THE PRESENT STATUS OF DEVELOPMENT ON SUPERCONDUCTING CAVITIES AT SHI

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Abstract

We have started development on superconducting cavities with KEK from 1997. First, we checked out the effect of removal thickness with electropolishing (EP) . In the results, We could obtain the maximum accelerating field of 32MV/m by a repeatedly small removal thickness (30μm) up to 150 μm material removal. Next, when fabricating the second, we directly removed as much the thickness as the optimized depth by the first cavity using heavy chemicalpolishing (CP) and final light EP in sequence. We are now in the stage of fabricating the third one, 3-cell cavity. In this paper, we report on these results and activities at Sumitomo Heavy Industries, Ltd.

1 INTRODUCTION

Last year, We set up three purposes as follows. First; fabricating a single-cell L-band niobium cavity to study surface treatment, and testing it to learn many operating systems in this fields. Second; fabricating multi-cell cavities by our own technics. Third; design and fabrication of a cryo-module.

On the first step, we have acquired two important data, namely, superiority of EP [1] and hydrogen Q-disease [2]. For the former, it showed the good relationship between an amount of removed thickness and accelerating gradient(Eacc), which could be obtained with only EP as surface treatment. Finally, the cavity obtained 32MV/m of gradient. For the latter, we checked out hydrogen Q-disease with our first fabricated cavity SHI-3. This cavity surface was removed 130μm in depth with CP. Annealing was not practiced for this cavity. After the first vertical test, the cavity was kept at 100K for two hours. Before and after this process (holding 100K) , the performance almost unchanged.

On the second step, we needed to check out the proper welding condition on niobium by our electron beam welding (EBW) machine, because of the different conditions from KEK's. Then, we applied our own conditions to single-cell and 3-cell cavities .

The all fabricated cavities are named individually as shown in Table 1. SHI-1 which was fabricated at KEK was applied to study the relationship between the removed thickness by EP and maximum gradient of the cavity. SHI-2 was only used to optimize EBW condition. For SHI-3 without annealing and mechanical treatment, it was used to investigate hydrogen Q_disease. SHI-4 is a 3-cell cavity and under fabrication at SHI factory.

Table 1: List of fabricated cavities.

Name	# of cell	Factory	Remarks
SHI-1	1	KEK	Investigate effect of EP :max. E_{acc}=32MV/m
SHI-2	1	SHI	Researching only EBW condition .
SHI-3	1	SHI	Investigate anneal effect :max. E_{acc}=7.3MV/m
SHI-4	3	SHI	Not measured

2 SURFACE TREATMENT ON SHI-1

The purpose of SHI-1 cavity was to study the dependence between the cavity performance and the removed thickness with EP. A similar relationship was already studied by P. Kneisel et al. using CP [3]. First, a light chemical polishing (20μm) was carried out on this cavity to remove the contaminated surface layer, and then annealing at 760° was done to prevent the hydrogen Q-disease. After that , the performance of this cavity was measured with adding a light EP(30μm) and high-pressure water rinsing (HPR) repeatedly. The experiments were continued until 210μm removed thickness. These experimental data are shown in Figures

1~3. All tests were executed using the KEK's vertical measuring system.

X-ray was detected at the 1st, 3rd and 4th measurements in Figure 1. X-ray was observed over the higher gradients than 16MV/m at 3rd and 4th. This radiation should be due to field emission by the reason that the relative X-ray intensity is enhanced in accordance with increasing field gradient.

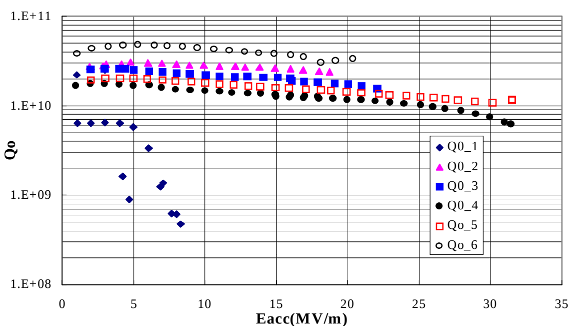

Figure 1: Q_o vs. E_{acc} at SHI-1 cavity.

