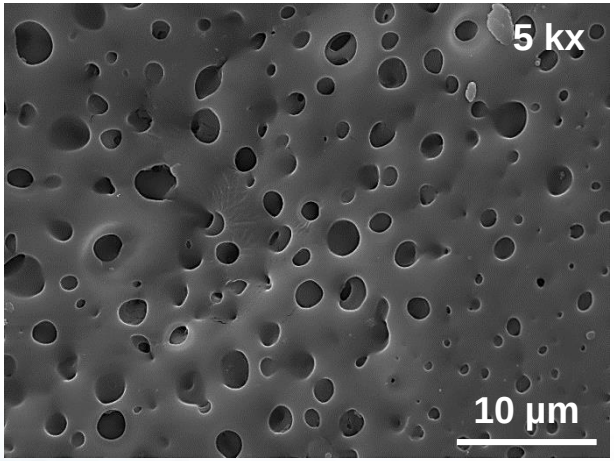
Siloxane: Organosilicon with Si-O-Si linkage

- **Siloxane** peaks were observed from incoming brush after dried on Si wafer substrate.
- This TOF-SIMS result is well matched with ICP-MS and LC-MS results.

FE-SEM Images of Ultrasonicated Brush

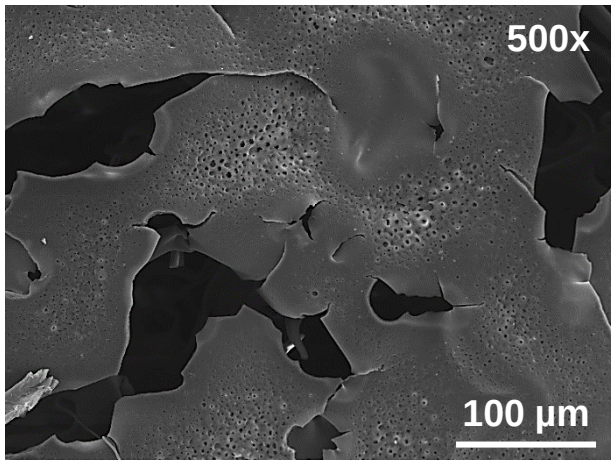
Initial

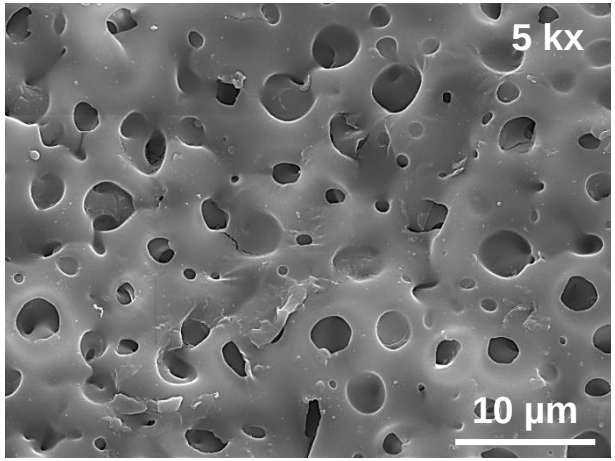




Ultrasonic treat.:
6 hr in DIW

Ultrasonic treat.



