Development of vertical electropolishing (VEP) for surface treatment of 9-cell Nb cavities at KEK

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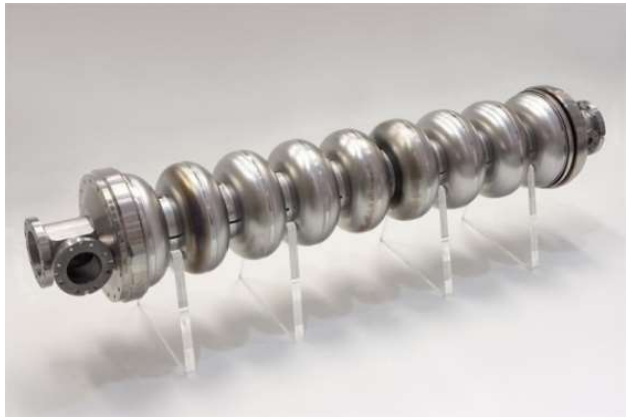
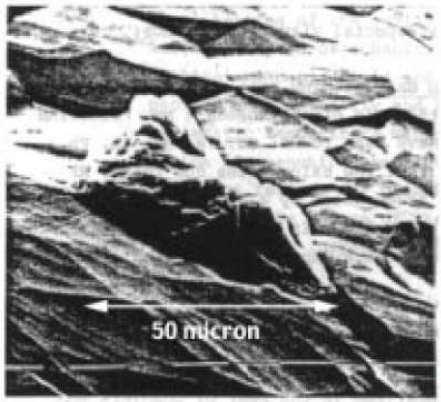


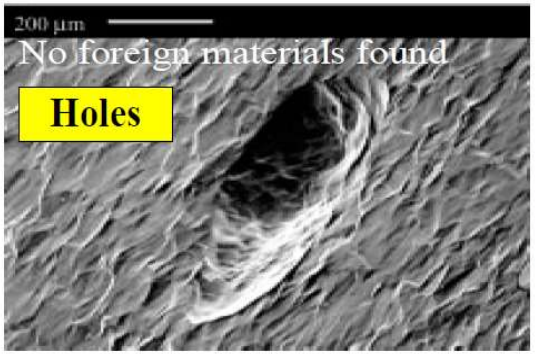
Introduction: electropolishing (EP) for Nb cavities

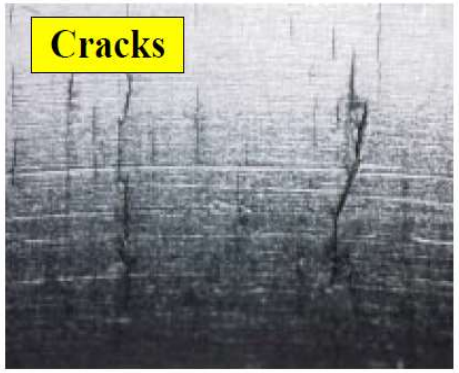
• Smoothness of the inner surface of Nb cavity is required for high superconducting radio frequency (SRF) resonance performance. (Q: 10^10, E_{acc}: ~31 MV/m)

- The surface of Nb cavity after fabrication has some structures such as scratches and weld marks.
- Mechanical polishing leaves polishing debris and abrasives on the surface.

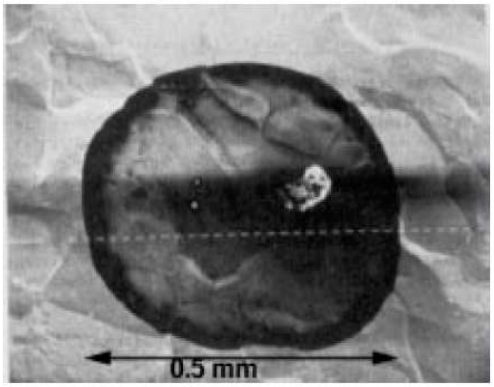
>> Electropolishing (EP) treatment of the cavity is required prior to assemble into the cryomodule.

