HIGH GRADIENT BEHAVIORS OF LARGE GRAIN ICHIRO SINGLE CELL CAVITY BY CHEMICAL POLISHING

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Abstract

We have started high gradient R&D with the combination of ICHIRO shape, sliced large grain niobium, and buffered chemical polishing (BCP). We fabricated one large grain ICHIRO single cell cavity that had end cell shape of ICHIRO 9-cell but no end group. We processed this cavity surface by centrifugal barrel polishing (CBP) and BCP. This cavity successfully achieved the high gradient of 42MV/m at the first vertical test. We made series test by repeating BCP on this cavity. The results of the series test will be reported.

INTRODUCTION

Large grain niobium SRF cavities have been developed in many laboratories, Jlab, DESY, IHEP, KEK, and so on. Our KEK LL group made breakthrough of LG Nb sheet production in 2008 [1]. We have successfully developed the multi-wire slicing method for niobium ingots with 270mm diameter collaborating with KEK, Tokyo Denkai Co. Ltd., TKX Co.Ltd., and Toyo Advanced Technologies Co. Ltd. This technology can reduce the cost of Nb sheet productions. LG cavity also can achieve high gradient of 40MV/m by BCP, not by electro polishing (EP) [2]. In order to make the breakthrough of ILC cavity cost, we are proposing the combination of sliced LG Nb materials + ICHIRO shape + BCP. This could promise the cheap, easy, and high reliable performance cavity production. In this paper, we will describe about our R&D on LG single cell cavity made of sliced Nb sheets.

LARGE GRAIN CAVITY

Fabrication

Figure 1 and 2 show the image of slicing principle and slicing machine, respectively. The friction between the ingot and the abrasives on the thin piano wire of which diameter is ϕ0.16mm slices the material. More details of slicing are reported on reference [1]. The impacts of this slicing technique are as follows; (1) We can directly slice many Nb sheets, more than 100 sheets, from an ingot at the same time, (2) The less material waste, about one third if compared with the current Nb sheet production. Both of these could bring the significant cost reduction of cavity production. At the first stage of the slicing test, we sliced 6 LG Nb sheets; thickness is 2.8mm, from an Nb ingot with 270mm diameter and 20mm long (figure 2). We made one single cell using 2 sheets of these 6 sheets. This cavity, named LG-ISE (figure 3), has end cell shape of ICHIRO, but no end group on beam tube. More results of slicing and studies on sliced Nb sheets can be seen in reference [1, 3, and 4].

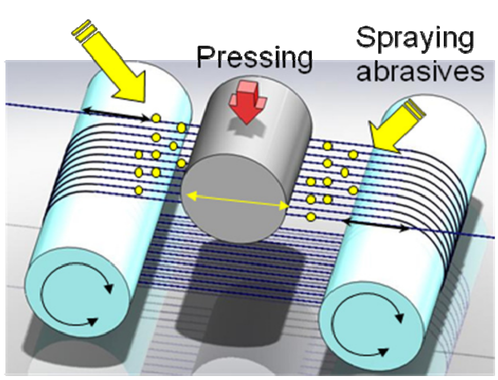

Figure 1: Slicing principle.

Figure 2: slicing machine, sliced Nb sheets.

1st VT Results of LG-ISE

We applied our standard recipe that replaced EP with BCP to LG-ISE. The recipe consists of centrifugal barrel polishing (CBP, ~80µm), light BCP (10µm), annealing

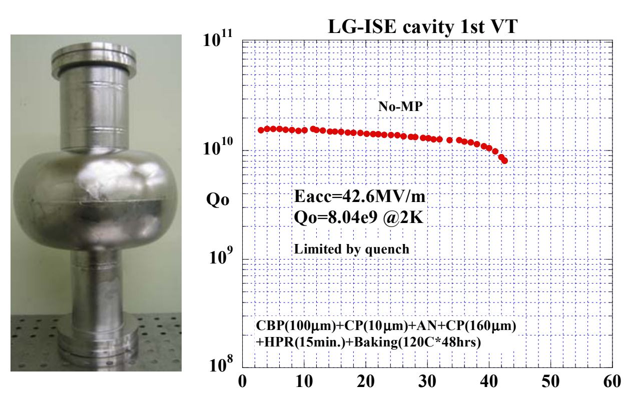

Figure 3: 1st VT results of LG-ISE.

