

TESTS ON THE 1.3 GHZ LOW LOSS SINGLE-CELL RF SUPERCONDUCTING LARGE GRAIN CAVITIES OF IHEP*

Z. G. Zong[#], J. Gao, H. Sun, F. C. Zhao, J. Gu, M. Q. Ge, Q. J. Xu, J. Y. Zhai, D. Wang, IHEP, Beijing, China

Z. G. Zong, T. X. Zhao, L. Q. Liu, L. Zhang, L. Y. Xiong, TIPC, Beijing, China
K. Saito, F. Furuta, T. Saeki, KEK, Tsukuba, Ibaraki-305-0801, Japan

Abstract

To contribute to the International Linear Collider (ILC) R&D on the 1.3 GHz low loss cavities has been carried out at IHEP since 2005. Six cavities had been fabricated by the standard technology and treated by some procedures of surface treatments, such as centrifugal barrel polishing, barrel chemical polishing, annealing, high pressure rinsing and baking at in-house IHEP. Because of the shortage of liquid helium in Beijing two large grain cavities with a fine grain cavity were sent to KEK for vertical tests. The large grain cavities was tested and treated at KEK and finally both reached the accelerating gradients of more than 35 MV/m with the maximum of 40.27 MV/m. This paper presents the testing and results of the large grain cavities.

INTRODUCTION

The accelerating gradient in the ILC main linac is supplied by over 16,000 9-cell superconducting RF cavities. The TESLA 9-cell superconducting cavity made of fine-grain polycrystal niobium was chosen as the baseline design[1]. For the vertical test the specific requirements on the accelerating gradient and Q -value of ILC baseline design are 35 MV/m and 0.8×10^{10} or greater. Although in the recent years this goal gradient has been demonstrated, reliable achievement in the 9-cell cavity is still a major challenge. On the other hand, the ILC cost could significantly be reduced by increasing the achievable gradient and simplifying the fabrication and surface treatments. Alternative cavity shapes, fabrication materials and recipes of surface treatments are being studied to solve current issues.

New cavity shapes, such as the re-entrant shape by Cornell University and the ICHIRO design by KEK, have been successfully tested as single cell structures to the gradients of near 50 MV/m. In 2006, a low loss cavity shape was also designed at IHEP (We called it IHEPLL, the same hereinafter) and it was similar to the ICHIRO shape[2]. Since the large grain (LG) niobium being available from some material vendors, many laboratories have developed the single or multi cell cavities made of large grain niobium [3]. The R&D resulted in the encouraging productions and the new material showed the potentials to address the present challenges. In the framework of ILC cooperation between IHEP and KEK, we studied the effect of electro-polishing (EP) on the

single-cell LG cavities with the ICHIRO shape [4]. The maximum accelerating field reached 47.9 MV/m and the features of surface treatments based on the EP on the LG cavities were summarized by our research program.

Encouraged by the promising results, we continue the single-cell LG cavity research with the low loss shape. Six single-cell cavities with the IHEPLL shape were manufactured at IHEP, two of which were made of China Ningxia large grain niobium [5]. A complete process of surface treatments (without EP), including centrifugal barrel polishing (CBP), annealing, barrel chemical polishing (CP) and baking, was carried out to the two LG cavities at IHEP. Unfortunately, the vertical test at IHEP was limited by the shortage of liquid helium. The two LG cavities and a fine grain cavity (shown in Figure 1) were sent to KEK. All the tests of the two LG cavities reached the accelerating gradients of more than 32 MV/m and the maximum was 40.2 MV/m.



Figure 1: Cavities (Left two: China Ningxia Large Grain Niobium; Right: China Ningxia fine grain niobium) with the IHEP low loss shape fabricated at IHEP.

