# VEP Status at Marui Galvanizing Co. Ltd/KEK

**LCWS14 at Belgrade / Serbia**
**7th Oct. 2014**

**Presented by**
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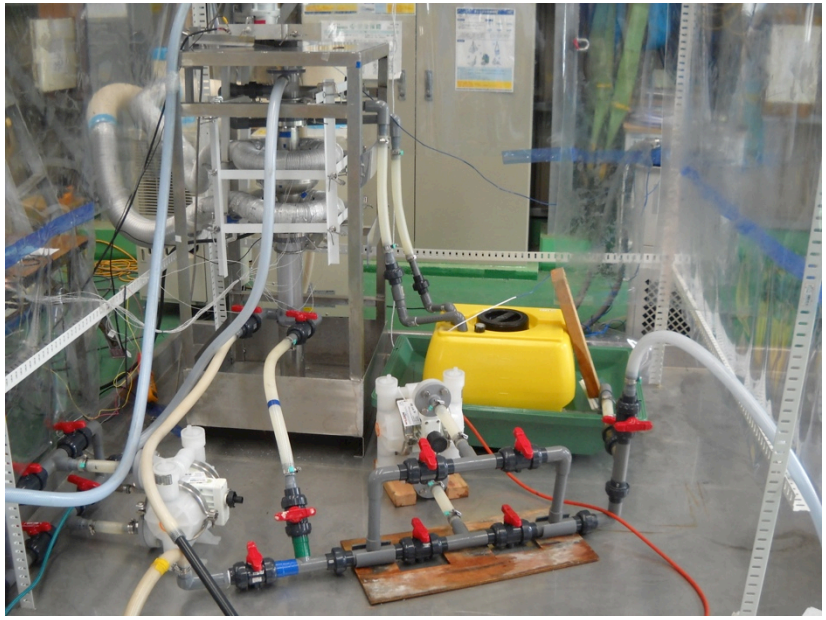
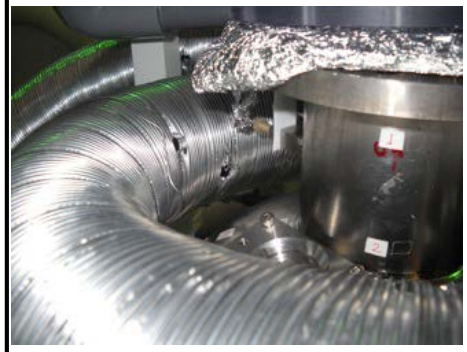
- Future Work

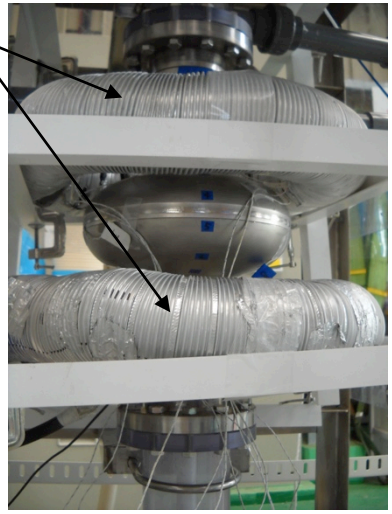
# VEP Setups for 1 and 9 cell Cavities at Marui

## VEP Setup for 1 Cell

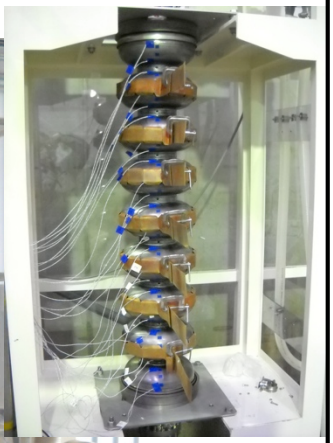


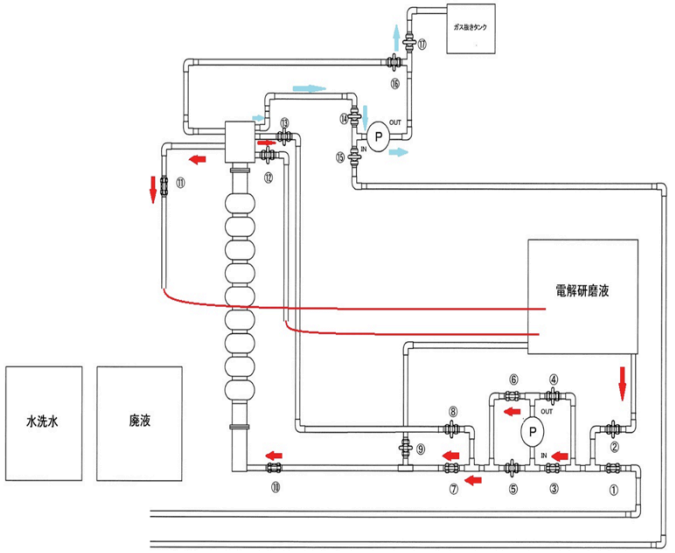
Wind guide ducts with several small holes





## VEP Setup for 9 Cell

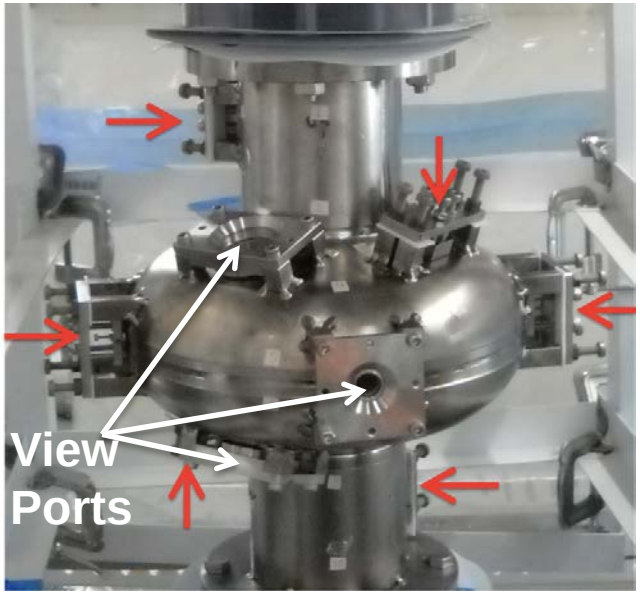




# Coupon Cavity

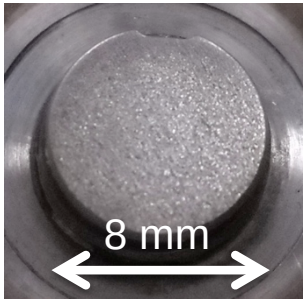
- The coupon cavity contains 6 Nb disk type coupon at beam pipes, irises and equator.
- The coupons were set to be electrically isolated from the cavity.
- The isolation allowed us to measure coupon current from individual coupon.
- The cavity is having 4 view ports also on the top iris, bottom iris and equator for light introduction and in-situ observation of wings and $H_2$ bubbles.

