VERTICAL ELECTRO-POLISHING AT TRIUMF

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Abstract

A set-up for electro-polishing (EP) of a superconducting niobium (Nb) single-cell cavity has been installed at TRIUMF. A vertical method was selected to make the setup compact. To increase removal speed at the equator and remove hydrogen bubbles at the iris surface, 4 cathode paddles were rotated in the cavity cell during EP. The interest in Vertical EP (VEP) of elliptical cavities in the Superconducting Radio Frequency (SRF) community has lead TRIUMF to begin its own VEP program to determine if the lessons learned at other institutions would be able to yield a positive result with TRIUMF's unique methodology and expertise.

Working with experts from KEK, TRIUMF began to develop its own solution to the VEP problem. We are reporting on our first EP results.

INTRODUCTION

Electro-polishing (EP) is a tool that has been used in the SRF community to remove and polish the inner surface of niobium (Nb). EP is now the process that has been used to a smooth inner surface of an SRF cavity, which has lead these cavities, that were EP processed, being able to achieve higher gradients [1,3]. The current method of EP processing an elliptical cavity is by using the Horizontal EP (HEP) process. In these systems the cavities are mounted in the horizontal plane. These systems are extremely complex, requiring a large foot-print, as well as having sophisticated rotating fluid coupling and electrical connectors and a large dumping apparatus.

This is why many labs including TRIUMF and KEK have been looking at VEP as a simpler solution that can be used more widespread. VEP bring with it many challenges that are directly related cathode shape and operation. The major obstacles encountered when developing any EP system are uniform material removal and surface quality. But this becomes especially difficult in the vertical orientation due to the hydrogen bubbles and cathode shapes.

SYSTEM OVERVIEW

The VEP set-up that was used at TRIUMF incorporated many of the components used in the current Buffered Chemical Polishing (BCP) facilities used at TRIUMF. The system includes Perfluoroalkoxy alkane (PFA) tubing and fittings, with Polytetrafluoroethylene (PTFE) manual valves from the BCP program, with the addition off a rotary electrical contact that was produced in-house, and a 12 V-100 A DC switching power supply as the source of the electrical power needed for the process. The cathode assembly is driven by a 12 V reduction motor that turns at 30 rpm. The overall system diagram for the VEP system is shown in Fig. 1.

The VEP system currently has 34.5 L of H_2SO_4 HF electrolyte. The electrolyte has the same composition as the one used by many labs [1,2]. With a flow rate of 3.1 L/min through the cavity during etching the temperature was stable with passive cooling at approximately 30.6^{o} C

During the last trial the voltage and current were 3.1-3.7 V and 55.1 A with the power supply set to constant current.

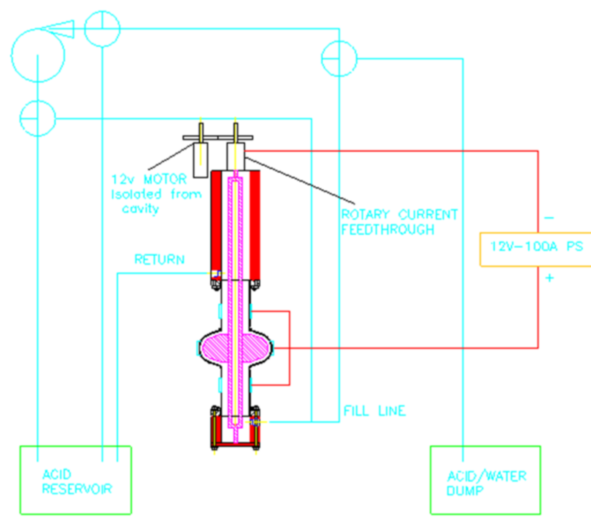

Figure 1: VEP system diagram.

EXPANDING CATHODE

To increase the chances of producing a uniform etch rate an expanding cathode was developed that increase the surface area inside the cell as well as decrease the electrical path length. This cathode has been nick-named D'Sonoqua. The major design requirement was to use pure aluminum for any part of the cathode that is in contact with the EP electrolyte.

It was decided to use 1100-H14 series aluminum for our cathode as that was the most readily available in our region. 1100 series aluminum is 99.0% pure at a minimum and it was decided that the increased availability would out weight the decrease in performance from the more pure 1050 series aluminum with a purity of 99.5%.

Interleaving Blade System

The system that was used to create the larger surface area inside the elliptical cell was by using a four blade system. The blades are able to be nested together to form

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a cylinder when in the closed position so that the cathode can be extracted from the cavity. When opened the blade expanded to fit into the area of the cavity cell.

