# Study on Vertical EP with Nb Coupon Cavity

**TTC Meeting**
**3rd Dec 2014**

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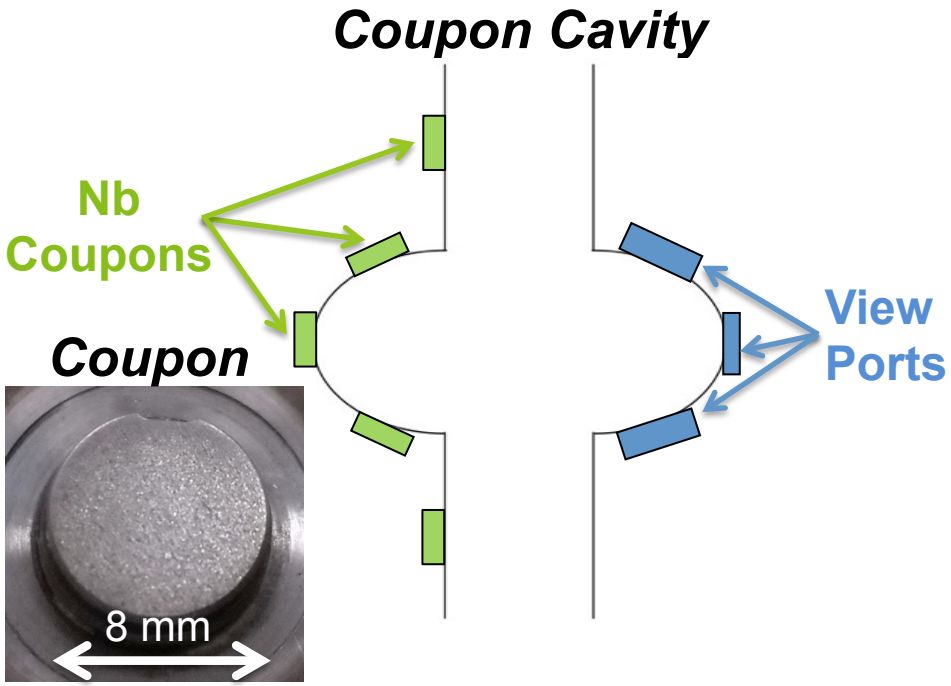
# Objective

- **To get homogeneous EP rate on entire cavity for smooth and contaminant free surface.**

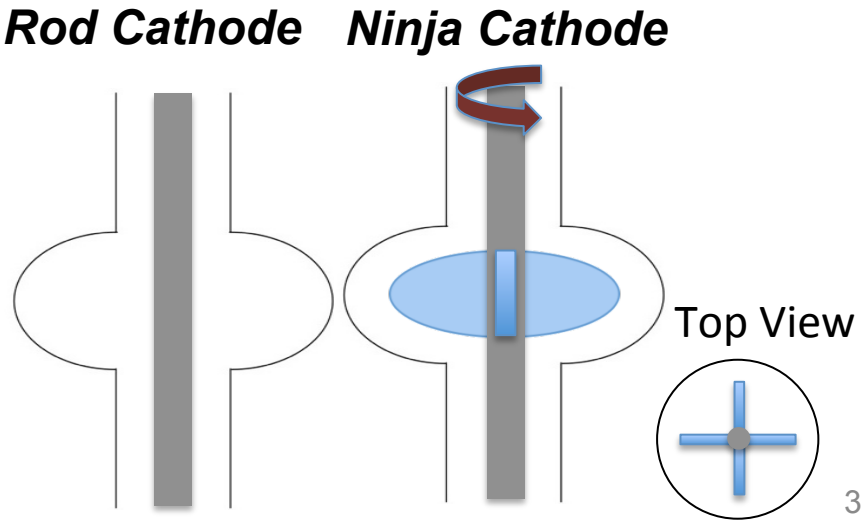
## Coupon Cavity

- Cavity contains 6 coupons.
- EP current can be measured for individual coupon.
- Coupon surfaces are analyzed with several surface analytical tools.
- The cavity is having 4 view ports on the top iris, bottom iris and equator for light introduction and in-situ observation of cathode wings and $H_2$ bubbles.



