SUMMARY OF VERTICAL TESTS FOR S1-GLOBAL PROJECT IN KEK-STF

Y. Yamamoto#, H. Hayano, E. Kako, S. Noguchi, M. Satoh, T. Shishido, K. Umemori, K. Watanabe, KEK, Tsukuba, Japan

Abstract

Vertical tests of five 1.3GHz 9-cell cavities (MHI#5-#9) have been done totally 18 times from 2008 to 2009 for S1-Global project [1] in KEK-STF, which is planned in 2010. MHI#7 achieved 33.6MV/m, which was the best result for S1-Global, and the others below 30MV/m. After the exchange for new EP acid on May/2009, many brown stains (niobium oxide) [2] were observed on the interior surface of the cavity, and onset gradient of radiation level measured at the top flange of cryostat was much lower. After several vertical tests, the effect by this phenomenon was gradually relaxed. After the cavity selection (MHI#5, #6, #7 and #9) for S1-Global, MHI#8 achieved 37.8MV/m with the heavy field emission in the fourth vertical test, which is the best result in STF. However, any cavity did not reach ILC specification (E_{acc}=35MV/m, $Q_0=0.8 \times 10^{10}$) yet. This means that more improvement for cavity fabrication and surface treatment is necessary. In this presentation, the summary of the vertical tests for S1-Global project in KEK-STF will be reported.

INTRODUCTION

It is necessary to reach above 35MV/m ($Q_0>0.8 \times 10^{10}$) in vertical test for ILC project. In STF Phase-1, which four cavities (MHI#1-#4, 1st batch) were used, one of them (MHI#2) reached around 29MV/m. However, other three ones were limited around 20MV/m. From the results of pass-band measurement and T-mapping, it was found that the quality of electron beam welding (EBW) around the equator of cell was somewhat poor.

In the fabrication of MHI#5 and #6 (2nd batch) in 2007-2008, the procedure of the EBW including the treatment before and after that was substantially changed and improved. Moreover, the optical inspection camera, which was developed by Kyoto University and KEK, was firstly introduced instead of the examination with the eyes for the evaluation of EBW seam. MHI#7-#9 (3rd batch) were fabricated in 2008-2009, which some parameters for the EBW were more improved and the bead weld more smoothed, compared to the MHI#5 and #6. Four cavities (MHI#5, #6, #7 and #9) were selected for the S1-Global project, which is carried out in 2010, within the MHI#5-#9. The assembly working for the S1-Global project have already started from January, which four cavities from KEK were assembled into Cryomodule A, and two from DESY and two from FNAL into Cryomodule C.

SEQUENCE FROM DELIVERY OF CAVITY TO VERTICAL TEST

Once a cavity is transferred from a vendor to KEK, it usually experiences the following process.

(1) Inspection by optical camera after delivery
(2) Measurement of cavity frequency and field flatness by bead method, and check of cavity dimensions
(3) Pre-EP (5μm)
(4) EP1 (100μm)
(5) Inspection by optical camera after EP1
(6) Measurement of cavity frequency and field flatness by bead method after EP1
(7) Measurement of thickness of cavity (check of consistency for electro-polished amount)
(8) Annealing (750℃, 3 hours)
(9) Inspection by optical camera after annealing
(10) Pre-tuning, frequency tuning (f_0=1297.2MHz, field flatness>96%) and check of cavity dimensions
(11) Q_{in}, Q_{HOM} and f_{HOM} measurement
(12) EP2 (50 or 20μm, 50 or 30mA/cm^2)
(13) H_2O_2, ethanol rinsing or degreaser with ultrasonic
(14) Hot water rinsing with ultrasonic (1 hour)
(15) HPR (8-12 hours)
(16) Assembly working in clean room and vacuum evacuation
(17) Baking (100℃, 50 hours)
(18) Putting on cavity stand
(19) Mounting T-mapping and X-ray-mapping system
(20) Vertical testing

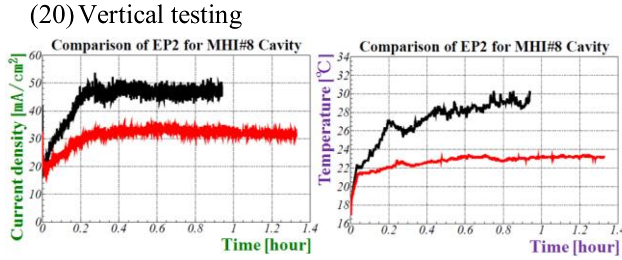

Figure 1: Comparison of EP parameters between the different conditions. Left shows the time trend of the current density (mA/cm^2) and right shows the temperature (℃) of the EP acid inside the cavity.