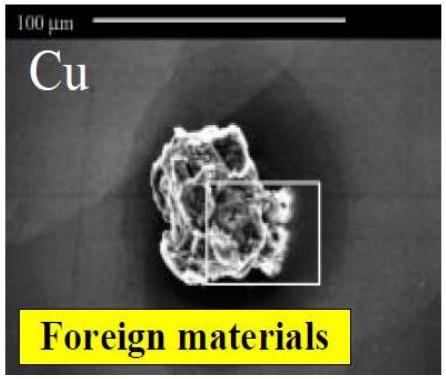






Surface defects, holes can also cause TB





• In KEK, in addition to the existing horizontal EP (working in ~15 years @STF), installation of the vertical EP (VEP) facility was completed in December last year at COI building.

Advantages of VEP system compared with HEP

(1) the simpler operational processes and the higher work safety. >> lower cost

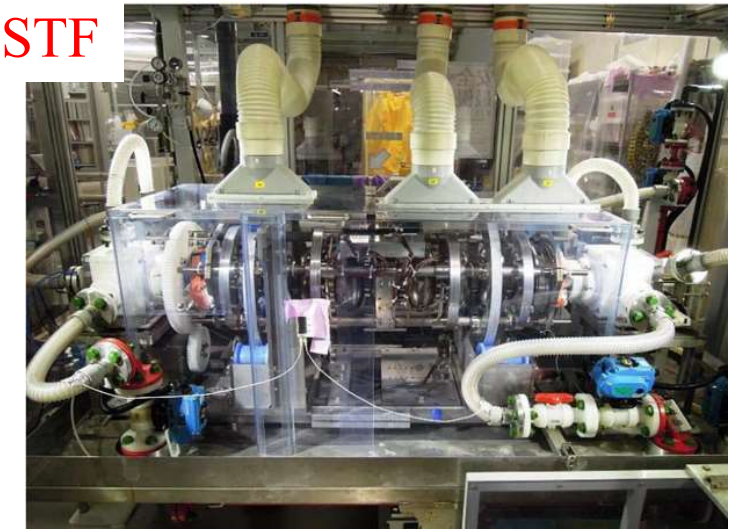
- The operator works with hands only in the EP bed cover.
- No accident factors: the cavity inversion system, the rotary sleeve resistant to strong acid.

(2) The reaction area of the Nb cavity is about 1.9 times larger, and the EP treatment time is shorter.

Disadvantages of VEP system

- H_2 gas bubbles mark on the cavity surface.
- Uneven polishing of the top and bottom caused by dripping diffusion layers by gravity.

HEP at STF



VEP at COI

VEP system at COI (~130 m^2), 1st floor

Electrolyte reserve tank (500 L)

Alarm system

The EP area is fenced off and requires a registered ID to enter.

Many tanks and pumps

- pure water for cavity cooling and HPR.
- Relay tank for washing waste liquid.
- Heat exchanger for electrolyte cooling.

electrolyte: HF(48wt%):H_2SO_4(98wt%) = 1:9 (v/v)

>> Extremely dangerous to handle

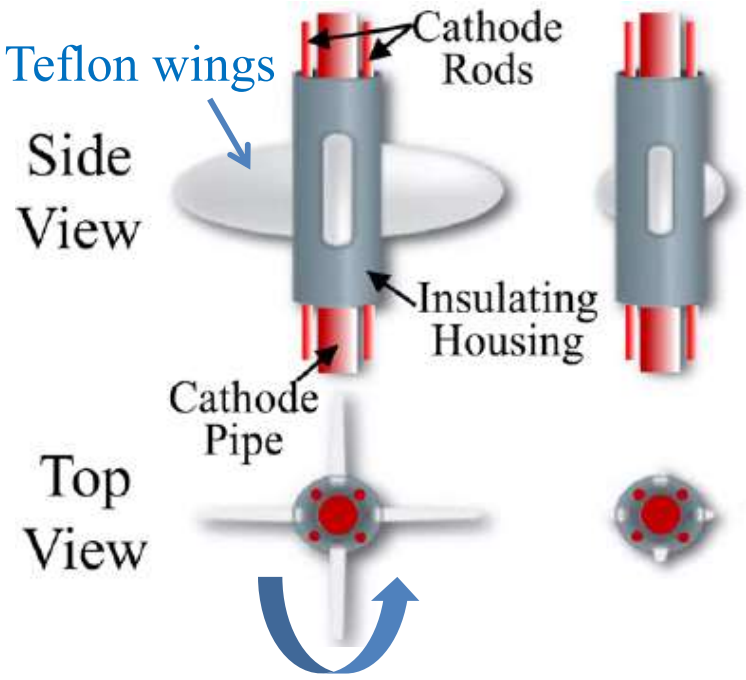
- Alarm and interlock system: leak detectors, HF gas sensors
- Double dikes for the tank.