**Coupon Cavity**




Coupon position by red arrow

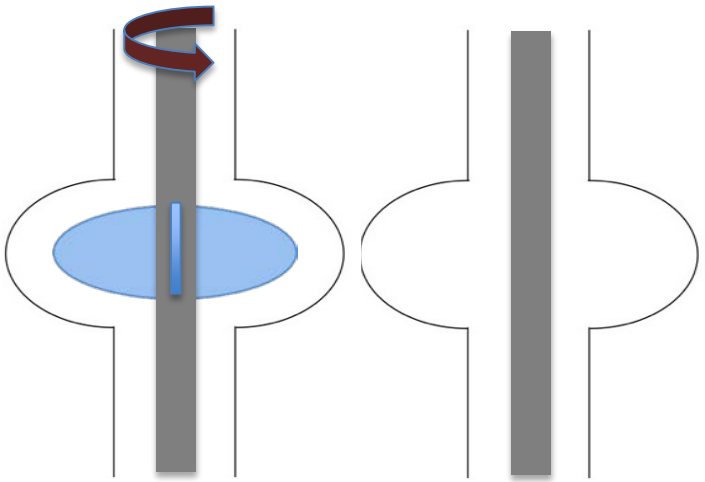
***Coupon***



# VEP Conditions

- Two Vertical Electropolishing (VEP) experiments of a coupon cavity were performed with our unique cathode called “Ninja cathode” and with a conventional rod cathode.
- The Ninja cathode has 4 retractable wings for agitation and uniform EP over the cavity.
- Results of both the VEPs were studied.

***Ninja & Rod Cathodes***



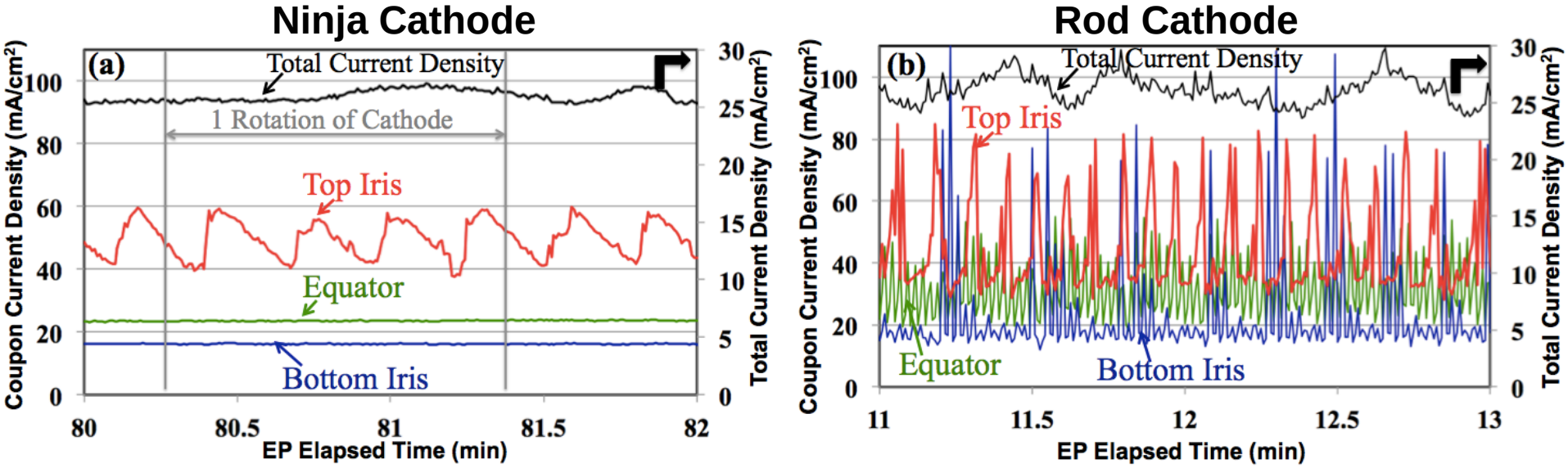
- Ninja cathode has 4 retractable wings.

**VEP conditions for both the VEPs performed with the Ninja and rod cathodes**

| Sample Positions | Ninja Cathode | Rod Cathode |
|---|---|---|
| $H_2SO_4$:HF | 9:1 | 9:1 |
| Electrolyte Flow Direction | Bottom to Top | Bottom to Top |
| Flow Rate | 5 L/min | 5 L/min |
| Cathode Rotational Speed | 1 rpm | Not Applicable |
| Applied Voltage | 9-11 V | 9 V |
| Current Density | 25 mA/cm$^2$ | 25-30 mA/cm$^2$ |
| Target Removal Thickness | 50 µm | 50 µm |
| EP Time | 2.5 hours | 2.5 hours |
| Cavity Surface Temperature | 17.5-23 °C | 24.5-27 °C |

- The VEP conditions were kept similar in both the VEPs so as to compare VEP results.

# Coupon Current Profiles by coupon cavity

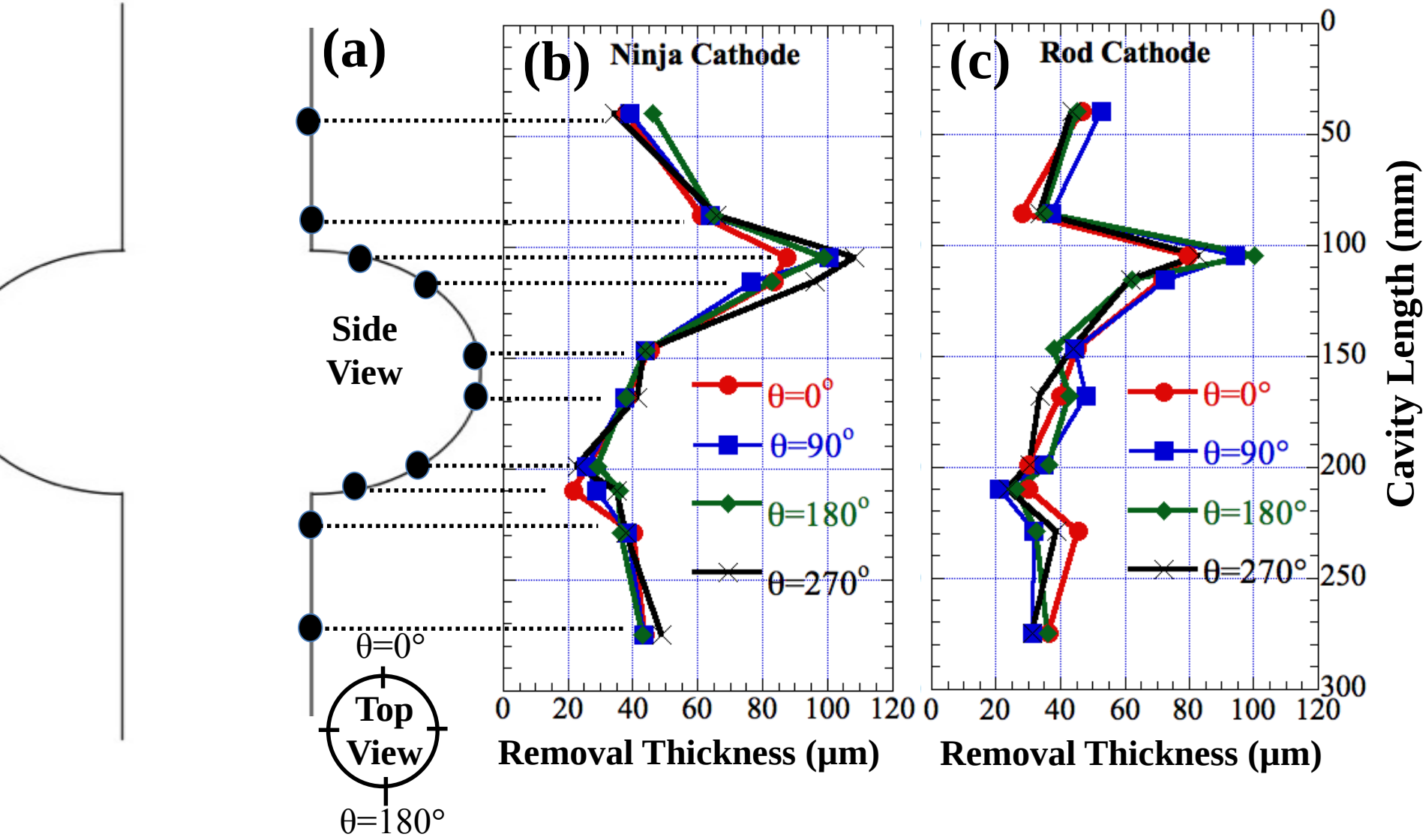



- The top iris should have a thinner viscous layer due to the gravity [1] and attack of resident $H_2$ bubbles [2].
- The oscillation on the top iris current was due to the cathode wings which enhanced the EP rate.
- In rod cathode many current spikes appeared in all the coupon current profiles. These might be due to attack of bubbles which damage viscous layer and enhance the EP rate.