The purpose of (3) Pre-EP is the removal of dust or impurity adhered to the cavity surface for the protection of contamination of EP acid. (10) Pre-tuning is the extremely important process, and the gradient error would become larger if this process was not done. (10) Frequency tuning is also important, since the cavity eventually experiences the cryomodule test and then the cavity frequency should be set to 1300MHz. (13) H_2O_2, ethanol rinsing or degreaser with ultrasonic is under study and the effect for the field emission is not clear at present. The rinsing process was not also effective for the brown stains. The component of degreaser is FM-20, which is diluted by 2%.

#yasuchika.yamamoto@kek.jp

Figure 1 shows the comparison of EP parameters between the different conditions. The black line shows the normal EP procedure and the red one shows the EP procedure with the low current density. Recently, the low current density EP (30mA/cm^2) in (12) EP2 is introduced. Moreover, the outside of the cavity during EP2 is cooled down by the cooling fan. After this new treatment, MHI#8 reached 37.8MV/m, which is the best result in STF, although the heavy field emission still remained. Two 2-cell cavities for ERL injector also reached above 40MV/m using this same treatment [3].

RESULTS OF VERTICAL TEST

$Q_0 - E_{acc}$ Curve

The vertical tests for S1-Global project have been done using MHI#5-#9 since Dec/2008. Figure 2 shows the final result for five cavities (MHI#5-#9) including MHI#1-#4, which were used for STF Phase-1. The MHI#5 was tested totally three times, the MHI#6 six times, the MHI#7 twice, the MHI#8 four times and the MHI#9 three times. The history of the achievable gradient in every vertical test for MHI#1-#9 cavities is also shown in Figure 2. Although the MHI#5 and #6 were improved from around 20MV/m to above 25MV/m compared to the MHI#1-#4, they did not reach the ILC specification (35MV/m, Q_0>0.8x10^{10}) yet. The MHI#7 and #8 are affected heavily by the brown stains.

Pass-band Mode Measurement

The pass-band mode measurement is important alongside of T-mapping in the evaluation of the field limitation for each cell. Seven pass-band modes from π to 3π/9 are usually measured in the vertical test at STF. Figure 3 shows the example of the pass-band mode measurement in the third vertical test for the MHI#5. The above table shows the result from the pass-band mode measurement and the bottom one shows the potentially maximum gradient for each cell. The sun mark at the cell #5 means the heating cell in π mode. Every cell except for the cell #5 is reachable above 30MV/m. The cause of the field limit in π mode is the thermal quenching, because the gradient at the cell #5 is almost same for π, 7π/9, 5π/9 and 3π/9 mode.

In the table of the Figure 3, the excitation of the other pass-band mode is also shown. This phenomenon frequently appears in the vertical test of the 9-cell cavity. Once the excitation occurs, it is not possible to do the precise measurement. Therefore, this problem is usually solved by the more-over-coupling. This phenomenon will be described in detail later.

Radiation Level

Two radiation monitors are set for the detection of the x-ray emission on the top flange of the cryostat. One has the high sensitivity in the range from 0.1μSv/h to 1mSv/h and the other has the low one from 0.1 to

