Application of Electro-Chemical Buffing to L-Band Superconducting RF Cavities

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Abstract

Electro-chemical buffing (ECB) is used to treat metallic materials to obtain a clean and smooth surface (surface roughness less than 0.1 m). In this process, electropolishing (EP) and mechanical buffing are performed simultaneously. ECB was adopted as a new method of surface treatment to a niobium L-band single cell cavity. As a result, by applying EP, annealing, and high-pressure rinsing (HPR) after ECB, field gradient of 33MV/m was attained.

1. Introduction

ECB is a technique to obtain a clean and smooth surface (surface roughness Rz less than 0.1m) of metallic materials.

We applied ECB to an L-band superconducting cavity and studied the effect on cavity performance. The result of the study is reported in this paper.

2. ECB process

ECB, shown in Figure 1, is a combined method of electropolishing (EP) and mechanical buffing. Electrode is rotated and pressed against the work under DC voltage between a work and the electrode to perform EP. At the same time, electrolytic fluid is provided from a hole at the center of the electrode. The main ingredient of the electrolyte is $NaNO_3$. The electrode has some pieces of nonwoven cloths including abrasives on it. Several kinds of electrodes are prepared to fit the cavity inner surface.

3. Observation of the surface of the Nb sample polished by ECB

A 2.5 mm thick niobium plate, removed by 96m from the surface by ECB, was used as a sample to make a surface observation. At first, surface roughness of the polished sample was measured. Figure 2 indicates the surface roughness, which was 0.16m (Rz). Then the niobium plate was rinsed in acetone with ultrasonic for two minutes. After that, an observation was carried out for the surface by scanning electron microscope (SEM). As many embedded abrasives were found, element analysis was performed by energy dispersive X-ray analyzer.

Results of the observations and element analysises of embedded abrasives are shown in Figure 3 and Figure 4. Most of the abrasives were 1 to 2m in size and Al was detected from them as a main element. As a special case, a particle as large as 4m, which contains not only Al but also Si and Fe, was found.

4. Procedure for surface treatment of cavity

Figure 5 is a shape of 1.3GHz superconducting RF cavity. Figure 6 indicates the procedure of manufacturing and surface treatment of the cavity prior to measurement #1. In order to achieve a high electric field exceeding 30MV/m, such factors as would limit the cavity performance were carefully removed (for example surface damage layer due to fabrication procedure).

Each procedure is following:

(1) To avoid problems caused by the shortage of removing thickness, inner surface layer of half cells was removed by barrel polishing [1]. Barrel polishing was carried out before ECB and electron beam welding (EBW). Figure 7 is a picture of the barrel polishing. The beam pipes and half cells were held together by a jig and taped. The cavity was filled with barrel chips and soapy water. It was then rotated at 100 rpm for 270 hours for polishing.

(2) After barrel polishing, the ECB was applied in parts before EBW, because it was difficult to apply ECB to all inner surface of the completed cavity with complex shape. The removed thickness was measured by ultrasonic thickness meter.

(3) The half cells were joined together by EBW. EBW was done from the inside of the cell. Before EBW, equator welding region was slightly (10m) removed by chemical polishing (CP) for cleaning.

(4) ECB was applied again to the equator seam to remove the weld defects.

(5) The cell and two beam pipes were cleaned out with megasonic rinsing (MSR) and HPR.

(6) The two beam pipes were joined to the cell by EBW after the edges were cleaned by CP (10m).

(7) To the completed cavity, MSR(2Hr) and HPR(1.5Hr) were applied. At this stage, ECB has been applied all inner surface except iris regions of the cavity.

(8) The measurement #1 was performed.

We applied the surface treatment as shown in table 1 to the cavity prior to each measurement.

Table 1 surface treatment of each measurement

	condition of surface treatment
#1	Barrel Polishing + ECB *+ MSR+HPR(1.5Hr,65kgf/cm^2
#2	max)
#3	ECB** + MSR +HPR(1.5Hr,65kf/cm^2 max)
#4	EP(10m) + MSR +HPR(1.5Hr,70kgf/cm^2 max)
#5	anneal(750,5Hr) + HPR(1.5Hr,60kgf/cm^2 max)
#6	EP(10m) + HPR(1.5Hr,60kgf/cm^2 max)
#7	EP(20m) + HPR(1.5Hr,60kgf/cm^2 max) HPR(1.5Hr,90kgf/cm^2 max)

*ECB was applied to all inner surface except iris regions.