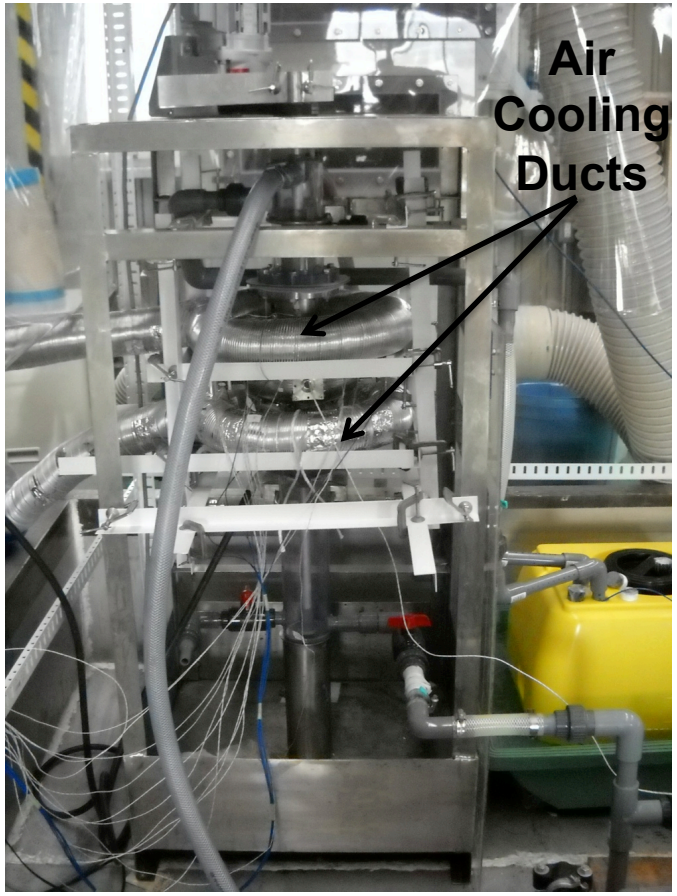

## Ninja Cathode

- Marui Galvanizing developed a unique cathode called Ninja cathode.
- The Ninja cathode has 4 retractable Al wings for agitation and uniform EP over the cavity.

