Lab EP Study on Inhomogeneous Removal in Vertical EP of Niobium Cavity

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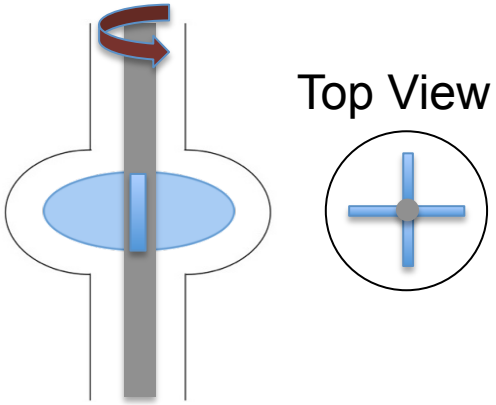
Ninja Cathode & Single Cell Coupon Cavity

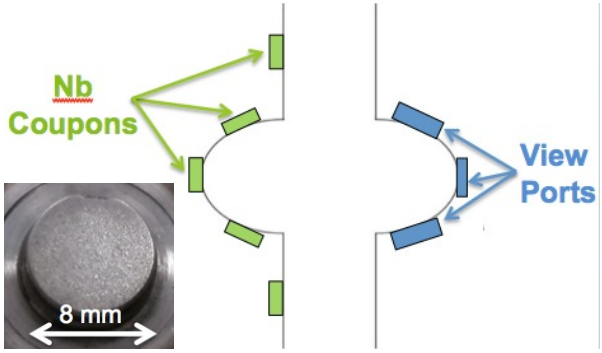
Ninja Cathode

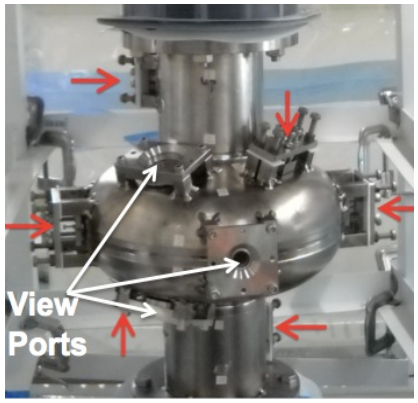
- There are a couple of advantages in VEP.
- However inhomogeneous removal along with cavity length is usually found and this is a primary issue in VEP.
- Marui Galvanizing developed a unique cathode called Ninja cathode for VEP with 4 retractable Al wings for agitation and uniform EP over the cavity.



Coupon Cavity

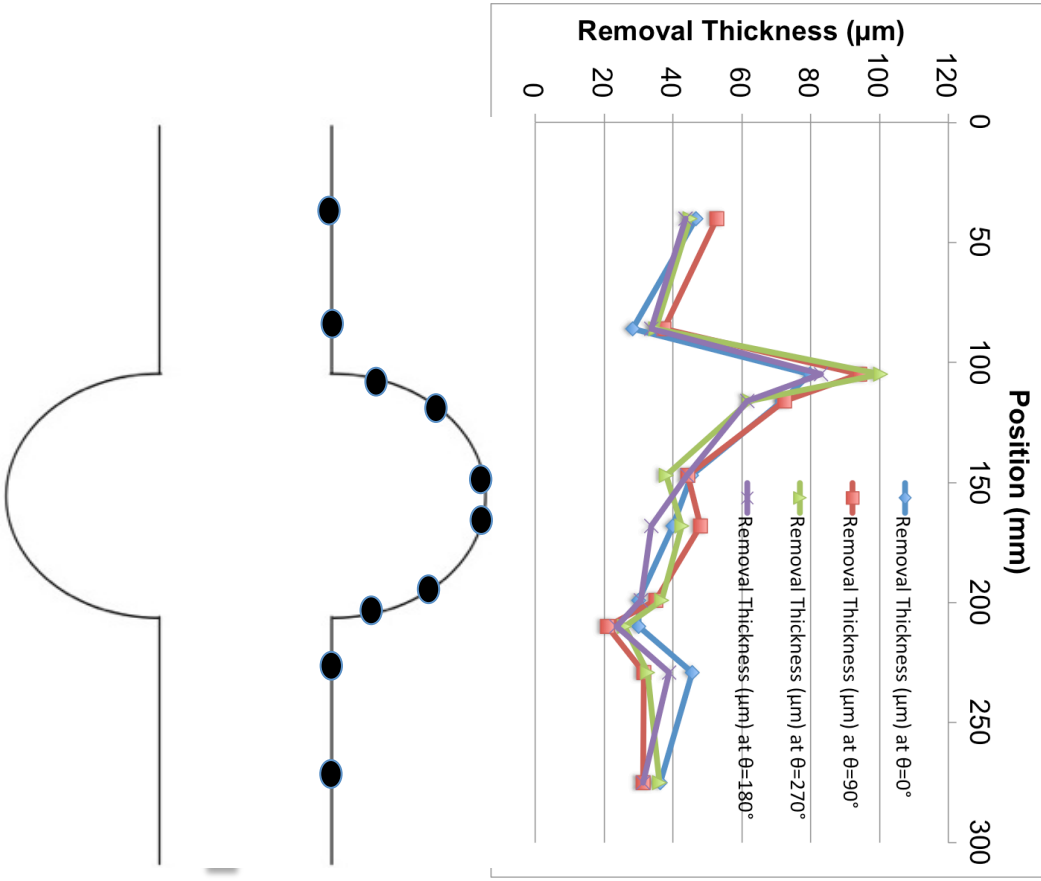
- A KEK coupon cavity was used in order to investigate VEP with Ninja.
- 6 Nb disk type coupons can be set at beam pipes, irises and equator of a single cell cavity.
- The individual coupon EP current is measurable.
- The cavity has also 4 view ports at the top iris, bottom iris and equator for in-situ observation of wings and H_2 bubbles.