**ECB was applied only iris regions.

5. The thickness removed during the process

Figure 8 shows the removed thickness distribution by barrel polishing and ECB along the cavity surface. Removed thickness by barrel polishing is about 70 m at the equator and about 30 m at the irises. By the ECB process, about 30m on the average was removed. At the equator seam, at least 100 m seemed to be removed because the equator seam became very smooth. And 50m was removed at the iris seams. Since the size of embedded grains by barrel polishing are about 5 m [2], ECB would reset the barrel polished surface enough.

6. Results of cold tests

Figure 9 is a result of cold tests of the cavity measured at 1.8 K after each step of surface treatment. All the measurement were performed after fast cooling down in an hour from room temperature to 4.2K. Q_0-value and Eacc,max in each measurements are shown in table 2.

Table 2 Q_0-value and Eacc,max in each measurement

	Q_0-value		Eacc,max [MV/m]
	initial	At Eacc,max	
#1	5.0E8	1.0E8	1.66
#2	2.5E8	6.7E7	2.91
#3	3.1E9	7.5E8	10.7
#4	2.9E10	9.2E9	30.8
#5	1.7E10	1.3E10	29.0
#6	2.7E10	1.0E10	29.3
#7	1.8E10	1.3E10	33.4

In measurement #1 and #2, breakdown occurred at low fields, and the Q_0-values were very low and decreased remarkably with increasing field. It seems to be caused by the contaminant of the embedded abrasives from the ECB.

Measurement #3 was taken after EP (10m) for removing the contaminant of embedded abrasives followed by MSR and HPR. Performance of the cavity was improved. Maximum field increased to 10.7 MV/m. But the Q_0-values were still low. And at the breakdown point, Q_0-value decreased to 1/4 of the lowest field. In this measurement, Q_0-values were low and drastically decreased in low field region. This phenomenon seemed to be Q_0-disease caused by H_2 gas absorption during EP process [3]. So, the cavity was annealed at 750 for 5 hours to degas hydrogen. And after taking HPR, measurement #4 was performed. This time, the cavity performance was remarkably improved. The maximum field attained 30.8 MV/m and the Q_0-value exceeded 10^{10}. But at higher gradient area the Q_0-value still decreased slightly likely caused by the contamination.

As it was thought to be difficult to remove contamination enough by conventional MSR and HPR, measurements #5 and #6 were taken immediately after additional slight EP. Removed thickness by EP before measurement #5 and #6 was 10m and 20m respectively. However there was little improvement.

Measurement #7 was taken after HPR with the increased pressure of 90 kg/cm^2. This time, maximum field achieved 33.4 MV/m with Q_0-values exceeding 10^{10}.

7. Conclusion

The ECB method was applied to a niobium superconducting cavity to obtain a smoother inner surface.

The measured field gradient of 33MV/m is comparable to the result using the conventional method atKEK [4]. However, by adopting EP (10m) after ECB, field gradient attained 30MV/m, whereas it need EP(30m) after barrel polishing to attain 30MV/m [4]. This might be an effect of ECB although only one record.

8. Acknowledgment

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9. References

[1] T. Higuchi et. al., «FINISHED NIOBIUM CAVITY SURFACE WITH BARREL POLISHING», Proc. Of the 21st Linear acceleratorator Meeting in Japan, 1996, p. 228

[2] K. Saito, private communications

[3] K.Saito et. al. »Q0-DEGRADATION DUE TO HYDROGEN IN HIGH PURE NOIBIUM CAVITIES», Proc. of the 18th Linear Accelerator Meeting in Japan, 1993 , p.299

[4] K.Saito et al., "Importance of the electropolishing for the high gradient SC cavity fabrication", Proc. of the 22nd Linear accelerator Meeting in Japan, 1997, p.50