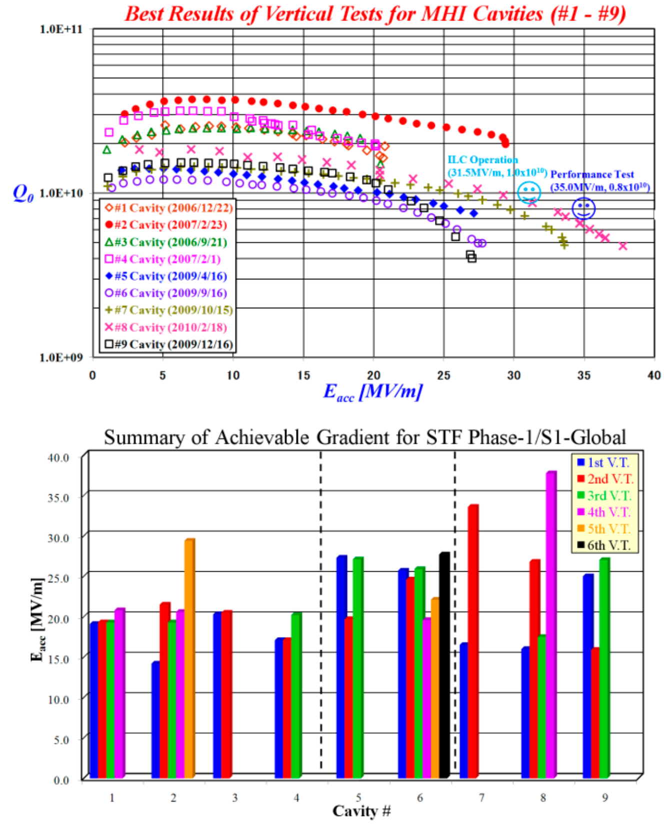

Figure 2: Final result of vertical tests for S1-Global.

unit : [MV/m]

cell	π	8π/9	7π/9	6π/9	5π/9	4π/9	3π/9	$E_{acc, max}$
1 & 9	27.1	34.9	26.0	31.2	21.5	20.9	14.1	34.9
2 & 8	27.1	31.0	13.8	0.0	14.7	27.3	28.1	31.0
3 & 7	27.1	23.0	5.2	31.2	25.4	11.9	14.1	31.2
4 & 6	27.1	12.9	20.0	31.2	4.3	30.2	14.1	31.2
5	27.1	0.0	27.8	0.0	27.4	0.0	28.1	28.1
limiting cause	#5 cell heating	No heating	#5 cell heating	#6 cell heating	#5 cell heating	#6 cell heating	#5 cell heating	
excitation of other pass-band modes	8π/9			4π/9		π, 5π/9		

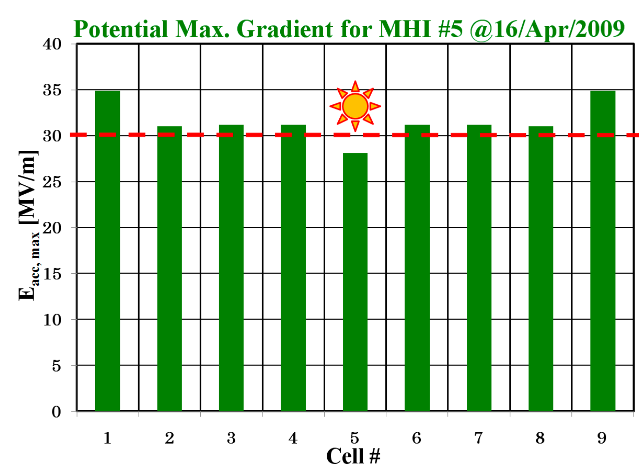

Figure 3: Table of pass-band measurement and potentially maximum gradient for each cell.

100mSv/h. Figure 4 shows the radiation level measured by the radiation monitors. When the brown stain problem occurred, the onset gradient of the radiation was around 10MV/m.

Although the level of the field emission is evaluated by these monitors, they are set at the only one direction. Therefore, many PIN diodes are also attached around the cavity including the both end flanges of the beam pipes. They are complementary each other. It is important to check the direction with the higher radiation level.

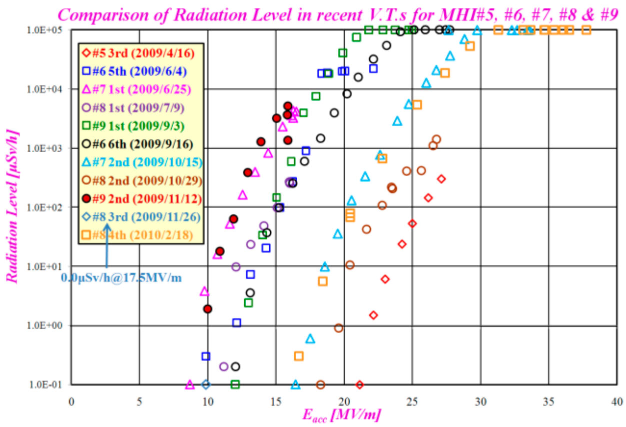

Figure 4: Radiation level measured on top flange of cryostat.