Inhomogeneous Removal in VEP

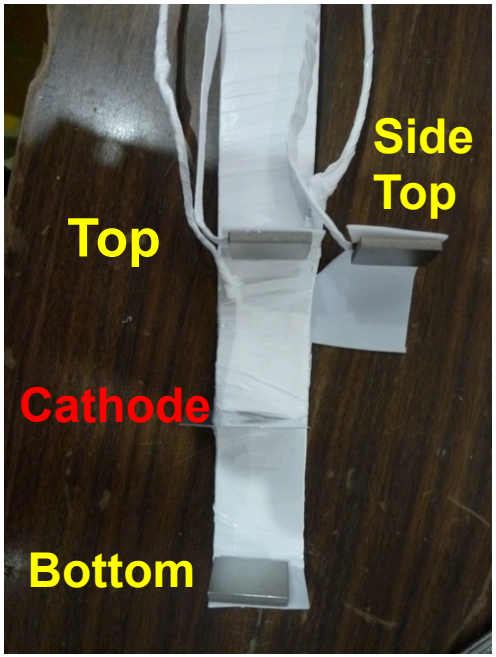
- VEP trials turned out inhomogeneous polishing along the length of the cavity (the highest for the top iris and the lowest for the bottom iris) even with Ninja.
- Lab EP experiments were performed to find the reason of the inhomogeneous EP.
- At the last TTC Meeting@DESY, we reported that H_2 gas bubble attack that may make local damage of viscous layer causes rougher surface and high removal rate.
- It was also pointed out that a limited size of Al cathode wings is necessary to mitigate direct H_2 attack to the top iris.

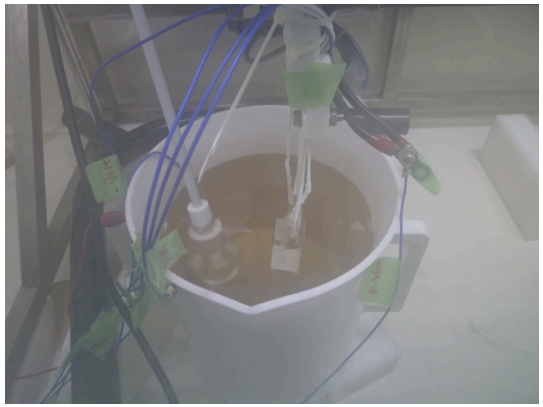


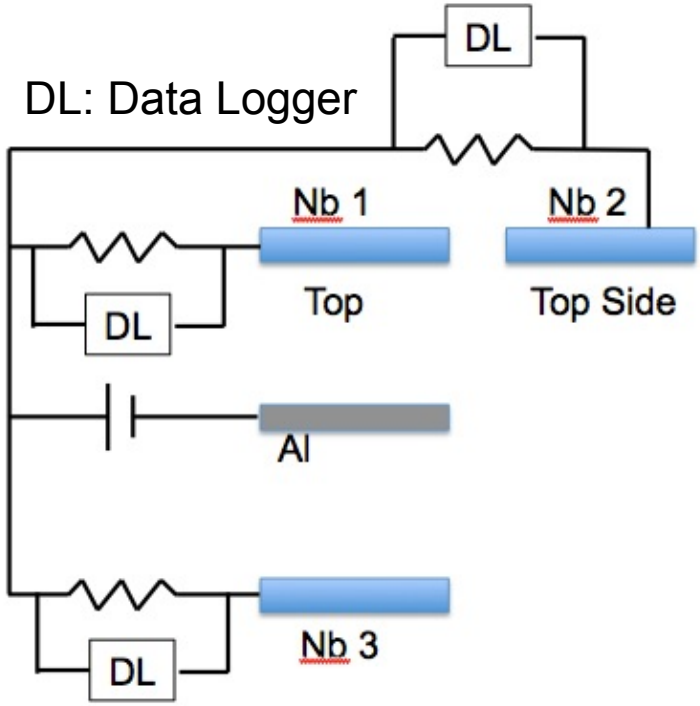
- This time additional lab EPs were performed for further understanding.

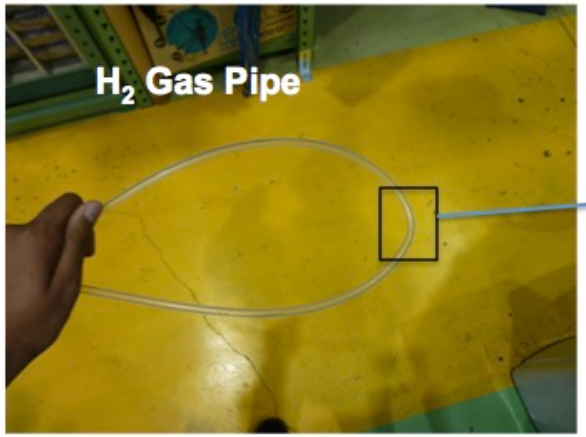
Lab EP with Intentional H_2 Bubble Flow

- Additional, intentional H_2 bubble flow was given to top and side top samples through tiny holes of pipe dipped in EP solution with sample current measurements.