CAVITIES FABRICATION AND SURFACE TREATMENTS

As details about cavities fabrication and surface treatments could be found in Ref. [5], just a brief review is given here. The IHEPLL shape has H_{pk}/E_{acc} of 35.47 Oe/(MV/m) for the single-cell cavity with beam-pipes. Standard technology was employed to fabricate the cavities. Although the deviation values of the roundness at the equator and iris region of the LG half-cells were larger, electron beam welding just from outside successfully joined them together. Two LG cavities were treated with CBP, annealing and CP. As the experimental condition was

*Supported by National Natural Science Foundation of China(10525525)
zongzg@gmail.com, TIPC & IHEP, CAS

limited, just a LG cavity, IHEPLG#2, was baked for the possible vertical test at IHEP.

RF TEST AND CAVITY PERFORMANCE

The two LG cavities, IHEPLG#1 and #2 with a fine grain cavity were sent to KEK for the vertical tests.

IHEPLG#2

At IHEP IHEPLG#2 had been treated with all the surface treatments and assembled with couplers. For the shipping the inside of the cavity was kept in vacuum. At KEK the cavity was evacuated again and tested firstly. Because the input coupler was loose and the input antenna would have perhaps touched the inner surface during shipping, the first RF test was limited by the strong field emission. The cavity was rinsed by high pressure water only for 15 min. and assembled with KEK couplers. (As our couplers disagreed with the flange support of the cryostat and all the tests in this paper adopted the KEK couplers). In the second test the accelerating gradient reached 36.5 MV/m before quench happened at the high gradient as shown in Figure 2. Then the field could reliably stay at 34.72 MV/m with a high quality factor of 1.49×10^{10} . This test confirmed our fabrication technology on the high gradient SRF cavity.

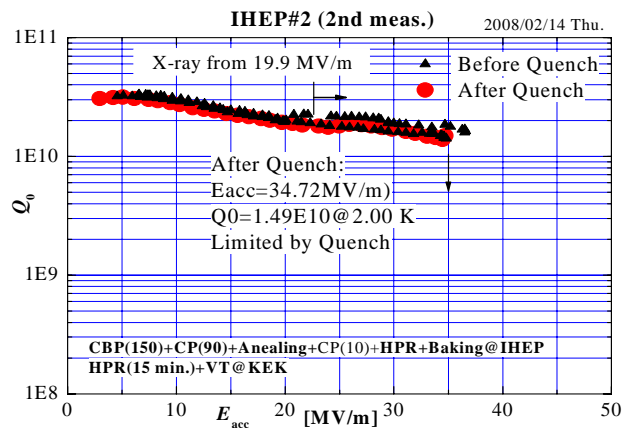


Figure 2: The second performance curve of IHEPLG#2.

Following the second test the cavity was warmed to about 95 K and stayed naturally at 100 ± 20 K for 39 hours as indicated in Figure 3. The performance of the 2nd and 3rd test was compared in Figure 4 and the performance was not affected by being exposed to the dangerous temperature region. Our technology was also qualified in the light of avoiding Q-disease.

To improve the performance of the cavity, the surface was removed 50 μm by additional chemical polishing and baked 48 hours at 125 $^{\circ}\text{C}$. In the following RF test, during the first power rise the initial field emission signal was caught at the gradient of 16.22 MV/m. A processing from 20 MV/m to 25 MV/m overcame the soft barriers of multipacting. The cavity looked to be limited by field emission with a distinct slope. At the gradient of 33 MV/m a multipacting barrier was also surmounted and

the quality factor was improved by the processing. The gradient reached 37.23 MV/m and relative to the other test the quality factor was low due to the field emission.