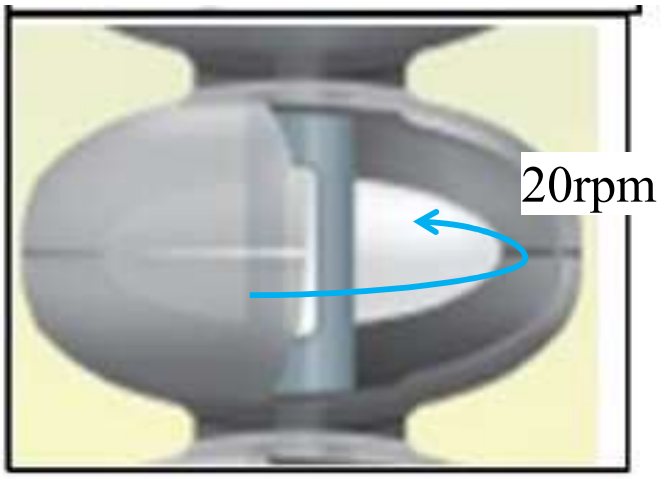
2nd floor: setup

The inside of the cavity and EP hat are vented to a scrubber.

Cavities are installed into the holder with a specialy developed electric lifter. (xyz translation and rotation of cavity)

Ninja-cathode (Al)





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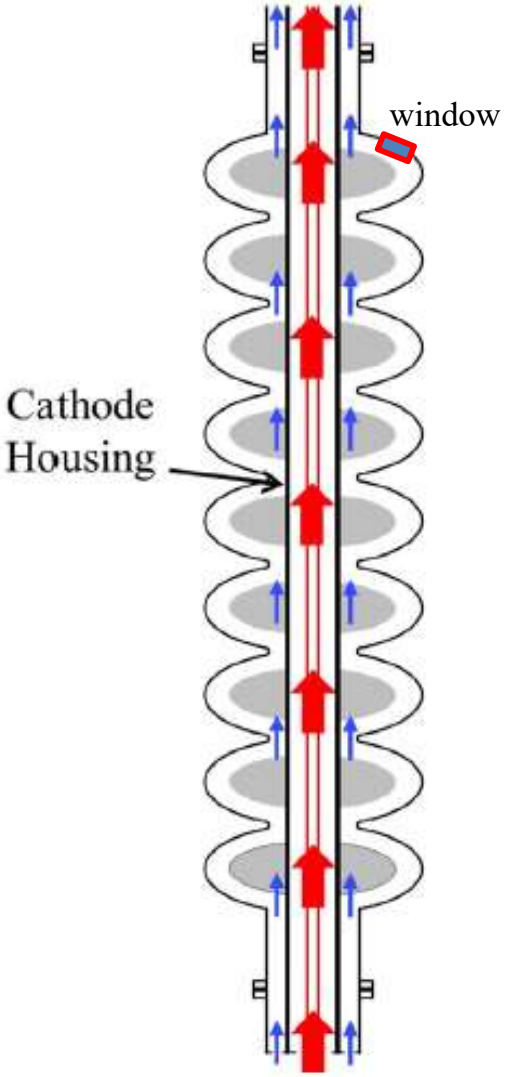
- The lifting machine lifts Ninja cathode above and inserts it into a cavity, and the Teflon wings are expanded in the cavity cell.
- During EP, the cathode is rotated at 20 rpm to agitate the electrolyte.

