

# VASSCAA-7

*7th Vacuum and Surface Sciences Conference of Asia and Australia  
October 5 - 9, 2014, Hsinchu Taiwan*



## **Comparison of abrasive flow polishing and chemical polishing for PAL-XFEL undulator vacuum chamber**

**C. D. Park, H. C. Kwon, D. H. Na, and T. G. Ha**

**Vacuum Gr., PAL-XFEL project  
Pohang Accelerator Laboratory**



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**Session: VS2-5 (11:50 a.m. on Wed.)**

## **current status of PAL-XFEL vacuum system**

**T. G. Ha, D. H. Na, and C. D. Park**  
**Vacuum Gr., PAL XFEL project**  
**Pohang Accelerator Laboratory**

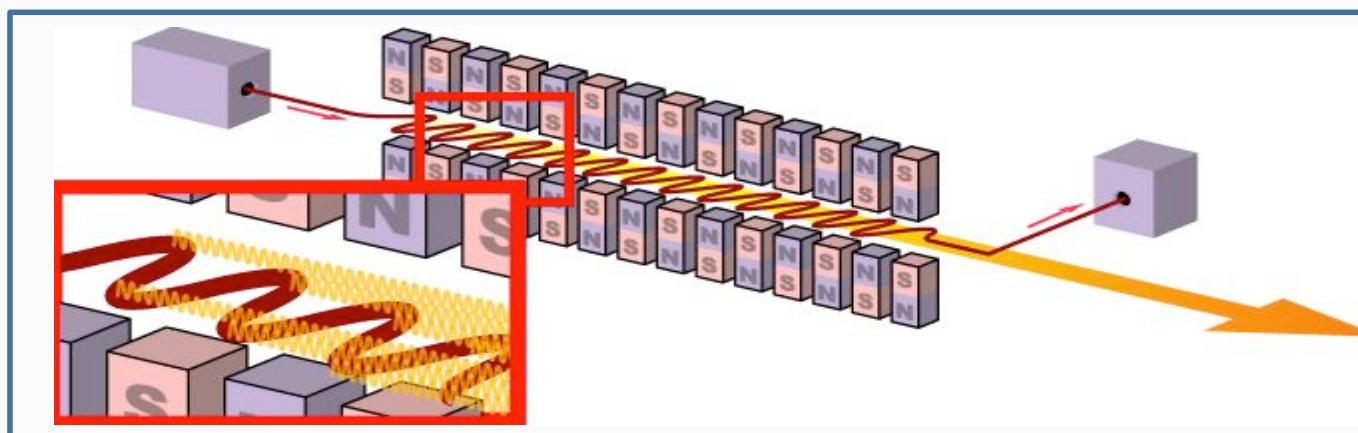


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## Undulators for PAL-XFEL



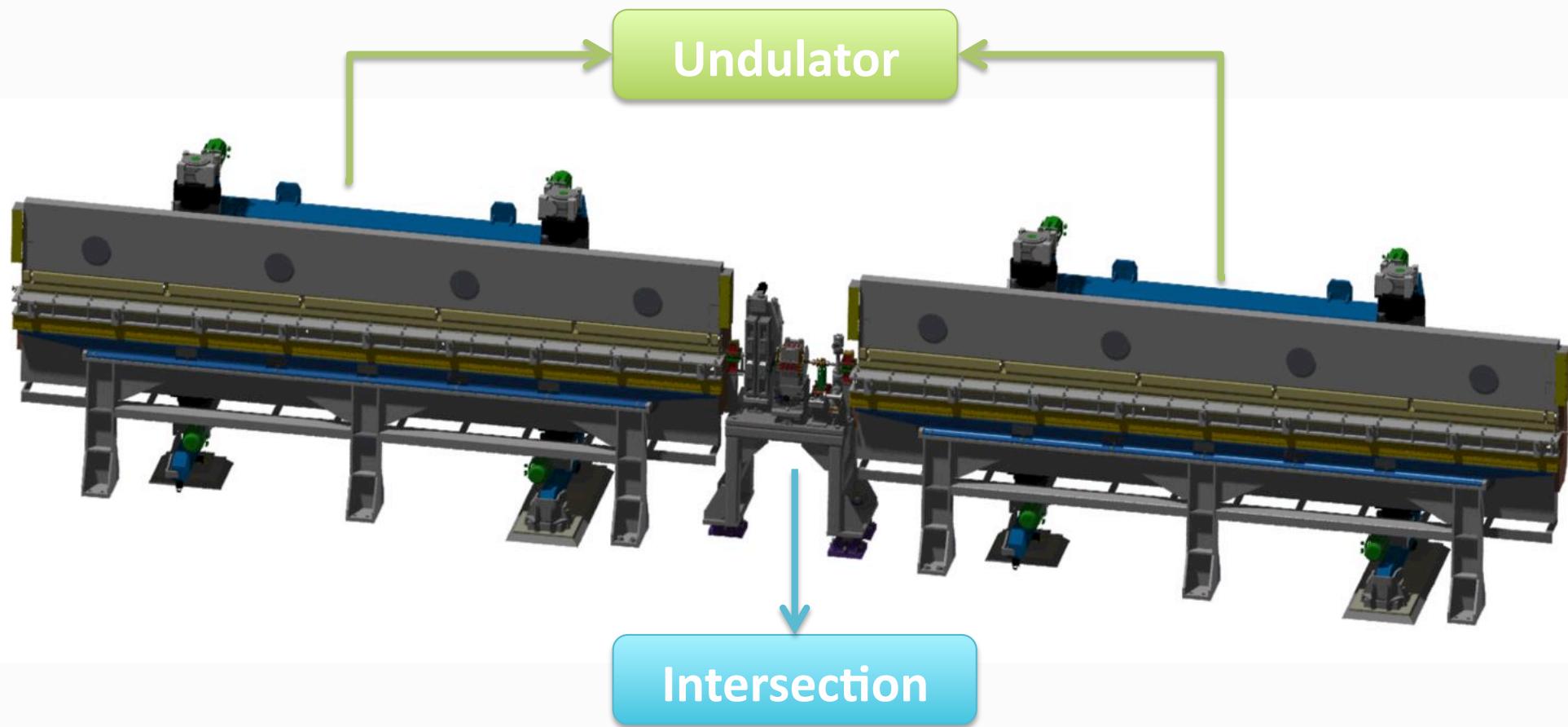
[www.Bandicam.co.kr](http://www.Bandicam.co.kr)





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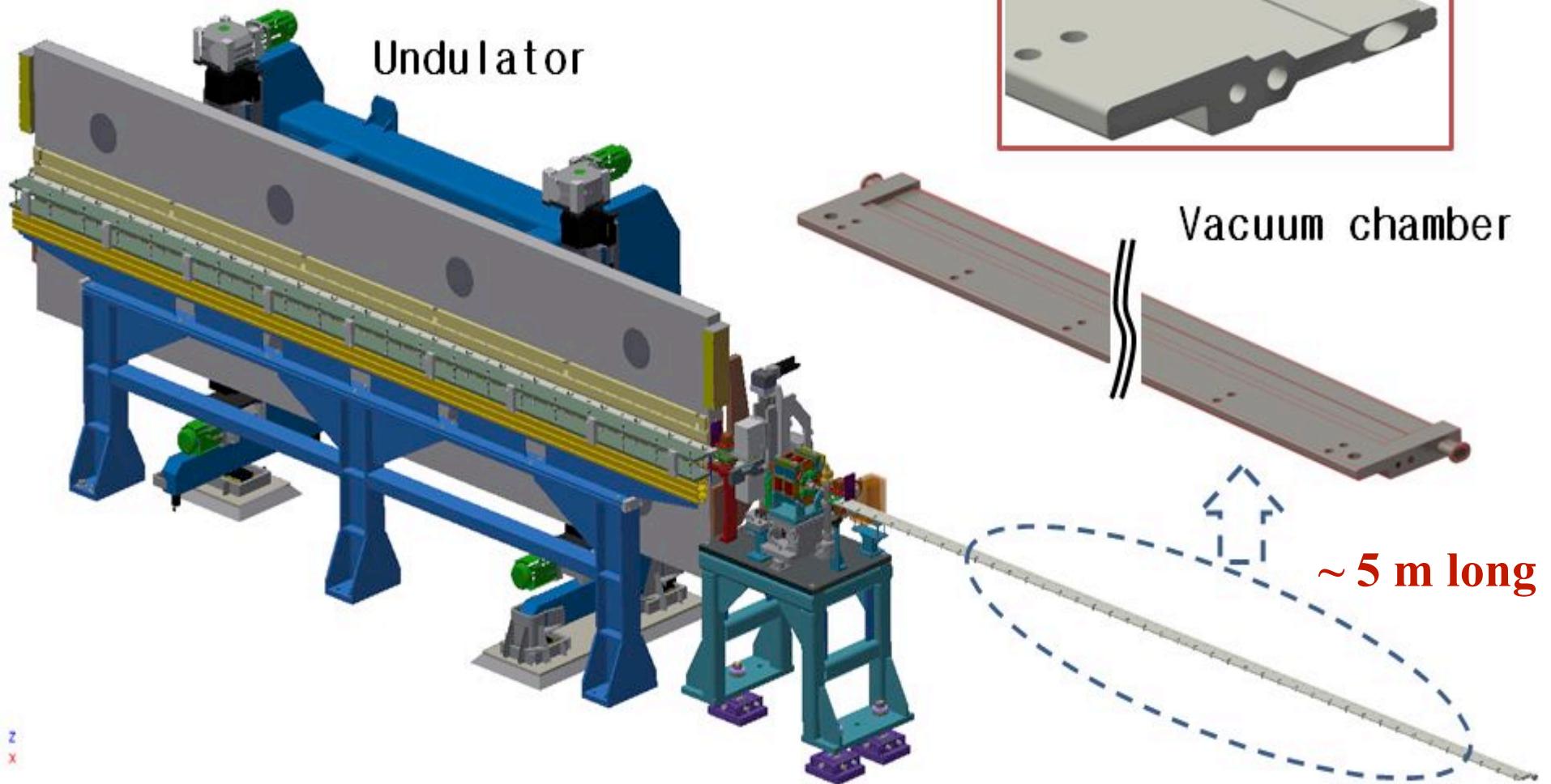
## Undulator and Intersection