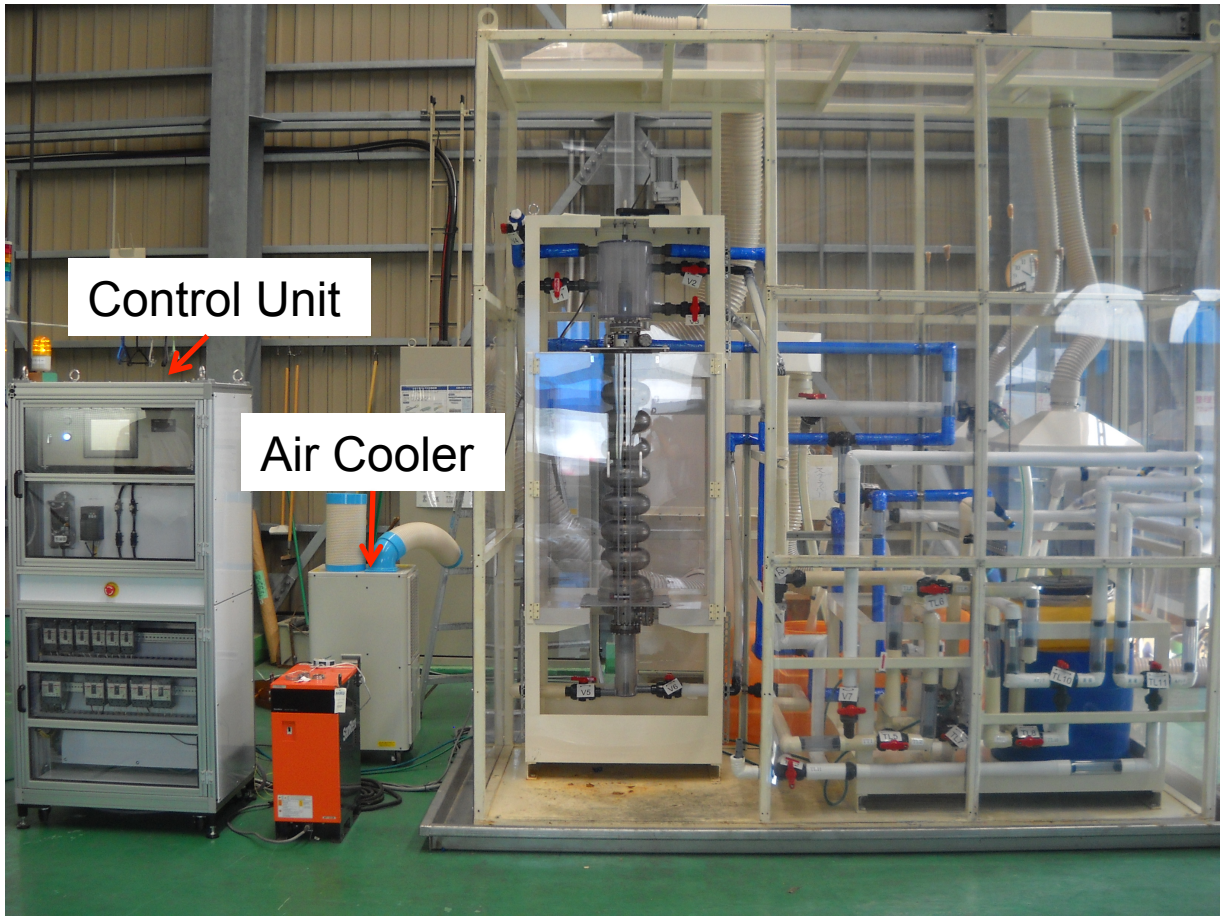


# 1 and 9 Cell Cavity VEP Setups

## VEP Setup for 1-Cell



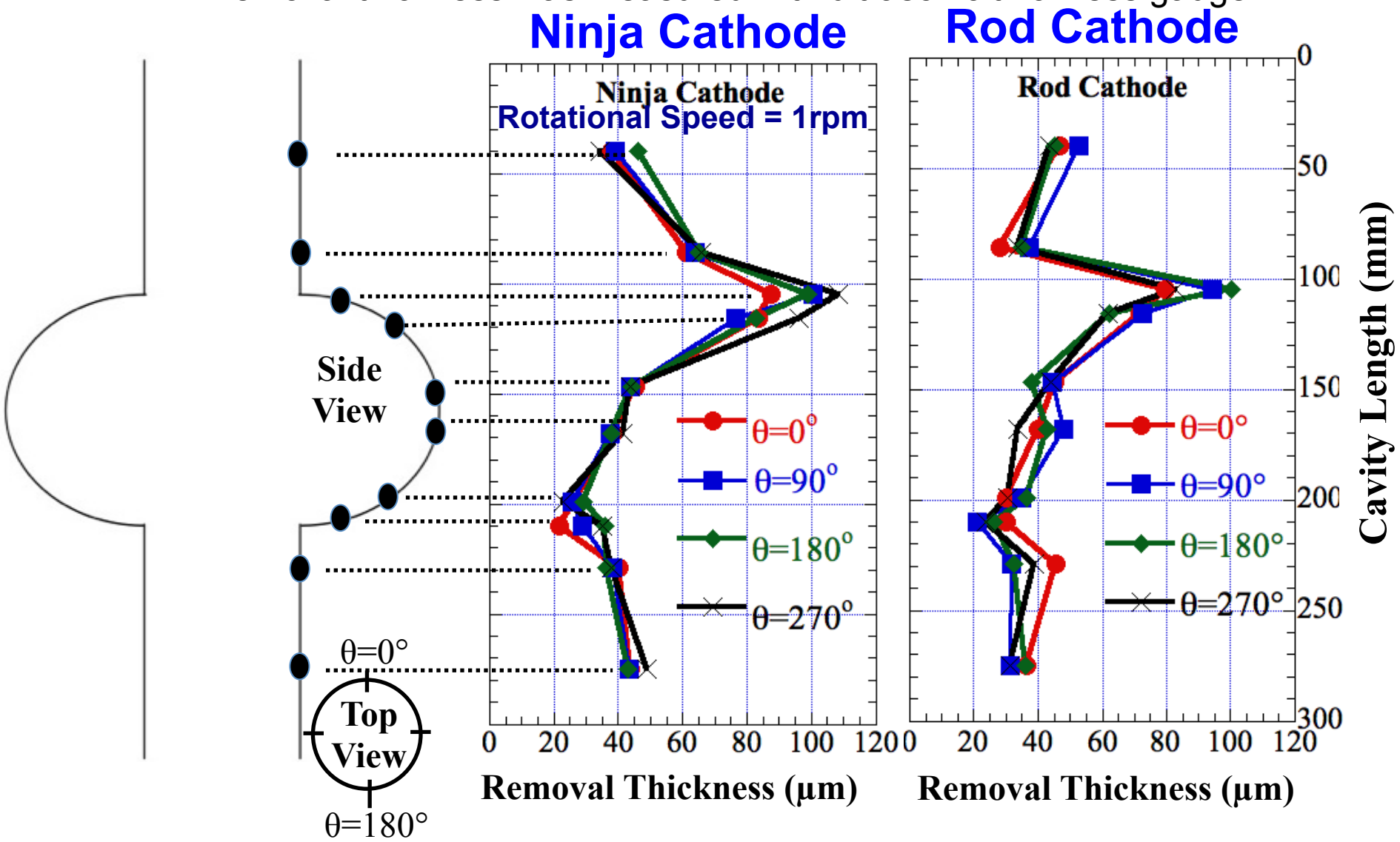

## VEP Setup for 9-Cell




- We challenged to make the setups with PVC material for mass production and cost reduction.
- The 9-cell cavity VEP system can be used for VEP of 1-cell cavity also.
- System contains separate pipe lines and pumps for water and EP solution.
- EP solution and water can be flown from bottom to top and vice versa.

# Inhomogeneous Removal Thickness with VEP

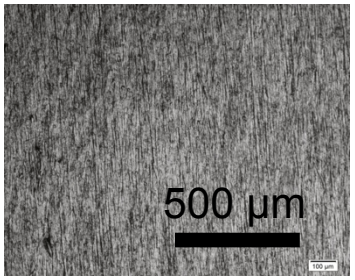
- Removal thickness was measured with ultrasonic thickness gauge.