[1] F. Furuta et al., TUP049 SRF2013, Paris, France (2013).
[2] S. Kato et al., TTC Meeting, Desy, Hamburg, Germany (2014).

# Cavity Removal Thickness

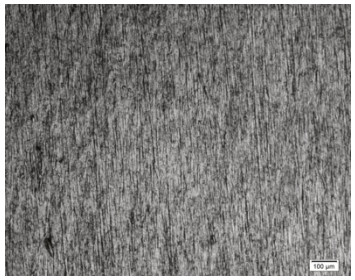
- Removal thickness was measured with ultrasonic thickness gauge.




- Removal thickness was the highest at the top iris and the lowest at the bottom iris.

# Optical Microscope Images

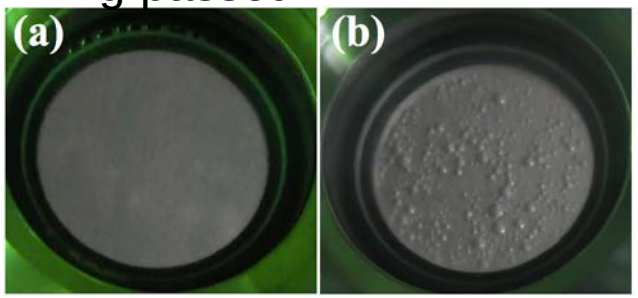
***Before VEP***



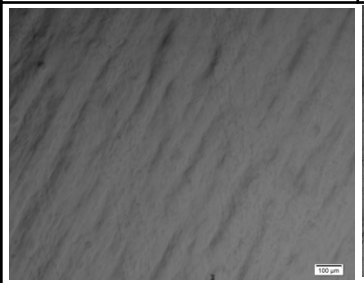
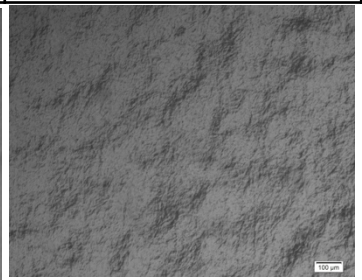
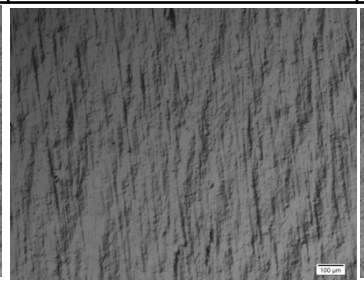
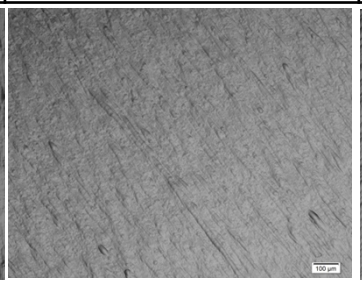
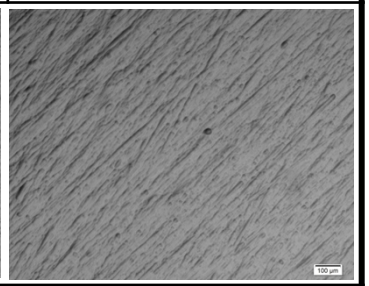
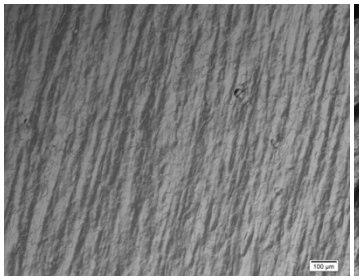
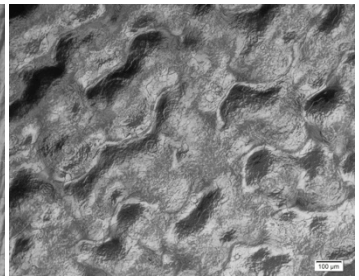
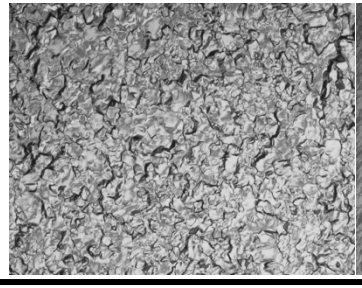
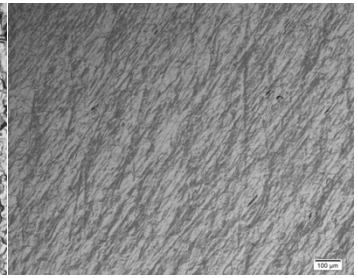
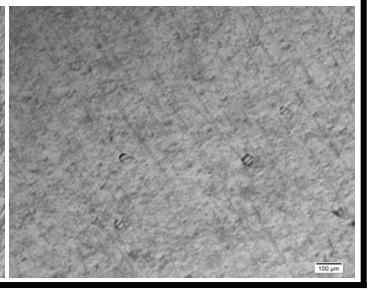
500 µm

Just after a wing passed

Rod cathode




10 mm

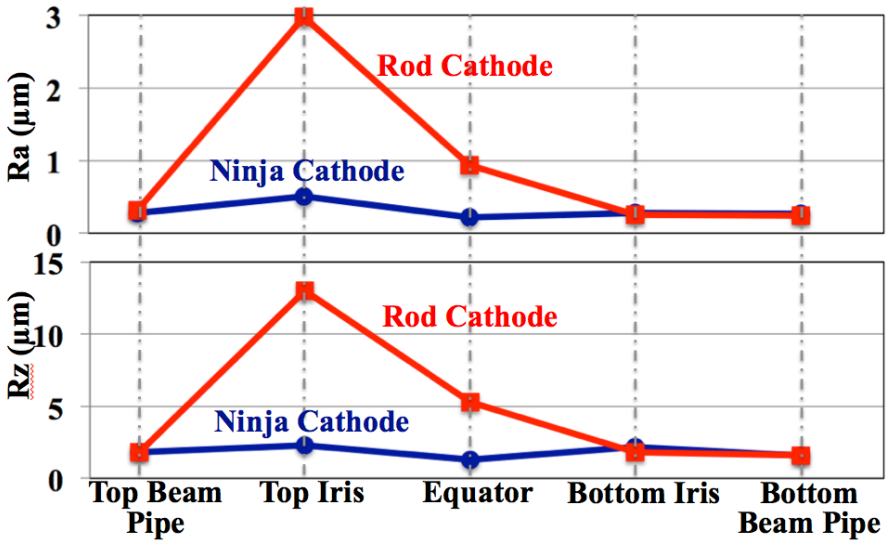
| | Top Beam Pipe | Top Iris | Equator | Bottom Iris | Bottom Beam Pipe |
|---|---|---|---|---|---|
| NINJA |  |  |  |  |  |
| ROD |  |  |  |  |  |

- The top iris surface always found rougher than other positions of the cavity.
- The rod cathode enhanced surface roughness at the top iris and equator.
- The bubbles attack the surface microscopically and make rough surface.

