50 MV/M RECIPE FOR ICHIRO END GROUPS WITH ETHANOL RINSING AND WIPING

F. Furuta*, K. Saito
KEK, High Energy Accelerator Research Organization, 1-1 Oho, Tsukuba 305-0801, Japan.

Abstract

Our high yield recipe for ICHIRO centre cell singles did not work well on ICHIRO end single cell cavities that have HOM coupler and high power RF input coupler port on beam tube: end group. The gradients were limited around 18-33MVm by field emission. The limitation seemed to relate to the complicate end group structures. Sulphur contaminations generated during EP process seem sticky and hard to remove only by degreasing and HPR. We tried ethanol rinsing after EP process which can dissolve sulphur. We also tried wiping with degreaser to remove contaminations. End single cell cavity with full end group reached 48MV/m so far by modified recipe combined ethanol rinsing and wiping.

INTRODUCTION

We have successfully demonstrated the principle proof of 50MV/m with KEK Low Loss (ICHIRO) single cell cavities [1]. On the other side, bare ICHIRO 9-cell cavity was limited at 30MV/m by hard quench. Other ICHIRO 9-cell with full end groups was limited around 20MV/m by field emission. We found these limitations related to end group [2]. End group includes HOM coupler, high power RF input coupler port, and transmitted RF power pick up port on beam tube. Multipacting (MP) in the HOM coupler might be a problem. We re-designed new ICHIRO 9-cell and new HOM coupler which has almost no MP barriers [3]. We also made end single cell cavities that have end cell shape of ICHIRO 9-cell. We focused on the end group problems by these single cell cavities.

PROOF OF 50MV/M WITH END CELL SHAPE

The Recipe for Centre Cell Singles

After demonstrating the principle proof of 50MV/m, we have established the high reliable recipe for ICHIRO centre cell singles(IS cavities). The recipe consists of centrifugal barrel polishing(CBP, ~100µm), chemical polishing(10µm), annealing(750C*3hrs), electropolishing (EP, 80µm+20µm), flash EP(3µm, new acid, no circulation), HPR, and Baking(120C*48hrs). This recipe achieved 46.7±1.9MV/m with 6 IS cavities [4]. This result satisfied the ILC-ACD target (Qo>0.8e10 at 40MV/m). In the recipe, the key is flash EP. We have found that the source of scattering is sulphur contaminations generated during EP. Some of its remains underneath of the SRF niobium surface as niobium sulphide (Nb_xS_y) after long EP durations [2]. The combination of light EP(20µm) + flash EP can remove Nb_xS_y most effectively. Other "rinsing" cannot. In recent study, we understood the mechanism of sulphur generation during EP and how to reduce it [5].

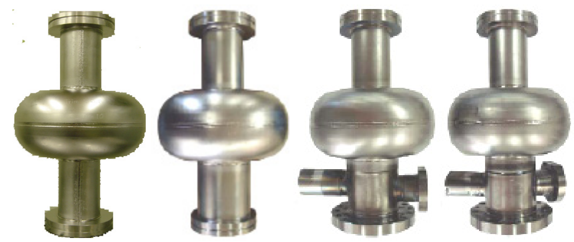

Figure 1 : ICHIRO single cell cavities, IS: centre cell shape, ISE : end cell shape

Proof of 50MV/m with End Single Cells

We fabricated end single cell cavities(ISE cavities, Figure 1). ISE#3 has no end group on beam tube. ISE#4 has end group but no antenna inside of HOM cylinder. ISE#5 has full end group includes HOM antenna. ISE#3 has achieved 50MV/m with the same recipe as centre cell. This result showed the RF design of ICHIRO end cell shape has no problem for high gradient. We also applied the same recipe to ISE#4 and #5. The gradients were limited around 18~33MV/m by field emission (Figure 2, blue dot). Additional HPR and degreasing did not cure