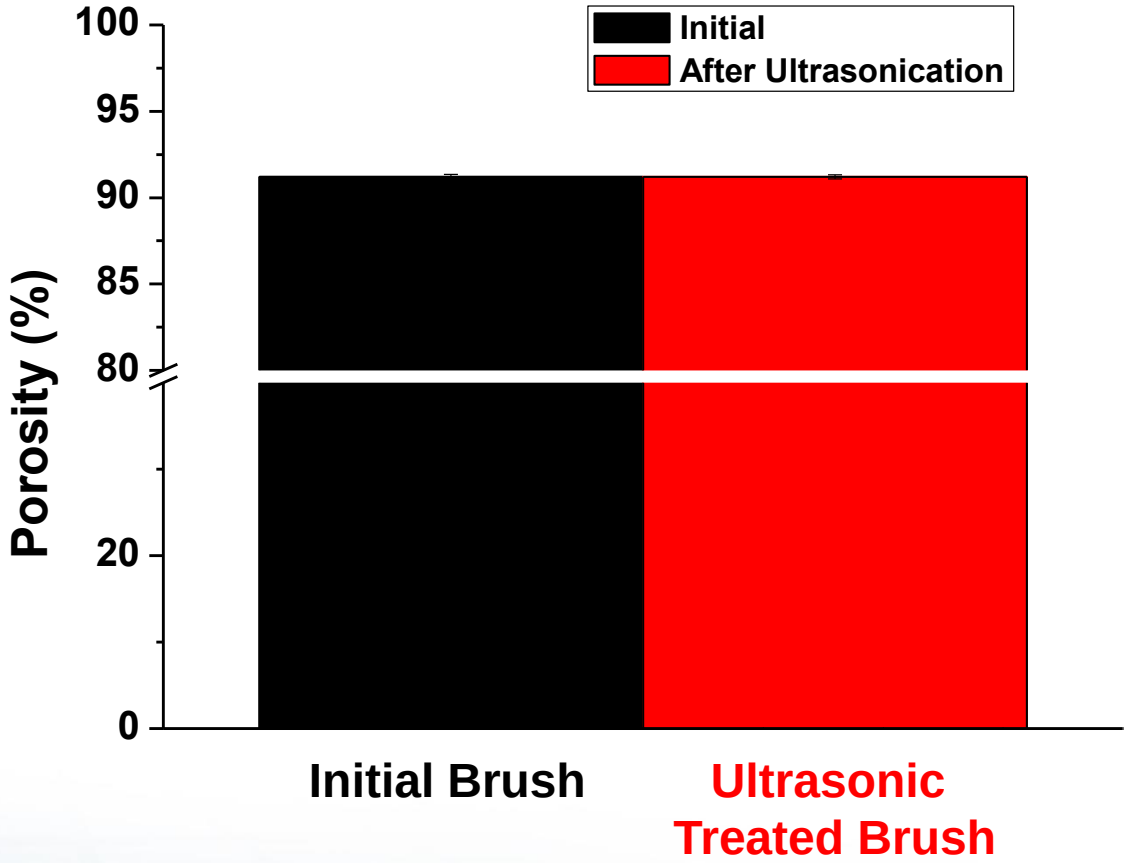


- **No noticeable damages were observed from ultrasonically characterization process**

Porosity Measurement of Ultrasonicated Brush

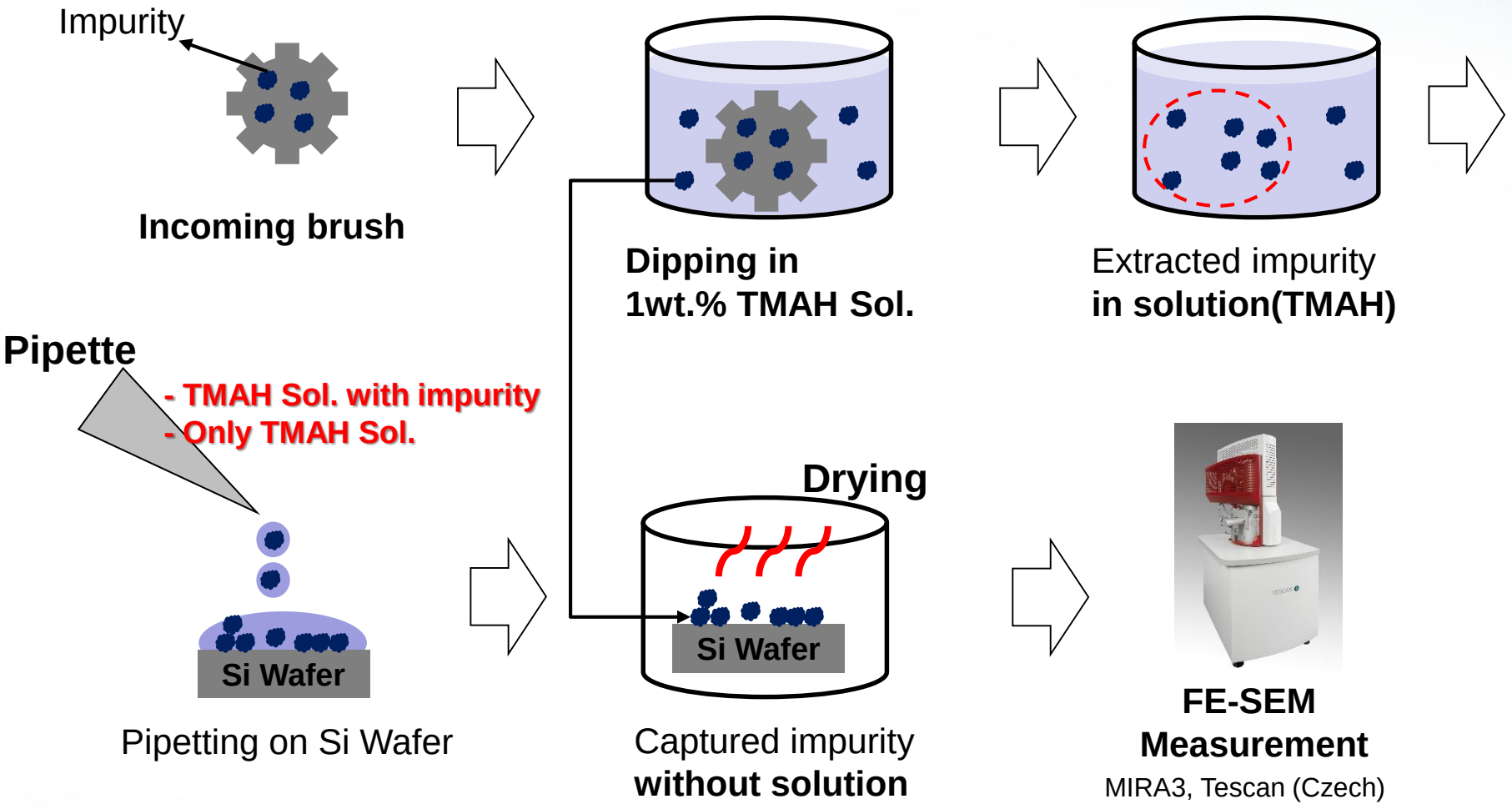
$$\text{Porosity \%} = \frac{B - A}{(B - A) + \frac{A}{D_{pva}}}$$