# Coupon Surface Roughness

Coupon surface roughness was measured with surface profile meter (SPM).

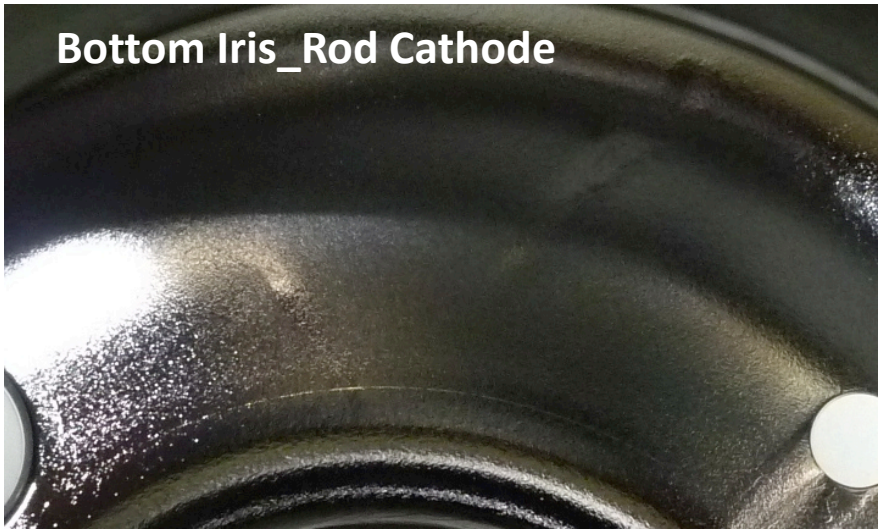
| | 2nd VEP (Ninja) | | 3rd VEP (Rod) | |
|---|---|---|---|---|
| Sample | Roughness Ra/Rz (μm) **Before 2nd EP** | Roughness Ra/Rz (μm) **After 2nd EP** | Roughness Ra/Rz (μm) **Before 3rdEP** | Roughness Ra/Rz (μm) **After 3rdEP** |
| Top BP | 0.53/4.2 | 0.28/1.8 | 0.57/3.9 | 0.31/1.8 |
| Top Iris | 0.51/3.3 | 0.5/2.3 | 0.43/3.4 | 2.98/13 |
| Equator_1 | 0.43/3.2 | 0.22/1.3 | 0.5/3.4 | 0.94/5.3 |
| Equator_2 | 0.38/2.9 | 0.23/1.4 | 0.46/3.5 | 0.95/5.7 |
| Bottom Iris | 0.45/3.2 | 0.28/2.2 | 0.46/3.7 | 0.26/1.8 |
| Bottom BP | 0.39/2.7 | 0.27/1.6 | 0.52/3.7 | 0.24/1.6 |




- The top iris and equator surfaces were found rougher after VEP with the rod cathode.
- For the rod cathode electrolyte flow rate of 5 l/min might not be enough to move out bubbles quickly.
- However faster movement of bubbles causes bubbles traces on the top iris.

# Cavity Irises




- The top iris surface was found to be rougher with vertical traces due to $H_2$ bubbles.

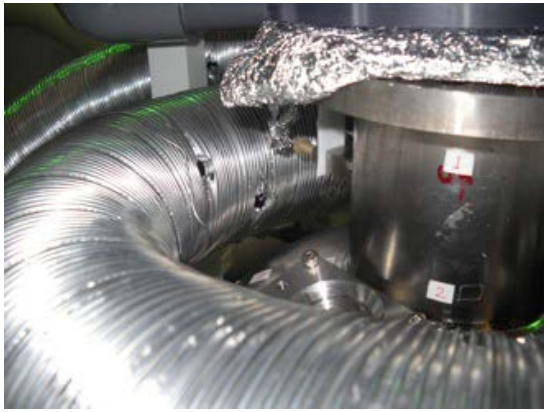
# 1st VEP of 1AC3 cavity

Purpose
VEP of 1AC3 cavity for vertical test
(1AC3 cavity is borrowed from CEA Saclay)

VEP condition
Electrolyte：$H_2SO_4$：HF＝9：1（New）
Voltage：5.0-6.0V (Power supply setting)
Time：150min (Continuous)
Flow direction：Bottom to top
Flow rate：5 L/min
Cathode rotation speed：1 rpm
Current target density： 20～30mA/cm$^2$
Tiller： 10℃ (in water bath)
Cathode： Our original cathode “Ninja”

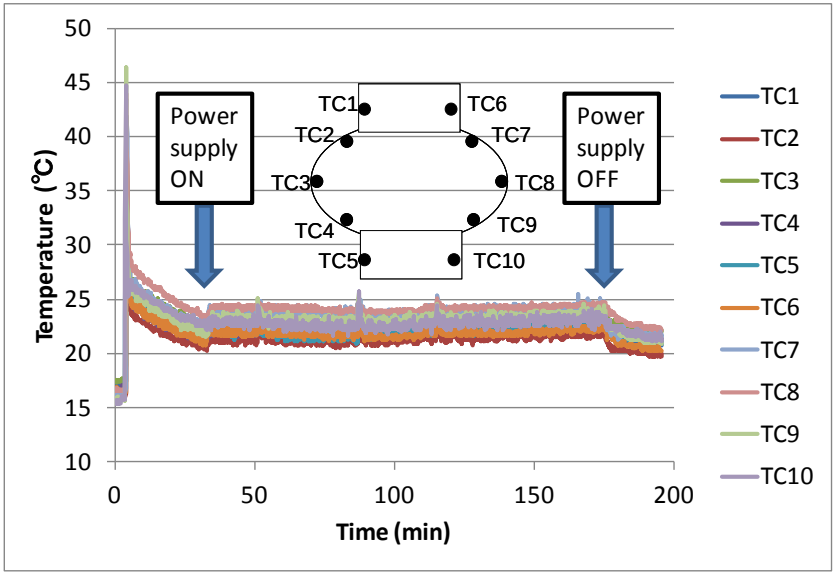
Improved cooling system is used.
(Using spot-cooler and wind guide ducts with several small holes.)


