HIGH FIELD Q-SLOPE PROBLEM IN END GROUP CAVITIES

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Abstract

In our high gradient R&D of ICHIRO cavities at KEK, we have found some problems related to HOM coupler and high power RF input coupler port on beam tube: end group. One is the difficulty of rinsing in complex structures like HOM coupler. The other is Q-slope at high filed more than 40MV/m. The cavities without end group did not show such a high field Q-slope. At first step, we tested much stronger and aggressive rinsing method; wiping, brushing, and mega-sonic rinsing on the end group. The details and results of these rinsing effects will be reported.

INTRODUCTION

We have successfully demonstrated the principle proof of 50MV/m with KEK Low Loss (ICHIRO) single cell cavities (IS cavities) [1]. IS cavity has the centre cell shape of ICHIRO 9cell cavity (I9 cavity), but no end group. End group includes HOM coupler, high power RF input coupler port, and transmitted RF power pick up port on beam tube. For the pilot study of I9 cavity, we also made end single cell cavities (ISE cavities) that have end cell shape of I9 cavity. ISE#3 that has end cell shape but no end group successfully achieved 50MV//m using same recipe as IS cavities. It will be described later about the recipe. ISE#5, and #7, those have full end group except transmitted RF power pick up port, have achieved around 48MV/m with modified recipe but limited by Q-slope so far (Figure 2). We confirmed that RF design of ICHIRO cavity has no problem for 50MV/m, but end group has Q-slope problem at more than 40MV/m. In this paper we focused on Q-slope problem of ISE cavities.

ISE CAVITY AND RECIPE

Our standard recipe for IS cavities consists of centrifugal barrel polishing (CBP, ~100μm), chemical polishing (CP, 10μm), annealing (AN, 750C°x3hrs), electropolishing (EP, 80μm+20μm), flash EP (3μm, new acid, no circulation), HPR, and Baking (120C°x48hrs). This recipe achieved 46.7±1.9MV/m with 6 IS cavities [2]. The key of this recipe is flash EP. We have found that sulphur contaminations generated during EP made scatter of performance. Some of sulphur remains underneath of the SRF niobium surface as niobium sulphide (Nb_xS_y) after long EP durations [3]. The combination of light EP (20μm) + flash EP can remove Nb_xS_y most effectively. We also understood the mechanism of sulphur generation during EP and how to reduce it [4]. For ISE cavities with end group, standard recipe did not work. They were limited by field emission (FE) at first. We considered one of the FE seeds of ISE cavities was sulphur contaminations remained at end group. End group has a complex structur, so it might be difficult to remove contamination by HPR only. We tried ethanol rinsing after EP which can dissolve sulphur. ISE#5 was improved but still limited around 40MV/m. We also tried wiping cavity inner surface directly. In common sense, RF surface is very sensitive, so nobody favours to touch the SRF surface after EP and before VT. We tried it to another cavity which limited by heavy FE as a pilot study. It was successfully improved. Then we tried it to ISE#5. We used very smooth cloth soaked in degreaser as wiper. ISE#5 was wiped whole SRF surface; cell, beam tubes, HOM cylinder and antenna by hand. The antenna was even rubbed by teeth brash. ISE#5 have achieved 48MV/m by combination of ethanol rinsing and wiping so far. We understood the problem of end group relates to the difficulties of rinsing in complex structures and post EP cleaning like ethanol rinsing and wiping are effective to rinse end group [5].

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Figure 1: ICHIRO single cell cavities
IS: centre cell shape, ISE: end cell shape

SERIES TEST OF POST EP CLEANINGS

From the experience of ethanol rinsing and wiping, we confirmed that the contaminations generated during EP process is very sticky and stronger rinsing is needed for the complex structure like end group to remove them. In

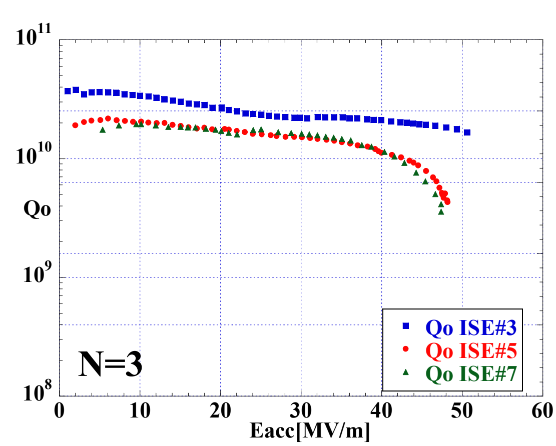

Figure 2: High Gradient Q-slope of ISE#5 and #7

this chapter we will describe about 4 kinds of post EP cleanings we tried; ethanol rinsing, wiping, steam cleaning and Horn rinsing.