Water cooling and two flow systems

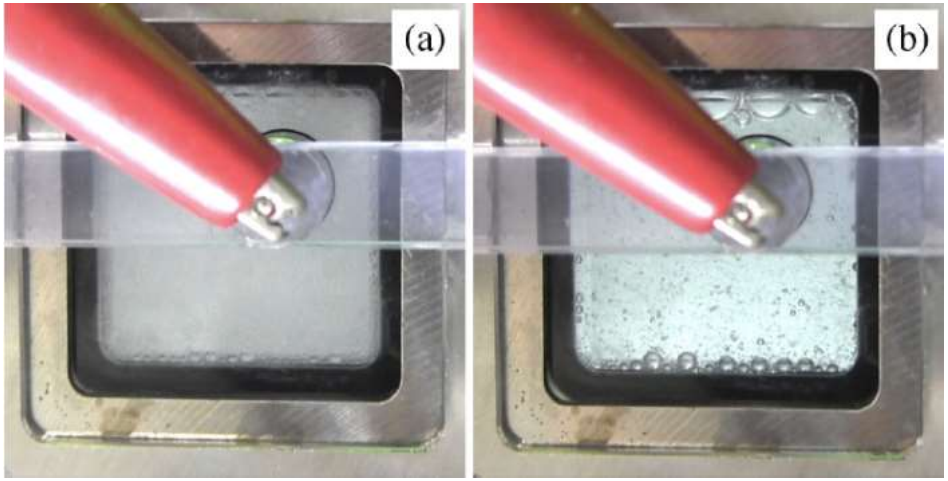
Hydrogen gas is generated from the Al cathode, and those bubbles make marks on the cavity surface.

Cavity heats up during EP.
>> The cavities are cooled using pure water.

>> Two flow system of electrolyte inside cavity



Flow rate: inside cathode (~10 L/min), outside (~5 L/min)
>> Higher flow velocity in the cathode quickly removes hydrogen bubbles.



Photographs of the interior of a cavity during EP.
(a) 1 flow: many fine bubbles all over
(b) 2 flow: some large bubbles only.

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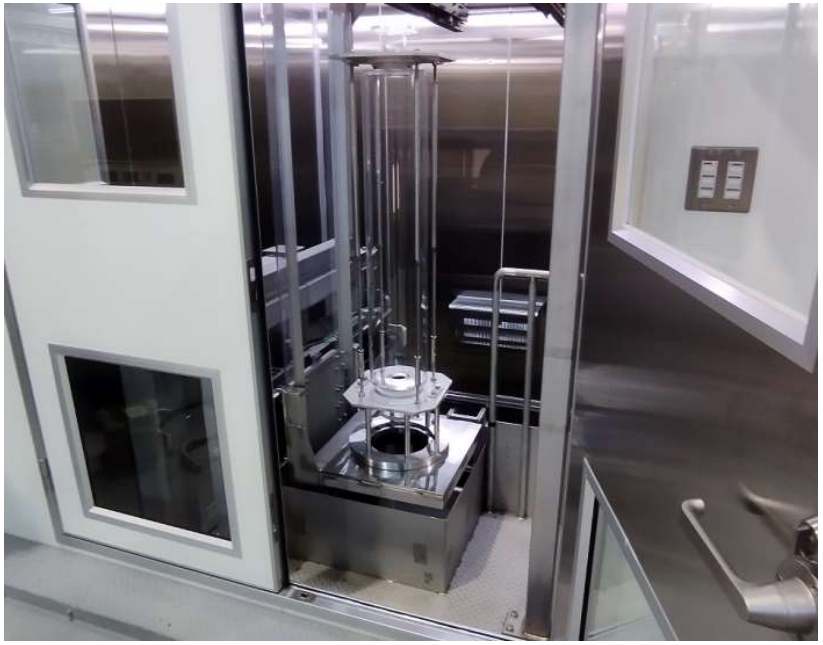
After EP (2nd floor),

Cavity washing with pure water.