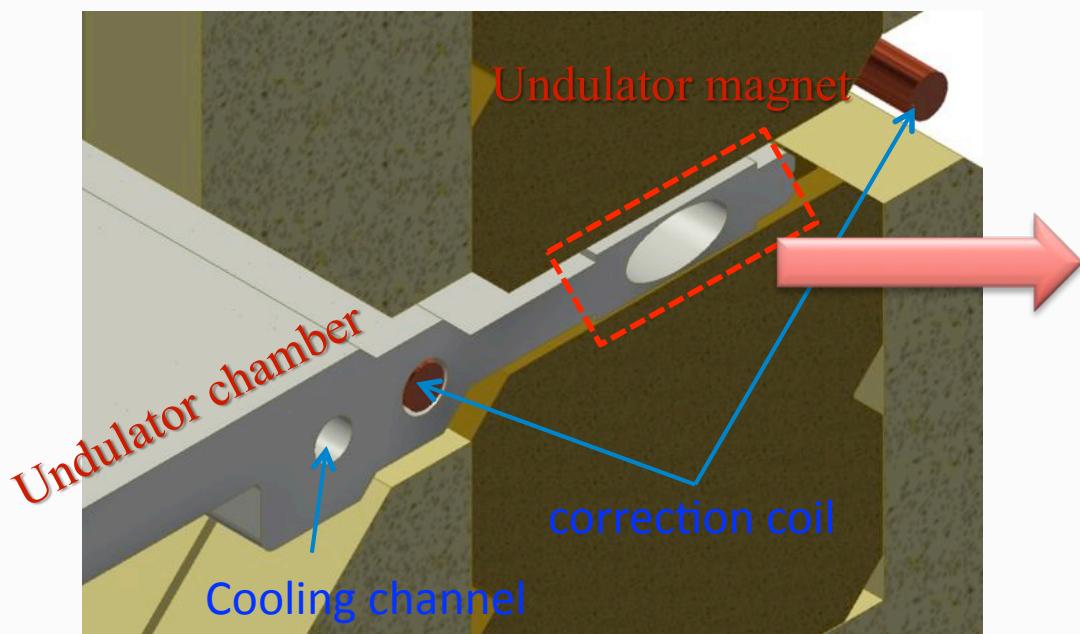
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## Undulator and Intersection

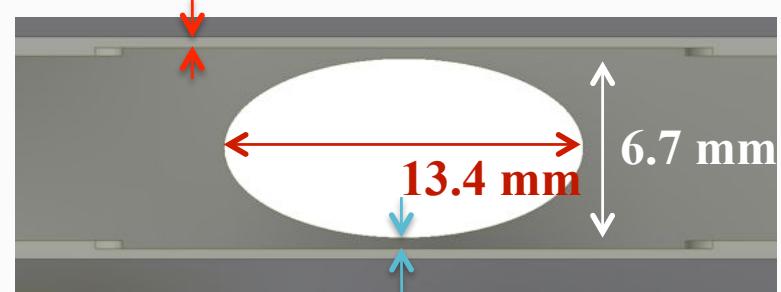




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Clearance 0.4 mm



Thickness 0.4 mm



## Vacuum Requirements

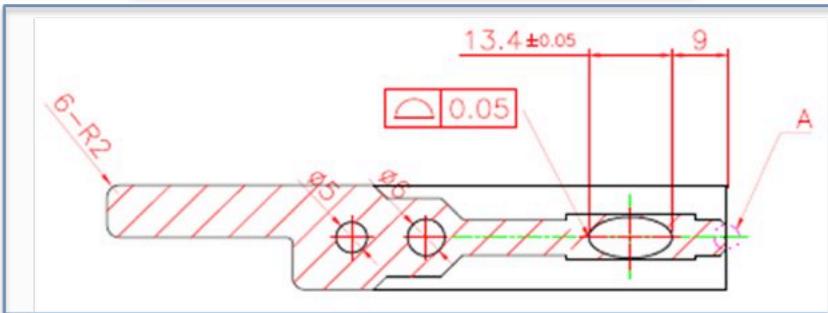
- Pressure  $< 1 \times 10^{-5}$  mbar
  - No significant beam-gas interaction effect
    - Collision (Beam loss/Bremstrulung)
    - Ionization (Emittance growth)
- Surface of inner wall/material
  - Low a.c. electrical resistance/Wake
    - **Roughness**  $< 150$  nm ( $R_a$ )
    - **Oxide layer**  $< 7$  nm
    - **Aluminum** alloy



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# chamber manufacturing

## Fabrication procedure



1. High quality Extrusion
  - controlled gas env.
2. Correction
  - stretching in controlled gas env.
3. High quality Polishing
  - AFP or CP
4. Precision machining
5. Chemical cleaning
6. Welding



## After Process

1. Extrusion
  - Roughness < 200 nm
2. Correction
  - Flatness < 0.1 mm / 5 m
3. Polishing
  - Roughness < 150 nm
4. Precision machining
  - Thickness:  $0.4 \text{ mm} \pm 50 \text{ um}$
5. Chemical cleaning
  - Oxide layer < 7 nm



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## I. abrasive flow polishing (AFP)