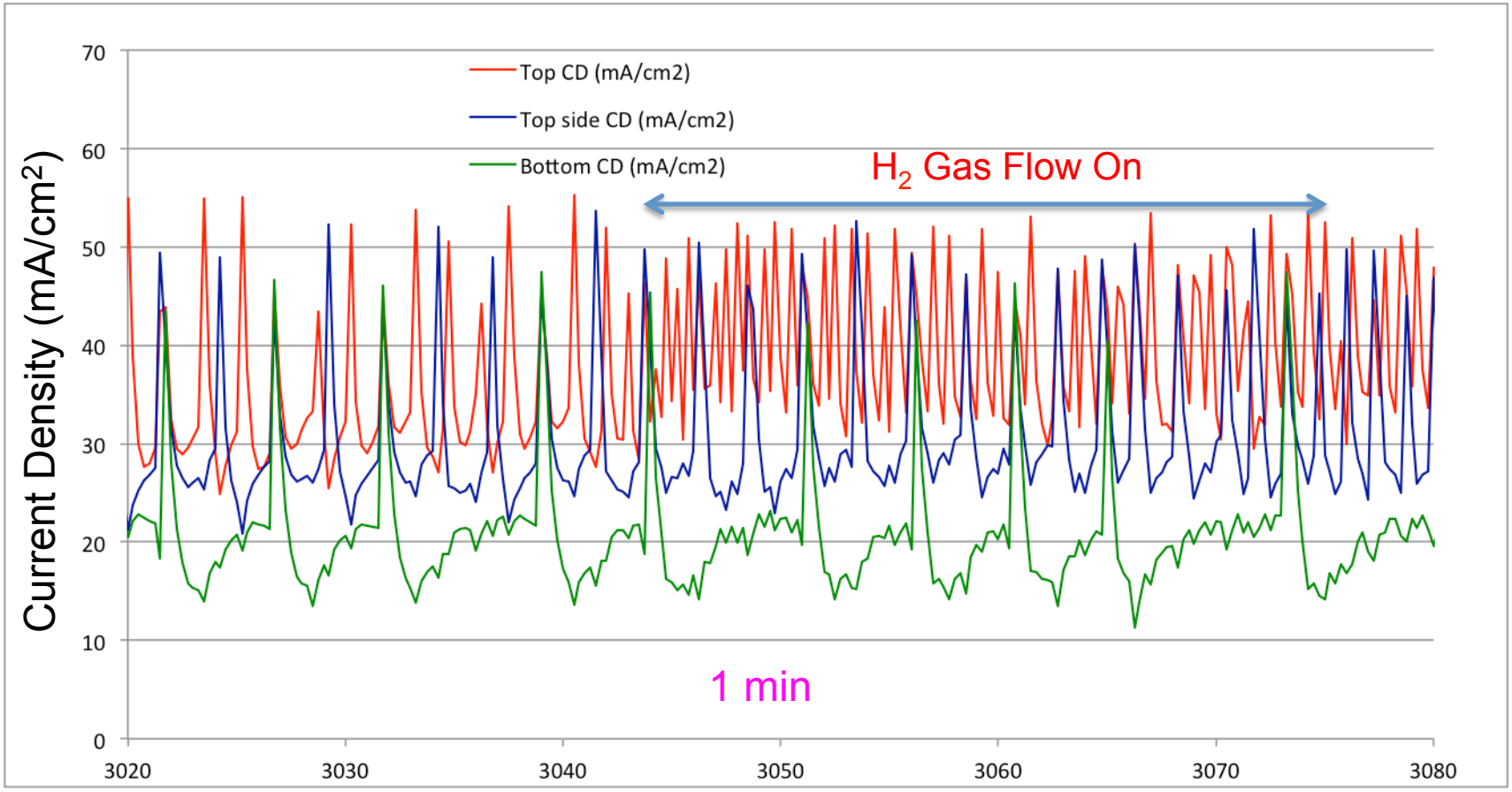




Applied Voltage: 5 V (Power supply set value)
Current Density ~ 30 mA/cm^2

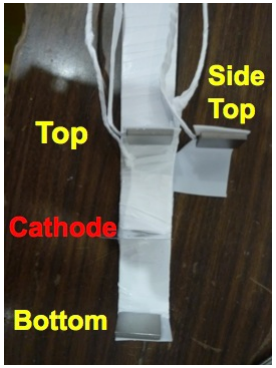
* We acknowledge Sawabe san for his support during experiment.

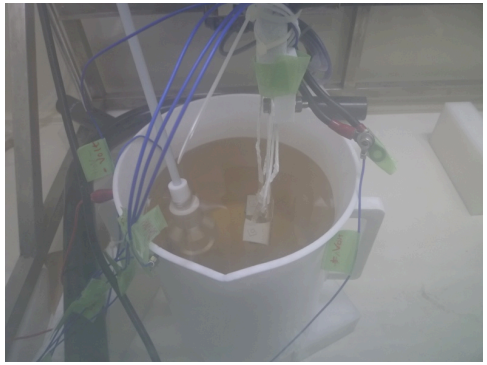
Current Profiles with H_2 Bubble Flow on Top Sample