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(AN, 750C° x 3hrs), BCP (160μm), HPR (15min., 55kg/cm^2), and Baking (120C° x 48hrs). The reason of large BCP material removal of 160μm is by the studies on LG+BCP at Jlab. BCP was done by the vertical (V) position, we wrote it as V-BCP in this paper. Figure 3 shows 1st VT results of LG-ISE. Maximum gradient achieved 42.6MV/m with Qo value of 0.8e10. No multipactings were observed through the test. No radiation was detected up to 40MV/m by radiation monitor (highest resolution is 0.1μSv/hr). Radiation level was less than 1.0μSv/hr at the highest gradient. Qo value kept more than 1.0e10 until 40MV/m. Small Q-slope happened more than 40MV/m. LG-ISE was limited by quench at first VT.

TIGHT LOOP FOR V-BCP

After the first VT, we did tight loop test of V-BCP to see the reproducibility. The repeated recipe consists of additional V-BCP (30μm), degreasing, HPR, and baking. We repeated this 4times, totally 5VT included 1st one were done as tight loop. Figure 4 shows the summary of tight loop test of V-BCP. The average maximum gradient was 38.5 ± 2.6MV/m. Maximum gradient was getting lower as the removal increased. Q-slope onset was also getting lower as the removal increased. Q-slope onset means the gradient of the shoulder on Qo vs. Eacc curve. We considered the reason for this Q-slope growing as the repeated BCP might enlarge the magnetic field enhancement factor at grain boundaries resulting in local heating and Q-slope.