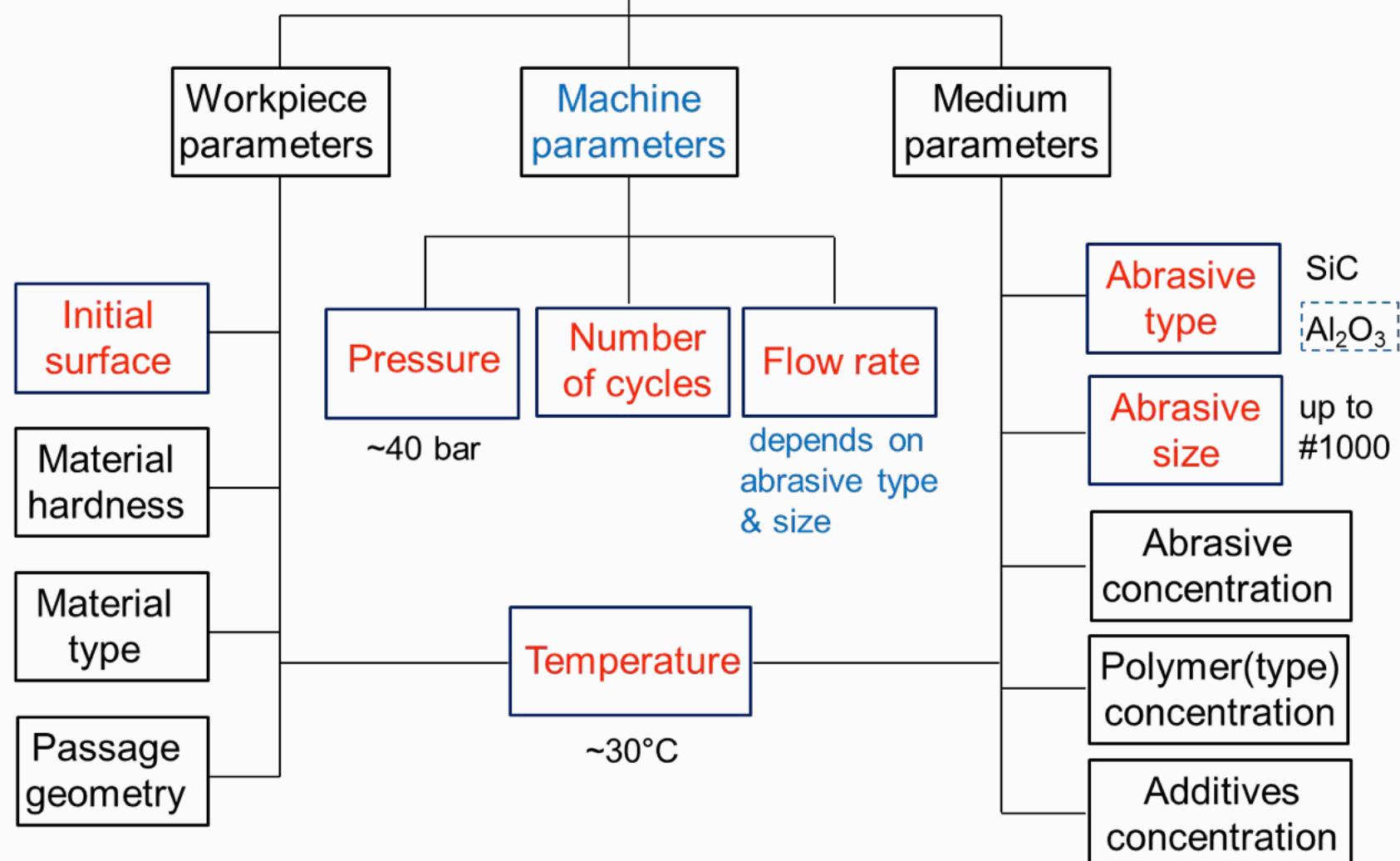
[ExtrudehoneAFM.com](http://ExtrudehoneAFM.com)

### Acknowledgements

The design and fabrication procedures are basically based on the previous works done by the vacuum group of **APS, LCLS, EuroXFEL, and Fermi**.



## Abrasive Flow Machining Process Parameters





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## I. AFP

unexpected pits



Pits have been found on the polished surface of the test specimens.

- improper pressure ? **No**
- viscosity? **No**
- aluminum material itself? **No**

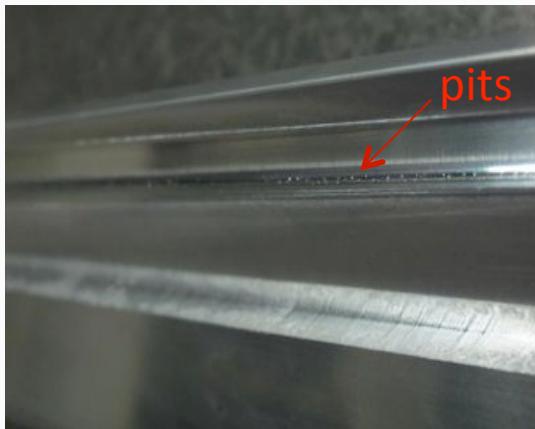
However, it was **only with abrasive SiC**. No pits are found with abrasive  $\text{Al}_2\text{O}_3$ .



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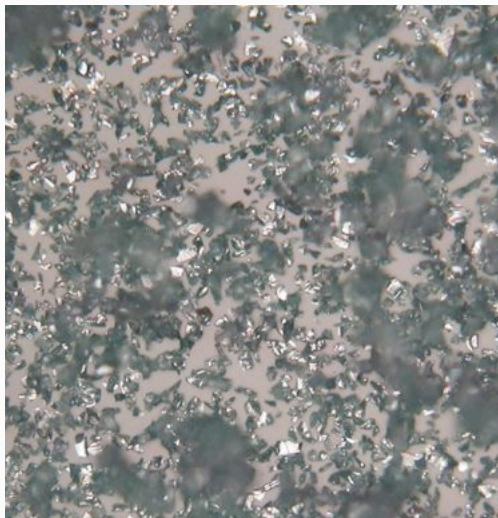
## I. AFP

unexpected pits → solved

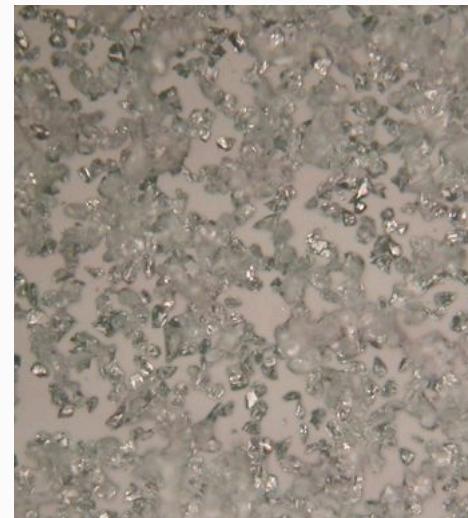


abrasive particle type

SiC #800  
(20~30 µm)



Al<sub>2</sub>O<sub>3</sub> #320  
(45 ± 5 µm)



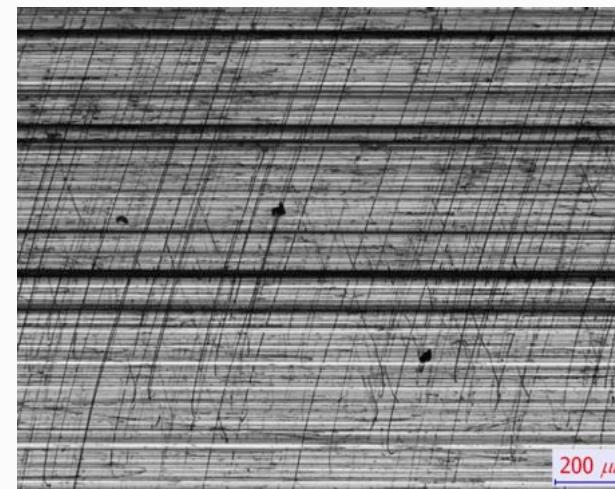
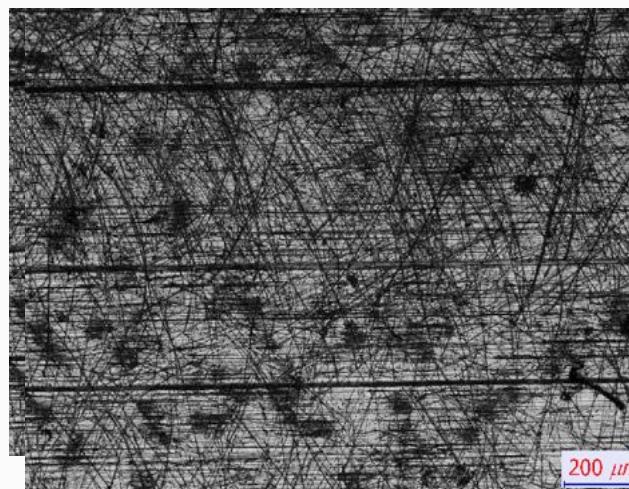
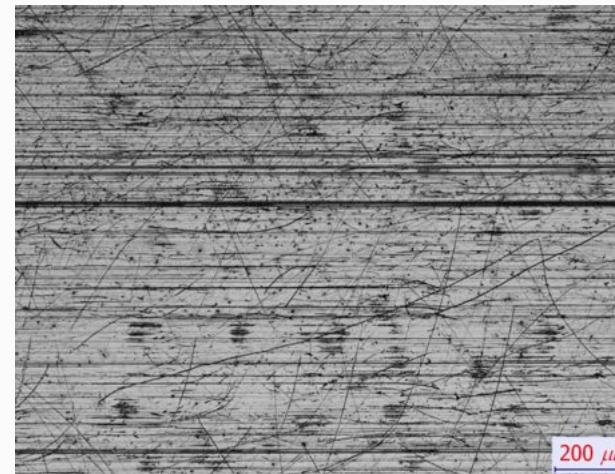
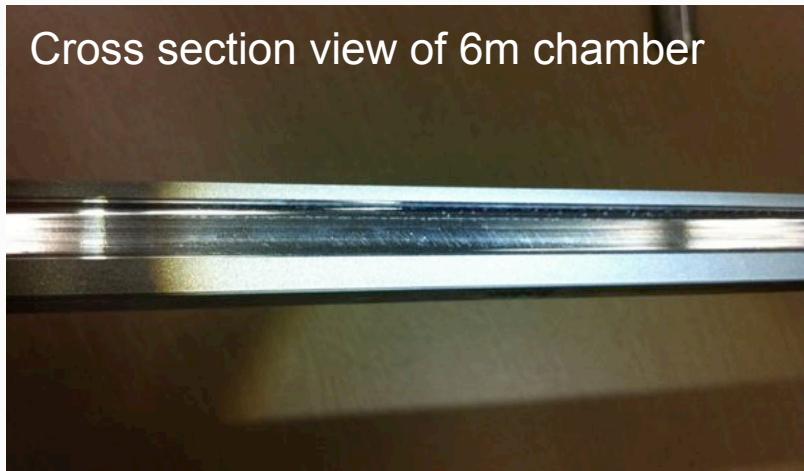


