IHEP LOW-LOSS LARGE GRAIN 9-CELL CAVITY FABRICATION AND PROCESSING

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Abstract

The combination of the low-loss shape and large grain niobium material is expected to be the possible way to achieve higher gradient and lower cost for ILC 9-cell cavities. As the key component of the "IHEP 1.3 GHz SRF Accelerating Unit and Horizontal Test Stand Project", a low-loss shape 9-cell cavity using Ningxia large grain niobium has been fabricated and surface treated at IHEP and will be tested at KEK. The fabrication procedure, surface treatment recipes as well as the SRF facilities are presented in this paper.

INTRODUCTION

As the key component of the "IHEP 1.3 GHz SRF Accelerating Unit and Horizontal Test Stand Project" [1, 2, 3], a low-loss shape 9-cell cavity using Ningxia large grain niobium was fabricated and processed at IHEP. At the same time, The CBP (centrifugal barrel polishing) machine, the BCP (buffered chemical polishing) facility, the pre-tuning machine and the large ultrasonic cleaner etc. for the 9-cell cavity were constructed, commissioned and successfully operated at IHEP. The cavity processing recipe is:

- CBP 190 μm
- BCP 110 μm
- Annealing 750 °C, 3 hours
- Pre-tuning
- BCP 20 μm
- Ultrasonic cleaning

The cavity will be sealed and shipped to KEK and tested after HPR and baking at STF.

CAVITY FABRICATION

The large grain niobium disks were provided by OTIC, Ningxia, China. The measured RRR value was 430. Ultrasonic and eddy current scanning were performed on some of the disks [4]. The measured mechanical behaviors at room temperature and 4.2 K (Fig. 1) are listed in Table 1. The data are the average of different samples with different crystal orientations. Due to the special properties of the large grain material, several mechanical and RF problems were found and successfully solved during the fabrication and EBW of half cells and dumbbells. The dumbbell equators were reshaped and trimmed to have the right length and frequency [4]. We inspected and carefully grinded most of the defects on the inner surface of the dumbbells, especially we totally removed one layer of the iris EBW area.

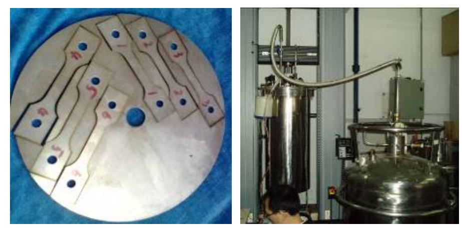

Figure 1: Large Grain Nb samples and test stand

Table 1: Mechanical behaviours of the large grain Nb

Temp.	Tensile Strength	Young's Modulus	Poisson's Ratio	Elong -ation
300 K	92.3 MPa	76.8 GPa	/	40 %
4.2 K	566.2 MPa	111.5 GPa	0.225	8 %

For the equator EBW, we matched the dumbbells with similar equator inner diameters and also to make the combined cell frequencies similar. Fig. 2 shows the cavity after final EBW. Fig. 3 shows the field flatness as delivered, which is 70 %, because the 2nd cell had the largest frequency before EBW.

Figure 2: IHEP low-loss large grain 9-cell cavity

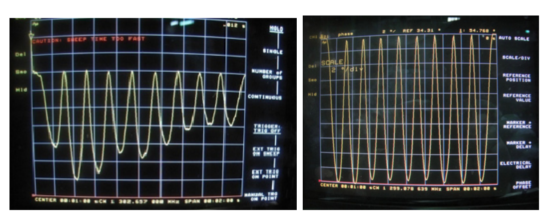

Figure 3: 9-cell cavity field flatness as delivered (70 %) and after pretuning (97.6 %)

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We used the laser tracking instrument to check the key dimensions of the cavity. The total length (flange to flange) is 1252.85 mm and the concentricity of the 9 cells is 0.86 mm. The designed value are 1247.4 mm and 0.8 mm respectively. During pretuning, we will only squeeze the cells to make the cavity frequency down and the cavity shorter as planned.

INNER SURFACE INSPECTION

We made a simple camera system to inspect the inner surface especially the equator EBW area of the cavity (Fig. 4). Many sputters were found in the equator area of cell#2 to cell#8. We are still investigating the reason of sputtering.

Figure 4: Inspection camera and the equator area of cell#2 as delivered

CBP

Due to the EBW problem, we made 12 times CBP on this cavity with different abrasives (SiC, Al_2O_3), bonders (ceramic and plastic), stone shapes and filling amount (Fig. 5). The rotation speed around the cavity axis was 100 - 150 rpm, and 100 rpm around the machine axis. It took about 62 hours to totally remove 190 μm of the equator wall thickness.