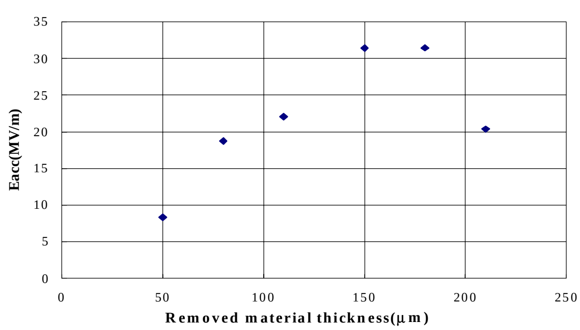

Figure 2: E_{acc} vs. removed thickness on SHI-1 cavity.

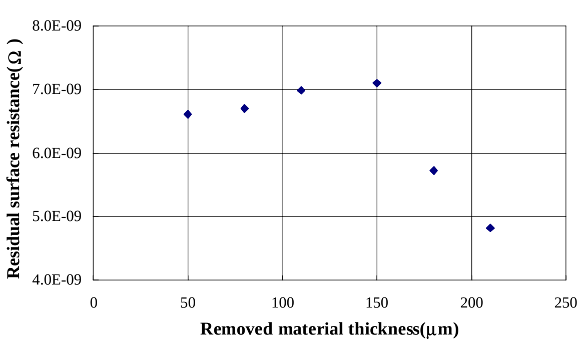

Figure 3: Residual resistance vs. removed thickness on SHI-1 cavity.

This cavity had a large pit (diameter: ~600µm) and many tiny pits (diameter: ~50 µm) on the initial stage. The tiny pits have gradually vanished with adding EP. The field gradient increased with adding 30µm EP until 150µm as shown Figure 2. At the 5th measurement (the removed thickness was in total 180µm), the performance just kept the same value as the case of 150µm removing and X-ray was not observed. After the 5th measurement, we inspected the inner surface of SHI-1 cavity and confirmed that the tiny pits have almost vanished except the large one.

Although we did not measure the temperature mapping, it is considered that the maximum performance at 6th measurements was limited by the pit. The magnetic field strength on the inner wall at 32MV/m is shown in Figure 4. At the 6th measurement (the removed thickness was in total 210µm), Eacc decreased to 20.5MV/m and X-ray was not observed. By the inspection after 6th measurement, we found the existence of many tiny pits similar to the initial stage. It might be due to EP processes.

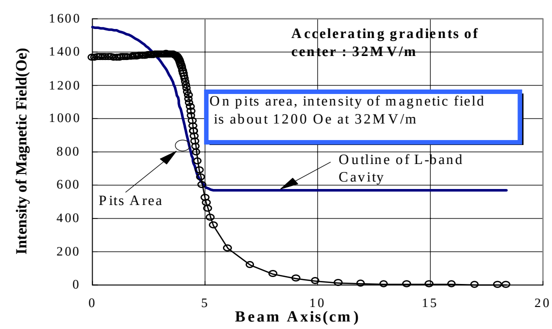

Figure 4: Distribution of magnetic field on the wall at 32MV/m on the axis.

3 SHI-3 CAVITY

3.1 Fabrication And Surface Treatment

We started fabricating a L-band single-cell cavity by our own factory while measuring SHI-1 cavity. First, we optimized an appropriate EBW condition with Nb flat sheets (thickness: 2.5mm) by our EBW machine(Table 2), and next, with beampipes (inner diameter: ϕ76mm, thickness: 2.5mm, length: 40mm). Then, we assembled SHI-2 cavity with two half-cells and two beampipes. SHI-2 got a small hole on the one iris EBW seam, because of the high electron beam currents. After modifying the EBW condition, we finished the assembling of SHI-3.

Table 2: Current condition of EBW

SECTION	VOLTAGE(kV)	CURRENT(mA)
Iris	150	14
Equator	150	16
Machine: JE-114 : Osaka henatsuki , Ltd. : Beam power-15KW (150KV- 100mA)		

Although the EBW is not perfectly optimized, our current condition is shown in Table 2. From the results of SHI-1, we decided the optimum removed thickness as 150-180µm to obtain over 30MV/m of high gradients. The subjects of SHI-3 were testing the high gradients and making sure of a hydrogen Q-disease without annealing. The treatments on SHI-3 are shown in Table 3.