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## I. AFP

### unexpected scratches

Cross section view of 6m chamber



Perpendicular-directional scratches were found on AFM polished surfaces of 6m chamber

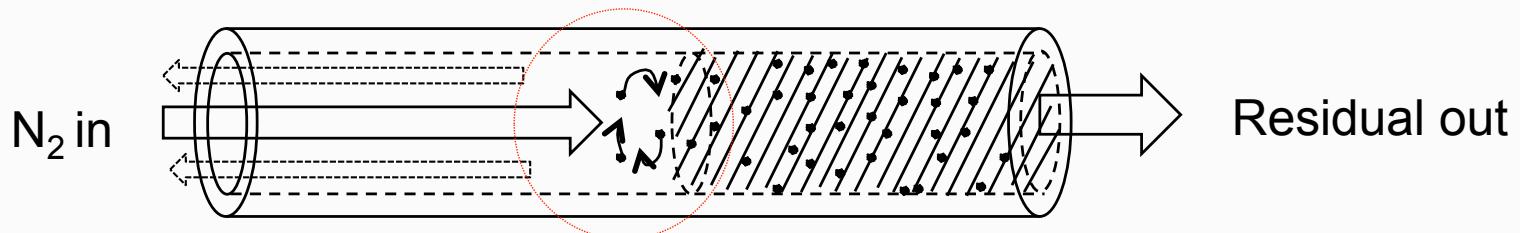


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## I. AFP

unexpected scratches

Cause : pressurized N<sub>2</sub> blowing for the residual removal



turbulence with abrasive particles

slow removal using gravity



no scratch

pressurized (5~6 bar) N<sub>2</sub>



perpendicular-directional  
scratches





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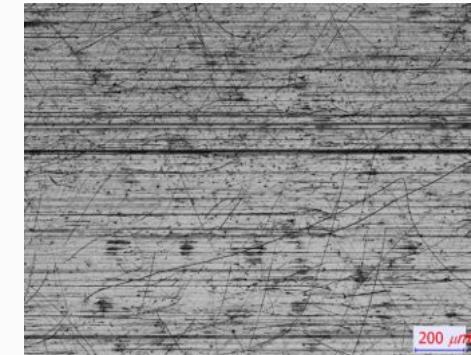
## I. AFP

unexpected scratches → solved

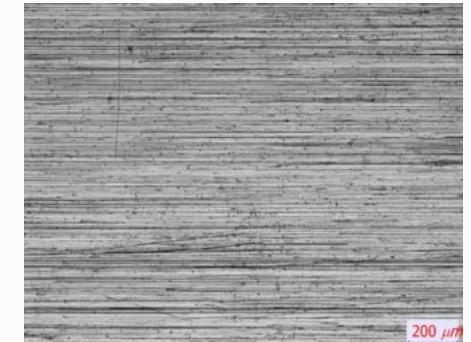
using pressurized non-oxidizing fluid for the residue removal



Equipment for regulated-  
pressurizing liquid



N<sub>2</sub> purge



Non-oxidizing liquid pushing

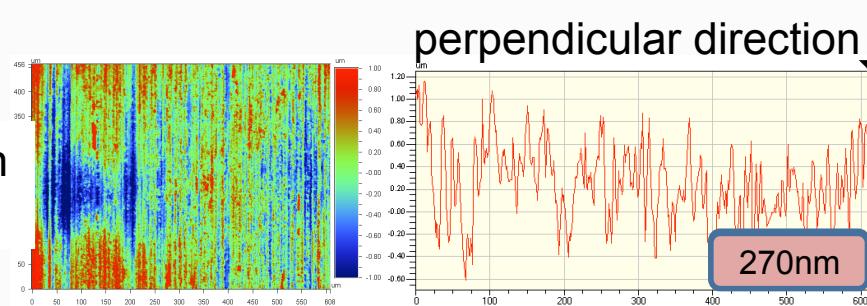


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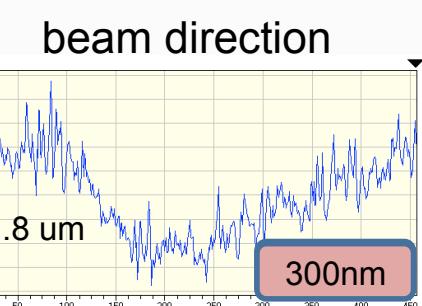
## I. AFP

### Roughness measurements

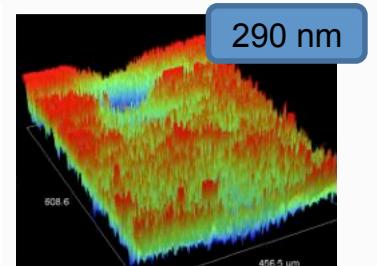
extrusion  
Only



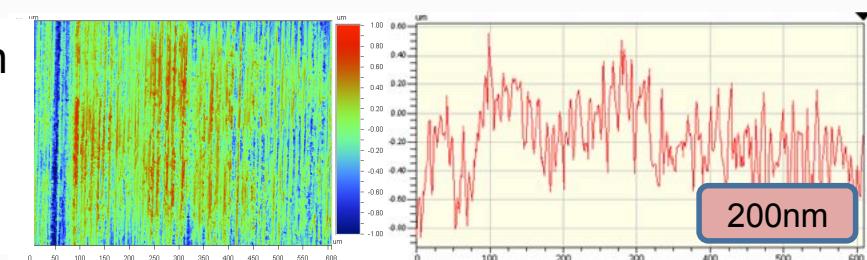
beam direction



608x456 (μm)

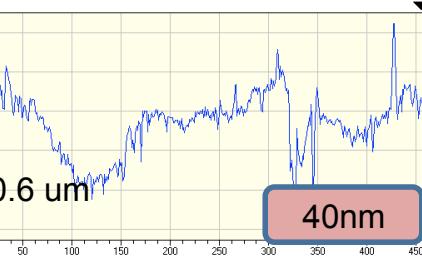
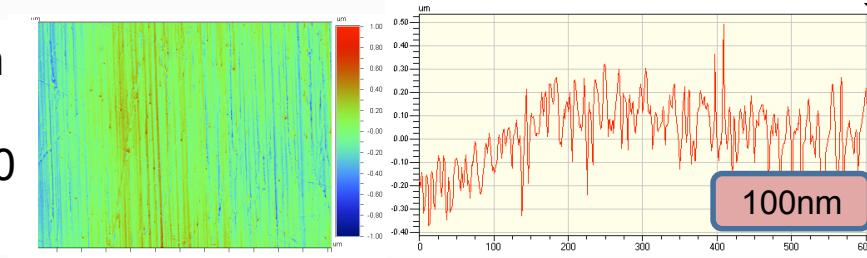