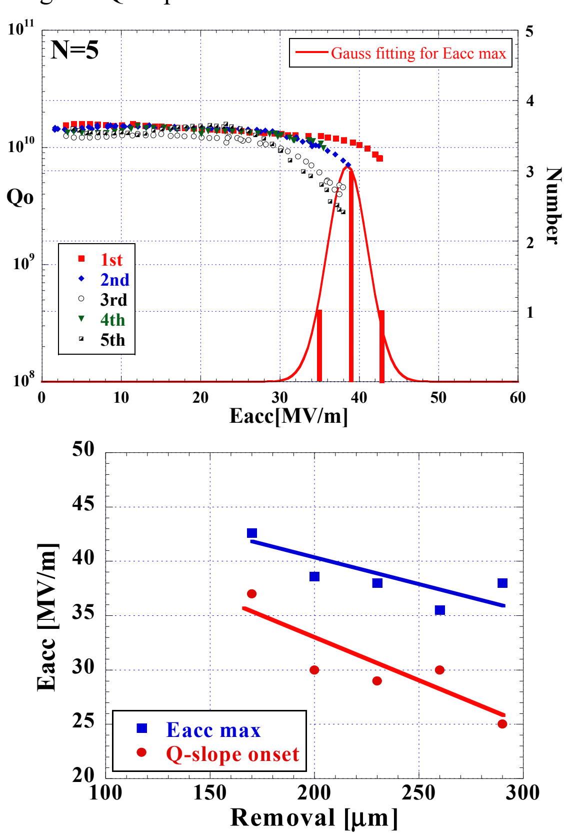

Figure 4: Summary of V-BCP tight loop test

PROBLEM OF V-BCP ON LG 9-CELL CAVITY

In parallel with the studies on LG-ISE, we also developed LG ICHIRO 9-cell cavities. We fabricated two LG ICHIRO 9-cell cavities, IHCIRO#9 and #10 [2]. We applied V-BCP 3times in total to ICHIRO#9 and measured. Figure 5 shows the photo of ICHIRO#9, the result of VT, and the removal thickness by V-BCP. ICHIRO#9 was limited at 27MV/m. Small Q-slope happened from 23MV/m. We checked the wall thickness near the equator before and after V-BCP. The average of total removal by V-BCP was 96±28μm, we found the removal was not uniform between centre and end cells of the cavity. Removal of centre cell showed twice as large as that of end cells. This depends on the procedures of V-BCP for the 9cell. We set cavity in the vertical direction on the jig and filled the BCP acid about half level of full length in the cavity. Then we rotated cavity up down several times. In this way, BCP acid stayed longer time in the middle cell than end cells. This caused larger removal in the centre cell. We considered from the results of LG-ISE that if we continue V-BCP to ICHIRO#9, the larger removal of centre cell might cause Q-slope earlier than end cells. This Q-slope of centre cell might limit the whole cavity performance. It should be also noted that the un-uniform removal destroyed the field flatness. To make removal uniform, we developed horizontal BCP (H-BCP) machine for LG 9-cell cavities.

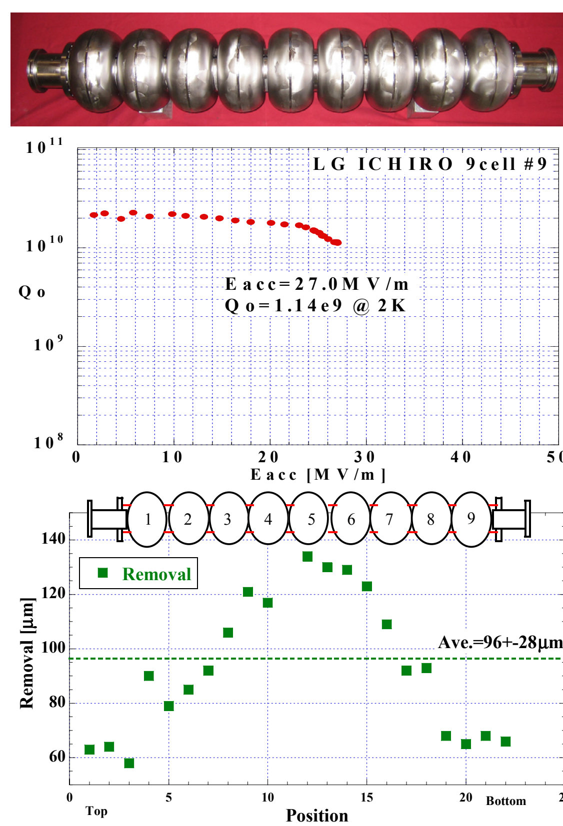

Figure 5: Top: picture of ICHIRO#9
Middle: VT results of ICHIRO#9
Bottom: Total removal by V-BCP

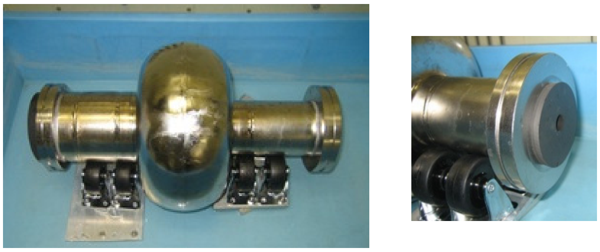

Figure 6: Set-up for horizontal BCP for LG-ISE.

TIGHT LOOP OF H-BCP

Horizontal BCP (H-BCP)

As a pilot study for horizontal BCP (H-BCP) of LG 9-cell, we tried H-BCP with the LG-ISE. After V-BCP tight loop test, SRF surface of the LG-ISE was reset by CBP, light BCP, and annealing. After that we tried H-BCP. Figure 6 shows the set-up of H-BCP. We put Viton plugs on both flanges which have a centre hole for gas exhausting during BCP. We fill the BCP acid in the cavity lower than the level of exhausting holes, and then put cavity on the rotation jigs in a draft. Rotation was done by hand in this set-up, about 10rpm, during H-BCP. In order to see how much BCP removal is needed for high gradient, we did H-BCP about 30µm step for each in this tight loop. After H-BCP, 1st rinsing with ultra pure water, degreasing, HPR, baking, and VT were done. We repeated these 5times.