All the sputters were removed while several defects were still found on the EBW seam of cell#3 (Fig. 6) and cell#4. Fig.7 shows the possible defects in the equator of cell#9 as delivered, but it disappeared after intense CBP.

Figure 5: 9-cell cavity installed in the CBP machine and the grinding stones (up: before use; down: after use)

Figure 6: Cell#3 equator area before and after CBP

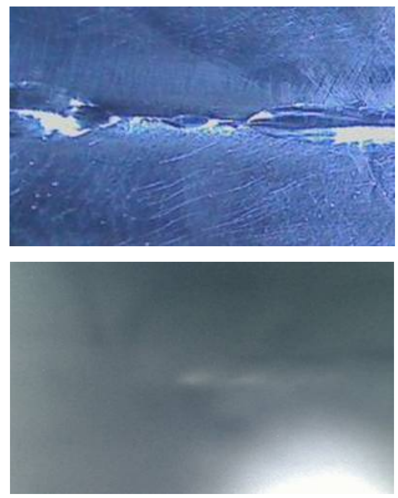

Figure 7: Cell#9 equator area before and after CBP

BCP

IHEP constructed and commissioned a closed loop buffered chemical polishing facility [2]. The cavity is vertically installed and the cooled water sprays on the cavity wall during CP. The mixed acids fill in the cavity by gravitation from the acid storage tank in 30 seconds. Then the circulating pump starts and the acids go through the cavity and the 1 kW heat exchanger. After the treatment, the acid is drained to the waste acid tank. Ultra pure water fills in and the pump stars again to rinse the cavity. This will repeat for 4 - 5 times. The acid flow rate can be monitored and adjusted. The normal flow rate is 10 - 30 liters per minute. The storage acid and the spray water are also chilled below 10 $^{\circ}$C. The acid temperature at the exit of the cavity and the temperature outside the cavity wall are monitored. Teflon coated Viton O-rings are used to seal the cavity flanges.

The planed CP amount was 100 μm and the estimated etching rate of the HF: HNO_3: H_3PO_4 1:1:2 acids is 1μm / min. The upper limit of the Nb solved in the acid is 10 g / L. So we made 4 times CP and each time took 25 minutes. For the second and fourth CP, we reversed the cavity to make the etching more uniformly. During CP, the acid temperature at the cavity exit was 13 - 15 $^{\circ}$C.

Fig. 8 shows the cavity installed in the CP cabinet, the thermal sensors attached on the cavity wall and the spray water nozzles. After CP, the cavity was rinsed by pressured water (10 - 20 bar). The measured etching amount of the equator wall thickness was 114 µm.

Figure 8: 9-cell cavity in the vertical CP facility

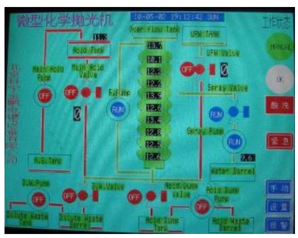

Figure 9: Control panel of the CP facility

ANNEALING

We made 750 °C, 3 hours annealing (out gassing) at OTIC, Ningxia. The vacuum was better than 10^{-3} Pa during annealing.

Figure 10: 9-cell cavity annealing

PRETUNING

We pre-tuned the cavity field flatness to 97.6 % (Fig. 3). The target pretuning frequency is 1299 MHz allowing for further surface treatment after the first vertical test and reach the final target 1297.4 MHz. The frequency and mass data of the 9-cell cavity during processing are summarized in Table 2.

Figure 11: 9-cell cavity pretuning

Table 2: Frequency and mass after each treatment

Treatment	Freq. / MHz	Mass / kg
EBW	1302.631	23.984
CBP	1300.718	23.028
1st CP	1300.007	22.048
Pretuning	1299.110	/

ULTRASONIC CLEANING

A large ultrasonic cleaner is made for the 9-cell cavity. The effective volume is 650 mm × 650 mm × 1500 mm. The total vibration power is 8 kW. The heater power is 12 kW. The oscillation frequency is 40 kHz. The water in the tank circulates through a filter during cleaning.

Figure 12: Ultrasonic cleaner for the 9-cell cavity

SUMMARY

IHEP has made a low loss shape large grain niobium 9-cell superconducting RF cavity. The cavity is fabricated, welded and successfully processed (CBP + CP) with the SRF facilities developed in IHEP. We will make the first vertical test of the cavity in KEK STF in this summer.

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