A : empty weight of the brush
B : weight of the brush after soaking in water
D_{pva} : density of the PVA (1.3 g/cm^3)



➢ **Porosity of PVA brush was not changed after ultrasonication for 6 hours.**

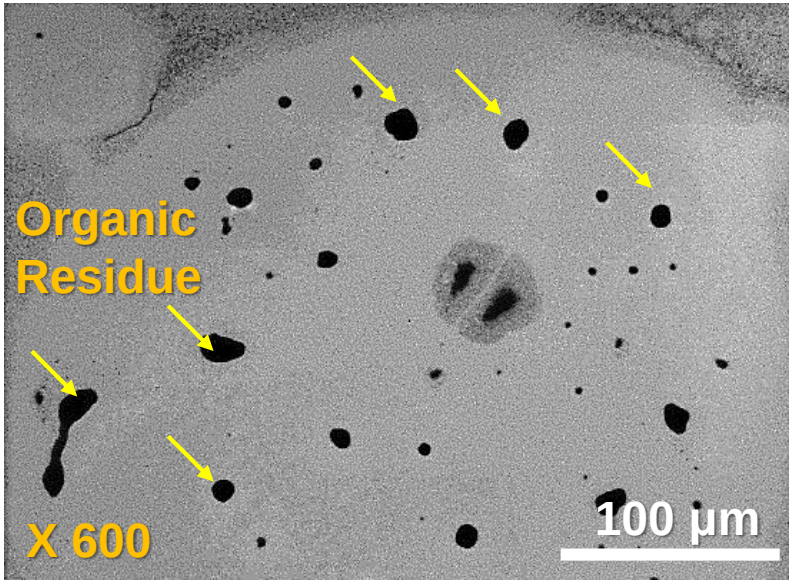
Analysis Procedure:
Effect of Cleaning Chemistry(TMAH) on PVA Brush

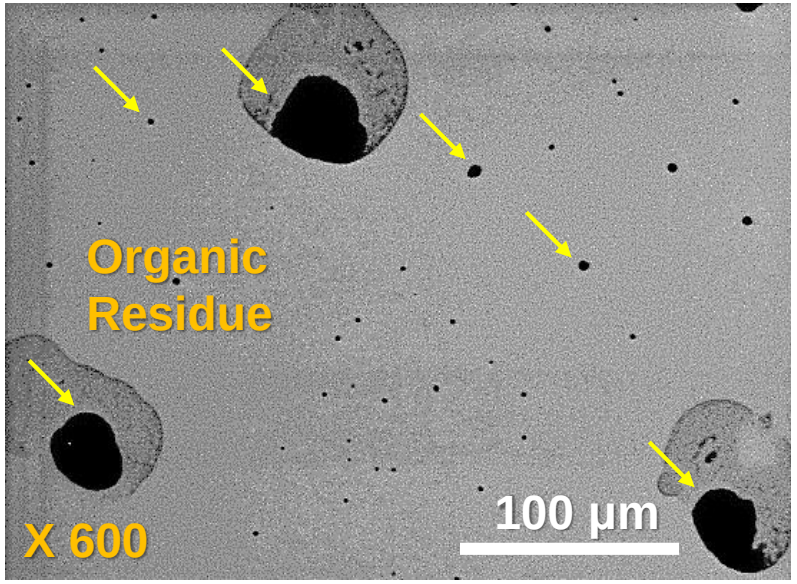


- **PVA brush was dipped in 1wt.% TMAH sol. to observe the effect of cleaning chemicals (TMAH) on impurity generation from brush.**