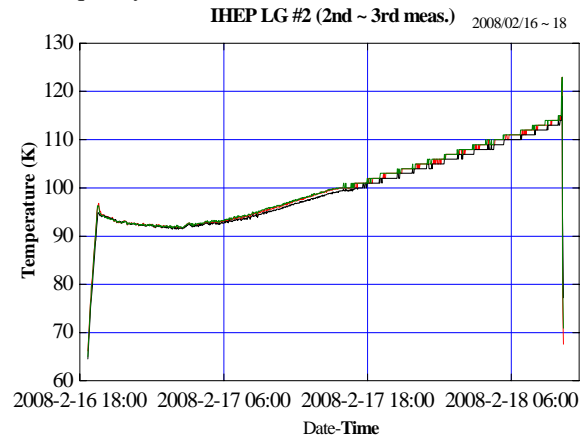


Figure 3: Temperature of the cavity at 100 ± 20 K

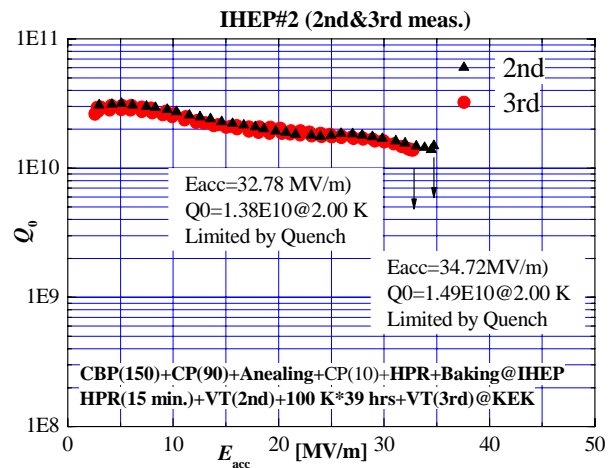


Figure 4: Comparison of the 2nd and 3rd test.

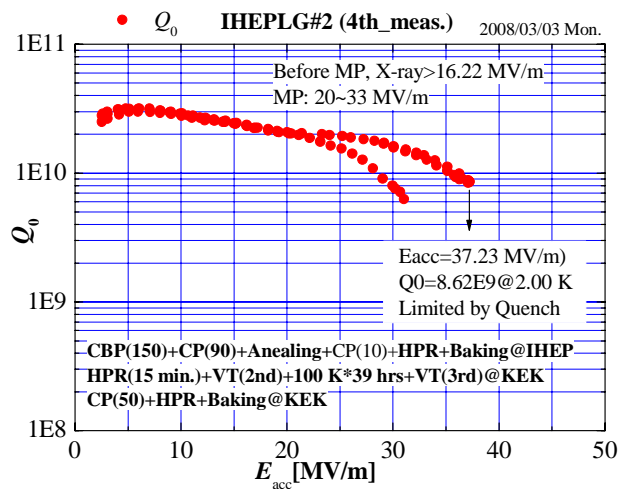


Figure 5: Excitation curve of the 4th test of IHEPLG#2.

For the 5th RF test the cavity was also removed 50 μm (total removal thickness reached 200 μm). The power could smoothly be increased to the gradient of 40.27

MV/m at Q_0 of 1.60×10^{10} without the signal of X-ray and multipacting as shown in Figure 6.

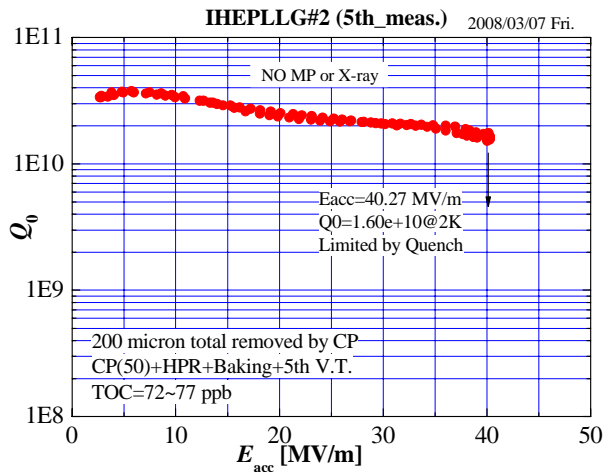


Figure 6: Excitation curve of the 5th test of IHEPLG#2.

