CORNELL VEP UPDATE, VT RESULTS AND R&D ON NB COUPON

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Abstract

Cornell's SRF group have continued R&D of Vertical Electro-Polishing (VEP) on SRF Nb Cavity. We have achieved high gradient with singel- and multi- cell cavities by our VEP. We also have started VEP'ed Nb coupon surface analysis based on surface roughness measurement. We will describe our status of VEP R&D, the vertical test results of VEP'ed cavities, and fundamental study on VEP using Nb coupons.

CORNELL'S VEP SYSTEM

Figure 1 shows images of single cell cavity and Cornell's VEP system with acid circulation. Cornell's VEP system could process 1.3GHz TESLA/Re-entrant/ICHIRO shape cavities. Half-cell coupon cavity has been fabricated and processed for fundamental study. EP acid agitation is controllable with puddle on stir tube. New acid mixing tank is now available for all single-/multi- cell cavities, easy acid mixing, acid circulation during VEP process. Temperature is controlled by spray water for cavity outside. We also have compact EP system for Nb sample sheet, mushroom cavities. Table 1 shows parameters of Cornell VEP.

RECENT ACHIEVEMENTS WITH VEP

We have processed and tested many single-/multi- cell cavities with VEP. Analysis on removal vs. voltage in Figure 2 shows a tendency that small removal as final etches could provide high gradient. Based on this analysis, additional 5µm VEP was applied on TESLA 9-cell cavity "A9". A9 successfully achieved high gradient of 38 MV/m with Qo of 0.9E10 at 2 K, satisfied ILC BL

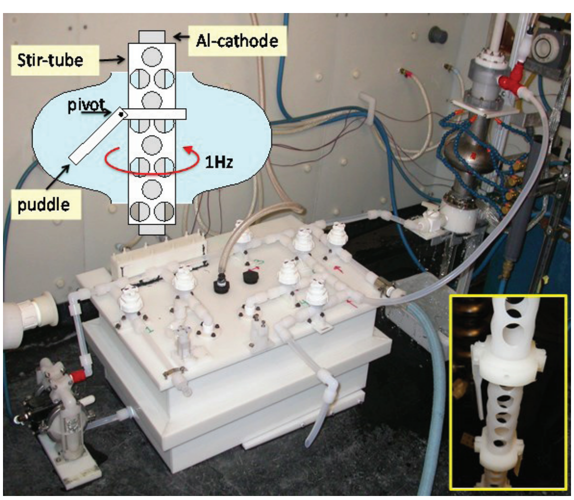

Figure 1: Cornell's VEP system.

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Table 1: VEP Parameters at Cornell

Parameters	
Cathode	Aluminium > 99.5%
Stir-tube, puddles	PVDF
End group	PVDF, HDPE
Electrolyte volume	24 liters / 9-cell
Electrolyte composition	10:1 (H_2SO_4:HF).
Maximum use	9 g/L dissolved Nb
Current-Voltage source	500A-20V max
Temp. (cavity outside wall)	15~19 degC
Stir-tube transparency	>50%
Stir frequency	0~3 Hz
EP removal rate (ave.)	~0.3 microns/min.

specs [1]. Figure 3 shows summary of VEP'ed 9-cell cavities at Cornell. Single cell "NR1-3" was also processed with 5 µm VEP and achieved 43 MV/m with high Qo [2].

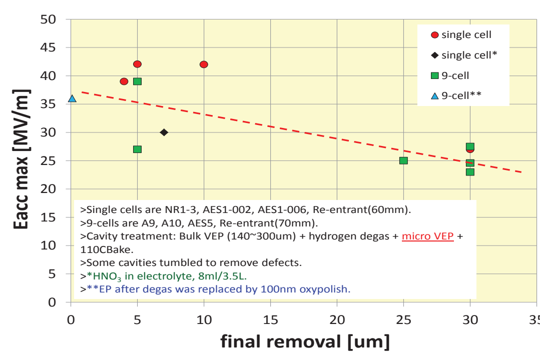

Figure 2: Analysis on VEP removal.