Ultrasonic cleaning with detergent water

High-pressure rinse with pure water (HPR) in EP area



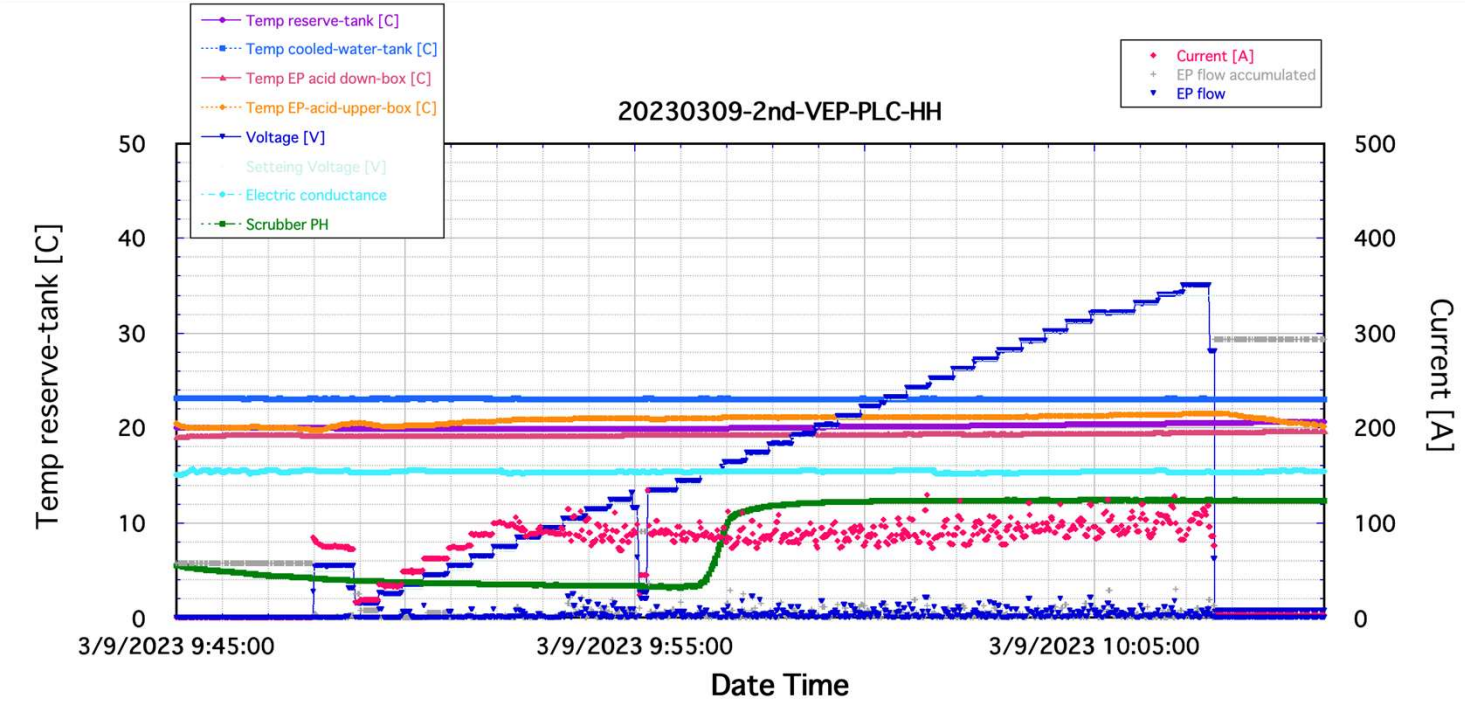
After HPR, the cavity is lowered to the 1st floor (the entrance to the clean room for assembly).

Two VEP processes were conducted at this moment.

- Bulk EP (EP1): 80 μm polished at ~35 V.

- Fine EP (EP2): 10 μm at ~11 V.

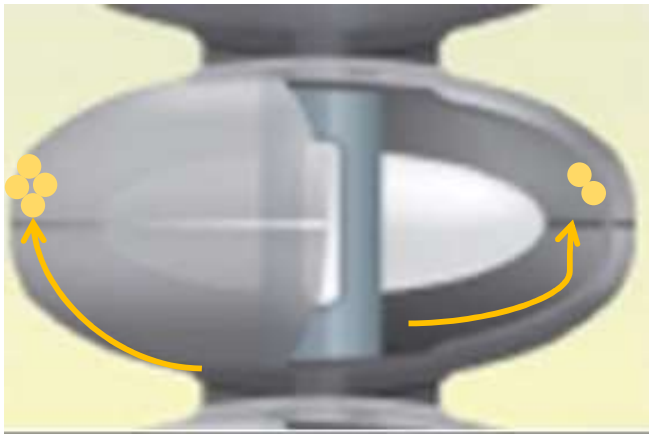
>> No serious safety issues occurred.
>> But some technical problems were found with the quality of the polishing, especially for EP1 process.