Wind guide ducts with several small holes

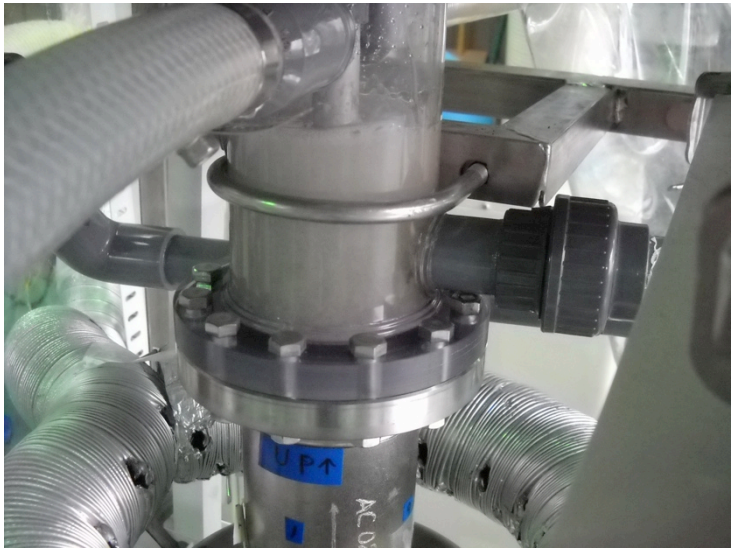


# 1st VEP of 1AC3 cavity

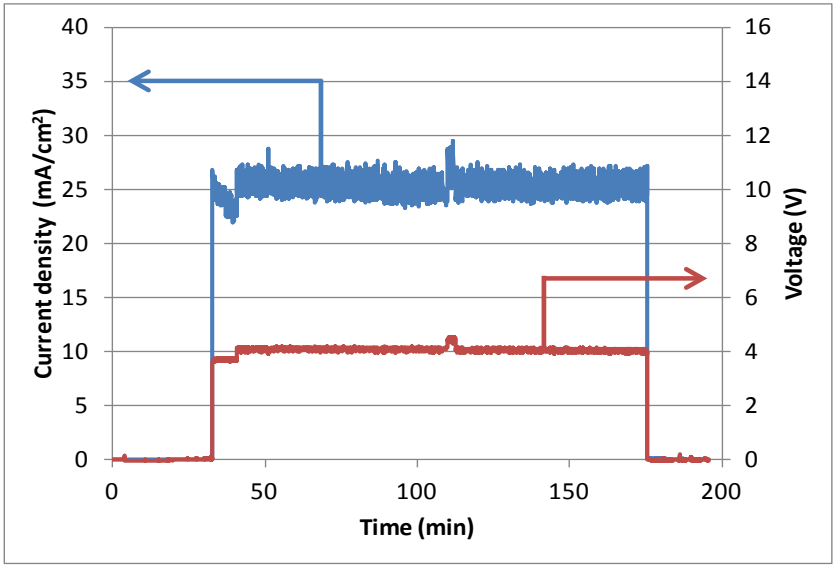
## Temperature during VEP




## Bubbles during VEP



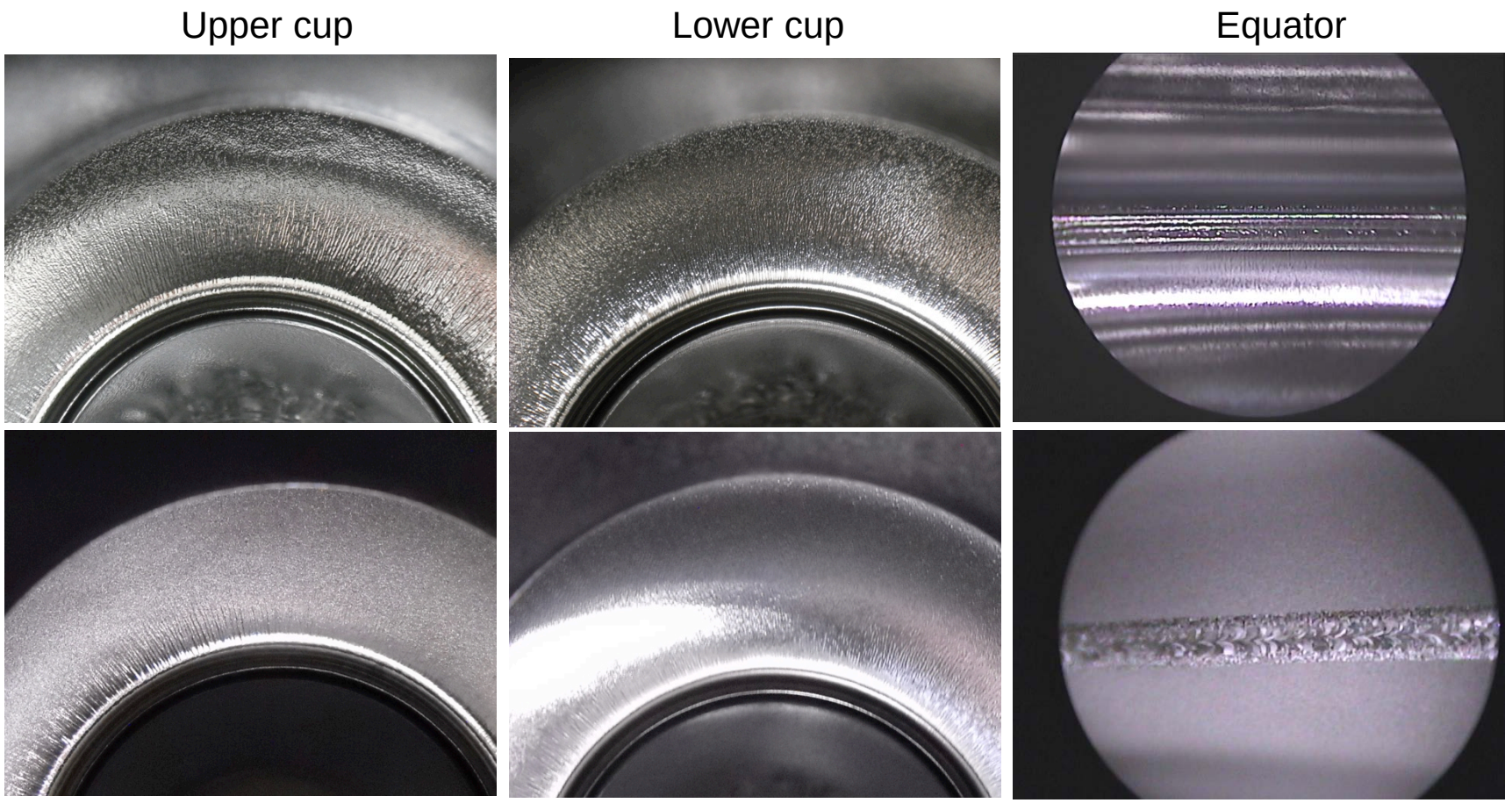
## Current density, voltage during VEP




- Cavity temperature was successfully kept around 20 – 25 ℃ at all measurement points.
- Current density was successfully kept around 25 mA/cm$^2$.
- Voltage drop occurred in this system. (Power supply setting 5 – 6V → measured 4V)

# 1st VEP of 1AC3 cavity

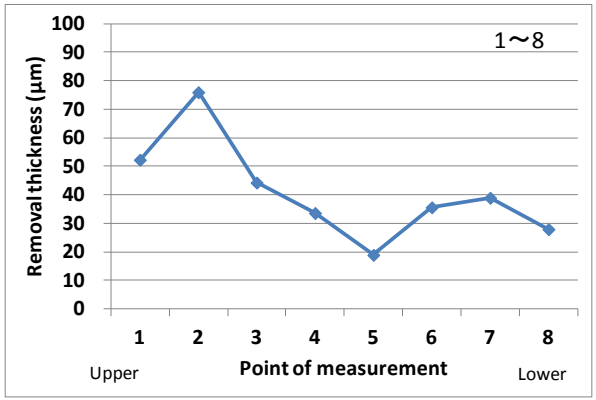
Inner surface inspection with a digital camera and an endoscope