Effect of TMAH chemistry on PVA brush

❖ **FE-SEM Images of Organic Residue from Brush Dipped in 1wt.% TMAH**

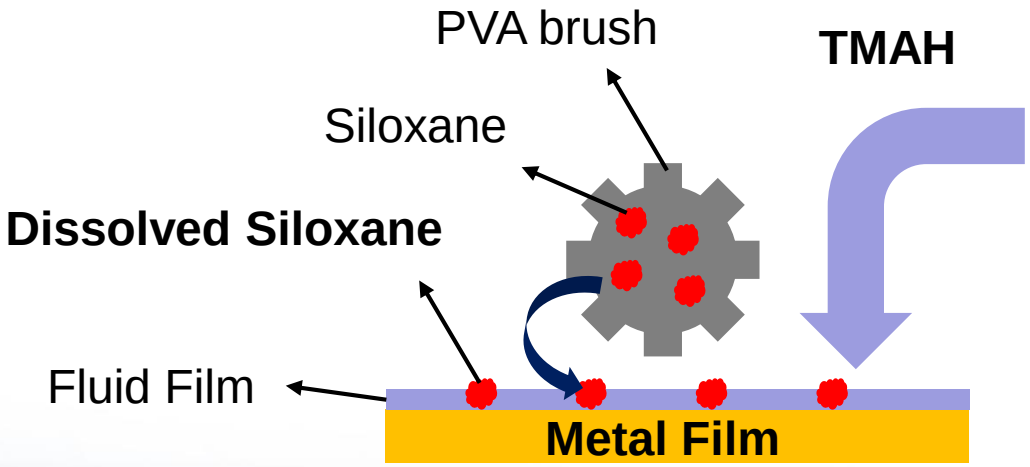




➢ **Brush dipped in 1wt.% TMAH solution shows organic residue contamination.**

Transport Mechanism of Siloxane by Cleaning Chemical

1. In general, organic residues were observed in metal(especially Cu) CMP process.
2. Cleaning chemical of Cu CMP include **TMAH**.
3. **TMAH has high dissolution ability of siloxane.**
4. **Siloxane can be delivered** from inside of brush **to metal surface due to cleaning chemical.**



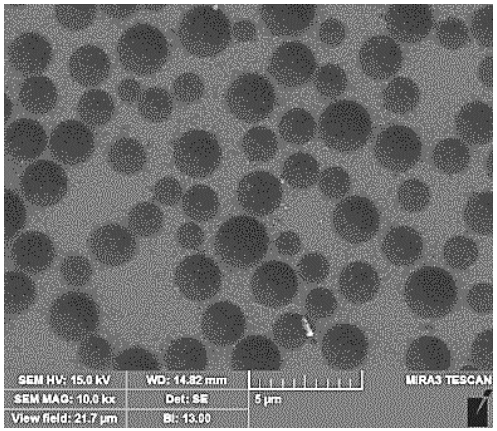
Summary

1. **Ultrasonication** is very effective and fast method to characterize the PVA brush.
2. Incoming PVA brush contains 2 types of impurities (**soluble and insoluble**).
3. Soluble impurities such as **siloxane** may create **organic residues**.
4. Insoluble impurities such as **PVA debris** may create **particle residues**.

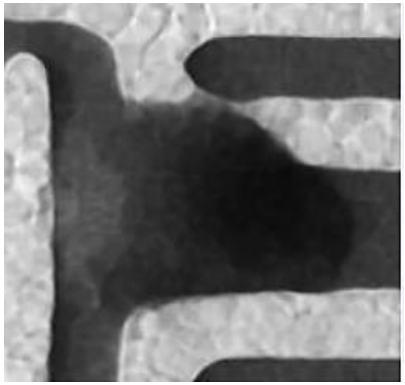
	Soluble Impurity	**Insoluble Impurity**
Composition	**Siloxane**	Weakly bonded **PVA** debris
Shape	Thin and circular organic residue	Particle
Analysis Method	ICP-MS, TOF-SIMS, LC-MS	LPC, FE-SEM, TOF-SIMS

Summary

5. **Soluble impurities may be a root cause of organic residues** after post CMP cleaning process.



(a) Organic Residue from Brush



(b) Organic Residue after post Cu CMP Cleaning

*Courtesy from GlobalFoundries

6. Siloxane can be delivered from inside of brush **to metal surface due to etching ability of cleaning chemical.**

THANK YOU FOR YOUR ATTENTION