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POST PROCESSING OF A 166.6 MHz HEPS-TF CAVITY AT INSTITUTE OF HIGH ENERGY PHYSICS*

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Abstract

A 166.6 MHz Proof-of-Principle (PoP) superconducting RF cavity has been fabricated by IHEP for the High Energy Photon Source Test Facility (HEPS-TF) [1]. After a series of post-processing including chemical etching (BCP), high temperature heat treatment, High Pressure water Rinsing (HPR) and 120℃ baking, the cavity was cold RF tested and reached $E_{peak} = 86.5\ \mathrm{MV/m}$ and $B_{peak} = 132.1\ \mathrm{mT}$ with $Q_0 = 5.1 \times 10^8$ at 4.2K. The cavity was RF tested again at 2K, and reached $E_{peak} = 85.5\ \mathrm{MV/m}$ and $B_{peak} = 131.1\ \mathrm{mT}$ with $Q_0 = 3.3 \times 10^9$.

INTRODUCTION

HEPS-TF mainly aims at the research and engineering verification of the key technologies needed for the construction and operation of High Energy Photon Source. The 166.6 MHz superconducting RF cavity is built to verify the key techniques of cavity parts in the program, mainly focus on cavity manufacturing and post-processing [2, 3]. The cavity was fabricated by Beijing HE-Racing Technology Co., Ltd. (HERT). After surface grinding, the cavity was sent to Ningxia Orient Superconducting Technology Co., Ltd (OSTEC) to proceed the chemical etching, 750℃ annealing and initial high pressure water rinsing. Then the cavity was sent back to IHEP in Beijing to perform the final HPR and 120 ℃ baking. The 4.2K cold RF test results suggest that cavity reaches $Q_0 = 2.4 \times 10^9$ when cavity voltage is 1.5MV, exceeding the design target 1.5MV, $Q_0 > 5 \times 10^8$ @ 4.2K.

CAVITY PROCESSING

The BCP facility is placed on a two storey house, with acid supply tank and acid circulating pipe on the first floor, and acid Storage Tank and pure water tank are placed on the second floor [4]. First, the acid solution is mixed in the acid supply tank according to the standard BCP recipe (Hydrofluoric HF (49%), Nitric (69.5%), and Orthophosphoric (85%)). The acid is mixed evenly by a blower inside the tank, meanwhile, is cooled to 12℃ through a cooling chiller.

The cavity structure is relatively complex for chemical etching. It has eight flanges, one for power coupler, one for pick-up, two for beam pipes and another four flanges for HPR. The acid flows through the larger beam pipe port and flows out of the other seven ports, allowing the flow of acid to be substantially uniform at each outlet, as shown in Fig. 1.

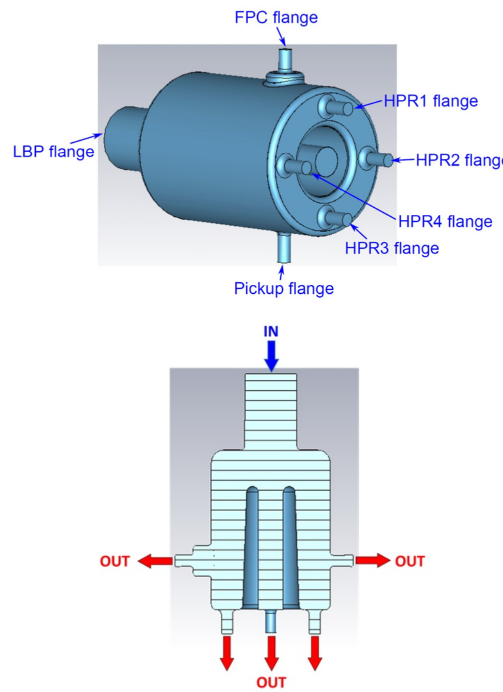

Figure 1: Acid path arrangement in cavity.