The paddles were then connected to a yoke that ensured that they would stay stable during the operation of the VEP equipment. This yoke made it possible to operate the cathode without having to come in contact with the EP electrolyte.

The cathode can go from the open to closed position by loosening four retaining plates and rotating the paddles 180^{o} as shown in both Fig. 2 and Fig. 3. The cathode in the closed position used to insert the cathode into beam port of the cavity. The cathode in the open position with the paddles extended is used to remove the hydrogen bubbles, during operation that may be on the top of the cavity cell.

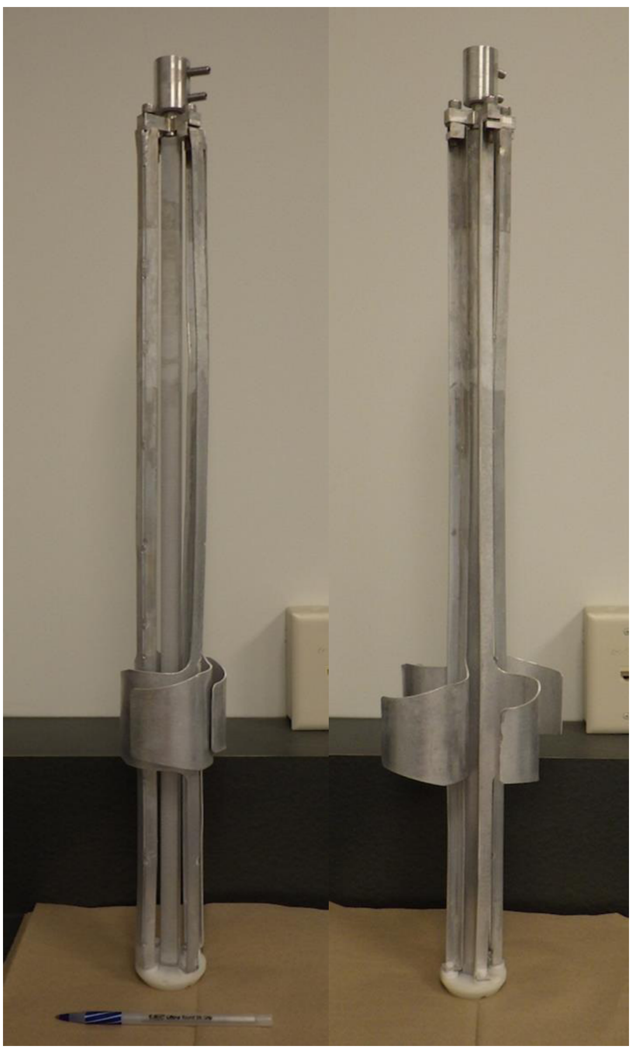

Figure 2: The cathode on the bench in both the closed and open configuration. Left-hand side: The cathode in the closed position. Right-hand side: The cathode in the open position.

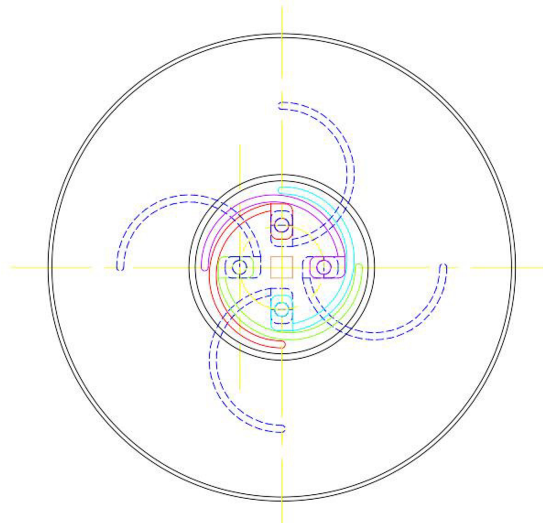

Figure 3: 2-dimensional drawing showing how the paddles would nest into one another to be able fit through the beam tube.

Cathode Rotation

To ensure that the cavity would have a uniform etch with a cathode shape that was not a simple profile, it was decided the cathode must be rotated. This also allowed the cathode to be used to move the hydrogen bubbles away from the upper half of the cell.

To allow the cathode to rotate it was necessary to use a rotary electrical coupling. For the sake of time a simple enclosed slip ring was constructed using beryllium-copper finger stock and a brass shaft. This was tested (Fig. 4) using 0.2 Ω/8 kW load bank at 12 V and 41.2 A for 30 mins under rotation with no heat generation in the contact.