Ethanol Rinsing

Figure 3 shows the results of the yield test for ethanol rinsing. The tested recipe consists of light EP, flash EP, ethanol rinsing, degreasing, HPR, and baking. We repeated this recipe + VT 6times for ISE#5. The average of maximum gradient is 39.2±5.7MV/m, scatter is 15%. The average of FE onset is 35.2 ± 6.7MV/m. In our measurements, FE onset corresponded to the gradient where the level of radiation reached more than 0.3μSv/hr. It is radiation monitor's sensitivity. The average Qo value at 40MV/m is (0.97±0.11)e10.

Wiping

Figure 3 shows the results of the yield test of wiping. Figure 4 shows the picture of wiping. The tested recipe consists of light EP, flash EP, ethanol rinsing, wiping with degreaser, HPR, and baking. We repeated this 5times for ISE#5. The average of maximum gradient is 42.6± 3.7MV/m, scatter is 9%. The average of FE onset is 31.8 ±7.1MV/m. The average Qo value at 40MV/m is (1.12± 0.21)e10. The Qo value is 15% higher than that of ethanol rinsing.

Steam Cleaning

Figure 4 shows steam cleaner and steam cleaning for end group. This steam cleaner is commercial one. We used pure water for the steam. Hot steam, about 100C°,

Figure 4: post EP cleaning, Top: Wiping, Bottom left: Steam cleaning, Bottom right: Horn rinsing

come out from nozzle of steam cleaner, we sprayed it all around end groups. The recipe for series test of steam cleaning did not include EP. It consists of steam cleaning, degreasing, HPR, short baking for degassing, and VT. We applied this for ISE#5, #7, and #8. We repeated this twice for ISE#7 and #8 to check the reproducibility. Qo vs. Eacc curves are summarized in figure 5. The average of maximum gradient is 41.6±3.9MV/m, scatter is 9%. The average of FE onset is 33.3±5.0MV/m. The average Qo value at 40MV/m is (0.93±0.19)e10.

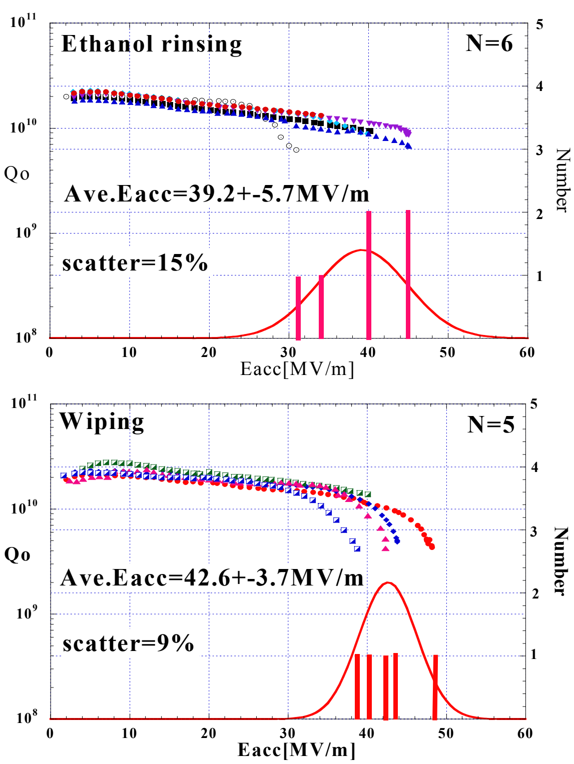

Figure 3: Series test of post EP cleaning Top: Ethanol rinsing, Bottom: Wiping

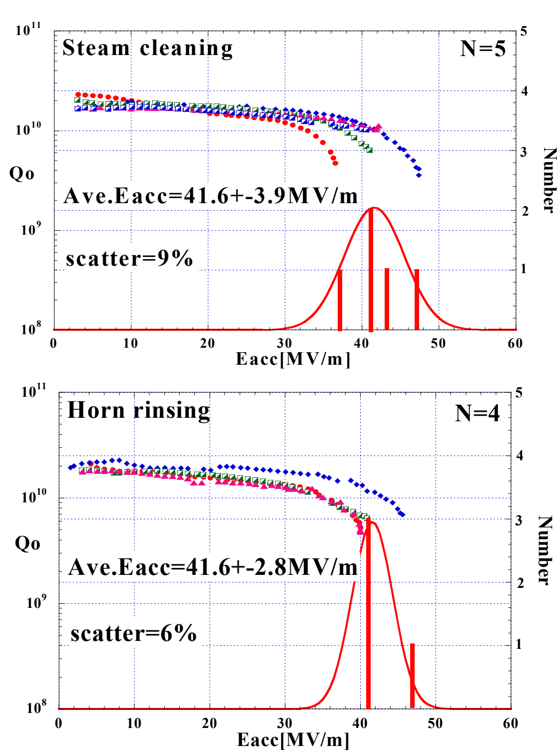

Figure 5: Series test of post EP cleaning Top: Steam cleaning, Bottom: Horn rinsing

Horn Ultrasonic Rinsing

Figure 3 shows schematic image and photo of horn ultrasonic rinsing. There are several oscillators in the horn. Frequency of oscillator is 28kHz. Power can be changed from 500~1000W. Pulse operation also possible. In this series test we applied duty of 50%. Total horn rinse is done about 10~20min. The condition of horn rinsing, power, time, and duty are still under optimization. Qo vs. Eacc curves are summarized in figure 5. The average of maximum gradient is 41.6±2.8MV/m, scatter is 6%. The average of FE onset is 35.8±2.9MV/m. The average Qo value at 40MV/m is (0.75±0.39)e10.