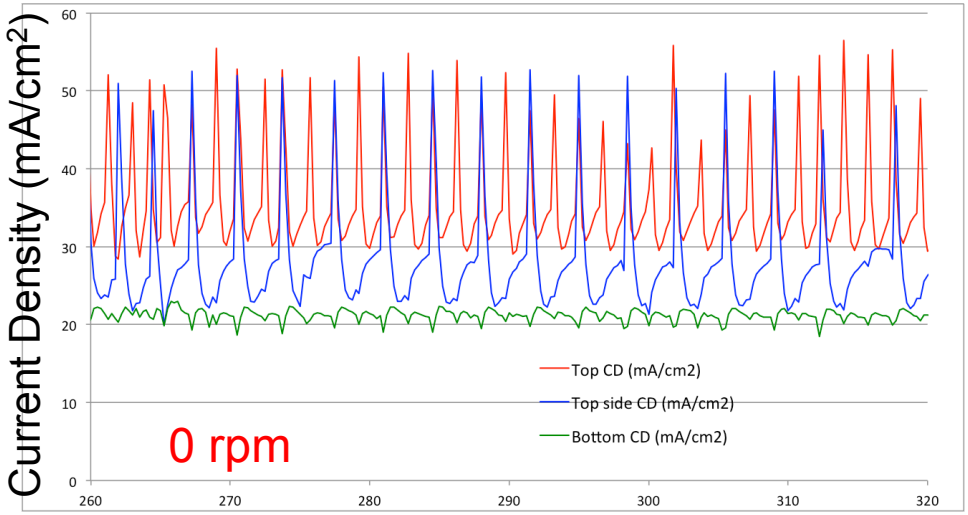
- H_2 gas flow on the top sample surface enhanced EP current of the top sample and frequency of the current spikes.
- It is because H_2 bubble attack would damage or thin the viscous layer at the top sample.