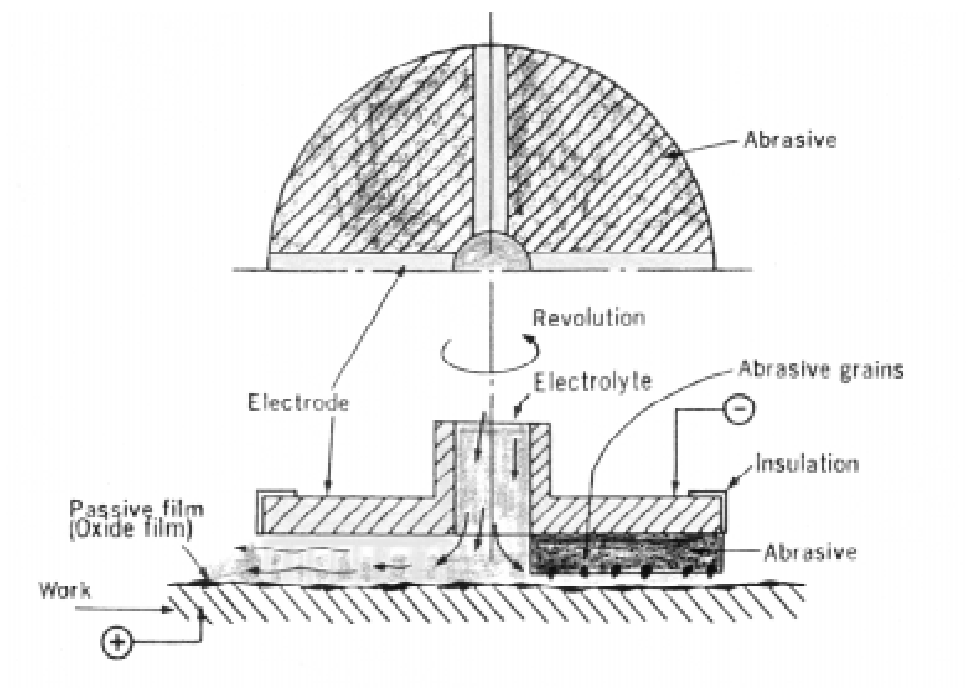


Figure 1 Polishing method of EBC

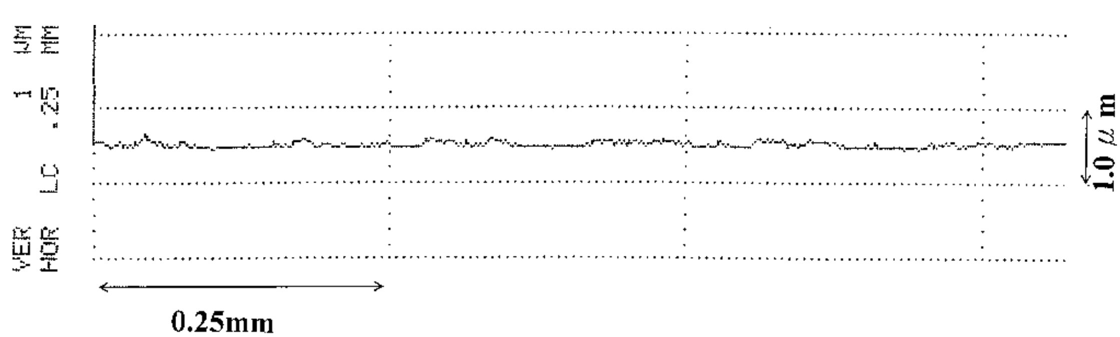
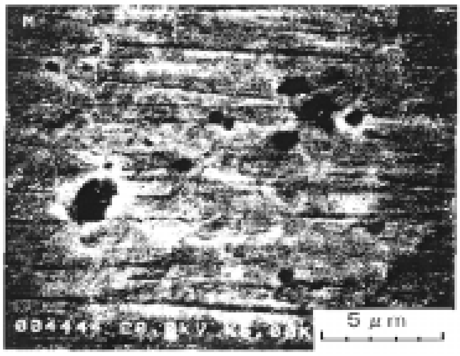
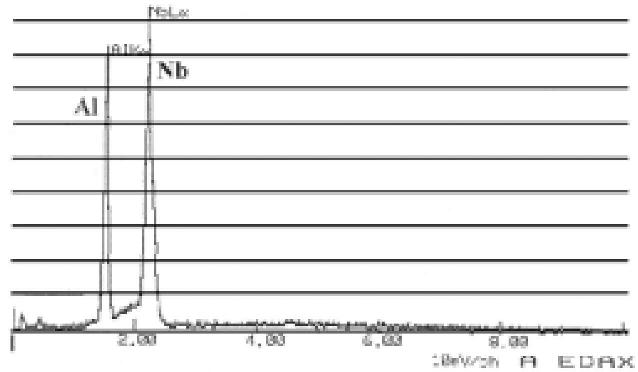


