DEVELOPMENT OF THE SUPERCONDUCTING CAVITY FOR ILC AT TOSHIBA

T. Ota#, N. Kuroiwa, K. Mori, T. Nagafuchi, K. Nakayama, S. Nomura, K. Sato, J. Shibuya, Y. Tajima, T. Tosaka, M. Urata, J. Watanabe, M. Yamada
TOSHIBA Corporation, 2-4 Suehiro-cho, Tsurumi-ku, Yokohama, JAPAN

Abstract

TOSHIBA has been developing the superconducting cavity for International Linear Collider (ILC) in cooperation with High Energy Accelerator Research Organization (KEK) since 2009. A 9-cell superconducting cavity was fabricated at TOSHIBA in 2010. Surface preparation and RF test of the cavity were performed at STF/KEK. The 2nd 9-cell cavity is just about to be fabricated now. This paper presents the status of superconducting cavity development for ILC at TOSHIBA.

INTRODUCTION

ILC is the next-generation particle accelerator and it is planned to have a collision energy of 500 GeV initially. Consisting of two linear accelerators that face with each other, the ILC will collide electrons with positrons, at nearly the light speed. Scientists and engineers around the world are collaborating to build the ILC.

KEK constructed Superconducting RF Test Facility (STF) to develop the cryomodule including high performance cavities and to establish the industrial design of a Main-Linac unit for ILC [1][2][3]. Development of the superconducting cavity is performed at TOSHIBA for the purpose of clarifying technical subjects and quality control to industrialize superconducting cavities through the collaboration with KEK.

9-CELL SUPERCONDUCTING CAVITY

The 9-cell superconducting cavity without HOM couplers was fabricated at TOSHIBA based on the STF Baseline cavity. Its main specifications are shown in Table 1. Figure 1 shows a drawing of the 9-cell cavity and figure 2 shows a completed 9-cell cavity.

Table 1: Specifications of 9-cell cavity

Frequency	1.3 GHz
Active length	1.038 m
Iris diameter	70 mm
Beam tube diameter	80 mm
R/Q	1036 Ω
Geometry factor	270 Ω

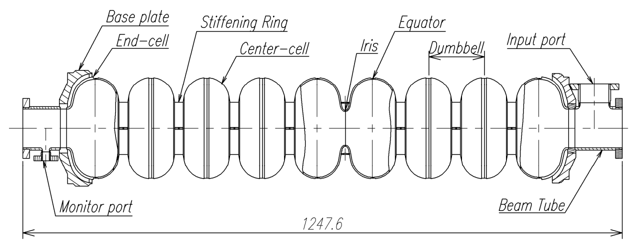

Figure 1: Drawing of 9-cell superconducting cavity without HOM couplers.

Figure 2: 9-cell superconducting cavity with supporting jig.

Cavity Fabrication

The half-cells shown in Figure 3 were formed from high purity niobium disks of thickness 2.8 mm by deep drawing. Figure 4 shows a dumbbell electron beam welded two half-cells at iris. To increase the stiffness of the cavity, stiffening rings were welded to the outside of iris. Two dumbbells were electron beam welded at equator as shown in Figure 5. Equator welds were all full penetration welds from the outside. 4-cell dumbbell is consists of two 2-cell dumbbells welded at equator, and 8-cell dumbbell is consists of two 4-cell dumbbells welded at equator. The 9-cell cavity was completed by welding two end-groups to the either ends of 8-cell dumbbell respectively. Figure 6 shows the end-group consisted of a niobium end-cell, a titanium base plate, a niobium beam tube welded the flange, and an input port welded the flange. All flanges are made from niobium-titanium. End-cells were formed from high purity niobium disk of thickness 3.7 mm by deep drawing.

#tomoko.ota@toshiba.co.jp

Figure 3: Niobium half-cells.

Figure 4: Dumbbell with stiffening rings.

Figure 5: 2-cell dumbbell.

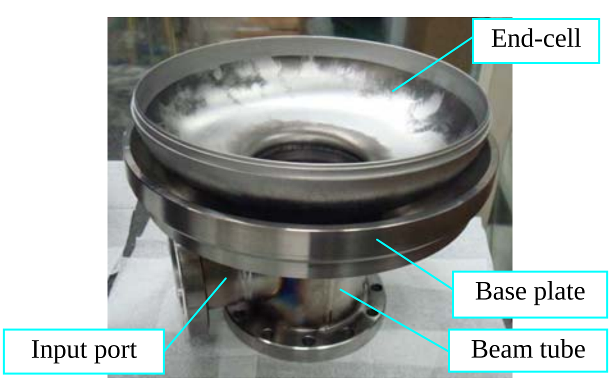

Figure 6: End-group by the side of input port.

Surface Preparation

The inner surface of the 9-cell cavity was inspected using the Kyoto camera system [4]. After the inspection, the standard surface preparation of KEK shown below was carried out to the 9-cell cavity. It took for about two months to carry out the surface preparation including the RF test.

- Initial electro-polishing to remove about 100 μm.
- Annealing in vacuum for about three hours at 750 °C, with a titanium box around the cavity to degas hydrogen out of the niobium material.
- Field flatness tuning.
- Final electro-polishing to remove about 20 μm.
- Hot water rinsing in the ultrasonic bath for about two hours at 50 °C with detergent FM_20 of 2%.
- High pressure pure water rinsing with 8 MPa for about ten hours.
- Baking out for about two days at 100 °C, with vacuum inside the cavity.