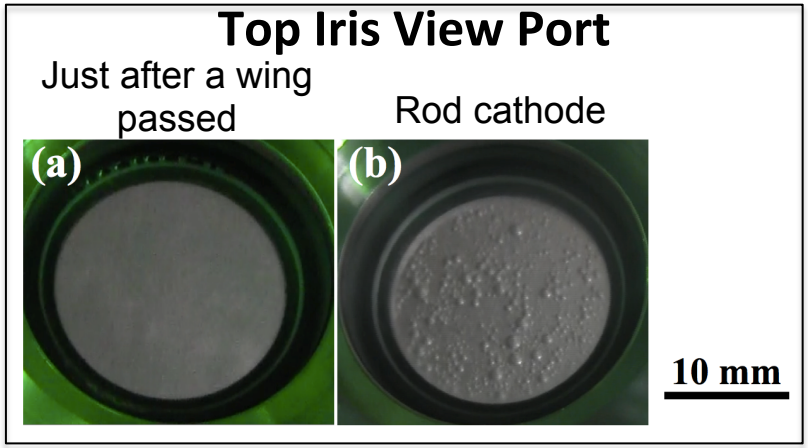


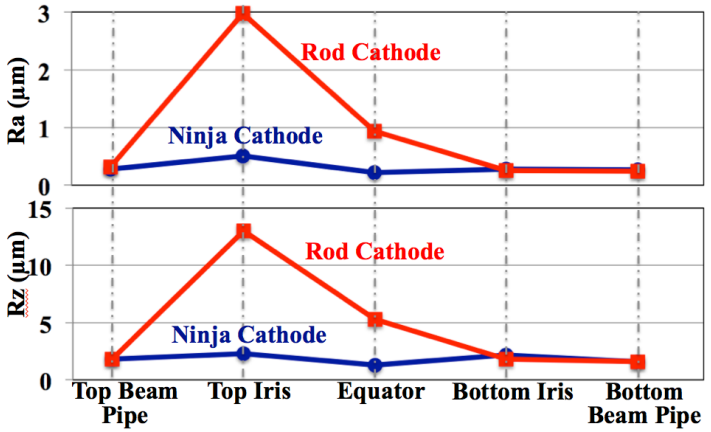

- Removal thickness was the highest at the top iris and the lowest at the bottom iris.
- The higher EP rate on the top iris was due to $H_2$ bubbles attack and gravity which reduce viscous layer thickness on the top iris.

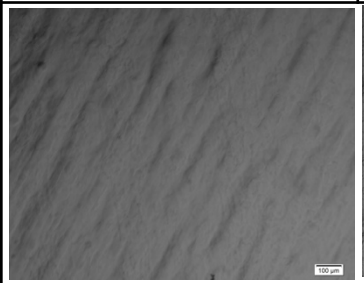
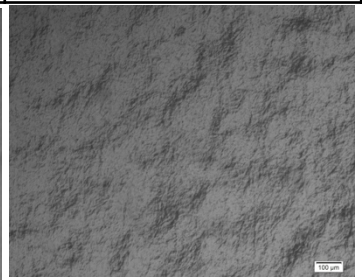
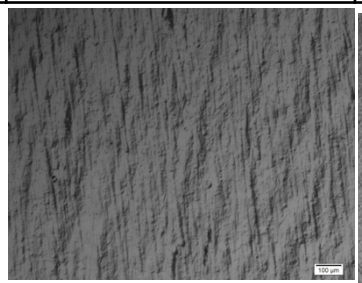
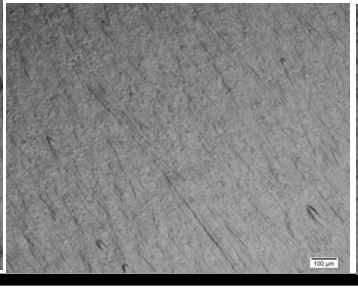
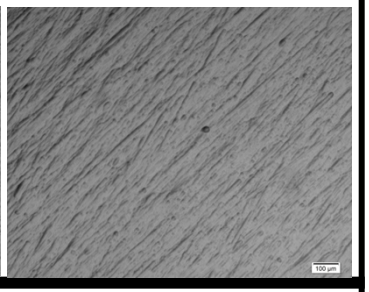
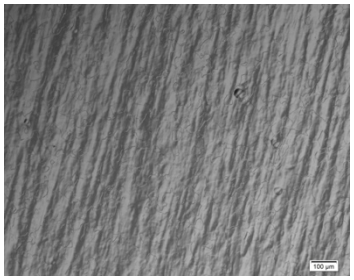
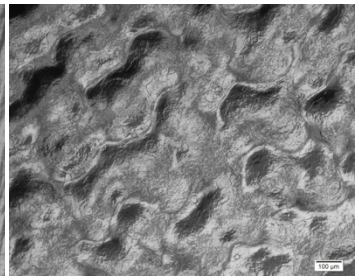
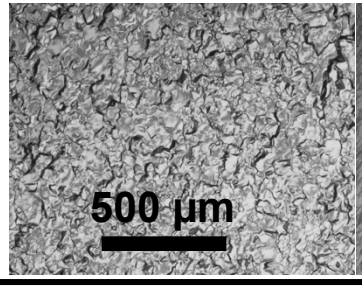
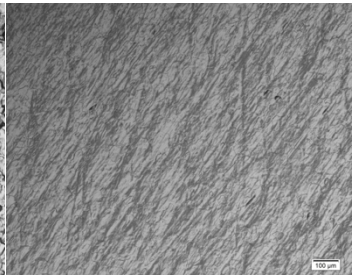
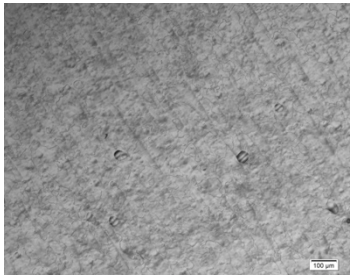
# Roughness and Microscope Images of Coupons

***Before VEP***




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

- The rod cathode enhanced surface roughness at the top iris and equator.
- The bubbles attack the surface microscopically and make rough surface.