extrusion  
& AFM  
SiC#600  
40hrs



150 nm

extrusion  
& AFM  
 $\text{Al}_2\text{O}_3$ #320  
40hrs

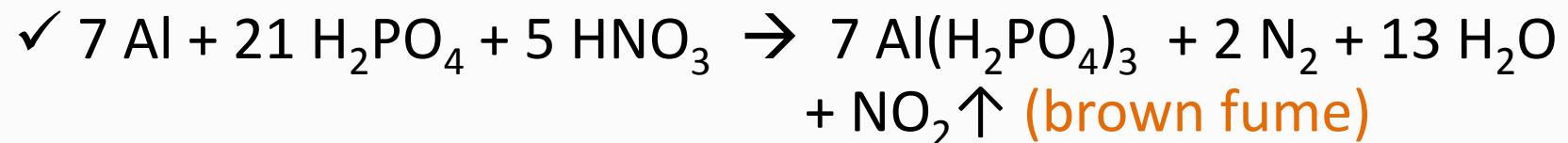


80 nm



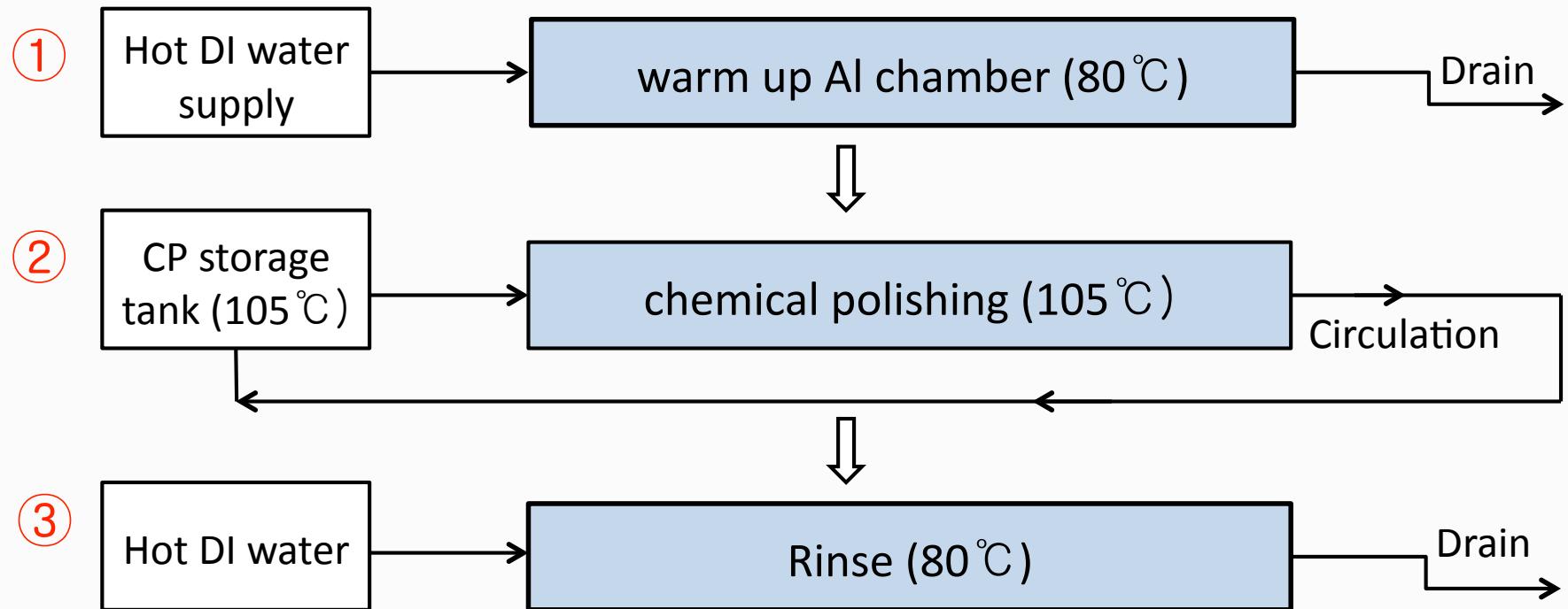
## II. chemical polishing (CP)

Without fume suppressant



With fume suppressant (Ammonium nitrate, Urea, Dicyananide)

