FIRST TEST RESULT OF THE IHEP-01 LARGE GRAIN 9-CELL CAVITY

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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, and will be essencial for the ILC 1 TeV upgrade. 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 (IHEP-01) was fabricated and surface treated (CBP, CP, annealing, pre-tuning) at IHEP. Then the cavity was shipped to KEK STF for ultrasonic cleaning, high pressure rinsing, baking and vertical test. The cavity reached 20 MV/m in the first vertical test on July 1st 2010. The quench locations have been found by T-mapping and optical inspection. The strong field emission and equator defects will be removed by further treatment. The fabrication procedure, surface treatment recipes and the first test results are summarized in this paper.

INTRODUCTION

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, and will be essencial for the ILC 1 TeV upgrade.

From the excellent single-cell test results (50 MV/m with very small scattering) by KEK, there is clear physical reason and enough data to support low-loss shape for higher gradient. However, for 9-cell cavities, the highest gradient of low-loss shape without end groups is about 35 MV/m and below 30 MV/m with end groups. Much more efforts are needed to solve this problem.

The cost reduction of the large grain niobium cavities lies in the newly developed multi-wire slicing technique on large grain niobium ingots. Large grain cavities were expected to reach ILC gradient specification with only buffered chemical polishing (BCP), thus reducing the cost of electro-polishing (EP). While some initial results in DESY showed that EP is still necessary for high gradient 9-cell large-grain cavities for ILC. More investigation and data are needed to verify this claim.

IHEP has started R&D on the 1.3 GHz large grain cavity since 2006. Three electro-polished ICHIRO single-cell cavities were fabricated and processed in KEK with Ningxia large grain niobium material provided by IHEP. The maximum gradient achieved was 47.9 MV/m [1-3].

Then two low-loss shape single-cell cavities using Ningxia large grain niobium were fabricated and surface treated by IHEP and tested at KEK in early 2008. One of the chemical polished cavities (without electropolishing) reached the high gradient of 40 MV/m without Q-slope [4-6]. These results showed apparent advantages of large grain over fine grain material.

As the key component of the "IHEP 1.3 GHz SRF Accelerating Unit and Horizontal Test Stand Project" [7, 8, 10], a low-loss shape 9-cell cavity without HOM couplers (IHEP-01) 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.

Then the IHEP-01 cavity (Fig. 1) was shipped to KEK STF for ultrasonic cleaning, high pressure rinsing, baking and vertical test.The cavity reached 20 MV/m in the first vertical test at KEK STF on July 1st 2010. The possible quench locations were found by T-mapping and optical inspection. Strong field emission needs to be removed by further treatment. The fabrication procedure, surface treatment recipes and the first test results are summarized in this paper.

Figure 1: IHEP-01 large grain 9-cell cavity.

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 [9].

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. Earrings and steps were found in the equator area. Large cracks and unsmoothness were found between adjacent grains in the iris area. Iris wall thickness was not uniform after trimming.

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The dumbbell equators were reshaped and trimmed to have the right length and frequency [9]. 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.

For the equator EBW, we matched the dumbbells with similar equator inner diameters and also to make the combined cell frequencies similar.

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.

SURFACE PROCESSING

The cavity processing recipe is (Fig. 2):

- CBP 190 μm
- LPR (Low Pressure water Rinsing)
- 1st BCP 110 μm
- Outer surface light CP
- Annealing 750 °C, 3 hours
- pre-tuning
- Ultrasonic cleaning with 2 % Micro-90 and UPW
- LPR
- 2nd BCP 20 μm
- ultrasonic cleaning with UPW
- LPR, dry in class 10 clean room
- fill in Ar gas and ship to KEK
- Flange grinding and CP
- Ultrasonic cleaning with 2 % Liquinox 3 h, 43°C
- HPR (8.5 h)
- Assembly, pumping
- Baking 48 h, 105°C

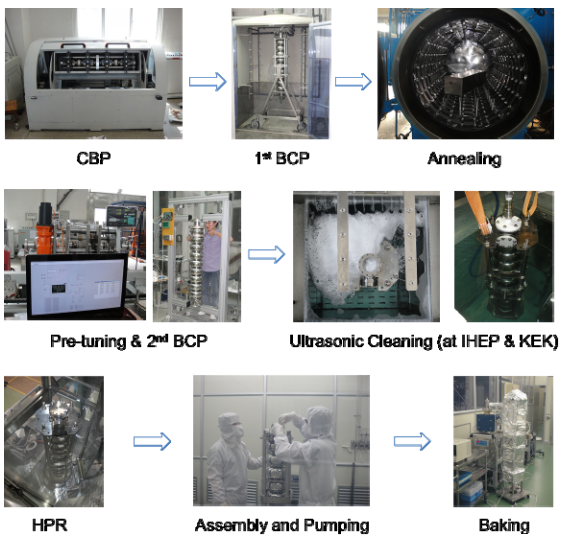

Figure 2: Surface processing for IHEP-01 cavity.