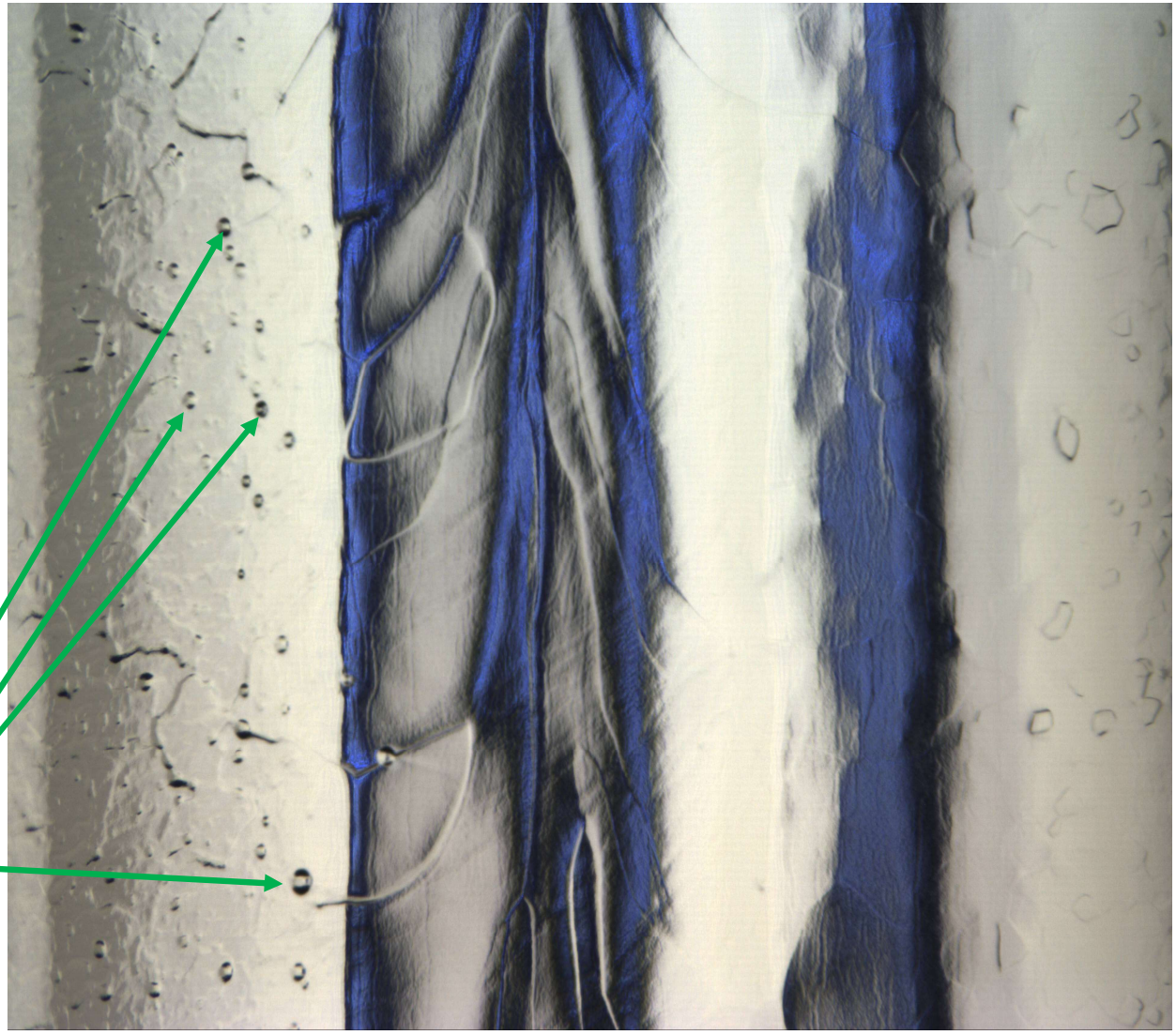


The cavity just after EP

Inner surface of cavity after bulk EP (35 V, Cell#2–equator)