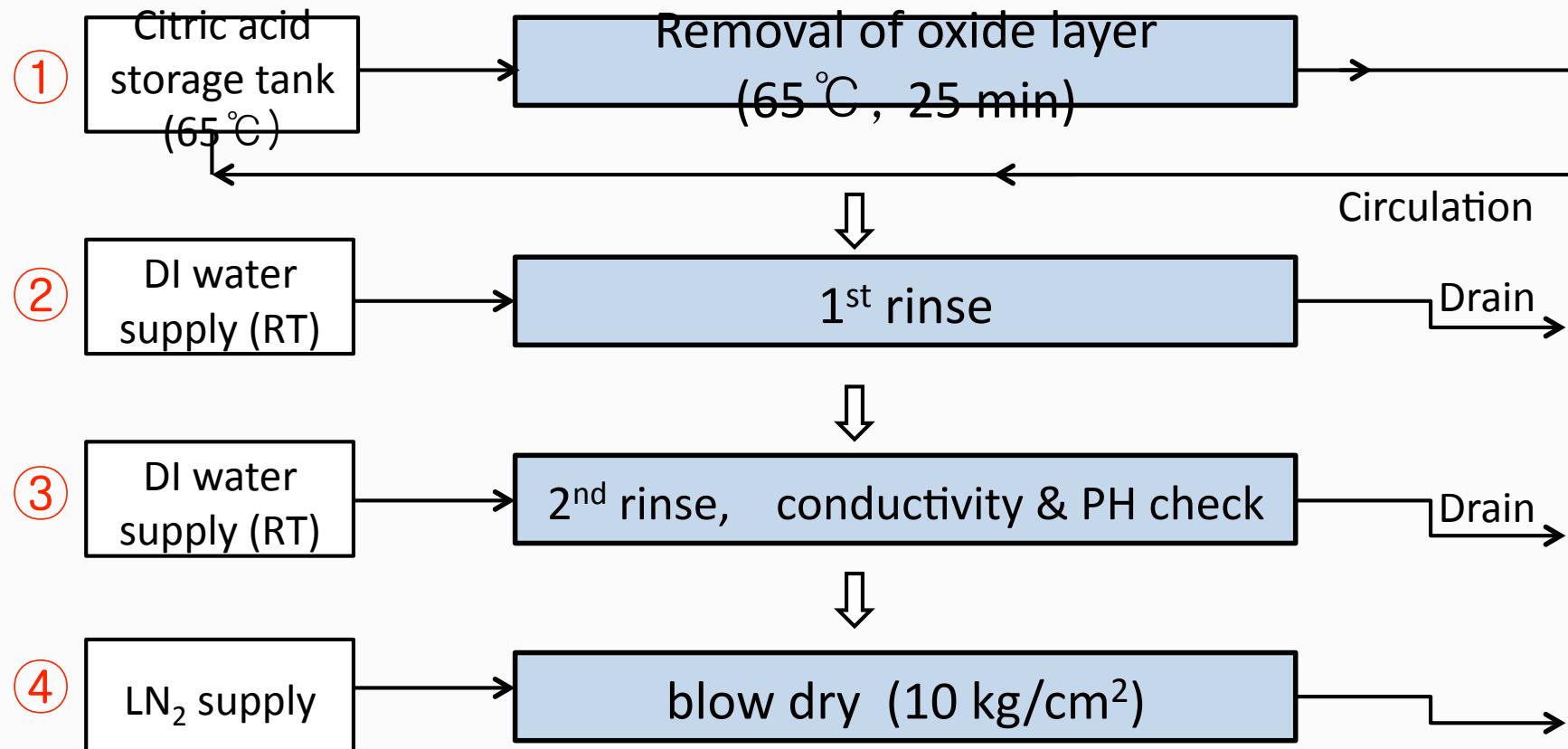






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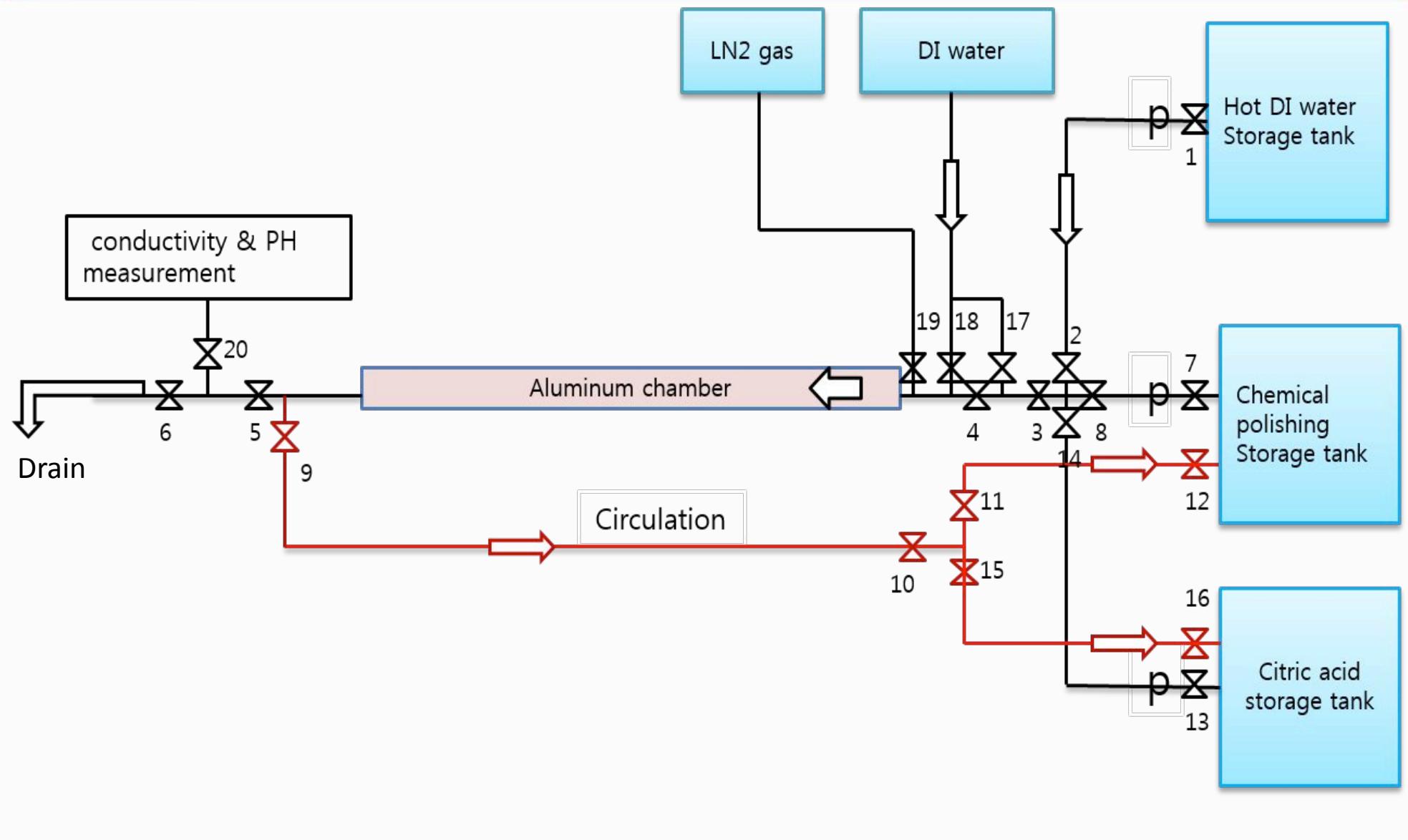
## Citranox® cleaning





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## II. CP

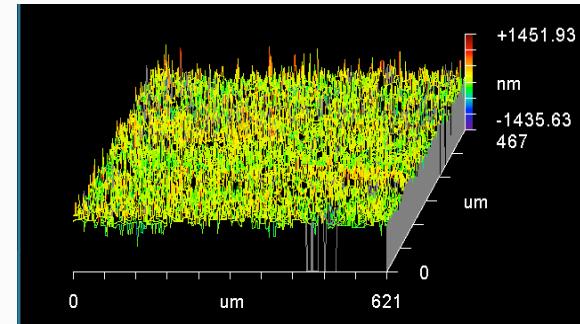
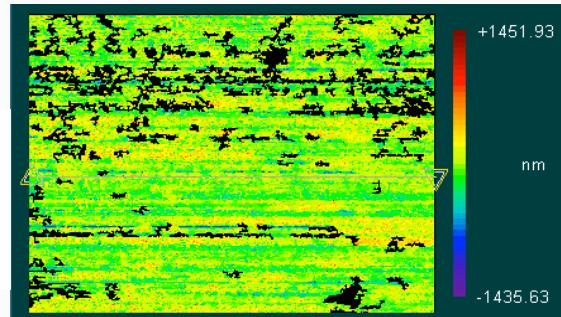




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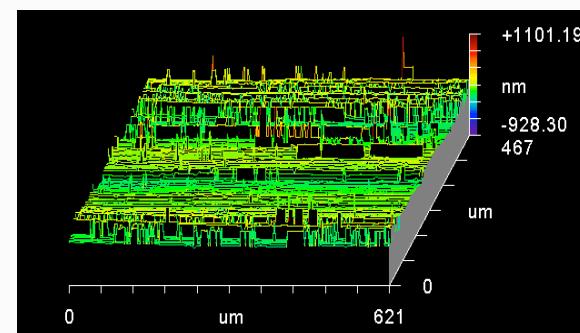
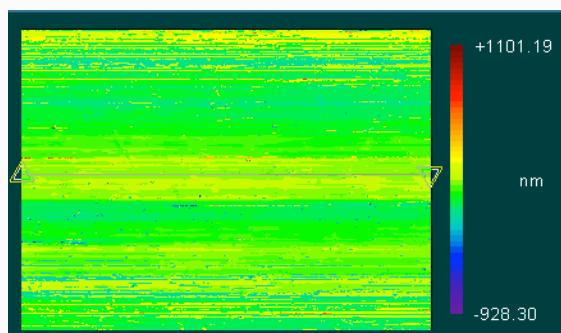
# surface roughness

extrusion  
only



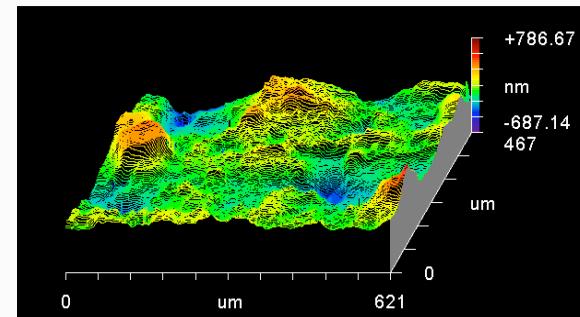
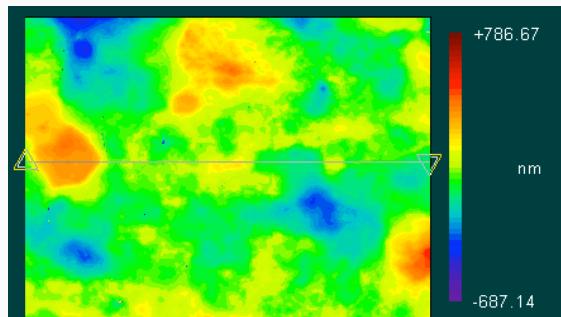
$$R_a \approx 180 \text{ nm}$$

AFP



$$R_a \approx 90 \text{ nm}$$

CP



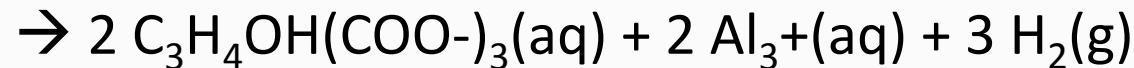
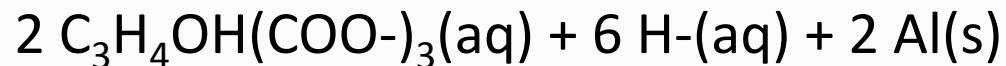
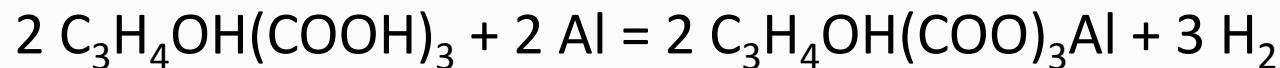
$$R_a \approx 110 \text{ nm}$$