Lab EP with Different Speeds of Stirrer

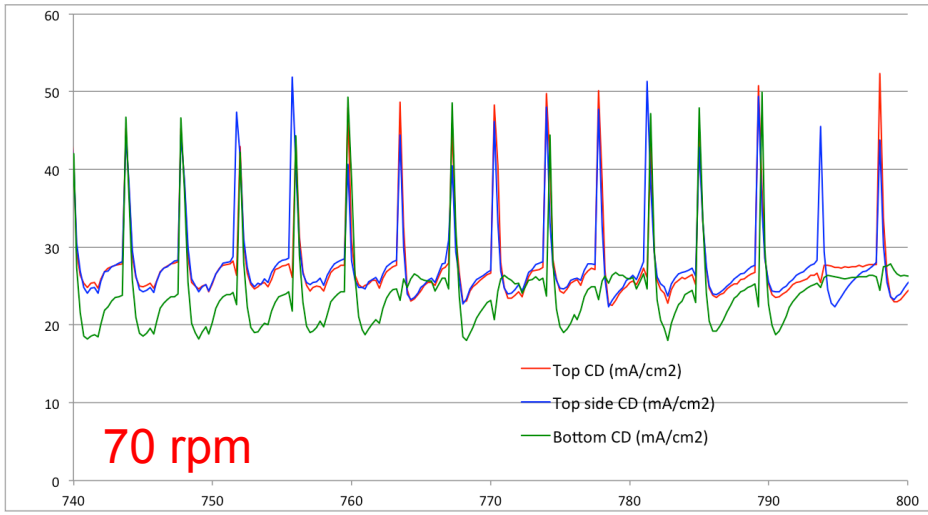




Current Profiles at 0, 70, 140, 210, 280 and 341 rpm



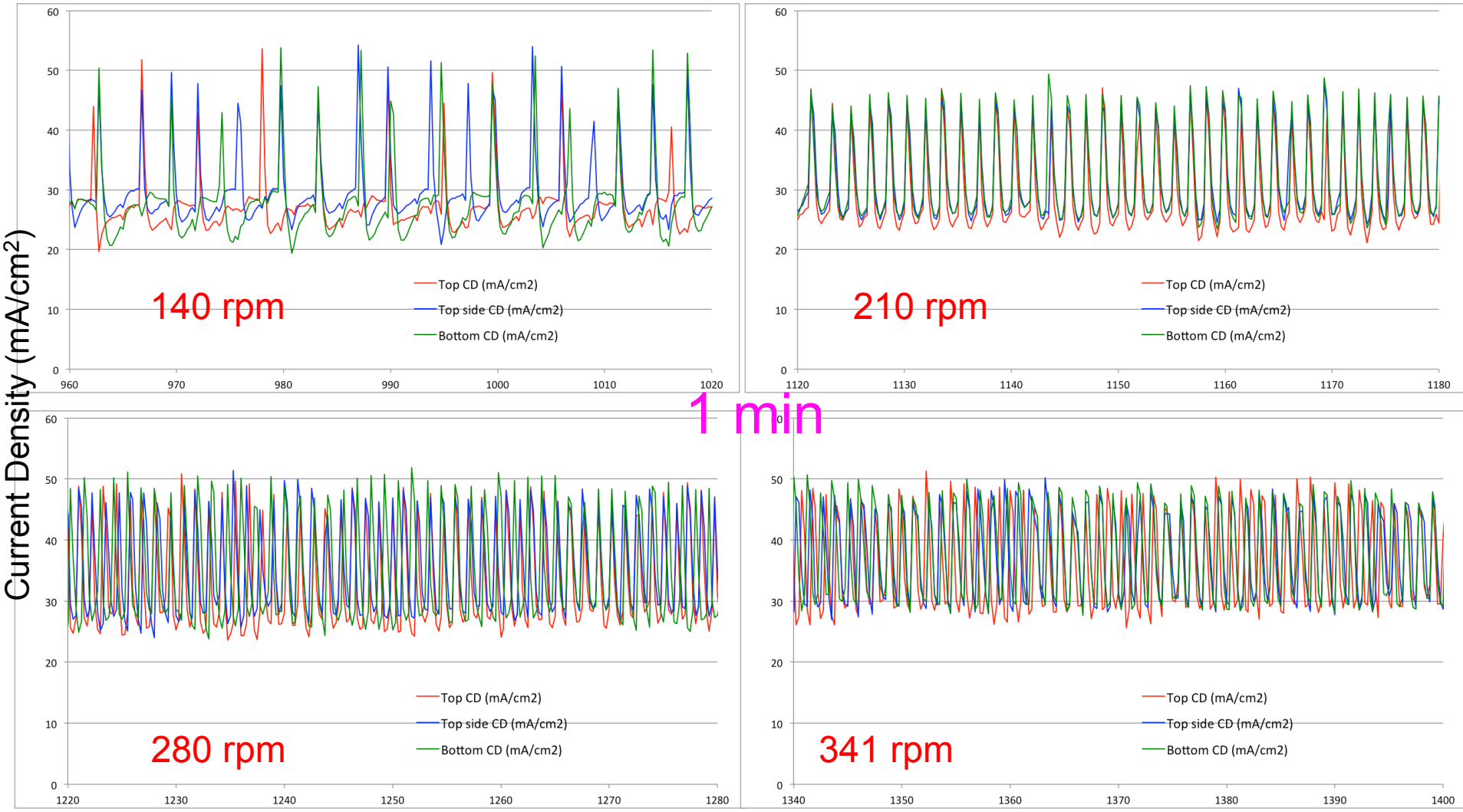
1 min



1 min

- Sample current densities for the top, the top side and the bottom become to be close together.
- It would mean that viscous layer thickness might start to become similar on all the samples when speed of the stirrer is increased.

Continue..

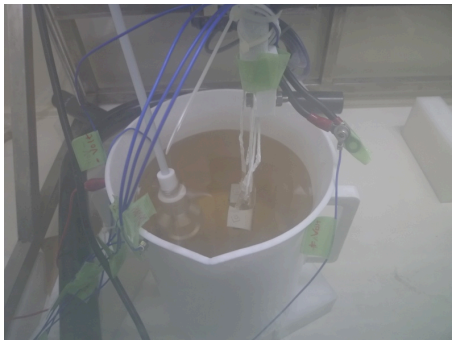


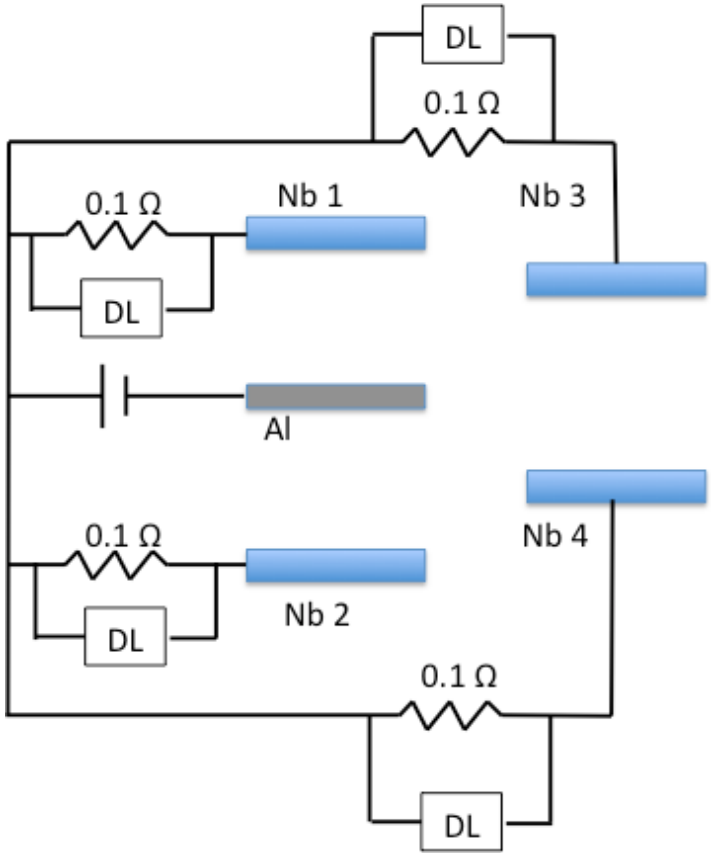
- Due the high speed agitation, residence time of H_2 bubbles on Nb surface would become very short due to self H_2 bubble attack. In other words, on surface where EP solution is stagnant, residence time of H_2 bubbles would be longer.

Lab EPs with Stirrer under Fixed Condition

Based on the previous results, two experiments were performed without and with stirrer to compare removal thickness, surface roughness and surface morphology.

