Cavity Processing Laboratory for SRF cavities

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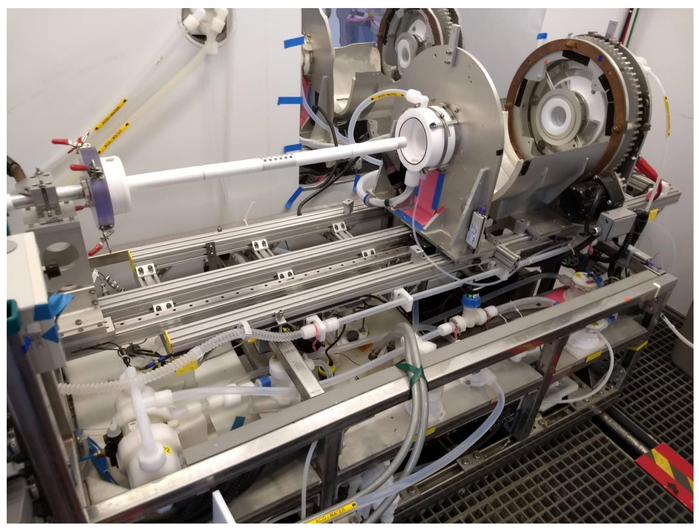
Electrochemical Polishing (EP)



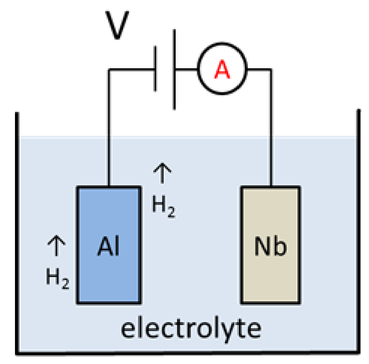
EP tool in IB4 CPL.
This tool can process a single-cell cavity with the frequency of 1.3GHz and higher. Multi-cell cavities and low frequency cavities are processed at ANL EP facility.

Electrochemical Polishing (EP) is an **electrochemical** process using an acid mixture (electrolyte) of sulfuric acid (H_2SO_4, ~96%) and hydrofluoric acid (HF, ~48%) with the ratio of 10:1 in volume. EP electrolyte was pre-mixed by the company and delivered to Fermilab.

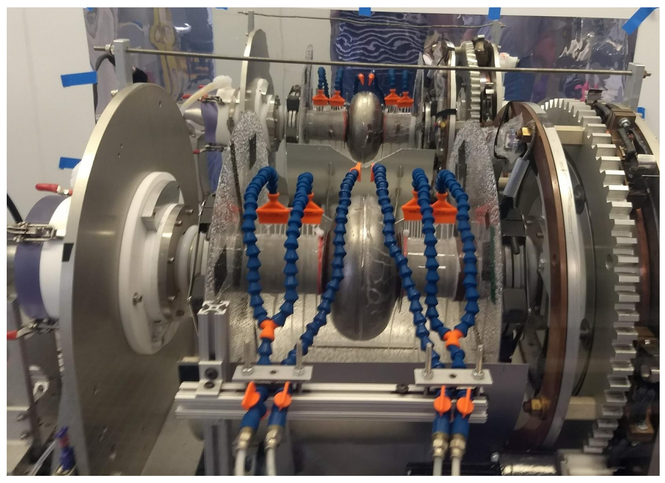
EP is performed by applying voltage between a cathode and an anode in an electrolyte bath. For the niobium cavities, aluminum (>99.5%) is used as a cathode and niobium works as an anode.

The reaction can be described in two parts; 1) the electrochemical reaction develops the niobium pentoxide on the niobium surface, 2) the HF acid removes that developed oxide layer. These chemical reactions are written as:

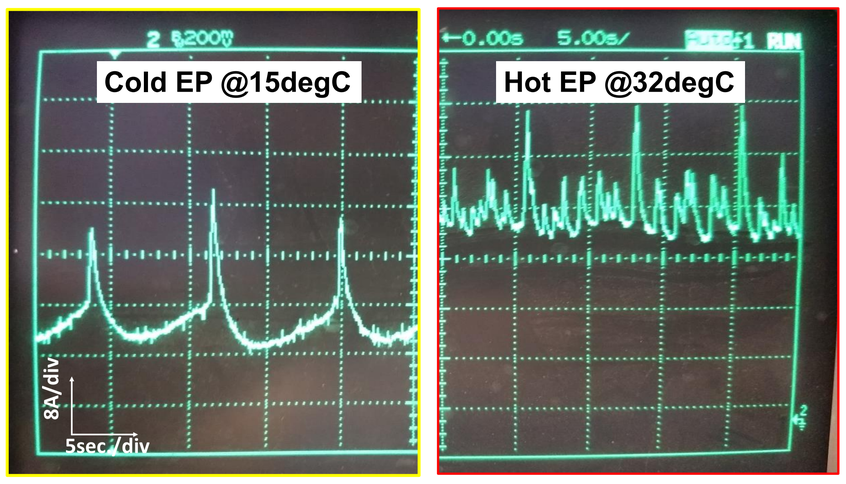
$$2Nb + 5SO_4^{2-} + 5H_2O \rightarrow Nb_2O_5 + 10H^+ + 5SO_4^{2-} + 10e^-$$
$$Nb_2O_5 + 6HF \rightarrow H_2NbOF_5 + NbO_2F{\cdot}0.5H_2O + 1.5H_2O$$
$$NbO_2F{\cdot}0.5H_2O + 4HF \rightarrow H_2NbOF_5 + 1.5H_2O$$



Schematic image of EP



Cooling shower for outer surface
This provides a precise control of EP temperature and Nb removal.



Current profiles during Cold/Hot EP process
Cold EP pushes a gradient higher than std. Hot EP on N-doped cavities. R&D on cold EP (15~2degC) is in progress to understand more details.

Parameters	Cold EP	Hot EP
Target removal	10 [μm] or less	>10 [μm]
EP voltage	18 [V]	
EP current	15 [A]	40 [A]
Equator temp.	15 [C]	32 [C]
Beam tube temp.	0 [C]	5 [C]
Acid temp.	12 [C] or below	20 [C]
Removal rate	5 [μm/hour]	13 [μm/hour]
Acid circulation	1.5~2.3 [L/min.]	
Cavity rotation	1 [revolution/min.]	
Nitrogen gas flow	1 [L/min.]	

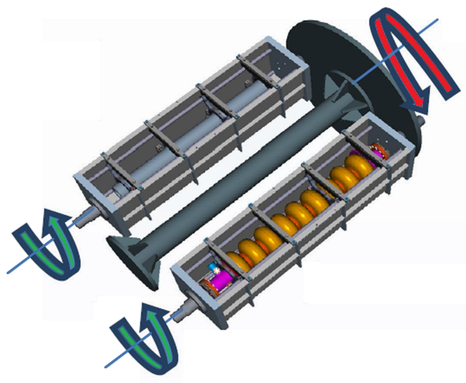
Fermi EP conditions for 1.3GHz single cell
Numbers are average values.

Centrifugal Barrel Polishing (CBP), so called "tumbling"

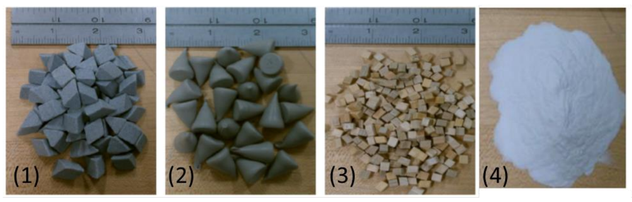
CBP tool and 1.3GHz 9-cell cavity in IB4 CPL
This tool has two cavity containers which could hold up to one 1.3GHz 9-cell cavity in each. The cavity rinsing tool post CBP is shown in front of CBP tool.

CBP is **mechanical** polishing techniques used on SRF cavities.
To perform CBP, the half volume of cavity is filled with polishing media and water.

The tool has two rotation axes: center axis and cavity axis.
The cavities rotated around the center axis with the rotation speed of ~100rpm and the cavity counter-rotated around its own axis (the cavity axis) with same rotation speed. These two rotation axes produce a strong centrifugal force on the media inside the cavity to remove material from the inner niobium surface.



CBP is performed in several steps, rough-, intermediate-, and fine-polishing, by using different sizes, shapes, and compositions of polishing media.



Examples of CBP media
(1) Course, K&M ceramic; (2) Medium, RG-22 cones; (3) hard wood blocks as carrier of (4) Al powder , size of below 18μm).

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