DISCUSSIONS

Average of Eacc max, FE onsets, and Qo values at 40MV/m of each post EP cleanings are summarized in Figure 6. Wiping shows highest average of Eacc max and Qo value at 40MV/m. Horn rinsing shows highest average FE onset. There are no big differences in averages between each post EP cleanings. We confirmed that some post EP cleanings are effective to remove contaminations of end group and improve cavity performances. But when we looked figure 3 and 5, Q-slope still remain and is not yet solved perfectly. Figure 7 shows the comparison of average Eacc max for all recipe we tested on IS and ISE cavities. In those studies, we focused on the sulphur contaminations generated during EP to improve the yield and solve high field Q-slope. For IS cavities it worked very well to get the narrow scatter and high performance. For ISE cavities it worked well to push up the gradient higher than 40MV/m. We confirmed that the sulphur contaminations should be removed or eliminated for the reliability of cavity performance. But high filed Q-slope cannot be solved by focusing only sulphur. There is still another contamination or mechanism that causes the high field Q-slope.

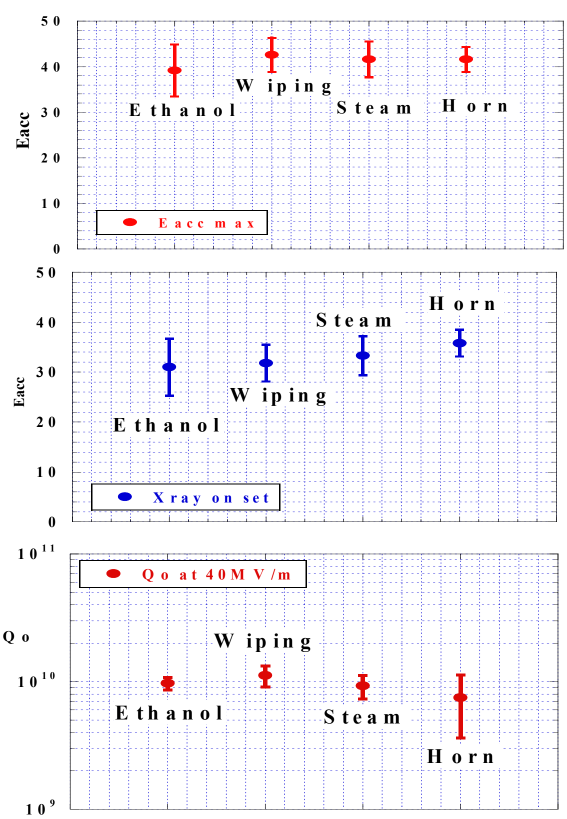

Figure 6: Summary of Eacc max, FE onset, and Qo value at 40MV/m of post EP cleanings

SUMMARY

We found high field Q-slope problem more than 40MV/m in end group. We considered that this Q-slope was caused by the contaminations generated during EP process, especially sulphur, and the difficulties of rinsing in complex structures of end group like HOM coupler. So we tried to solve this by strengthen post EP cleaning. We tried ethanol rinsing at first that can dissolve sulphur. Then we tried wiping to remove sticky contaminations. We also applied steam cleaning and horn rinsing; those conditions are still under the optimization. Post EP cleanings were effective to reduce FE and improve Qo value, but Q-slope was not yet solved. We focused on the sulphur contamination and tried to reduce or eliminate it so far. As the next step we should focus on the oxide contaminations which also generated during EP process. We will continue the study on high field Q-slope with ISE cavities and feedback it to ICHIRO 9cell cavity to achieve high gradient.

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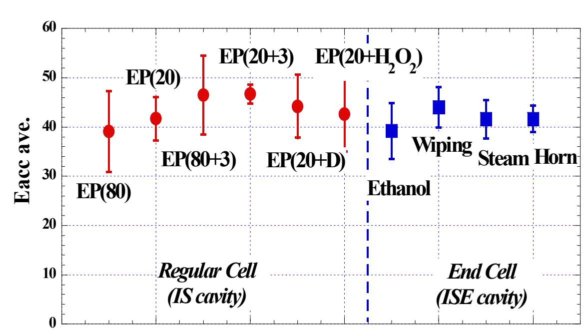

Figure 7: Comparison of recipe for IS and ISE cavities.