# Conditions for VEP of Coupon Cavity

In order to solve the problem of inhomogeneous removal, cathode rotational speed was optimized.

- Rotation: 50 rpm (Coupon currents were recorded for 1, 10, 20, 30, 40 and 50 rpm)

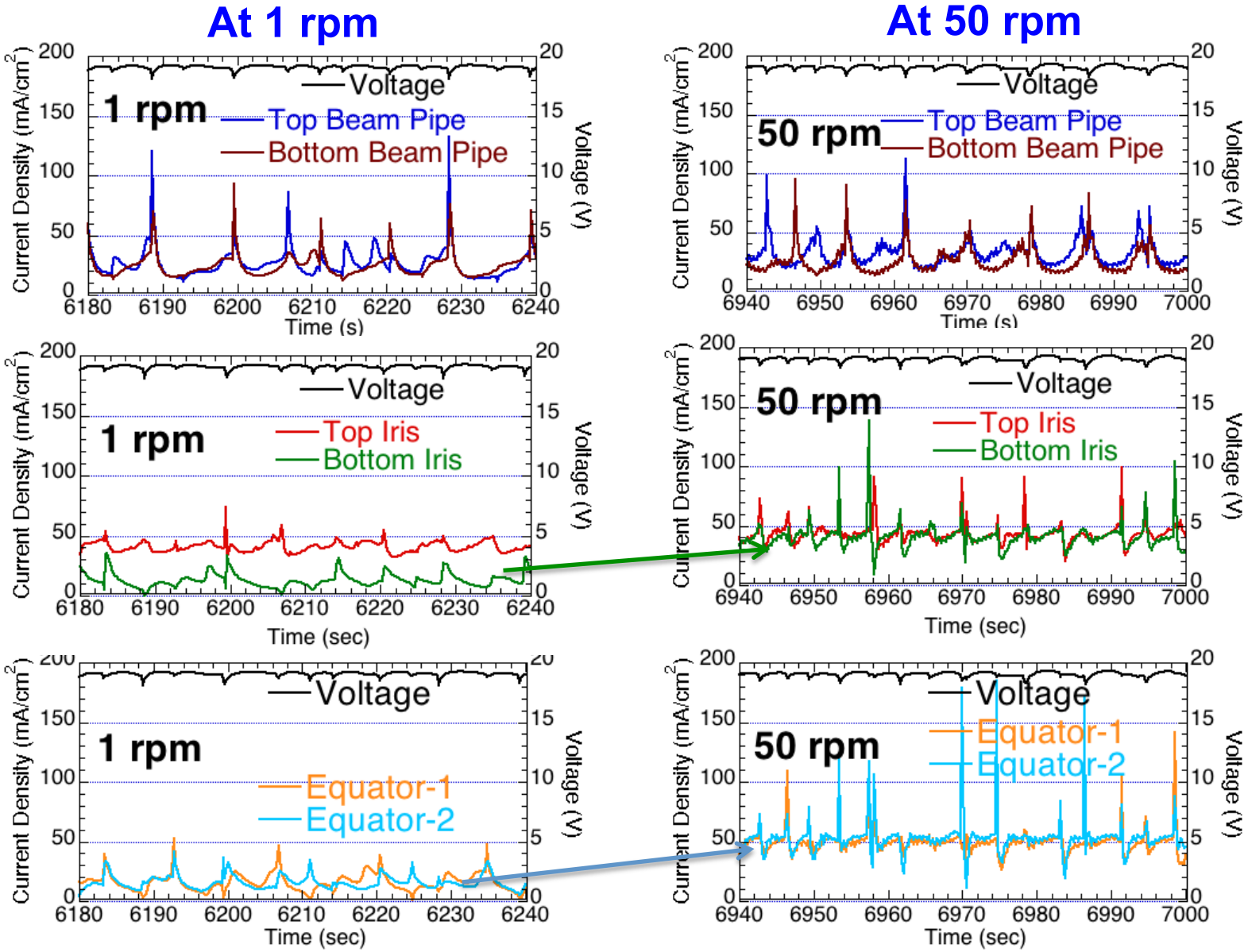
  At higher rotational speed of cathode

  – Flow of EP solution might be uniform to generate uniform viscous layer on cavity surface

  – $H_2$ bubbles can be removed from the top iris

- EP Solution Flow Rate: 5 l/min
- Voltage: 12-20 V
- Current density: ~30 mA/cm$^2$
- EP tank temperature: 16-27 °C
- EP time: 2 hours
- Target removal thickness=50 μm