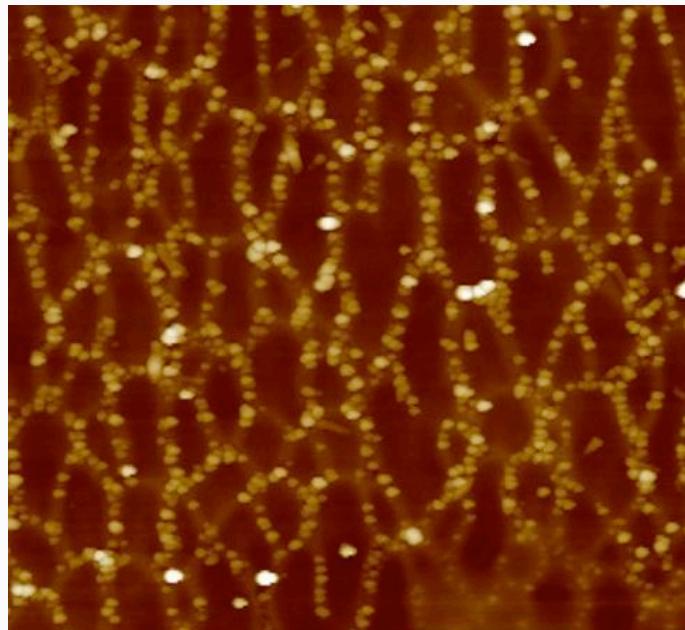
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# Citranox

✓ Citric acid is a triprotic acid :  $\text{C}_3\text{H}_4\text{OH}(\text{COOH})_3$



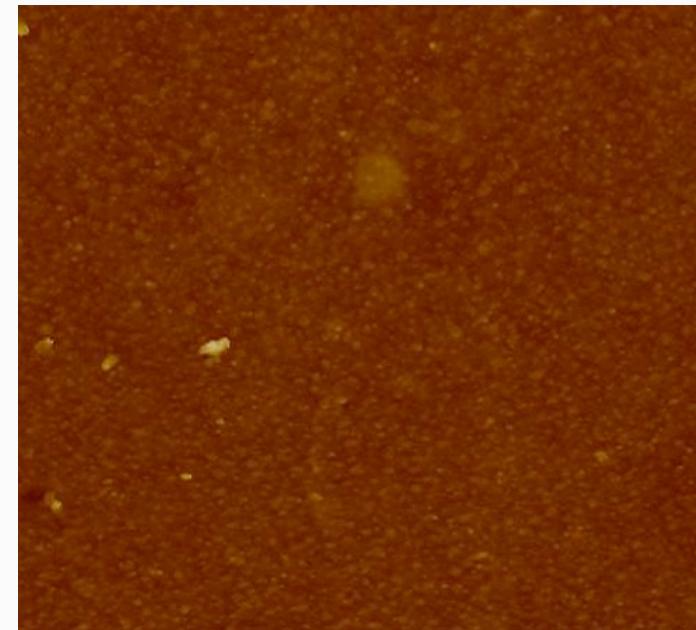
CP only



Cleaning effect



CP + Citranox

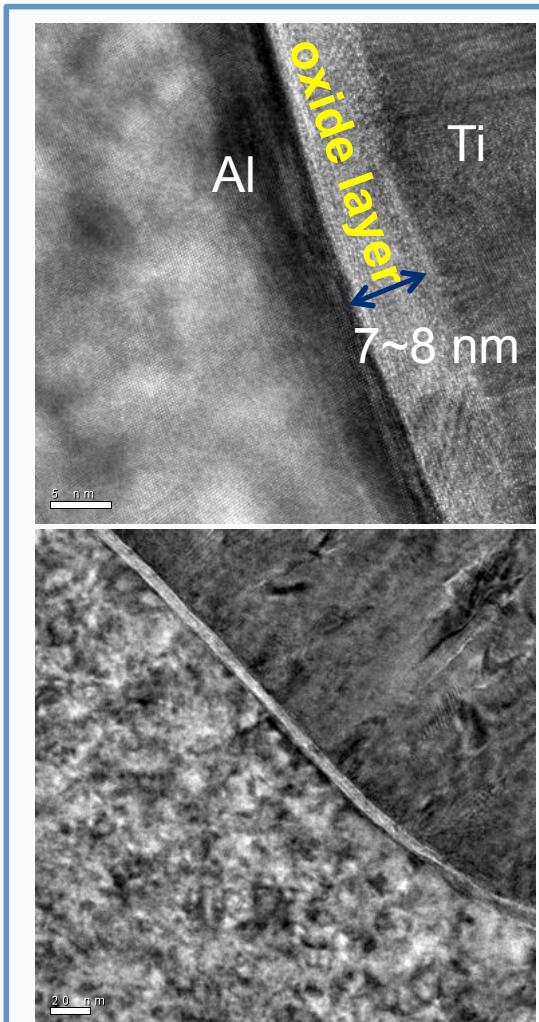


AFM image (5 x 5 um)

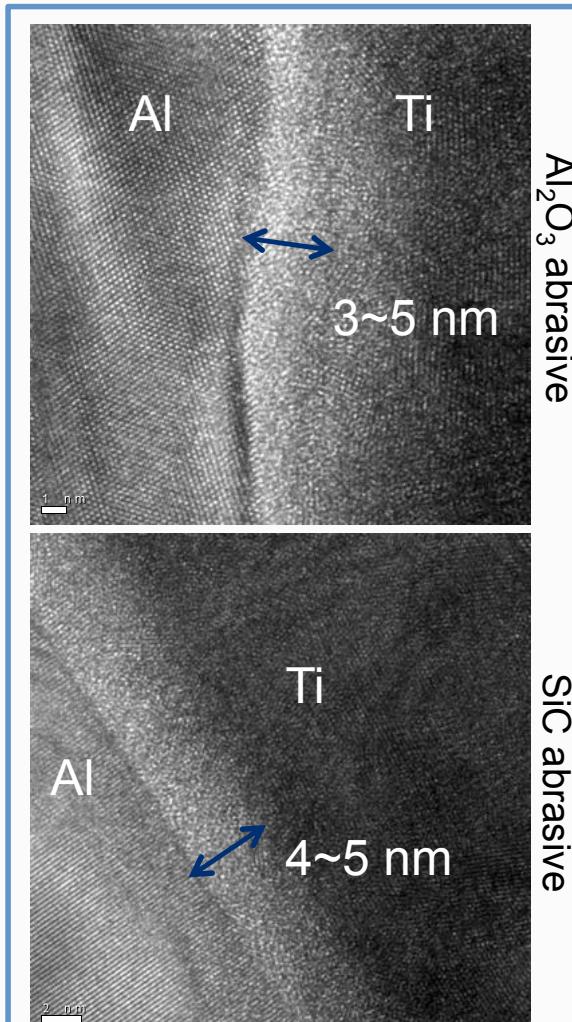


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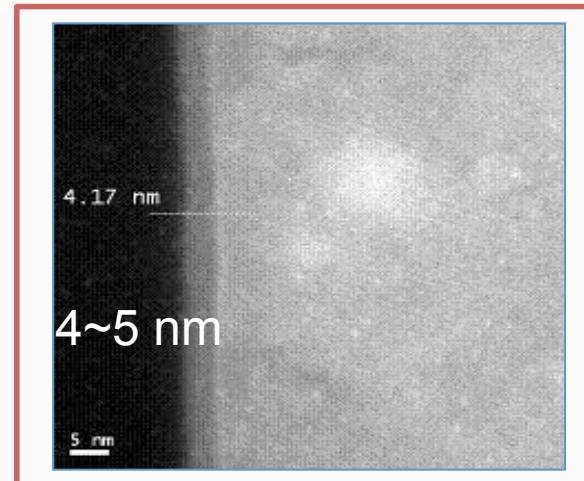
## Oxide thickness