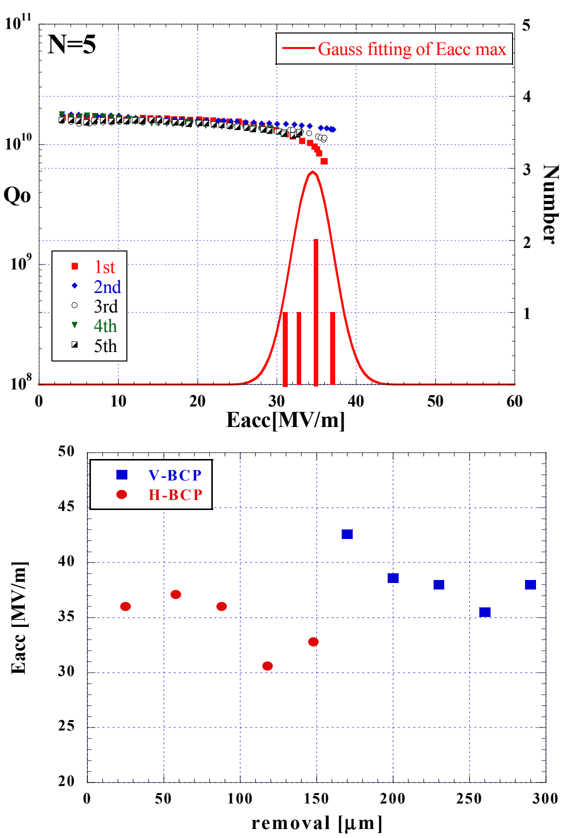

Figure 7: Results of tight loop of H-BCP.

Results of Tight Loop

Figure 7 shows the summary of tight loop test of H-BCP. The average maximum gradient was 34.5 ± 2.7MV/m. The 1st results limited at 36MV/m and Q-slope happened. The 2nd results limited at 37MV/m but no Q-slope happened. We considered that the 1st result might be caused by some memory of CBP, and it removed by the 2nd H-BCP. After that we repeated H-BCP 3times, but didn't achieve more than 40MV/m. The maximum gradient was limited at 37MV/m. Gradients were low, so Q-slope problem was not clear for H-BCP. Bottom figure of fig. 7 shows the removal vs. Eacc max. Results of V-BCP are also plotted for the comparison. Before tight loop of H-BCP, we thought that we could see the threshold of BCP removal for high gradient until the removal of 170µm that was the start points of V-BCP. But gradient of H-BCP showed different behaviours on removal from that of V-BCP. One concern of why H-BCP could not achieve high gradient is the half area of SRF surface was exposed to NO_x gas produced by BCP during H-BCP. After 5th H-BCP, we tried additional 30µm by V-BCP to remove some effect of H-BCP. It was not effective to improve the gradient so far. We also did SRF surface inspection by CCD camera of the LG-ISE after VT, but could not find any visible defect. In the studies on 9-cell + EP, we sometimes found emerged defects after EP. The last figure suggests that there might be another mechanism of Q-slope, for instance, related to deep defect. We will repeat additional V-BCP + VT, and then try CBP or annealing for reset again.

SUMMARY

Our 1st LG ICHIRO single cell cavity (LG-ISE) made of sliced LG Nb sheet successfully achieved high gradient of 42MV/m at first test by V-BCP, it should be noted again that not by EP. We did tight loop test for both of vertical and horizontal BCPs for LG-ISE. Vertical BCP showed Q-slope growing up as the removal increased. Horizontal BCP limited less than 37MV/m. We need some cure or more study for this limit to get high gradient with LG 9cell by H-BCP. Some cure might be possible by additional V-BCP after H-BCP, but not yet get good result. It seems to be still difficult to conclude how much removal is needed for high gradient by BCP. We will collect more data about LG ISE + BCP and feedback to LG ICHIRO 9-cell cavities.

REFERENCES

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