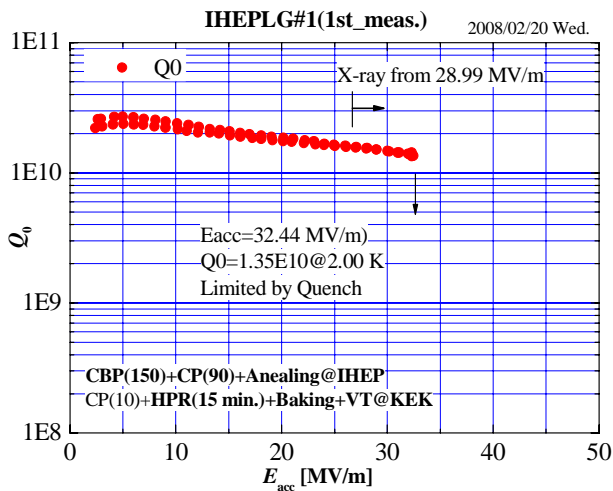


Figure 7: Excitation curve of the 1st test of IHEPLG#1.

IHEPLG#1

At IHEP IHEPLG#1 was processed parallel to IHEPLG#2 including the procedures of heavy chemical polishing of 90 μm and annealing. At KEK the cavity was polished by light CP of 10 μm , rinsed for 15 min. by high pressure water and baked as usual. The maximum accelerating gradient was 32.44 MV/m (Figure 7).

Finally the cavity reliably achieved 36.17 MV/m and 1.37×10^{10} after 30 μm and 70 μm chemical polishing as shown in Figure 8.

CONCLUSION

All the tests of IHEPLG#1 and #2 were limited by quench and the field levels continually improved with each CP removal thickness was shown in Figure 9. LG cavities treated by CP could be compared to the performance of EP and from this point of view they deserved the more attention of R&D. Our technology of the cavity design, fabrication and surface treatments was

confirmed from the series of the tests. R&D on the 9-Cell LG cavity has been started at IHEP, Beijing.

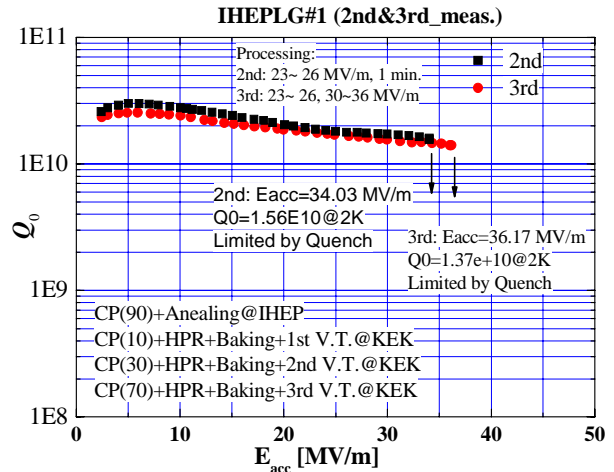


Figure 8: Excitation curve of the 2nd&3rd of IHEPLG#1.

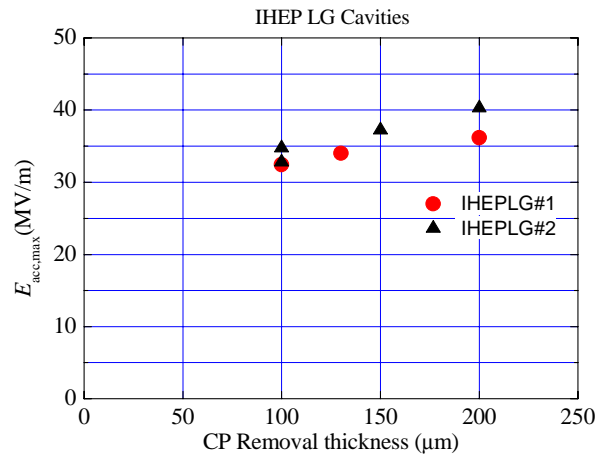


Figure 9: E_{acc} vs. CP removal thickness on IHEP large grain cavities (IHEPLG#1&IHEPLG#2).

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