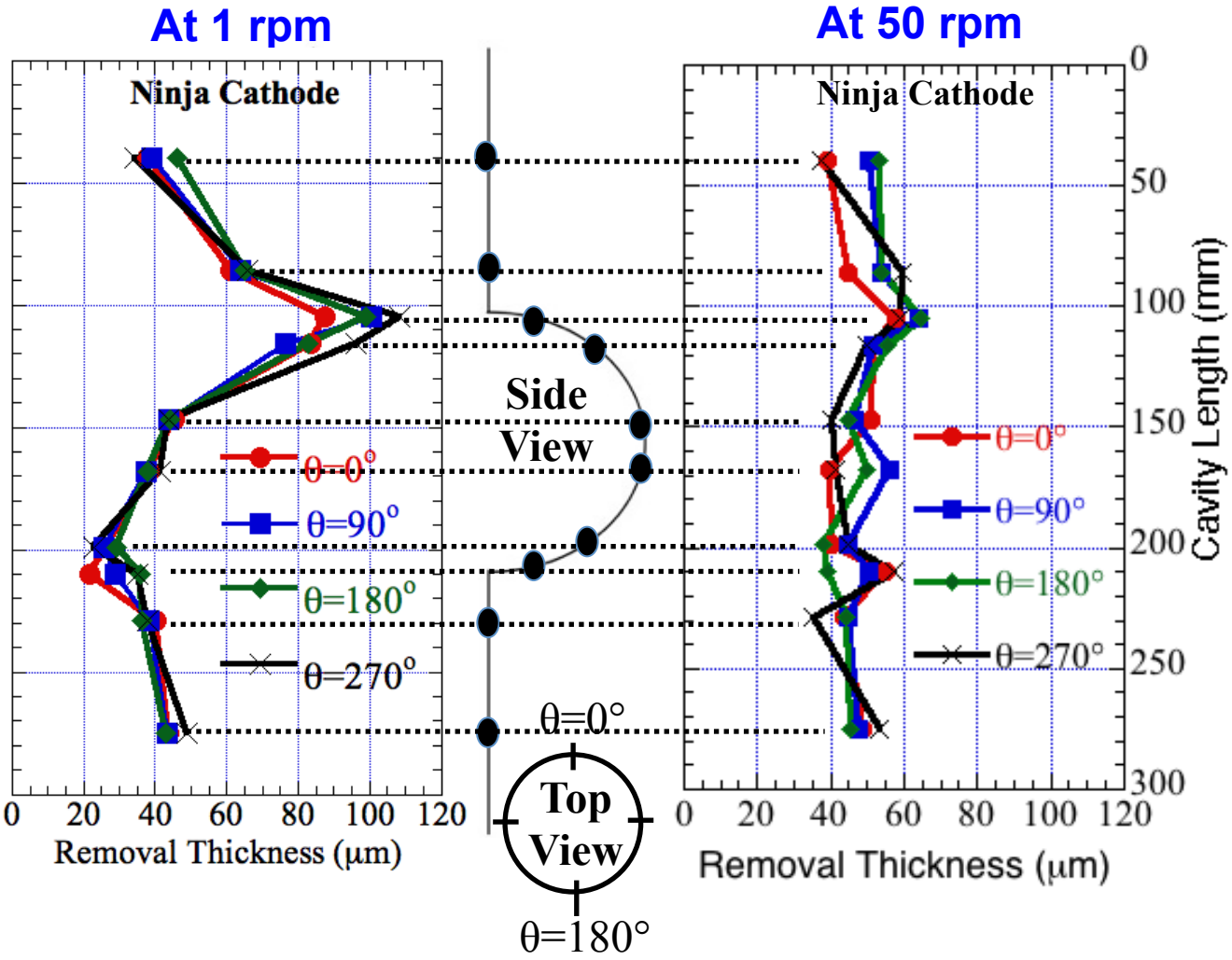
# Coupon Current Profiles at 1 and 50 rpm




- The top iris coupon current was the highest at 1 rpm because of thin viscous layer on the top iris.
- The bottom iris current increased with increase in cathode rotational speed and became similar to the top iris current at 50 rpm.

