SURFACE TREATMENT FACILITIES FOR SCRF CAVITIES AT RISP

J. Joo#, D. Jeon, M. J. Joung, Y. Jung, H. J. Kim, M. Lee, IBS, Daejeon, Korea

Abstract

Rare isotope science project (RISP) is engaged in the fabrication of four types of superconducting RF cavities. The surface treatment is one of the important processes of superconducting RF cavity fabrication. New superconducting RF cavity processing systems have been designed and developed for the etching of niobium in buffered chemical polish at RISP. The safety precautions used in protecting the operator from the acids used in the etchant and from the fumes given of during the process are discussed. All of the new hardware will be located in RISP Munji superconducting cavity test facility.

INTRODUCTION

The heavy-ion Accelerator complex, RAON, has been constructing in Daejeon, Korea [1]. Four different types of superconducting niobium cavities for RAON have been developed: Quarter Wave Resonator (QWR), Half Wave Resonator (HWR), Single Spoke Resonator 1 (SSR1) and Single Spoke Resonator 2 (SSR2). The cleanliness of the inner surface of cavities is an essential condition for the successful performance [2]. In the preparation of superconducting niobium cavities for testing at cryogenic temperature, surface damage and contamination caused by mechanical deformation are must removed by chemical etching. This is followed by a high pressure water rinse (HPWR) of the inside of the cavity to remove any chemical stain or niobium salts that remain following the chemical etching. After the HPWR the cavity is dried in a class 100 cleanroom to keep the cavity is particulate free prior to attachment of vacuum components and RF test probes. In addition, following a particularly aggressive chemical etching commonly referred to as buffered chemical polishing (BCP), where 100-150 μm of material is removed, the cavity is baked at 600-1200 °C in a high vacuum furnace for hydrogen degasing from the bulk niobium.

FACILITY DESCRIPTION

RISP Munji superconducting cavity test facility contains chemical processing room, ultrasonic cleaning, wet cleanroom for HPWR and heat treatment room for high vacuum furnace. Each specific area to be mentioned below has its own purposed, optimum size and class. Chemical processing room has 9 x 8 m^2 and is set a class 1000 cleanroom. Ultrasonic cleaning area has 5 x 3 m^2 and is set a class 1000 cleanroom. HPWR area has 3 x 3 m^2 and is set a class 100 cleanroom. Heat treatment room has 14 x 10 m^2 and is set a class 1000 cleanroom. DI water supply system is also installed inside cavity process area. The layout of surface treatment area in RISP Munji superconducting cavity test facility is shown in Figure 1.

#joojd@ibs.re.kr

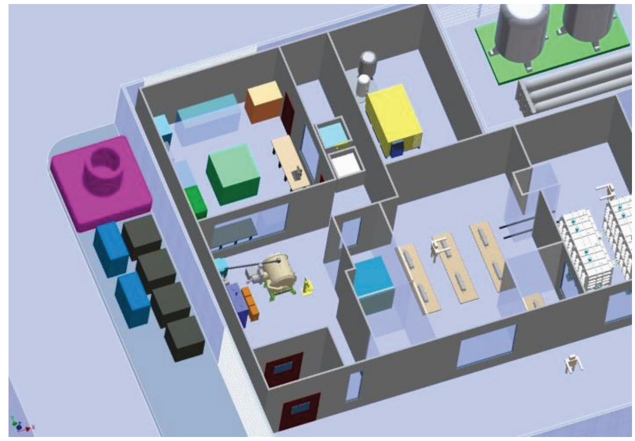

Figure 1: 3-dimensional view of the surface treatment facilities

BCP Cabinet

Chemical etching is accepted worldwide as a method to remove mechanically damaged and contaminated surface from superconducting cavities. There are two major approaches to chemical etching used for superconducting cavity production: BCP [3] and electrochemical polishing (EP) [4].

In RISP, BCP is chosen as a chemical treatment because BCP has been widely understood. Mixture of 1 part HF (49%), 1 part HNO_3 (69%) and 2 parts H_3PO_4 (85%) are used in BCP. The BCP cabinet is currently under construction. The BCP cabinet, manufactured by VITZRO TECH, is designed to accommodate a cavity that is 1000mm long, 250mm in diameter. The BCP cabinet, shown in Figure 2, is designed with safety as a first consideration [5]. The chemical storage tank can hold 100 liters of acid.