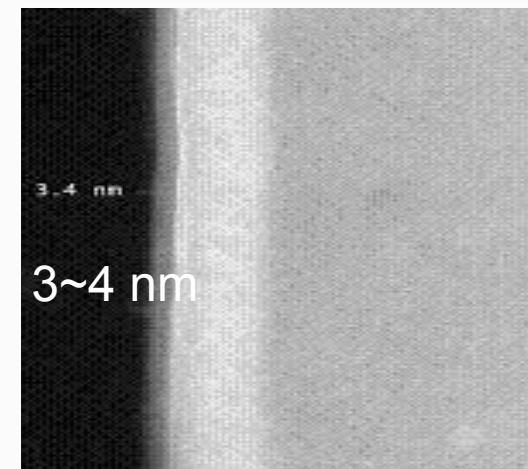
Extrusion



Extrusion + AFP +  
Citronox



Extrusion + CP

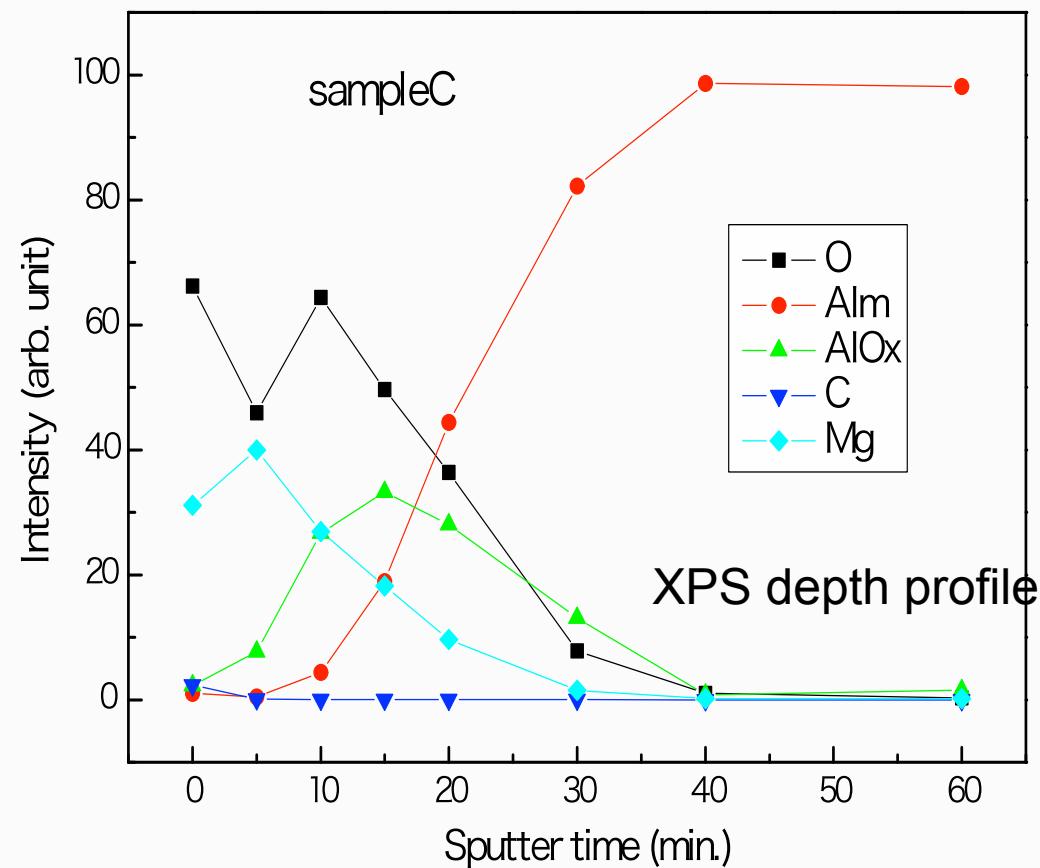


Extrusion + CP +  
Citronox



## Oxide layer

Extrusion only with polished tip and controlled environment (Ar90%+O<sub>2</sub>10%)



**oxide:** mostly MgO + some Al<sub>2</sub>O<sub>3</sub>  
(+ MgAl<sub>2</sub>O<sub>4</sub>?)

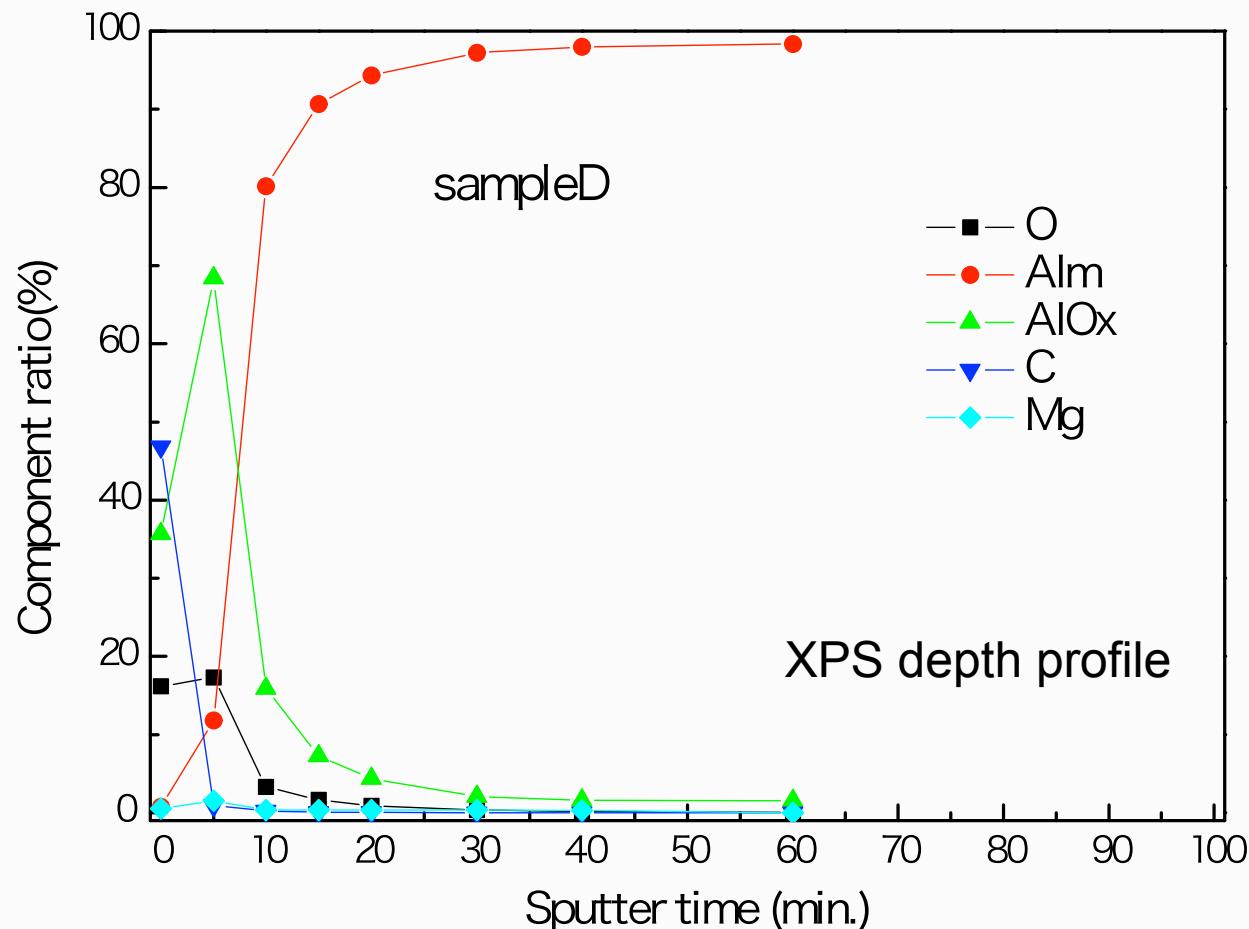
**thickness :** < 10 nm



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## Oxide layer

Extrusion with polished tip in a controlled environment (Ar 90%+O<sub>2</sub> 10%)  
+ AFP + Citronox



**oxide:** mostly Al<sub>2</sub>O<sub>3</sub>

**thickness:** ~ 5 nm



## Comparison of AFP and CP

	AFP/Citronox♪	CP/Citronox♪	Goal♪
<b>polishing time</b>	<b>40 ~ 100 hr</b>	<b>1 ~ 2 min ♪</b>	
<b>surf. roughness</b>	<b>&lt; 100 nm♪</b>	<b>&lt; 120 nm♪</b>	<b>&lt; 150 nm♪</b>
<b>oxide thickness (after Citronox)</b>	<b>&lt; 10 nm</b>	<b>&lt; 5 nm</b>	<b>&lt; 7 nm♪</b>
<b>price</b>	<b>10 ♪</b>	<b>1 ♪</b>	
	<b>Outsourcing</b>	<b>in-house</b>	



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## CP: a final decision

- ✓ # of chambers: 40
  - : HX 18 + 2 ea, SX 8 + 2 ea(spares)
  - : witness sample chamber 10 ea
  
- ✓ CP at PAL
  - 2 ea/day including all related works
  - = 10 ea/week
  - = 40 ea in one month



## Summary

- ✓ We established two surface finish procedures for PAL-XFEL undulator vacuum chamber.
- ✓ Both surface polishing methods satisfied the requirements.
- ✓ CP is chosen for the mass production.
- ✓ We will start the chamber Fab. in next Spring.



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Thank you for your attention