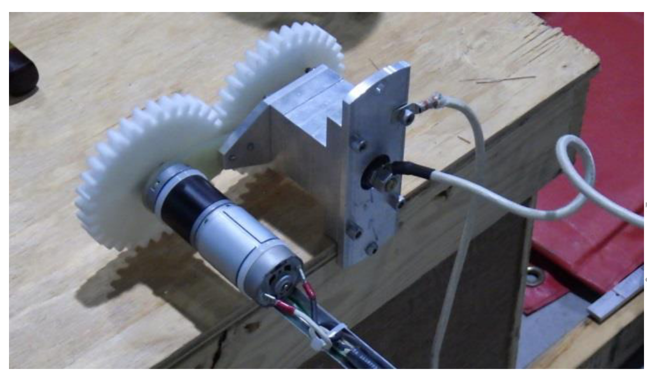

Figure 4: Rotary electrical contact and motor during load test.

To rotate the cavity a 12 V planetary reduction motor was used to rotate the cathode at ≈30 rpm. This speed was chosen as it was though it would be most likely to case the hydrogen bubbles to be removed from the surface of the Nb.

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THICKNESS MEASUREMENT

An important component to determine the validity of an etching process whether that be EP or BCP is to complete ultrasonic thickness measurements before and after the process to determine if there is any differential etching happening, as that effect the frequency of the cavity.

In our lab we have an Olympus 38DL PLUS that we created fixing rings on the cavity to locate the transducer in precisely the same location pre and post etch. This probe fixture and the position locations is shown in Fig. 5. That in combination with a large over-all VEP etch amount we were able to create a precise number at each of these locations.

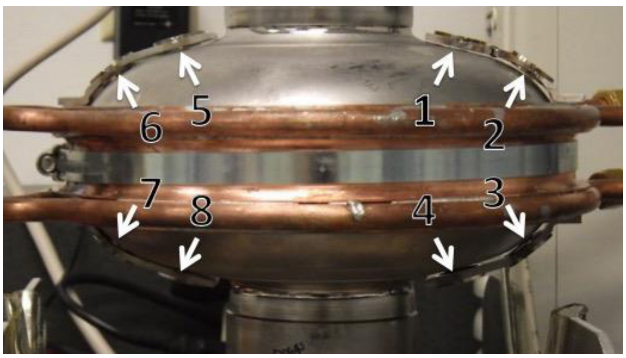

Figure 5: US probe fixture and positions.

Table 1 list the removed thickness at each of the eight locations on the US probe fixture, for the 120 min VEP with the current set-up.

Table 1: Summary of Etch Amounts

Position	Removal µm
1	125
2	69
3	55
4	52
5	125
6	74
7	57
8	51
Average	76

SURFACE FINISH

The surface finish of the cavity is extremely important. That is why we took great pains to photograph the inside of the cavity during the process. Pictures were taken before any VEP processing was done to the cavity to gain a base line of the surface finish before processing. After our first EP (30 min) we notice significant defining of the gran structure at both iris' and the equator. After our second EP (120 min) we noticed an improvement at the lower iris (Fig. 6), but the same grain definition to the upper iris and the equator.

The theory we have about this is that the hydrogen bubbles are causing those areas to be pitted by the a chemical interaction

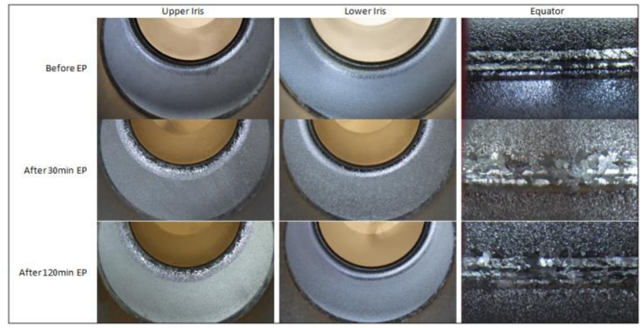

Figure 6: These pictures represent the different areas of the cavity after the first and second VEP experiments.

FUTURE IMPROVEMENTS

With these first few tests on VEP completed we can look at the deficiencies in our process and create a system that is able to perform as well as HEP. A number of these deficiencies have been identified. These include the following; adding a cathode bag to prevent hydrogen bubbles from migrating from the cathode to the Nb surface and causing pits, as well as decreasing the surface area to decrease the surface area of the cathode to increase the electrolytic cell resistance of the process to improve the polishing characteristics.

SUMMARY

With these first test results we have been able to identify where there is room to expand out, to improve our VEP set-up. We need to correct the hydrogen bubble pitting on the upper iris as this will have a very negative effect on performance. This test will be the first step to TRIUMF having a VEP process that will work on our 1.3 GHz cavities.

ACKNOWLEDGMENT

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