Table 3: Surface treatments on SHI-3 cavity.

No	Treatment	Method	Remarks
1	Pre_polishing	CP	130 μm
2	Final polishing	EP	30 μm
3	Cleaning 1	HWMR*	80°C / 90min.
4	Cleaning 2	HPR	8.3 MPa / 90min.

* : Hot Water with Megasonic Rinsing

3.2 Measurement Results of SHI-3

The measurements were carried out twice on the cavity. First cooling was to check out SHI-3 cavity performance after our treatment. After that, SHI-3 was kept constant temperature at 100K for two hours to make sure of a hydrogen Q-disease. From the second measurement, Q-degradation did not observed as shown Figure 5. A hydrogen Q-disease might not happen by removing sufficient amount with CP before light EP. We showed have to study the process of making Nb sheets and aging effect on the material properties.

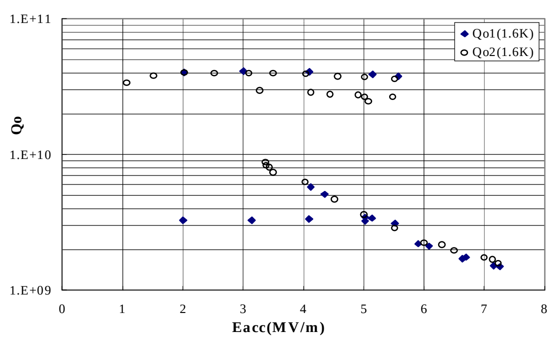

Figure 5: Q_o vs. E_{acc} at SHI-3 cavity.

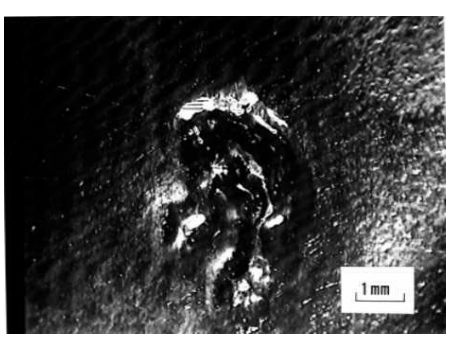

Figure 6: Equator defect found on SHI-3.

The Qo vs. Eacc curve in Figure 5, we can observe that Qo was switched to the lower level after the first quench at 5.7MV/m. The maximum Eacc was limited at 7.4MV/m. On the reverse process when decreasing Eacc from 7.4MV/m, Q jump did not appear at 5.7MV/m and kept the lower values. I suppose that this phenomenon is related to two defect. Through the inspection after measurement, we discovered a big defect on nearly the equator portion as shown in Figure 6. At the time of assembling, no such defect had been found.

4 FABRICATION OF A 3 CELL CAVITY

The manufacturing of a 3 cell cavity (SHI-4) has just been finished. Whole view is in Figure 7. This will be cold testing soon.

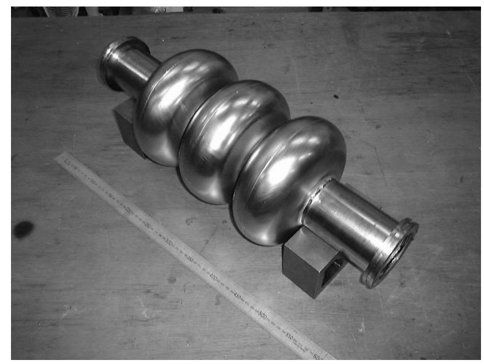

Figure 7: Overall view of 3 cell-cavity.

5 SUMMARY

We obtained the dependence of accelerating gradient upon an amount of removed thickness using EP. The optimum removal by EP to get high gradient is in over 150μm. In case of using a large amount of CP, annealing process for hydrogen degassing does not always need to avoid hydrogen Q-disease.

ACKNOWLEDGMENTS

The authors would like to thank Mr. N. Yasumitsu, Y. Kumata and K. Sawada at SHI, Mr. T. Minakuchi and Y. Tateishi at STC, and Mr. Shiratake at Nomura Techno Research Co. Ltd. for helpful discussions and their supports.

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