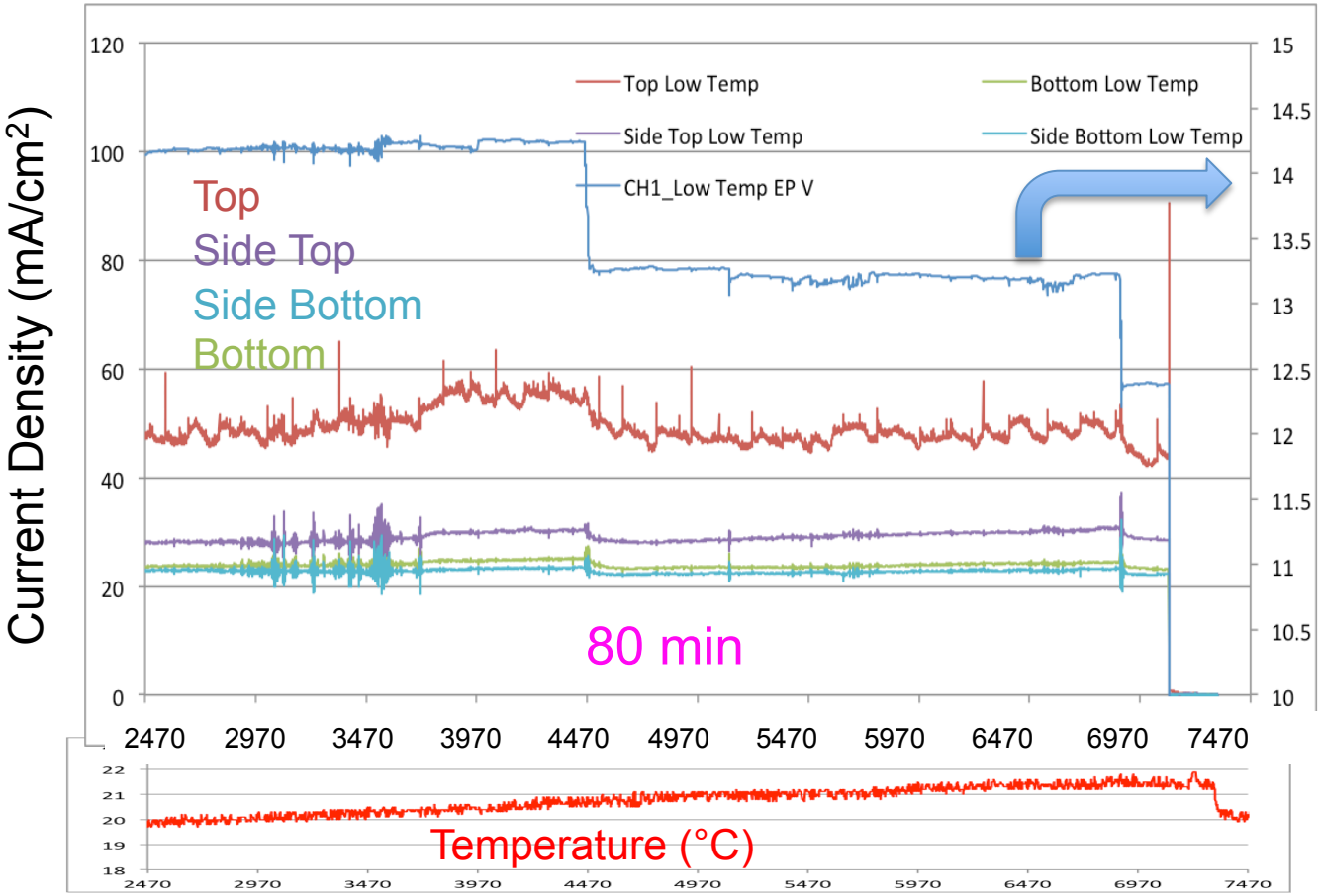
Sample Positions

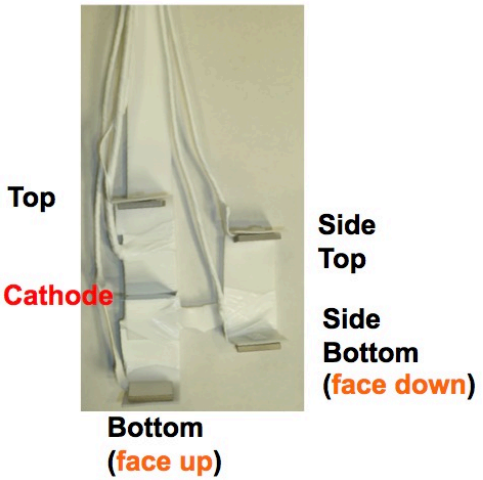




- EP Solution Temperature <22 °C
- Voltage: 11-14 V
- Average Current Density: 30-35 mA/cm^2

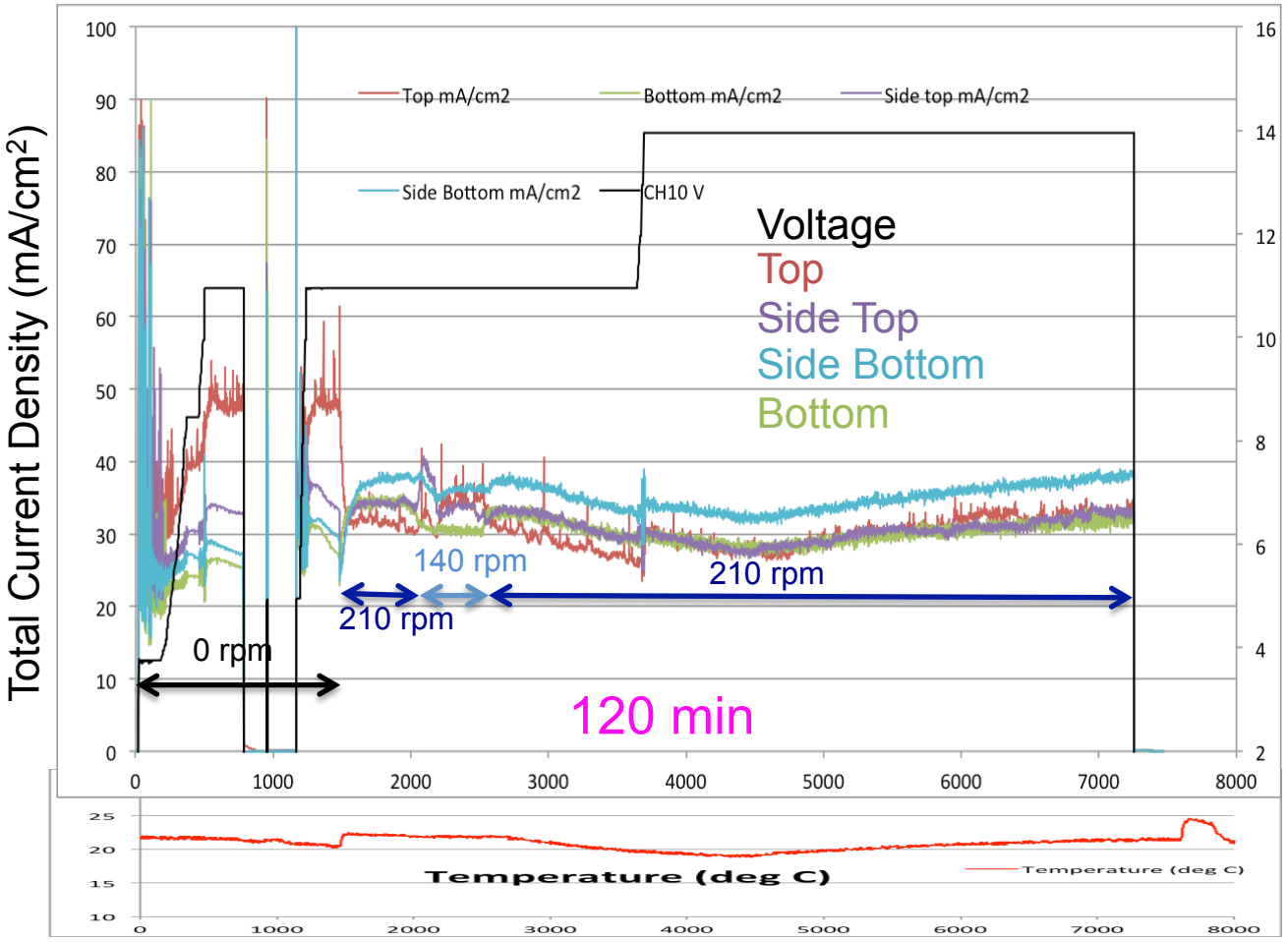
Sample Current Profiles of Lab EP without Stirring