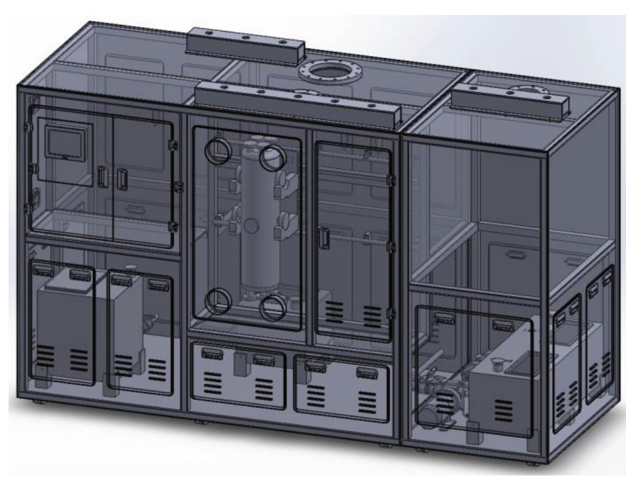

Figure 2: Perspective view of BCP cabinet for RISP cavities

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Since the acid temperature must be kept below 15 °C during BCP for the uniform and reliable etch rate, RISP uses a heat exchanger made of PVDF. In order to prevent any chemical exposure from users during BCP, all of acid circuits and barrels are made by Teflon, HDPE and PFA. After BCP is finished, the acid is dumped into the storage tank. Then the cavity must be filled with ultra-pure water immediately for rough rinse. Several rinsing cycles are performed in order to reach the target level of resistivity. The entire process can be controlled by a semi-automatic system and programmed with a variety of recipes depending on the cavity being processed. The system is also equipped with PLC control system so that monitored in real time as a function of time and temperature. To neutralize toxic gases released during BCP, RISP will install scrubber that has an enough capability for neutralization. Table 1 summarizes the specifications and parameters of BCP for RISP.

Table 1: RISP BCP system specifications and parameters

Mixed acids	HF, HNO_3, H_3PO_4
Nb concentration in acid	not exceed 15 g/L
Operation temperature	10-15 °C
Acid flow rate	10-80 lpm
Etch rate	1-2 μm/min.
DI water for rinse	18 Mohm
Materials	PVDF, PTFE, HDPE, PFA, stainless steel, etc.

Ultrasonic Cleaning

The ultrasonic cleaning process is for the removal of impurities and inclusions of metallic particles created by deep drawing deformation and electron beam weld. Also, in order to degrease, cavity undergoes ultrasonic cleaning in 1% liquinox solution. Ultra-pure water made from DI water supply system will be supplied through a 0.1 μm filter. The ultrasonic cleaning bath is under construction.

High Pressure Water Rinse

The HPWR using ultra-pure water is used to remove residual particles and reduce the chance of field emission from the inner surface of cavity [6]. The HPWR cabinet was developed by RISP and is designed to accommodate all types of RISP cavities. The HPWR cabinet can be reconfigured vertically or horizontally easily to process all types of RISP cavities. Design goal of this HPWR cabinet is to set up a prototype HPWR stand applicable in mass production line. After commissioning, the new HPWR cabinet will be developed as a standard hardware in use for the surface treatment processes at RISP. This HPWR cabinet will be located in a class 100 cleanroom. The HPWR can provide up to 20 liter per minute water flow at 250 bar maximum pressure to rinse the inside of the superconducting cavities. The ultra-pure water for the HPWR is supplied through 0.01 and 0.05 μm filters. Table 2 shows specifications of the HPWR cabinet. 3-dimensional model of HPWR is shown in Figure 3.

Table 2: Specifications of high pressure water rinse cabinet for RISP

Water quality	18 Mohm
Water filter	0.01 and 0.5 μm
Max. water pressure	250 bar
Nozzle rotation speed	0-10 rpm
Nozzle travel range	0-1500 mm
Dimension	1600 x 1200 x 2800 mm

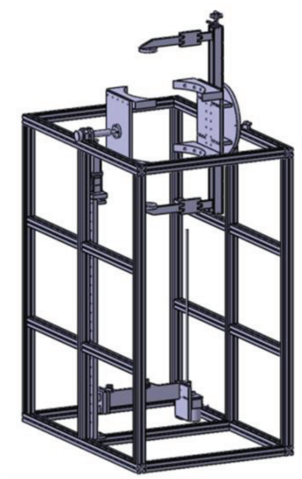

Figure 3: 3-dimensional model of high pressure water rinse cabinet

DI Water Supply System

Both BCP and HPWR cabinets will be connected into the 18 Mohm DI water supply system. The DI water supply system, shown in Figure 4, is designed to provide 18 Mohm DI water at a make-up rate of ~8 lpm and is equipped with a 4000 liter storage tank to allow for HPWR and BCP processes to be carried out without worrying about the DI water shortage.

Figure 4: Picture of DI water supply system

High Vacuum Furnace

The superconducting cavity has to be baked in High vacuum furnace (HVF), shown in Figure 5, in order to degas hydrogen and remove some of the residual stress introduced during the mechanical deformation process. RISP has a plan to heat treatment at 600-1200 °C for 6-24 hours. The vacuum system of HVF is equipped with a cryo-pump to ensure the < 1 x 10^{-7} torr vacuum is maintained at high temperature. Also, the RISP's furnace has Molybdenum heating element and will be installed in a class 1000 cleanroom to minimize contamination of the furnace and subsequently the cavities during heat treatment. Table 3 summarizes the detailed specifications of HVF for RISP.

Figure 5: High vacuum furnace of RISP

Table 3: Specifications of high vacuum furnace for RISP

Ultimate vacuum range	1 x 10^{-7} torr
Operating vacuum range	1 x 10^{-6} torr (@600°C) 1 x 10^{-5} torr (@1000°C)
Operation temperature	600-1200 °C
Temperature uniformity	± 5 °C
Usable work space	1000 x 1000 x 1500 mm
Heating material	Molybdenum

CONCLUSION

RISP has been developed to perform surface treatment facilities of superconducting cavity. These facilities will be installed at RISP Munji superconducting cavity test facility. The BCP cabinet is designed with safety as a first consideration. Before the first mock-up cavity process, safety review and personnel training will be completed.

ACKNOWLEDGMENT

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