RF Test Result

After the surface preparation, the 9-cell cavity was assembled for the RF test in a clean room. In the RF tests, the monitoring system was used to search heating spots and to check the radiation level. Fixed 44 carbon resistors and 40 PIN photo diodes were attached on the equator of each cell at every 90 ° [5].

The 9-cell cavity was cooled with superfluid helium and RF tested at 2 K. Figure 7 shows the result of RF test. It was ultimately limited by quench at the accelerating gradient (E_{acc}) of 8.6 MV/m. Heating spots were detected at equator of cell #2. In the result of inner surface inspection, defects were observed at the equator of cell #2.

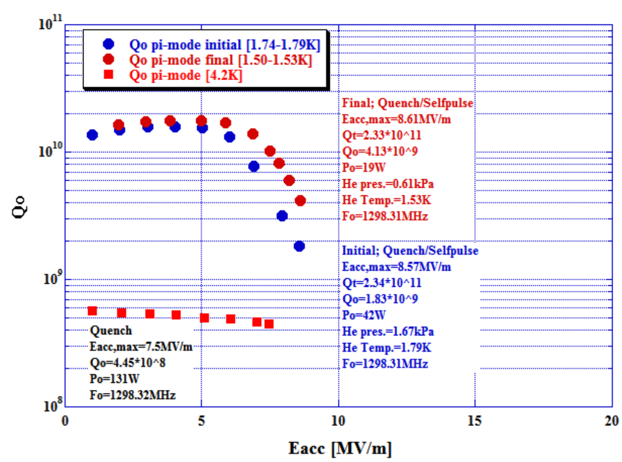

Figure 7: RF test result of the 9-cell cavity. Low current density EP-II (20 μm) with N_2 gas flow, rinse with ultra-pure water (1.5 hrs), detergent rinse with FM_20 of 2 % (50 °C, 2 hrs), HPR (10 hrs).

FABRICATION OF THE 2ND 9-CELL CAVITY

The 2nd 9-cell cavity is just about to be fabricated to achieve a target accelerating gradient of 35 MV/m.

Electron Beam Welding

Electron beam welding parameters are being optimised for iris and equator welds again to improve seam of welds. The 1st cavity iris welds were done from the inside, but iris welds for the 2nd cavity are all full penetration welds done from the outside.

Seamless Beam Tube

Beam tubes for the 1st 9-cell cavity were formed by electron beam welded two half-pipes as shown in Figure 8. It is not suitable to fabricate beam tubes with HOM couplers in this fabrication method. Therefore, development of seamless beam tubes by deep drawing is performed for the 2nd 9-cell cavity. Two long cups were formed from niobium disks by three times drawings without intermediate annealing as shown in Figure 9. Figure 10 shows two long cups formed by deep drawing. Two beam tubes will be fabricated by cutting both ends of these long cups.

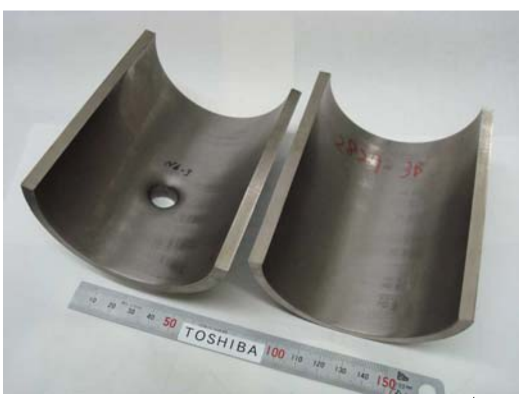

Figure 8: Half-pipes for the beam tube of the 1st cavity.

Figure 9: Fabricating process of long cups. (Left: after 1st deep drawing, Center: after 2nd deep drawing, Right: after 3rd deep drawing).

Figure 10: Two long cups formed by deep drawing.

CONCLUSION

The 9-cell superconducting cavity without HOM couplers was fabricated at TOSHIBA. The cavity was prepared and RF tested at STF/KEK. It was ultimately limited by quench at the accelerating gradient (E_{acc}) of 8.6 MV/m. The 2nd 9-cell cavity is just about to be fabricated now. It is in progress favourably.

ACKNOWLEDGMENTS

Special thanks to E. Kako, S. Noguchi, T. Shishido, Y. Yamamoto, K. Watanabe and T. Saeki at KEK for this paper and technical supports.

REFERENCES

[1] H. Hayano, "Superconducting RF Test Facility (STF) in KEK", SRF2005, Cornell Univ., Ithaca, NY, USA (2005) p409-411.

[2] S. Noguchi, et al., "STF Baseline Cavities and RF Components", SRF2005, Cornell Univ., Ithaca, USA (2005) http://www.lns.cornell.edu/public/SRF2005/. Also, presentation for the ILC seminar at KEK, (May 11th, 2007), http://lcdev.kek.jp/LocalMeetings/.

[3] E. Kako, et al., "Vertical Test Results on the STF Baseline 9-cell Cavity at KEK", SRF2007, Peking Univ., Beijing, China, (2007) p453-457.

[4] Y. Iwashita et al., Phys. Rev. ST Accel. Beams 11, 093501 (2008).

[5] Y. Yamamoto et al., "Cavity Diagnostic System for the Vertical Test of the Baseline SC Cavity in KEK-STF", SRF2007, Peking Univ., Beijing, China (2007) p464-468.