Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Vertical Electro-Polishing studies at Cornell

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Introduction;
Vertical Electro-Polishing (VEP) has been developed and applied on various SRF R&Ds at Cornell as primary surface process of Nb.
The poster presents 1) Cornell's VEP system, 2) Recent VEP achievements on high voltage cavities and high-Q cavities, and 3)new VEP collaborations toward further improvement and new breakthrough on EP.

Cornell's VEP system

- The system is designed to process 1.3GHz cavities.
- Removal rate between upper and bottom half cell is different (see the graph). Cavity is need to be flipped after finishing the half of target removal to compensate un-uniform removal. Even if the target removal was only 5um, we will flip cavity after 2.5um removal.
- Recent Cornell VEP process has NO acid agitation during voltage on, or NO acid circulation. But the system is capable of circulating and agitating electrolyte during the process.
- Process temperature is controlled by spraying water on cavity outside .
- Teflon mesh is lapped on stir tube to guide hydrogen bubble along the cathode into outside air. Exposing Nb surface on hydrogen bubble during VEP has a potential risk of degradation of cavity performance by getting hydrogen Q-disease or generating defect on RF surface.

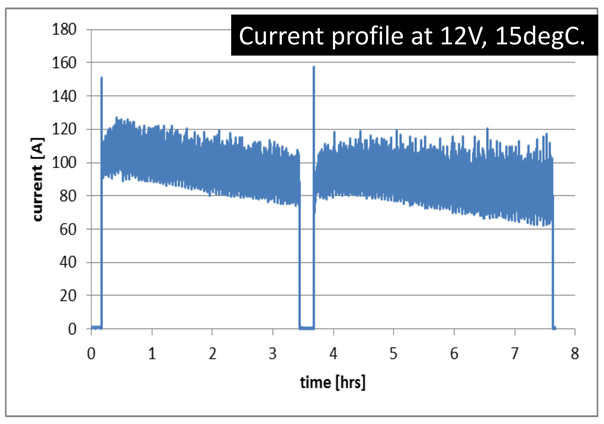
Average removal calculation

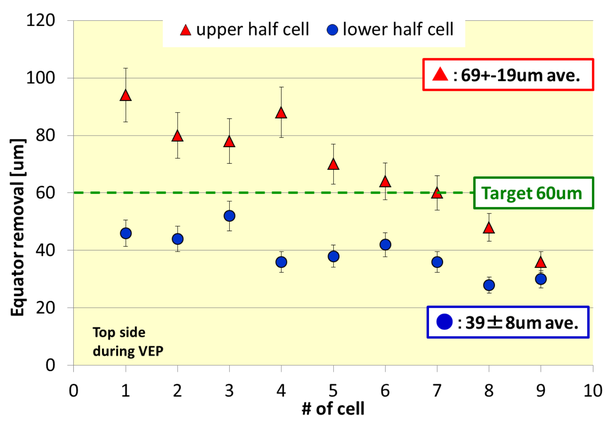
$$\frac{t \cdot S \cdot \rho}{M} \cdot N_A \cdot 5 \cdot e = \int Idt$$

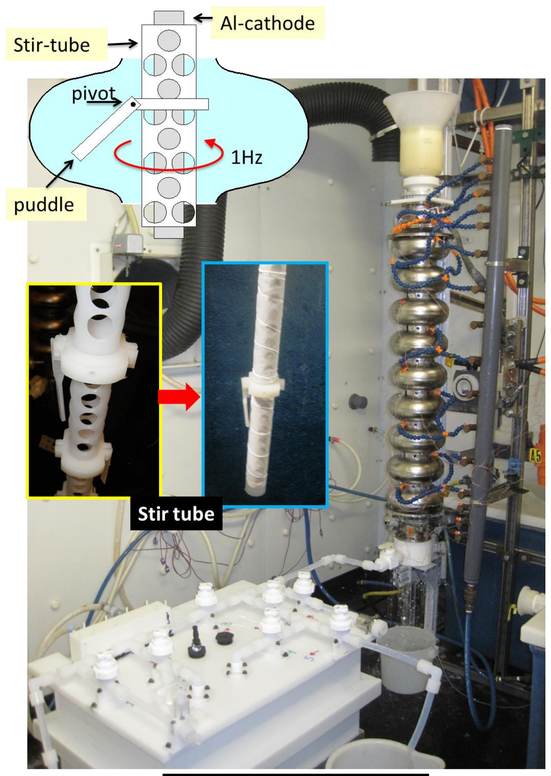
$$t_{[um]} = 2.25\text{E-}01 \cdot \frac{\int Idt}{S_{[cm\text{^}2]}}$$

t = ave. removal [um]
S = surface area [cm^2]
M (Nb) = 92.9 [g/mol]
ρ (Nb) = 8.57 [g/cm^3]
e = 1.60e-19 [coulomb]
N_A = 6.02e23

Parameters	
Cathode	aluminum >99.5%
Stir-tube	PVDF
Paddles	PVDF
Seals	FEP encapsulated O-ring
End group	PTFE, HDPE
Electrolyte volume	24 liters/9-cell
Electrolyte composition	10:1 (H_2SO_4: HF)
Maximum use	9g/L dissolved Nb
Current-Voltage source	500A-20V max
Current for 9-cell	80-120A
EP Voltage	12 Volts
Temp. (cavity outside)	15 to 19 C
Stir frequency	0~3 Hz
EP removal rate (ave.)	~0.2um/min.