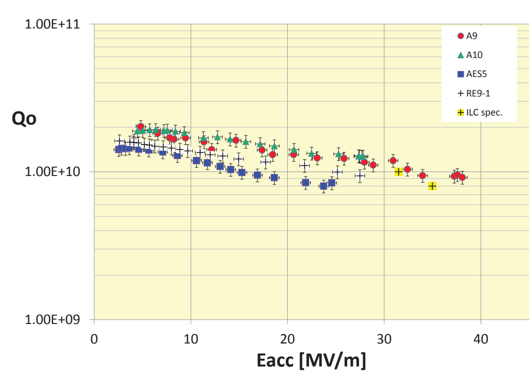

Figure 3: Results of VEP'ed 9-cells at Cornell.

HALF-CELL COUPON CAVITY

Half-cell coupon cavity has been fabricated for fundamental study on VEP. Figure 4 shows image. Nb half-cell can be oriented to both of top and bottom side of dummy cavity, so we could compare the current and temperature profiles of both sides. Four Nb coupons with diameter of 11 mm are attached on half-cell surface (2 on equator, 2 on iris), these coupons are available for surface analysis (roughens, removal, and contaminants, etc.).

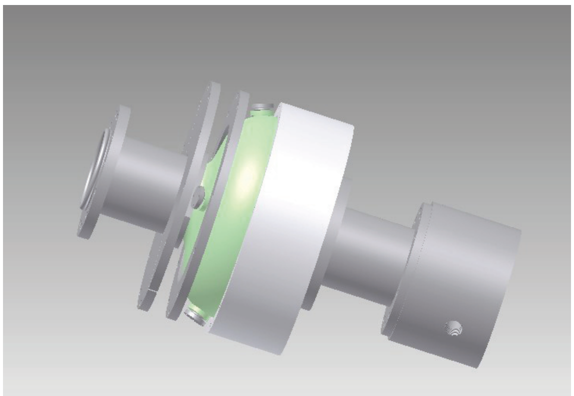

Figure 4: Half-cell Nb coupon cavity.

Current Profiles

Figure 5 shows current profiles of top and bottom half-cell at VEP voltage of 17 volts with agitation of 1 Hz. Top half-cell current has no oscillation during VEP process, bottom half-cell has oscillation. Figure 6 shows current profiles of top and bottom half-cell at VEP voltage of 17 volts without agitation. Oscillation was observed both of top and bottom currents. But oscillation of top current was much smaller than bottom.

I-V Curve

Figure 7 shows I-V curve comparison of top and bottom half-cell with acid agitation of 1 Hz. In this plot, current means average current. Top half-cell has 30~40% higher current than bottom half-cell. Current seems to increase gradually but difference is about 10% from 5 volts to 17 volts.

Acid Agitation Effect

Figure 8 shows agitation speed vs. average current at VEP voltage of 17 volts. Number of data point for top half-cell is just two, but Top agitation effect seems much stronger than bottom half-cell. We will take more data point for top half-cell.

Discussion

Electrolytic action generate oxide layer on Nb surface, this corresponds to current drop off. HF react with Nb oxide layer and remove it, this corresponds to current rise up. The balance of these two reactions could make current oscillation of EP. Viscous layer is formed on Nb surface during EP process and thickness of this layer also could affect reaction balance and oscillation. In case of vertical

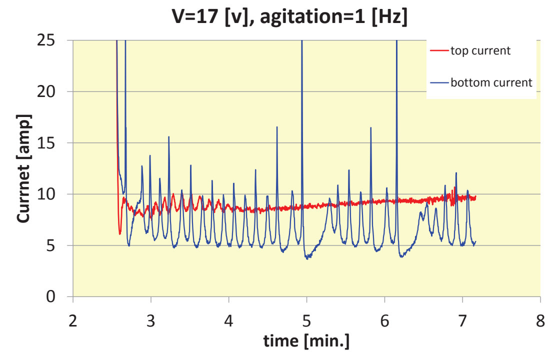

Figure 5: Current profiles with acid agitation.