Upper side ← H_2 gas bubbles ← bottom side



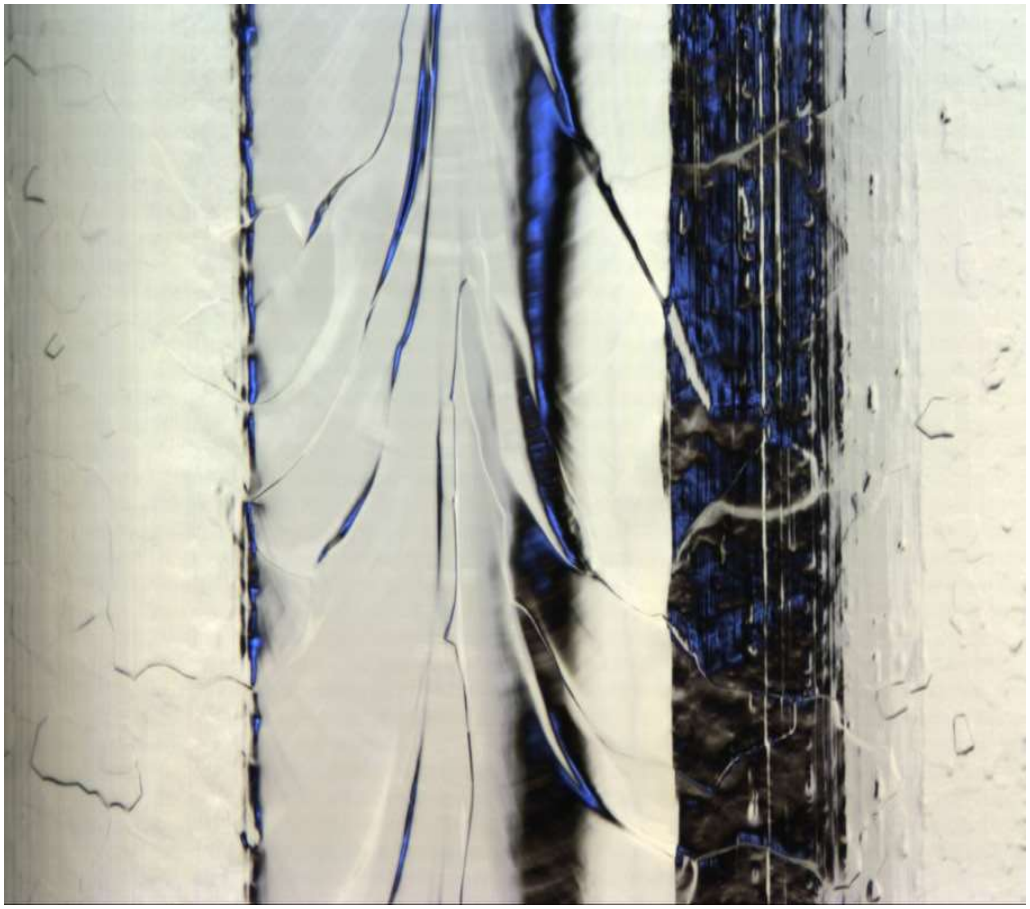


many pits formed
during bulk EP

These pits were observed only in the equator parts of the upper three cells of the cavity, ascribed by H_2 gas bubble adsorption.

Comparison of inner surface of cavity (Cell#1–equator-center, fine EP at 11 V)

Before VEP



After

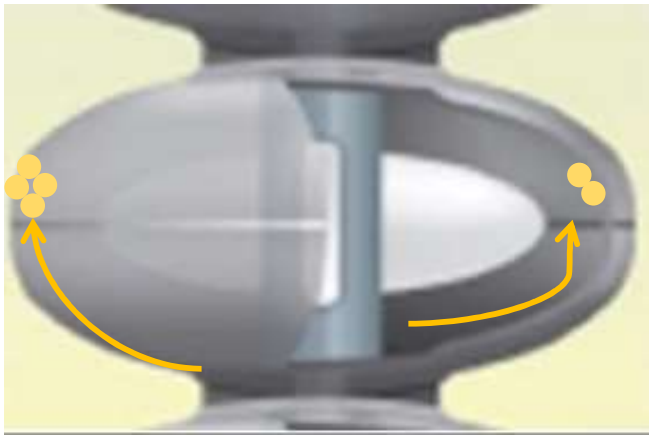
No pits due to hydrogen gas bubble adsorption on the surface were observed for fine EP process.