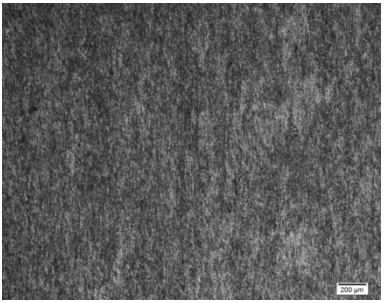
- EP current for the top sample was the highest with oscillation because of direct bubble hitting on the thin viscous layer. The 2nd highest was for the side top sample.
- Another important message is that EP currents for the bottom and the side bottom showed almost the same, meaning that gravity effect on viscous layer is not strong. It is because the face-down bottom side sample is along the gravity while the face-up bottom one is against the gravity under the condition of almost no H_2 bubble hitting for the samples.

Sample Current Profiles of Lab EP with Stirring

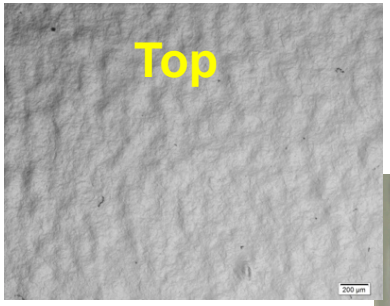


- Stirrer was not used at the beginning for the reproducible test.
- Sample currents were found similar when the stirrer was used. The bubble hitting and consequent viscous thickness should be equivalent at any position.
- The side bottom current was a bit higher than the others. This might be because a cable to the side bottom one was partially exposed to the EP solution.

Surfaces after EP without Stirring

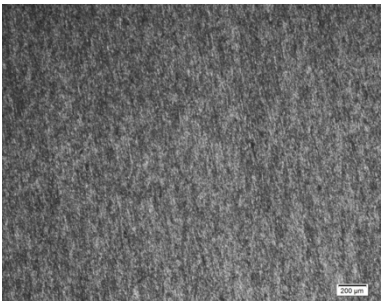


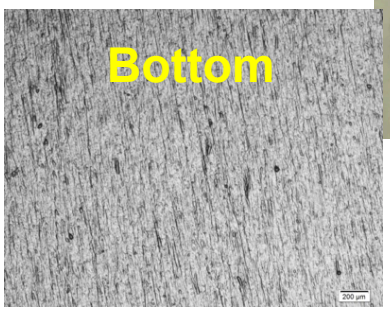
before



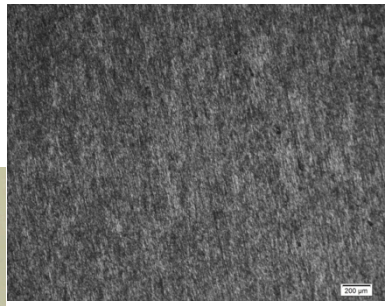
RT = 77.8 μm
Ra/Rz
=0.25/1.3 μm

RT :
Removal Thickness





RT = 40.7 μm
Ra/Rz
=0.36/2.5 μm



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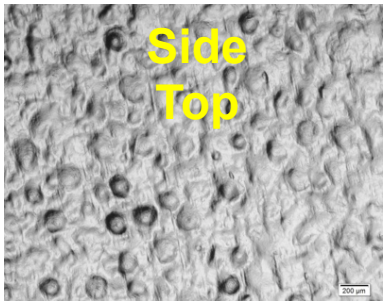
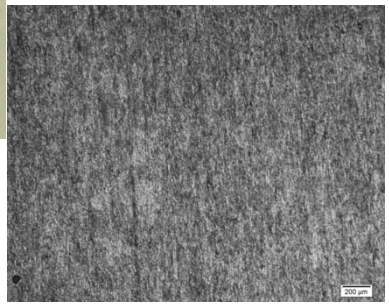
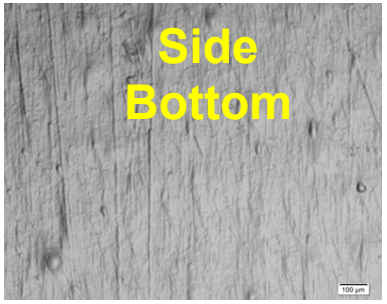