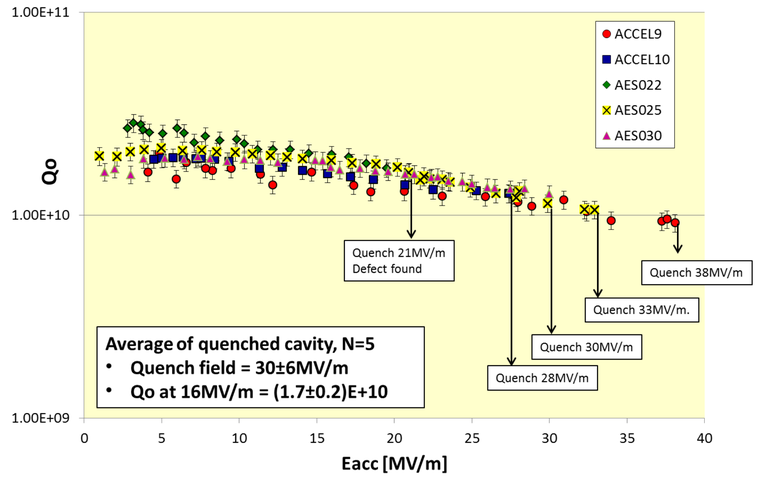
9-cell on VEP system

Results of High voltage/High-Q cavities

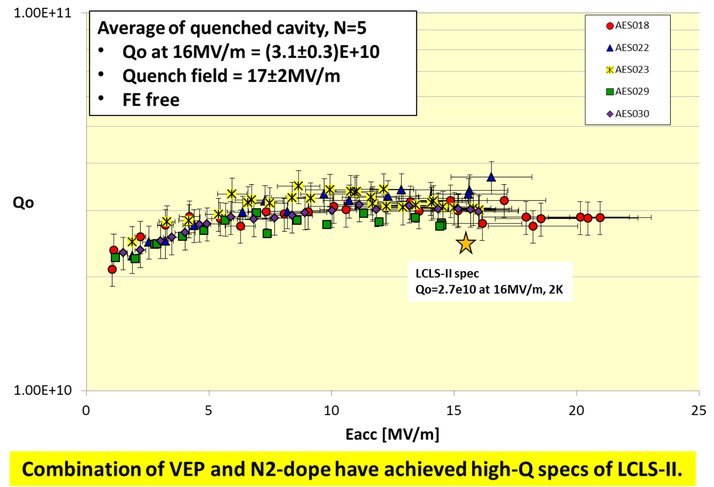
- High voltage cavity; VEP+120degC bake on 1.3GHz TESLA 9-cell cavities had achieved ~40MV/m, and satisfied ILC specs (Qo of 1e10 at 36MV/m) during VT. VEP is now very promising up to 30MV/m. Further R&D on achieving high yield above 30MV/m is necessary.

- High-Q cavity; N-dope +VEP had achieved LCLS-II specs (Qo of 2.7e10 at 16MV/m) and high yield. The yield is comparable with that of Horizontal EP'ed high-Q cavities. VEP is fully capable of achieving high-Q cavity requirements. Systematic study on optimizing N-dope condition and removal after N-dope is highly recommended.

Standard VEP'ed 9-cell for High Voltage



VEP + N-dope 9-cell for High-Q



Combination of VEP and N2-dope have achieved high-Q specs of LCLS-II.

VEP collaborations

Cornell-Faraday Technology Inc. collaborations as phase-II SBIR projects
- Optimization of bipolar EP conditions using Cornell's Nb coupon cavity (Faraday).
- Demonstration of 9-cell scale bipolar EP (Faraday) + RF tests (Cornell).
- Bipolar system upgrading for multi-cell cavity s on going (Faraday), three single cells will be fabricated (Cornell) and processed at once (Faraday).
- Design of Bipolar EP system for Cornell.

Cornell-KEK-Marui Galvanizing collaboration on *"NINJA"* cathode for VEP.
- Demonstration of 9-cell cavity process using new " Ninja" cathode.
- Install Ninja cathode into Cornell's VEP system, design and fabrications are on going.
- KEK 9-cell (MHI-02) was sent to Cornell. Bulk BCP and degas were done at Cornell. Cavity was now at KEK. Ninja-cathode and MHI-02 will be sent to Cornell again, and processed.
- Maui's staffs will visit Cornell and guide new cathode installations and process.

Summary

- System upgrading and parameter optimization on Cornell's VEP system has been continued. VEP is used routinely on Nb SRF cavities and works very reliably.
- VEP on High voltage cavities had achieved 40MV/m with TESLA 9-cell, high yield had been achieved up to 30MV/m. High yield against high voltage is high priority.
- VEP on High Q cavities based on N-dope had successfully achieved the requirements on LCLS-II, 2.7e10 at 16MV/m, 2K, with high yield. VEP results on high-Q cavities are comparable with horizontal EP.
- VEP collaborations toward further improvement and new breakthrough on EP has started between Cornell and Faraday, and also Cornell and KEK, Marui Galvanizing.
- We also have 1.3GHz Nb coupon host cavity and lab EP system for 3.9GHz TE cavity, Nb 5" disc and small coupons. These systems are very strong tool for further R&D on Nb SRF cavity related.

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