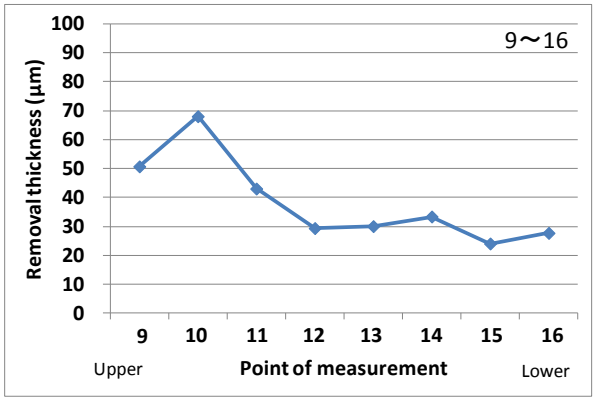


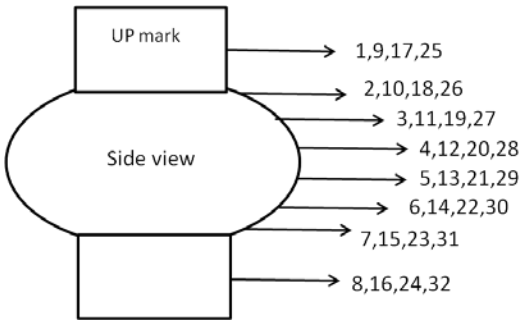

- At macroscopic area, the surface became flatter and pits were disappeared.
- At microscopic area, crystal grain like pattern was appeared.
- Brightness was reduced little by check with eyes.

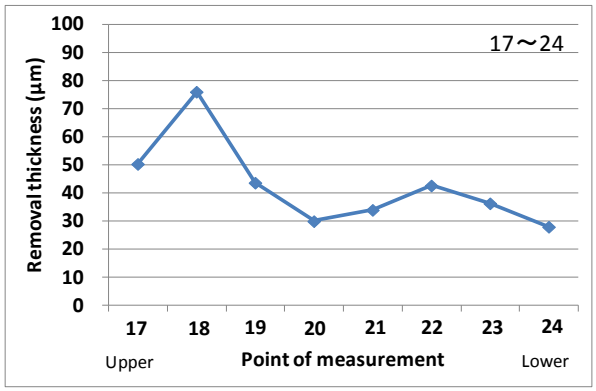
# 1st VEP of 1AC3 cavity

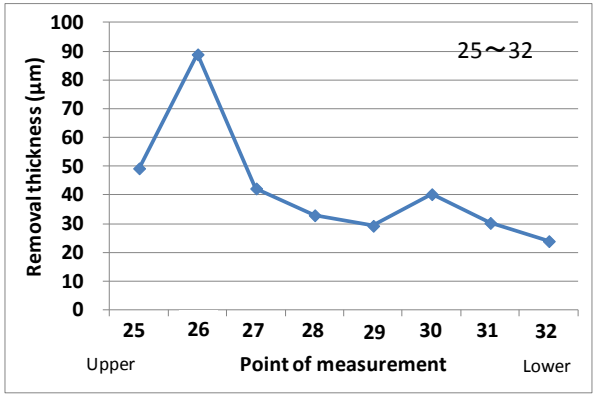
Removal thickness measurement by ultrasonic thickness gauge

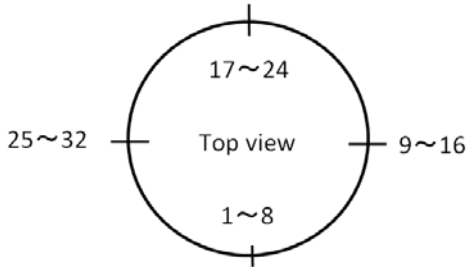


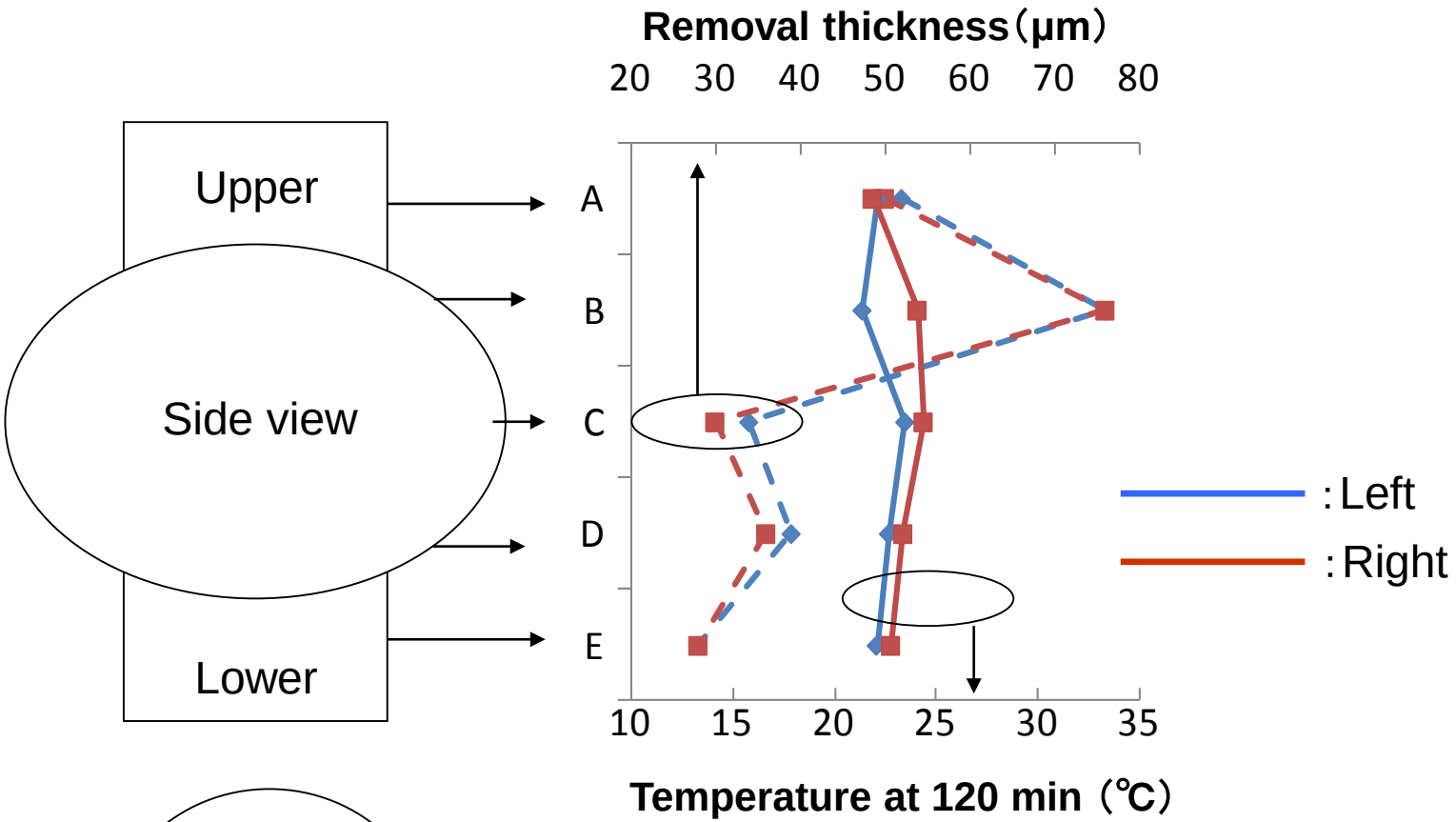



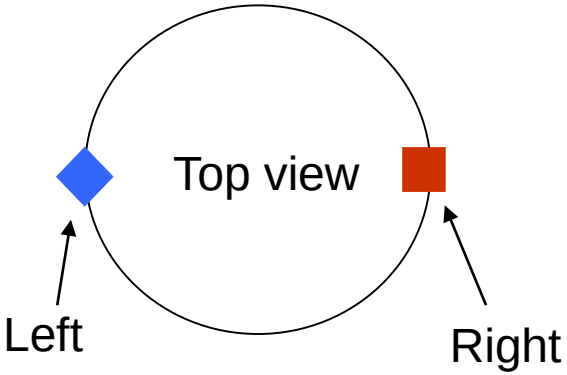




Total average removal thickness：41μm

Removal thickness of upper iris is the largest (2 – 3 times larger than other points).