RT = 47.5 μm
Ra/Rz
=0.80/4.6 μm

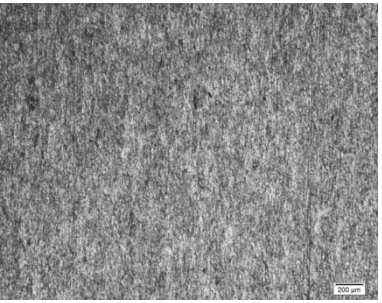




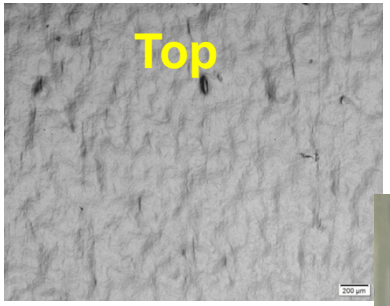
RT = 39.0 μm
Ra/Rz
=0.29/2.2 μm

- H_2 bubbles directly hit and remove sticking bubbles quickly from the top sample surface to make the surface smoother.
- Bubbles might remain at surface of the side top sample with a longer residence time to make it rougher. This was also observed after VEP done with rod cathode.

Surfaces after EP with Stirring

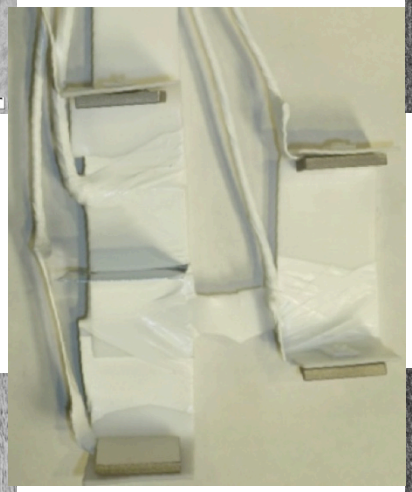


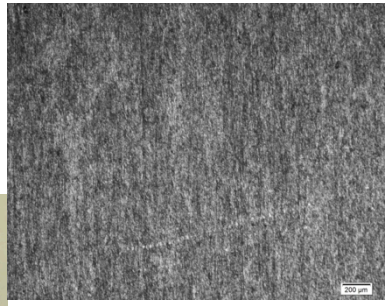
before



RT = 47.6 μm
Ra/Rz
=0.44/2.2 μm

RT :
Removal Thickness





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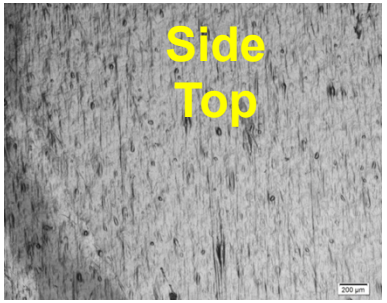
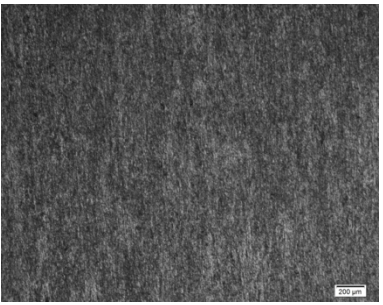
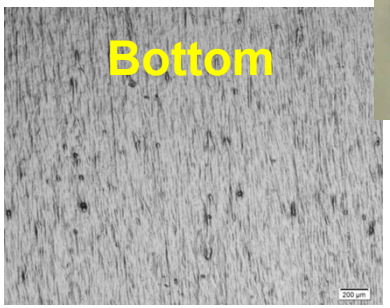
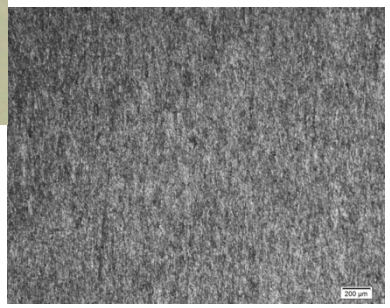


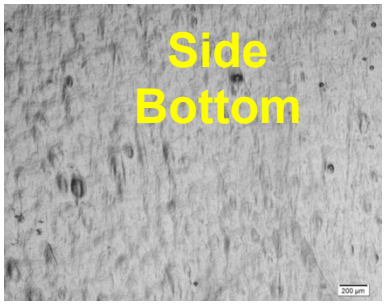
RT = 44.3 μm
Ra/Rz
=0.39/2.4 μm





RT = 45.0 μm
Ra/Rz
=0.32/2.0 μm





RT = 46.7 μm
Ra/Rz
=0.31/1.8 μm

- The higher speed of the stirrer surely makes a uniform viscous layer on the sample surfaces.

Summary

- Lab EP experiments were performed to know the reason of inhomogeneous EP.
- It was for the first time shown that cause of localized higher EP rate is H_2 bubble attack to Nb surface and residence time of H_2 bubbles at Nb surface strongly affects surface roughness.
- Therefore both separation of H_2 bubbles and high speed stirring to generate the uniform viscous layer are very important in VEP.
- The primary issue in VEP for SRF cavity seems to be solved.
- These lab EP results were fed back to cavity EP as shown in the next talk.
- A new cathode design for further improvement has been already done and is now in manufacturing.

Fin

Diana

Thank you for attention!