After the cavity is assembled in BCP system (see Fig. 2), the acid is pumped into the acid storage tank on the second floor, and then flowed into the circulation pipeline on the first floor by the action of gravity. In order to bring the heat generated by chemical action to cooling system, the acid is circulated in the system by a recirculation pump. This circulation and acid flow also help remove bubbles generated on the cavity surface so as to obtain a smooth cavity surface. During the acid circulation, two water chiller control the acid temperature ~15℃. After 75 minutes, ~70 μm etch is performed. The waste acid is dumped into an acid dump tank on the first floor and the DI water on the upstairs flows into the cavity and circulates about six circles to remove the residual acid on the cavity surface. Then the cavity is dismounted from the system and flipped vertically 180 degrees to perform another 50 μm chemical etching. During chemical etching, an ultrasonic gauge is placed on 28 locations on the outside surface of the cavity to monitor the etching amount. After 50 minutes etch and the following six cycles of DI water rinsing, the cavity is taken out of the pipe circulation system and sent to perform HPR to remove the residual chemicals on the surface.

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Figure 2: Buffered chemical polishing system.

After 120 μm of chemical polishing and following HPR, the cavity is sent to a vacuum furnace for high temperature annealing (Fig. 3). The recipe used here is 750℃ @ 3 hours, not the common recipe 600℃ @ 10 hours. This recipe refers to the spoke cavity annealing experience in Accelerator Driven Sub-critical System program (ADS) [5], it can greatly save annealing time. After annealing, 30 μm light chemical etching is performed to remove surface impurities. Then, for an hour of HPR, removing the surface chemical residue, the cavity is packed up and sent back to IHEP.

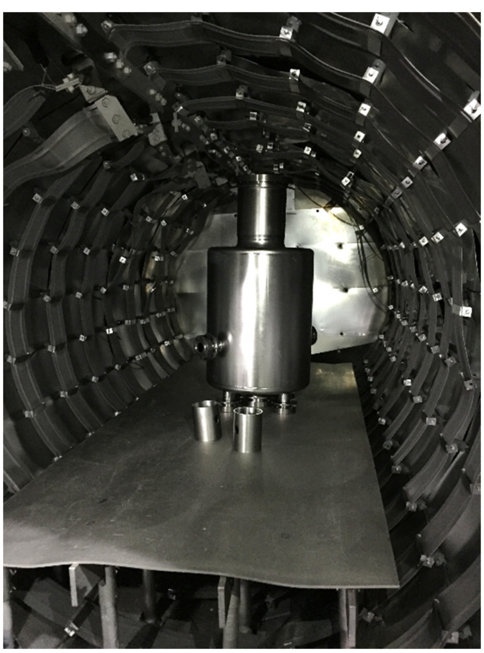
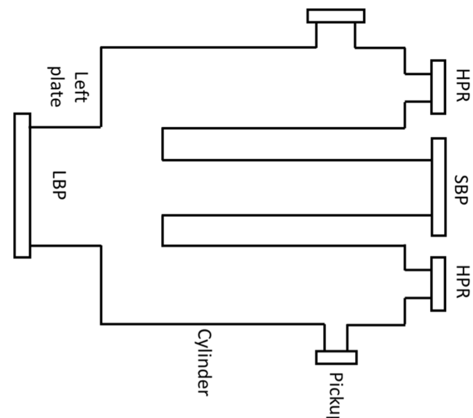


Figure 3: High temperature annealing furnace.

Fig. 4 shows the amount of etching at each part of the cavity after three rounds of chemical polishing. As can be seen from the diagram, the average surface removal of the main cylinder is approximately the same. LBP is removed by 135 μm, the cylinder left of the cavity is removed by 136.5 μm, and the right surface of cylinder is removed by 137.5 μm. The removal rate of the two end plates seems relatively large, the average removal amount of the left end plate reaches 180 μm, and the four HPR ports is averagely removed 211 μm. This is mainly because the acid liquid is flushed to the end plates of the cavity during the etching cycle, increasing the chemical reaction rate on the end plate of the cavity. Four data points are measured at each part in the diagram. The acid flow in the cavity is not completely homogeneous, so there is a discrete between the data points. The maximum discrete position is on the HPR port, the positive and negative deviation reaches 28 μm. The deviations of the data points measured in other four positions are less than 10 μm.