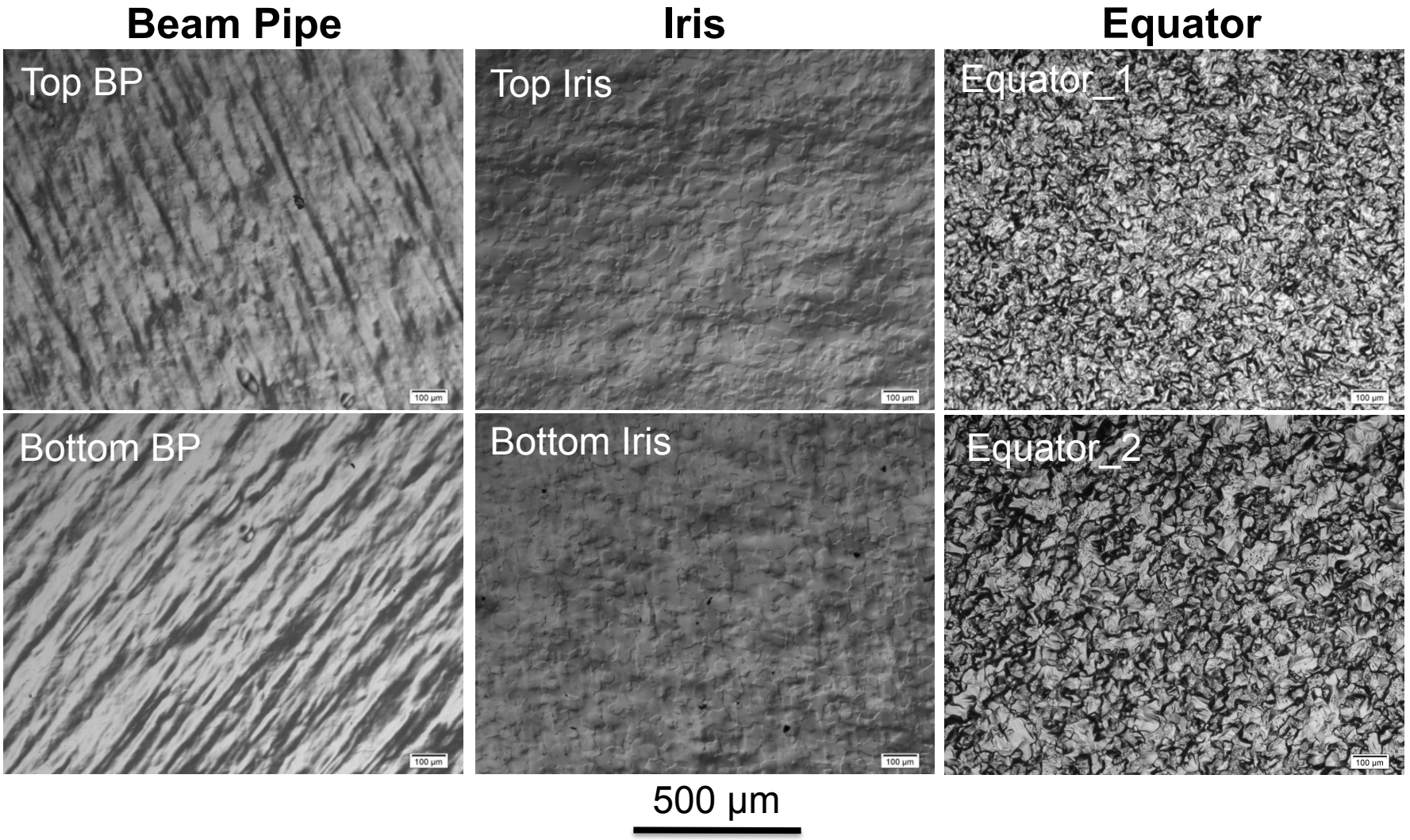
# Removal Thickness of the Cavity

- Average cavity removal thickness (from cavity weight loss) = 55 μm



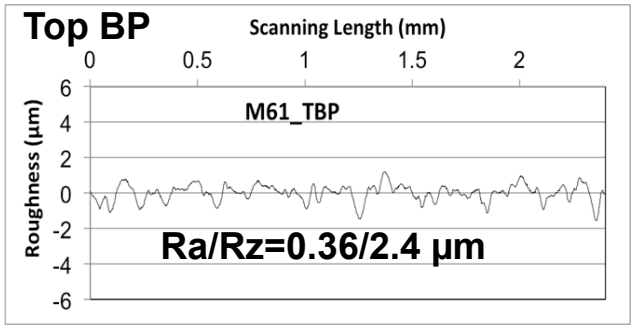

- The removal thickness was almost homogeneous on entire cavity including the top and the bottom irises.
- The high rotation speed might generate uniform viscous layer on the surface of cavity cell since the high flow of EP solution remove $H_2$ bubbles form the top iris.

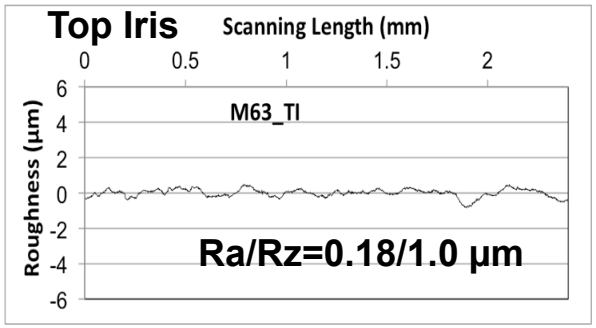
# Optical Microscope Images of Coupons (50 rpm)