Residual Resistance

During the decompression from 4.2K to 2K, the residual resistance is measured at the gradient of 3-4MV/m in every vertical test. The geometrical factor G for the STF Baseline cavity is 277. The typical result is 10-14nΩ, which is dependent on the condition of the cavity surface and the environment around the test area. This value is slightly higher than that at the other laboratories, because of the insufficient magnetic shielding or the higher residual magnetic field in STF. This leads to the lower unloaded Q value.

The study of the magnetic shielding effect was carried out in the 2nd and 3rd vertical test for the MHI#6 cavity. The lowest residual resistance (8.3nΩ) in the 3rd test was obtained due to the double magnetic shielding.

Excitation of other pass-band mode

The other pass-band mode than the measured mode frequently excites in the vertical test of the 9-cell cavity. There are two types for the excitation. One is the continuous type, which the excitation of the other pass-band mode appears continuously. The other is the instant type, which the excitation appears only once at the cavity quenching. Figure 5 shows the examples of these two types measured by the real time spectrum analyzer. It is clear that the electron activity in the cavity is concerned with this phenomenon, although the mechanism of the occurrence is not understood in detail. The electrons emitted from the surface of the cavity behave as the beams and excites the other pass-band modes in the cavity. This mechanism is similar to the klystron. On the other hand, it should be noted that this phenomenon is dependent on the coupler position, when the variable coupler is used for the vertical test. Normally, the excitation disappears or decreases by setting the more-over-coupling.

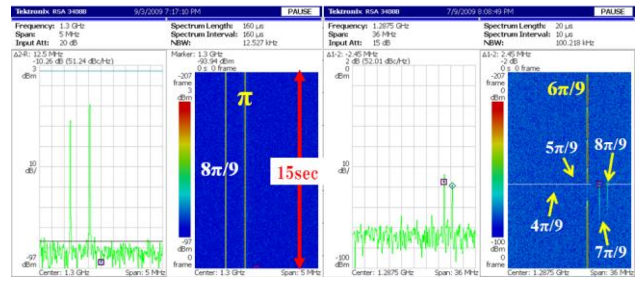

Figure 5: Two types of mode excitation. The left is the continuous type and the right is the instant one.

SUMMARY AND FUTURE PLAN

The vertical tests have been performed for MHI#5-#9 to use at the S1-Global project. At this moment, the cavities have not yet cleared the ILC specifications. More studies with attempted improvements of the surface processing are repeatedly done using niobium samples. However, the cause of the heavy field emission at STF is not clear at present and any rinsing process was not effective for it.

ACKNOWLEDGEMENT

The authors are indebted to K. Sennyu and H. Hara (MHI, Mitsubishi Heavy Industries) for the fabrication of the STF cavities and H. Umezawa (TOKYO DENKAI Co., LTD). Special thanks are given to T. Suzuki (Nomura Plating Co., Ltd.), K. Nakamura, N. Tasaki and F. Tsukada (Assist Engineering Co.), M. Sawabe at KEK for the surface preparation of these cavities, T. Okada and M. Iitake (k-VAC), S. Imada and M. Asano (NAT) for the preparation of the vertical test.

REFERENCES

[1] N. Ohuchi, et al., "Construction of the S1-Global Cryomodules for ILC", IPAC'10, Kyoto, Japan, (2010) , WEPE008, in this proceeding.

[2] T. Saeki, et al., TTC meeting 2010, FNAL, U.S. "http://indico.fnal.gov/conferenceDisplay.py?confId=3000"

[3] S. Noguchi, et al., "Present Status of Superconducting Cavity System in cERL Injector Linac at KEK", IPAC'10, Kyoto, Japan, (2010) , WEPEC024, in this proceeding.