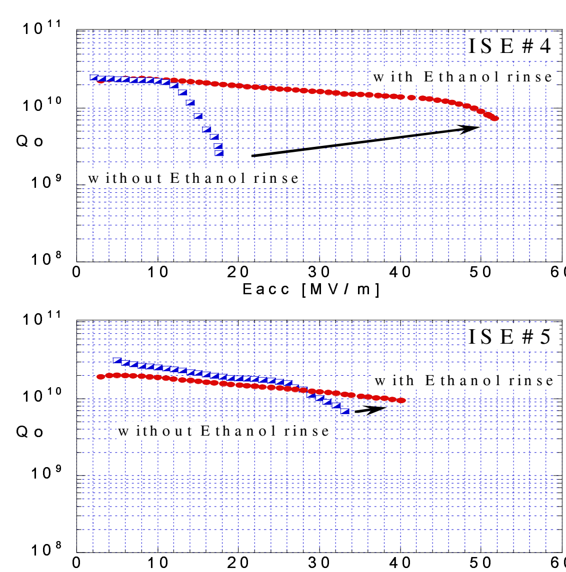

Figure 2: Improvement by ethanol rinsing, Top: ISE#4, Bottom: ISE#5

*fumio.furuta@kek.jp

these field emissions. We considered these field emissions were caused by sulphur contaminations remained at end group. End group has complex structures, so it might be difficult to remove contaminations by HPR only. We tried ethanol rinsing after EP which can dissolve sulphur. We did the additional light EP, flash EP, ethanol rinsing, degreasing, HPR and baking to ISE#4 and #5. The gradients had been improved up to 52MV/m in ISE#4. ISE#5, which has full end group, also improved up to 40MV/m but still stayed the lower field compared to ISE#4(Figure 2, red dots). We understood the problem of end group relates to the difficulties of rinsing in complex structures. We also confirmed the great effect of ethanol rinsing for sulphur contaminations.

SERIES TESTS OF ETHANOL RINSING

We did the yield test of ethanol rinsing. The tested recipe consists of light EP, flash EP, ethanol rinsing, degreasing, HPR, and Baking. Numbers of test were 5times for ISE#4 and 6times for ISE#5. The results are summarized in figure 3.

Baking Effects on HOM

For IS cavities, we usually bake only the cell. When ISE#4 achieved 52MV/m, baking was applied only for the cell. ISE#5 also baked only the cell. The results of 1st~3rd test for ISE#5 were limited at 40, 40, 31MV/m. We thought those results might relate to no baking for end group. We baked ISE#5 including end group at 4th~6th test. Gradients achieved 45, 34, 45MV/m. We confirmed full HOM also needs baking for oxygen diffusion into bulk or

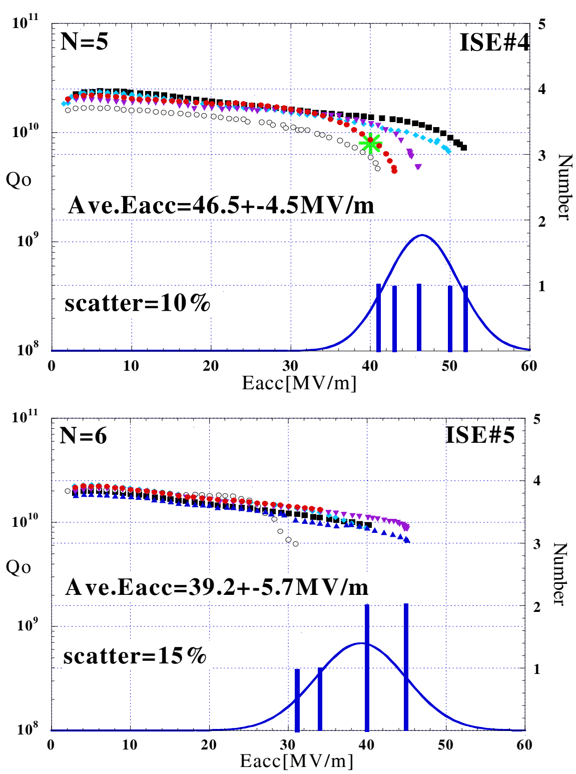

Figure 3: Series test of ethanol rinsing. Top: ISE#4, Bottom: ISE#5

improving vacuum condition like less residual gas adsorption. The 9-cell cavity is baked entirely in a baking box, so this problem does not happen.