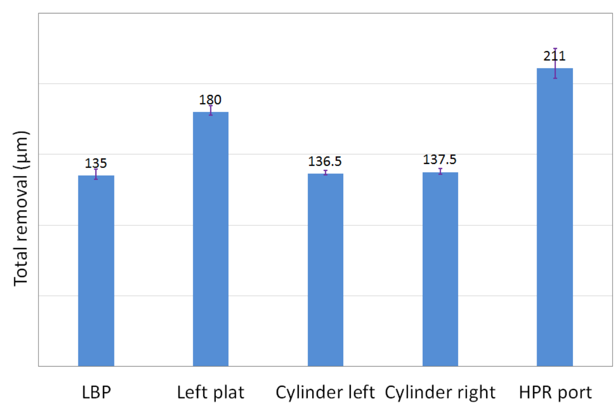


Figure 4: Amount of chemical etching.

The cavity is performed another HPR again at IHEP to remove the contamination during transportation for the final assembly. The cavity has eight ports, six of them are selected for HPR, two beam pipe ports and four HPR ports respectively. Through simulation and computation, these six ports can cover the inner surface of the whole cavity. During HPR, the spray wand moves up and down, with a movement rate of 30 mm per minute. The cavity is fixed on the turntable of the equipment and rotates at 4 rounds per minute. The pure water supplied to the HPR system is 1 tons of water output, and the resistivity is

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18MΩ · cm, which can satisfy the flow of 16 liters per minute in the HPR process. Since the four HPR ports are not on the central axis of the cavity, an eccentric counterweight is developed to balance the cavity during the four HPR port rinsing, as shown in Fig. 5.

After the HPR was finished, the cavity was assembled in a 10 class clean room and vacuum sealed then moved outside the clean room. A 120℃ @ 48 hours baking is performed after that as the last step of the post processing.

Figure 5: High pressure rinsing facility.

CAVITY TEST RESULTS

The cavity was vertically tested both at 2K and 4.2K temperature. The test results show that the cavity has reached the design goal and has a higher Q_0 value. As shown in Fig. 6, when the cavity voltage reached 1.5 MV at 4.2K, Q_0 reached 2.4×10^9 which is much bigger than the design objectives: $Q_0 > 5 \times 10^8, 1.5\text{MV}@\ 4.2K$.

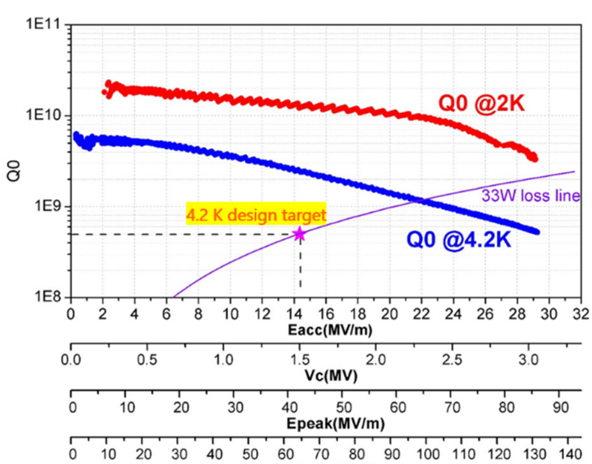

Figure 6: vertical RF test results of the PoP #1 cavity.

During RF test, increasing power in cavity continually, the cavity reached voltage 3.1 MV, $E_{peak} = 86.5$ MV/m and $B_{peak} = 132.1$ mT with $Q_0 = 5.1 \times 10^8$ at 4.2K. In 2K RF test, it reached voltage 3.0 MV, $E_{peak} = 85.5$ MV/m and $B_{peak} = 131.1$ mT with $Q_0 = 3.3 \times 10^9$.

CONCLUSION

This 166.6MHz superconducting cavity is the world's first low-frequency (<200MHz), high current (>200mA), high power (>150kW), beta=1 superconducting cavity. The cavity is fabricated by Beijing HE-Racing Technology Co., Ltd., and the post-processing is performed both in Ningxia Orient Superconducting Technology Co., Ltd (OSTEC) and IHEP. The test results reaches the design target and associated fabrication and post-processing techniques is verified. It is an important milestone of HEPS-TF project.

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