# 1st VEP of 1AC3 cavity




Horizontal direction (Left – Right)：
Both temperature and removal thickness is almost the same.
Vertical direction (Upper – Lower)：
Temperature is almost the same, but removal thickness is different.

Bubble hit seems to be the cause of difference.

# 1st VEP of 9-cell cavity

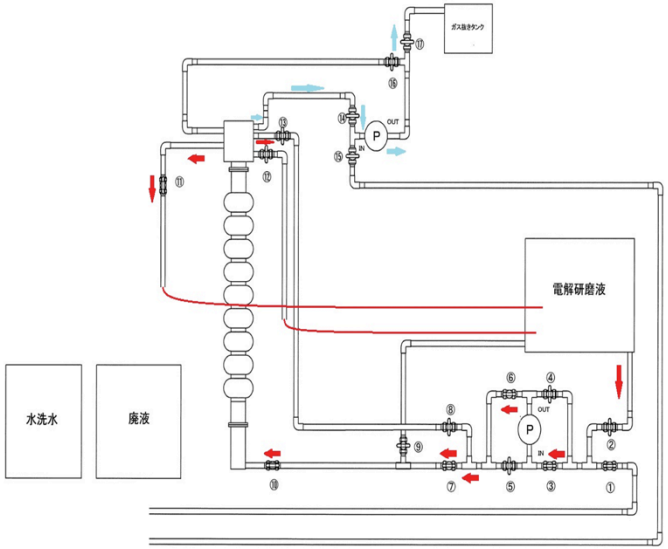
Purpose

The facility is made in Marui first time and try to VEP

VEP condition

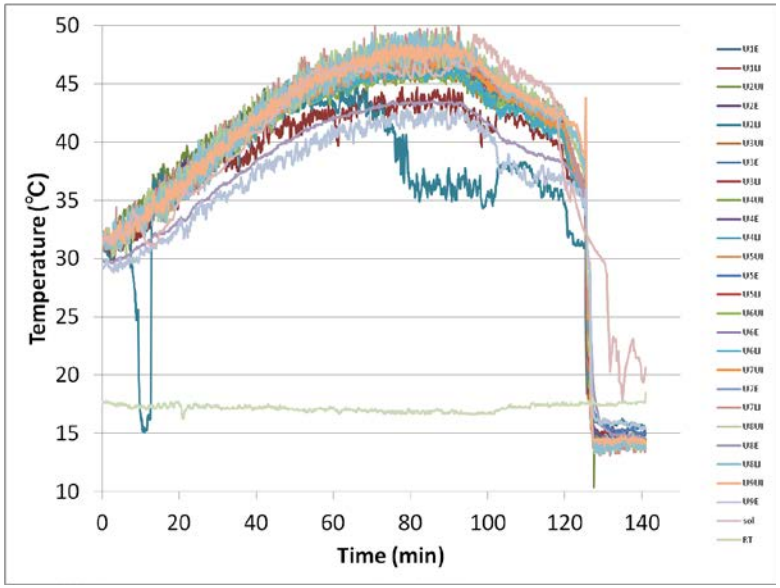
Electrolyte：$H_2SO_4$：HF＝9：1（New）
Voltage：7-9V (Power supply setting)
Time：90min (Continuous)
Flow direction：Bottom to top
Flow rate：10L/min
Cathode rotation speed：1rpm
Current target: 25mA/cm$^2$
Cathode： Our original cathode “Ninja”

No cavity cooling system



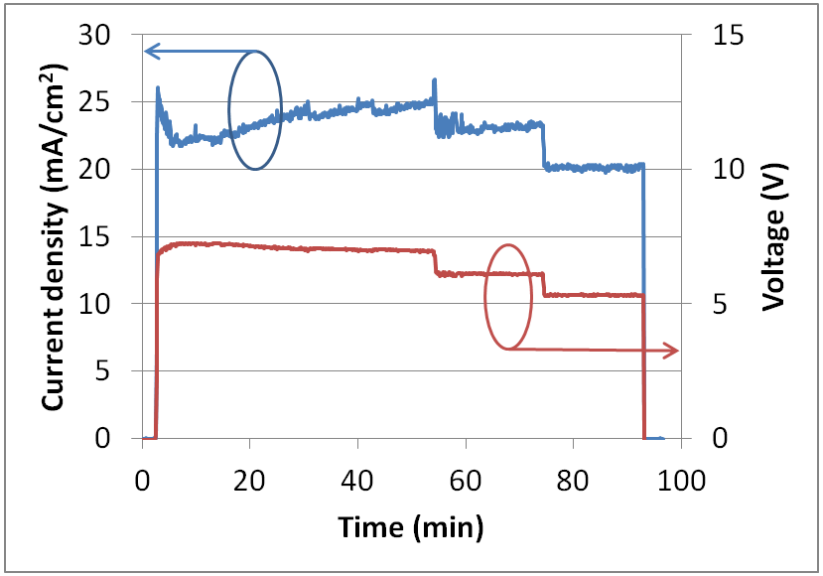
# 1st VEP of 9-cell cavity

Temperature during VEP




Bubbles during VEP

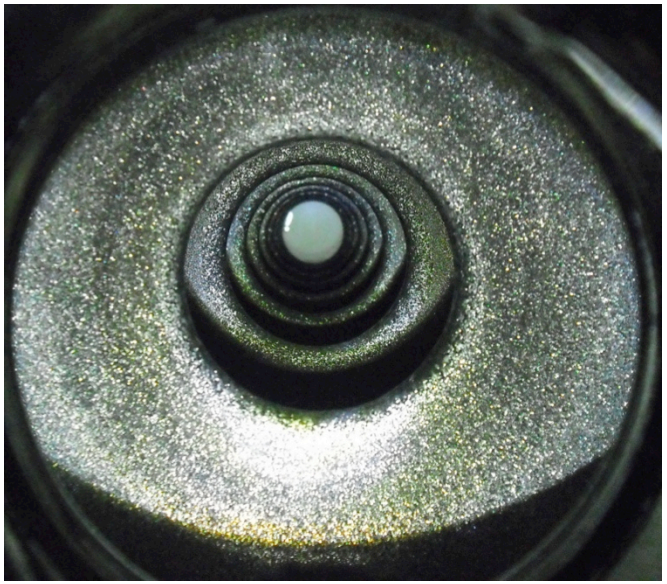
Current density, voltage during VEP



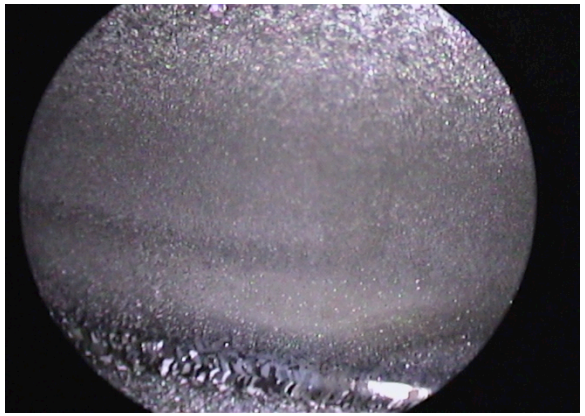

- Cavity temperature became very high.
  (Around 50 ℃)
- Current density was successfully kept around 20 - 25 mA/cm$^2$.
- Voltage drop occurred in this system.
  (Power supply setting 7 – 9V
  → measured 5 - 7V)