High Field Q-Slope

At the results of ISE#4, the average gradient was more than 45MV/m, but the scatter of 10% was twice larger than that of the centre cell results. Q-slope became very clear at more than 40MV/m. For the ISE#5, the maximum gradient was limited at 45MV/m. The average was lower than ISE#4, so Q-slope is not so clear in ISE#5. The difference between the results of ISE#4 and #5 might depend on HOM antenna. ISE#5 has HOM antenna, but ISE#4 doesn't. High field Q-slope seems to be special to end group. HOM cylinder has dead end structure and HOM antenna has a part of shadow for HPR water jet, some sticky contaminations might remain after HPR. To remove such sticky contaminations, another much stronger rinsing might be needed.

WIPING

ISE#5 cavity once had very heavy field emission during the sulphur investigating. It could not be cured by additional rinsing, HPR, ethanol rinsing, or degreasing. We tried to cure this field emission by wiping cavity inner surface directly. We used very smooth cloth soaked in degreaser as wiper (Figure 4). We wiped whole inside of cavity, cell, beam tubes, HOM cylinder and antenna by hand. The antenna was even rubbed by teeth brash. In common sense, electropolished surface is very sensitive, so nobody favours to touch inside before VT. But we tried it as a pilot study. The result is shown in figure 5. Gradient was improved from 11MV/m to 30MV/m

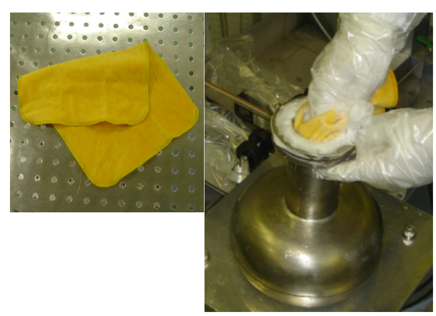

Figure 4: Photo of wiping and cloth

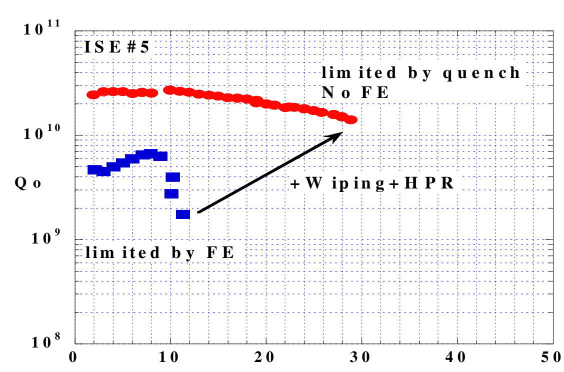

Figure 5: Pilot study of wiping

without field emission, the limitation was quenching. Wiping seems effective to cure heavy field emission by removing sticky contaminations. Electropolished surface seems to be not effected by wiping. We added wiping in our recipe and did series test to check the yield.

SERIES TESTS OF WIPING

We have been doing the yield test of wiping. The testing recipe consists of light EP, flash EP, ethanol rinsing, wiping with degreaser, HPR, and baking. The numbers of test were 3times for ISE#4 and 5times for ISE#5 so far. The results are summarized in figure 6. In the graph, the blue line shows the Gaussian fitting of tight loop results from ethanol rinsing as the comparison.

ISE#4 showed high reproducibility of high gradient. The source of large scatter of ISE#4 seemed to be removed by wiping. ISE#5 achieved the maximum gradient of 48MV/m. Wiping pushed up gradient from 39.2MV/m to 42.6MV/m in average, then high field Q-slope becomes clear. Table 1 shows the averages of maximum gradient and Qo values at 40MV/m for ethanol rinsing and wiping. Qo values were also improved about 15% by wiping.