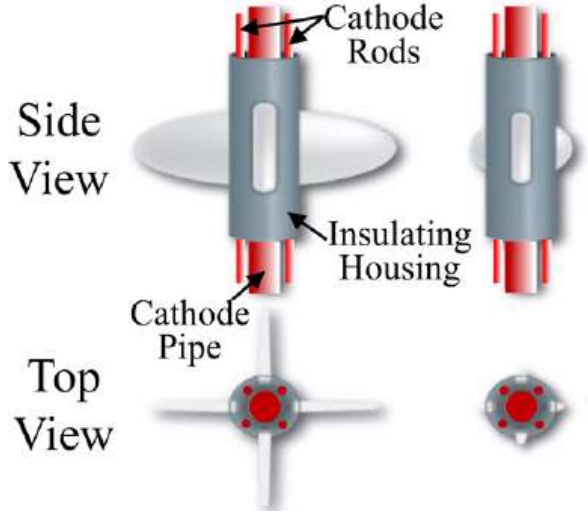
>> Because the applied voltage is low (11 V), the amount of hydrogen gas produced from the cathode is small.

Countermeasures against H_2 gas bubble adsorption on the cavity surface

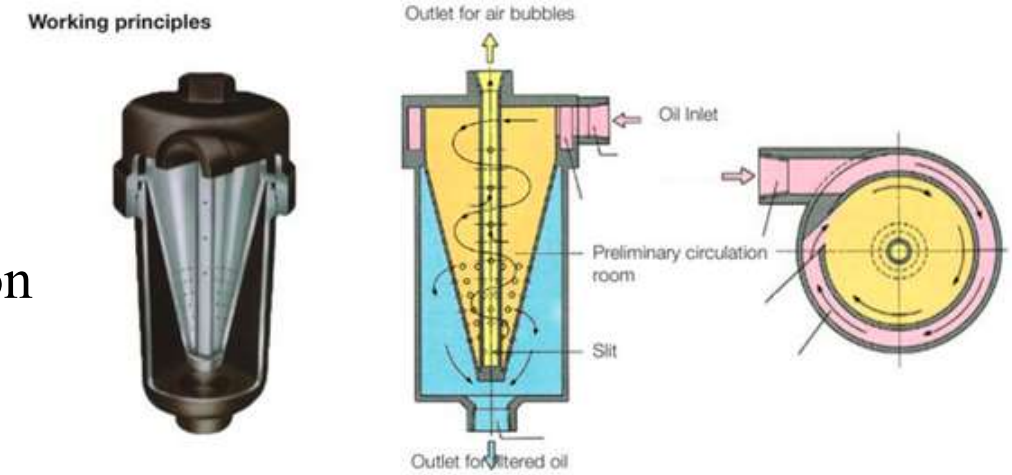
1. The optimization of Ninja cathode rotation speed and shape of Teflon wings.

2. The H_2 gas bubbles have a long life and remain in the circulating electrolyte.
>> Introduction of a defoaming machine for the electrolytic solution.





Cyclone separator Quicktoron



https://www.directindustry.com/ja/prod/triple-r-europe-nv/product-115545-1951177.html

Conclusions

- Installation of a VEP system for 9 cell Nb cavities was just completed at KEK and started the test operation in December 2022.

- We have introduced some new equipment to overcome the technical issues of VEP, including Ninja cathode, cavity water cooling system, and two-flow system of the electrolyte solution.

- At this time, we have done one bulk EP (80 μm polished at ~35 V) and one fine EP (10 μm at ~11 V) without any major safety issues.

- The internal surface inspection of the treated cavities (bulk EP at 35 V) has confirmed the presence of the pits around the equator positions caused by hydrogen gas bubbles. The introduction of a de-aeration mechanism for the electrolytic solution is under consideration.