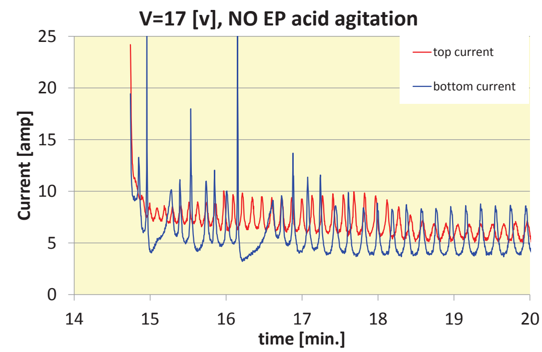

Figure 6: Current profiles without acid agitation.

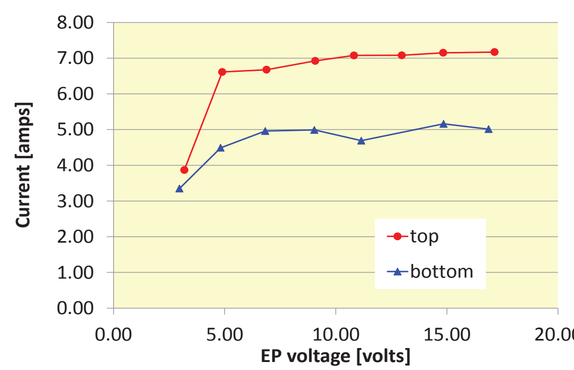

Figure 7: Current vs. voltage with agitation.

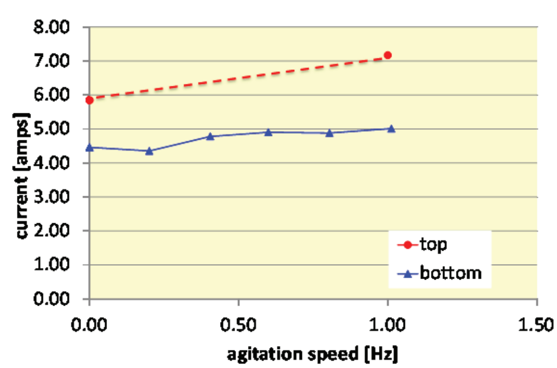

Figure 8: Current vs. agitation at 17 volts.

elector-polishing, gravity effect could make viscous layer on top half-cell thinner than that of bottom half-cell. Thinner viscous layer could result in thinner oxidation

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layer and smaller current oscillation, but average current could be larger. Agitation effect on top half-cell seems to be larger than bottom. That means our puddle on cathode stir tube make agitation effectively only for top half-cell, this also could result in thinner viscous layer, small current oscillation, and larger average current on top half cell. Difference of current profile could be corresponds to difference of surface finish. To make uniform surface, we might need to make uniform viscous layer by applying effective agitation or acid flow. Maybe smaller removal make this difference as possible as small, help to make uniform surface, and result in higher performance.

COUPON ANALYSIS

Many coupons had been processed with different parameters. Figure 9 shows images of those Nb coupons. Surface roughness analysis is on-going. Based on analysis on surface roughness of coupon, current profiles, and VT results; we could optimize VEP parameters. We will also investigate contaminants on coupon that formed during VEP process. Small removal could benefit to prevent RF surface from contaminating.

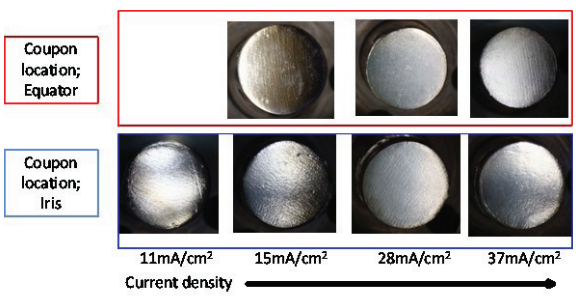

Figure 9: Images of coupons processed with different conditions.

SUMMARY

Cornell's VEP had successfully achieved ILC specs with TESLA 9-cell cavity and demonstrated availability of VEP for high gradient and high Qo. Half-cell coupon cavity provides us more details of VEP current profile and understandings of VEP process. We could optimize VEP conditions from coupon study and analysis on VT results As further upgrading, full-cell coupon cavity is under designed.

REFERENCES

[1] F. Furuta et al., Proc. of IPAC12, New Orleans, USA 2012, TUPPR045.
[2] D. Gonnella et al., in these proceedings, TUP028.