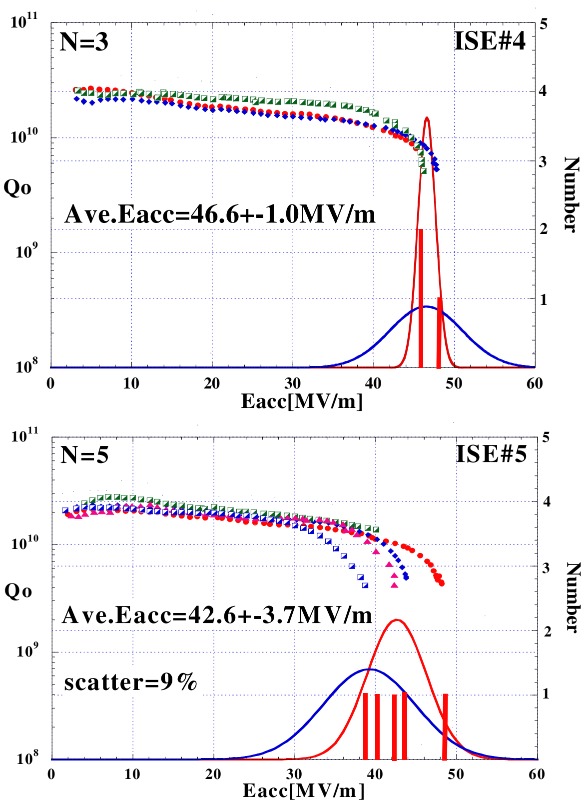

Figure 6: Series test of wiping. Top: ISE#4, Bottom: ISE#5

Table 1: Average of Eacc max and Qo value at 40MV/m.

	EP+Ethanol		EP+Ethanol+Wiping	
	Eacc[MV/m]	Qo [e10]	Eacc[MV/m]	Qo [e10]
ISE#4	46.5±4.5	1.15±0.22	46.6±1.0	1.37±0.22
ISE#5	39.2±5.7	0.97±0.11	42.6±3.7	1.12±0.21

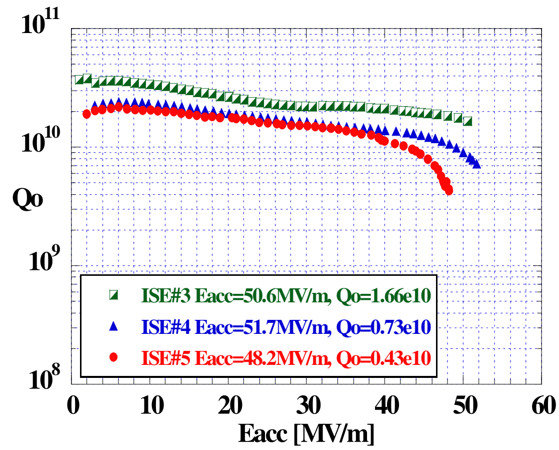

Figure 7: Best Qo vs. Eacc plots of end-singles

High field Q-slope still remained in both of ISE#4 and #5, did not cured by wiping. Another mechanism should be there. We are investigating about it.

SUMMARY

We have demonstrated high gradient of 48~52MV/m with end single cell cavities (Figure 7). The RF design of ICHIRO end cell has no problem for 50MV/m. We found the end group problems. One is the difficulties of rinsing in complex structures like HOM coupler. The other is high filed Q-slope. We have improved our recipe and the yield by taking steps against sulphur contaminations. 1st step was ethanol rinsing that can dissolve sulphur, 2nd was wiping to remove sticky contaminations. We also applied wiping on 9-cell cavities [6]. It worked well for both of singles and 9-cells so far.

Remained subjects in singles are understanding of high field Q-slope mechanism and the achievement of 50MV/m with full end group cavity.

REFERENCES

[1] F. Furuta et al., Proc. 10th Eur. Part. Acc. Conf. (EPAC2006), Edinburgh, June 2006, p.750
[2] K. Saito, Proc. of 13th International Workshop on RF Superconductivity, Peking University, Beijing, China 2007, TU202.
[3] Y. Morozumi et al., Proc. 22nd Part. Acc. Conf. (PAC07), Albuquerque, New Mexico, June 2007, p2439, p2575.
[4] F. Furuta et al., Proc. of 13th International Workshop on RF Superconductivity, Peking University, Beijing, China 2007, TUP10.
[5] K. Saito et al., “Sulfur Generation Mechanism During Electro polishing with Niobium Cavities”, in this proceedings, THPPO090.
[6] F. Furuta et al., “S0 Tight loop studies on ICHIRO 9-cell cavities”, in this proceedings, THPPO082.