PRETUNING

We pre-tuned the cavity field flatness to 97.6 % without the cavity jig and 94 % after jig fitting (Fig. 3 left). 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. After vertical test, the field flatness reduced to 90 % (Fig. 3 right).

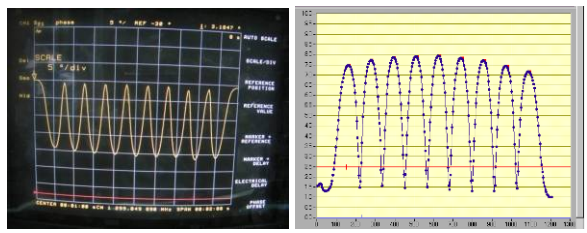

Figure 3: IHEP-01 9-cell cavity field flatness before (94 %) and after vertical test (90 %).

VERTICAL TEST RESULTS

Figure 4 shows the first test result of IHEP-01. Strong filed emission was found in 4 K test. Field emission started at 15 MV/m and became very strong at higher gradient at 2K. The gradient was limited by hard quench at 20 MV/m on the equator of cell #9 270-300°.

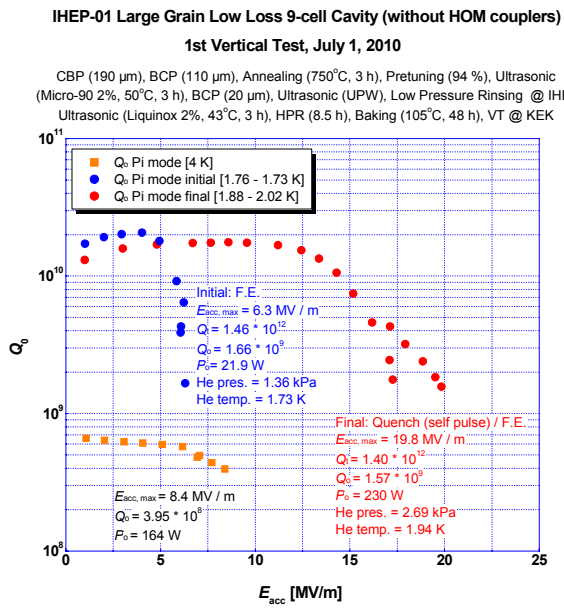

Figure 4: Test result of the IHEP-01 large grain los-loss shape 9-cell cavity (without HOM couplers).

Passband modes test (Fig.5) showed that the gradient of three cells were higher than 30 MV/m. T-mapping showed that the quench locations were on the equator of cell #9 (20 MV/m) and cell #2 (33 MV/m).

The 270-300° area on the equator of cell #9 was suspected to be problamatic as delivered (Fig. 6 top). After CBP, all the defects seemed to be removed (Fig. 6 middle). After the vertical test, two small defects (about 1mm long) were found in this area by optical inspection

with Kyoto Camera, which may be the reason for the hard quench.

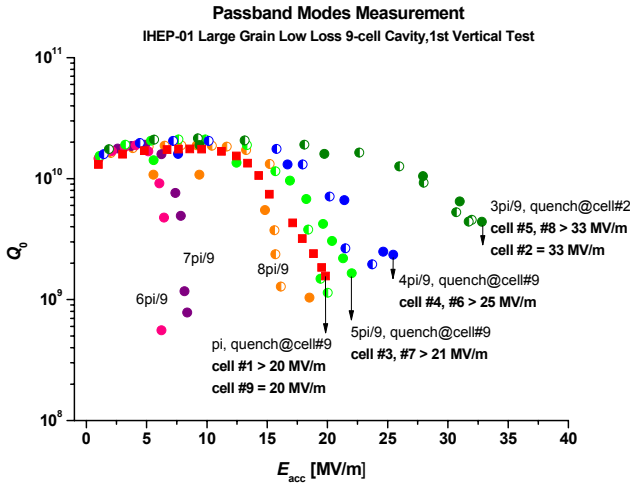

Figure 5: Passband test results of IHEP-01.

Figure 6: Cell #9 equator 270-300° as delivered(top), after final CBP (middile) and the 1st vertical test (bottom).

SUMMARY

IHEP has made a low loss shape large grain niobium 9-cell superconducting RF cavity. The cavity was fabricated, welded and successfully processed (CBP + CP) with the SRF facilities developed in IHEP. The gradient was limited by hard quench in the vertical test at KEK STF. We will grind the defects and make further surface treatment and test again in the near future.

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