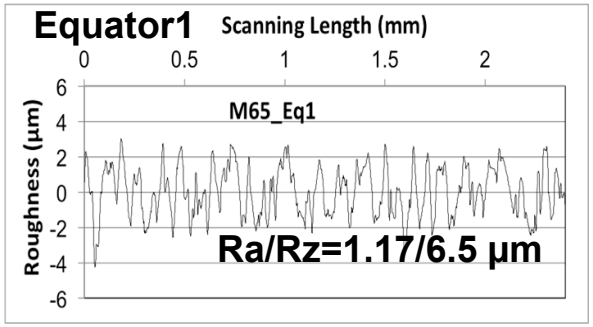


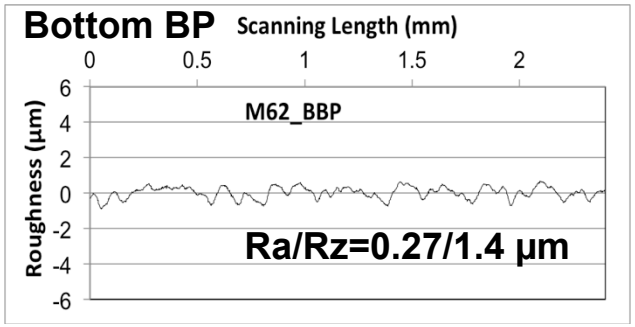

- The equator surface was found to be the roughest.

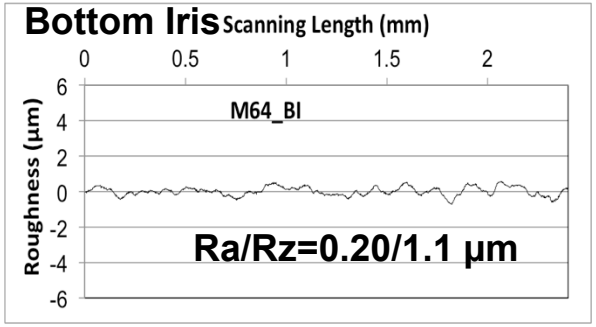
# Coupon Surface Roughness (50 rpm)

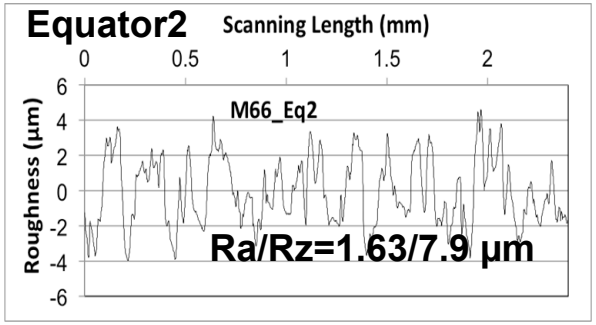


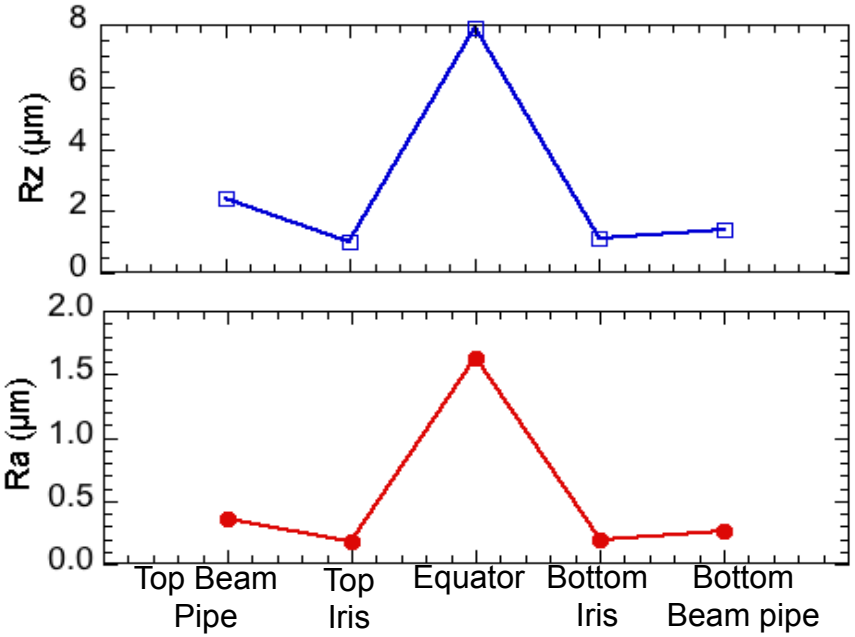




- Attack of $H_2$ bubbles on equator due to centrifugal force might cause rough surface.

# Summary

- VEP setups were made with PVC material.
- PVC made systems can be used in industries for mass production and cost reduction of the cavity surface treatment.
- In VEP removal thickness was always found to be inhomogeneous along the cavity length.
- Homogeneous EP rate was obtained with a high rotational speed of the Ninja cathode.
- Coupon surfaces except equator coupons were found to be very smooth and shiny.
- The rough equator surface might be due to bubbles attack on the equator.

# Future Work

- Cathode geometry will be optimized for further smooth surface specially the equator surface.
- 1-cell and 9-cell cavities will be VEPed using the optimized parameters and vertical test will be performed.

# Thank You