# 1st VEP of 9-cell cavity

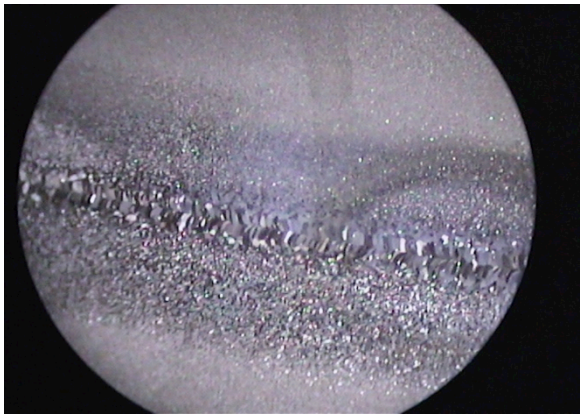
Inner surface inspection by digital camera



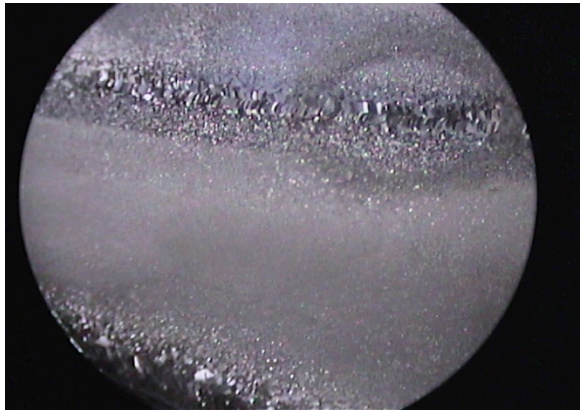
Inner surface inspection by endoscope



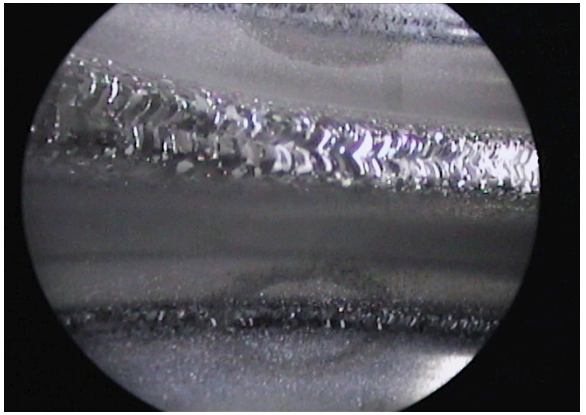
5th cell upper iris



5th cell equator



5th cell lower iris



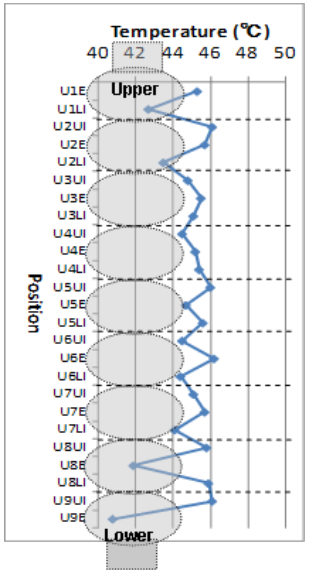
5th cell – 6th cell

Rough and crystal grain like surface is appeared.
One reason seems to be high cavity temperature.

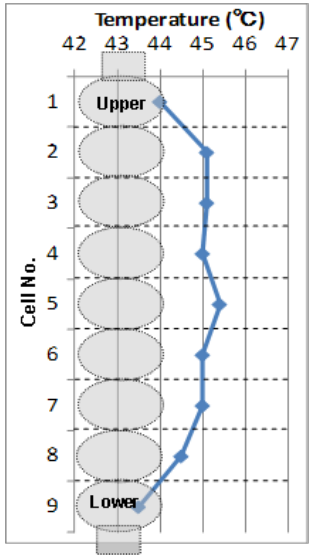
# 1st VEP of 9-cell cavity

At 60 min

Temperature distribution



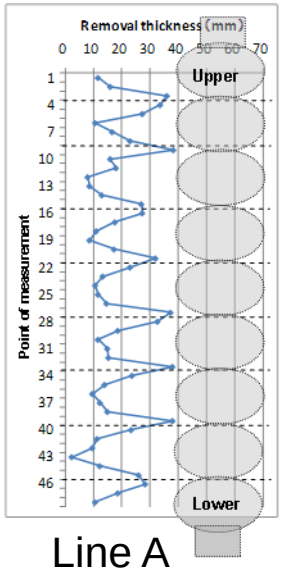

Each parts



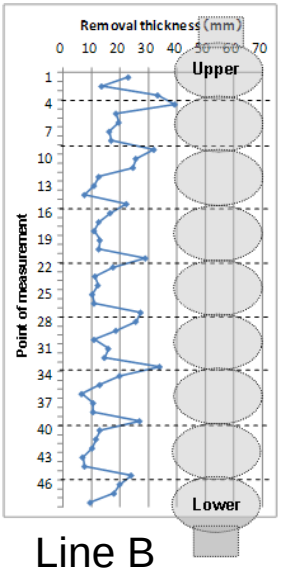

Average of each cells

- There was no clear tendency of each parts temperature.

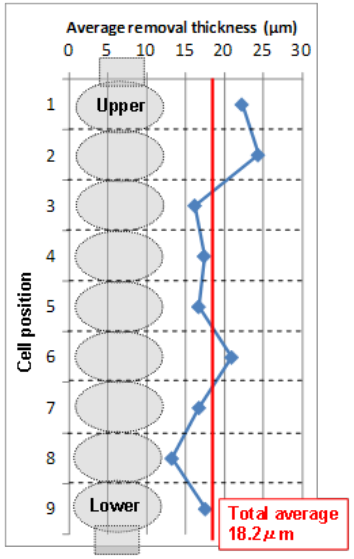
Removal thickness




Line A




Line B




- Removal thickness of iris is 3 – 4 times larger than that of equator.
- 2 upper cell is larger than other cells.

# Summary

- The 4 wings Ninja and the conventional rod cathodes were used for VEP of the coupon cavity.
- Inhomogeneous removal thickness was found over the cavity with both the cathodes.
- The Ninja cathode could not help to achieve homogeneous EP rate over the cavity.
- However the Ninja cathode provided smoother surface possibly due to agitation of electrolyte and wiping of $H_2$ bubbles from the surface.
- The single cell (1AC3) cavity was also VEPed with a target of vertical test.
- Testing of 9 cell VEP setup was successfully done by performing VEP of a 9-cell cavity.

# Future Plan

## VEP of Coupon Cavity

- Ninja cathode and EP parameters will be modified to achieve homogeneous EP rate in the cavity and further smooth surface.

## VEP of 1AC3 Cavity

- Confirm vertical test result using this cavity.
- More parameter investigation to improve inner surface and removal thickness distribution.

## VEP of 9-cell Cavity

- Making cavity cooling system.
- More parameter investigation to improve inner surface and removal thickness distribution.
- VEP of new 9-cell cavity for vertical test.

# Thank You