Figure 2 Surface roughness of Nb sample 96mm removed by electro chemical buffing

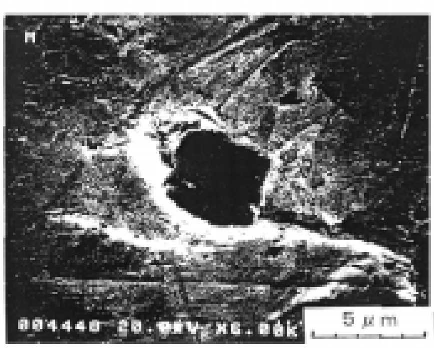


SEM image and size of embedded abrasives (× 6000)

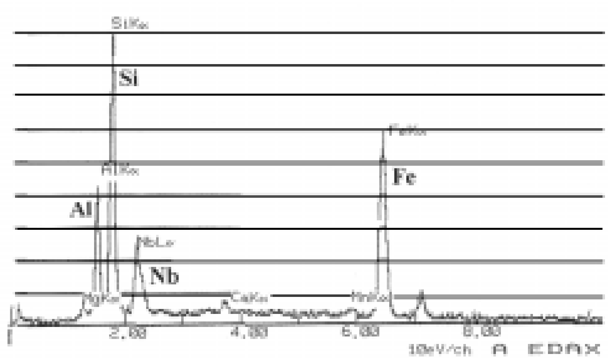


Result of element analysis of an embedded abrasive with energy dispersive X-ray analyzer

Figure 3 Typical embedded abrasives on the surface of a Nb sample after ECB



SEM image and size of an embedded abrasive (× 6000)



Result of element analysis of an embedded abrasive with energy dispersive X-ray analyzer

Figure 4 An especially large embedded abrasive on the surface of a Nb sample after ECB

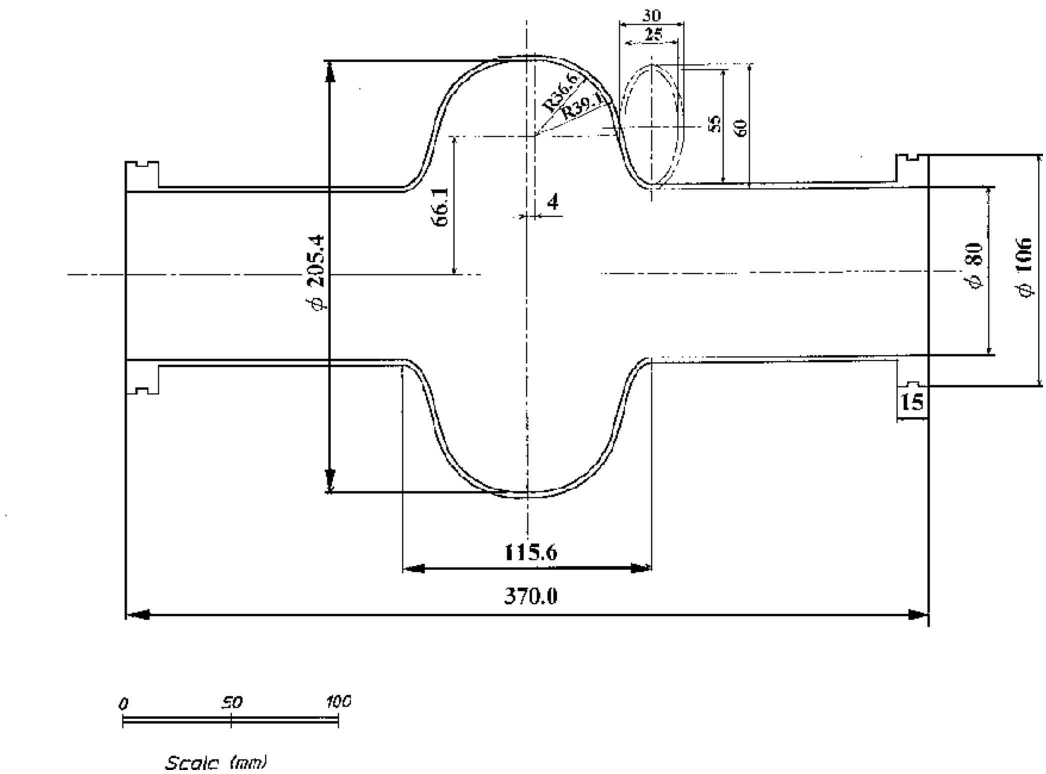


Figure 5 1.3GHz Superconducting RF Cavity

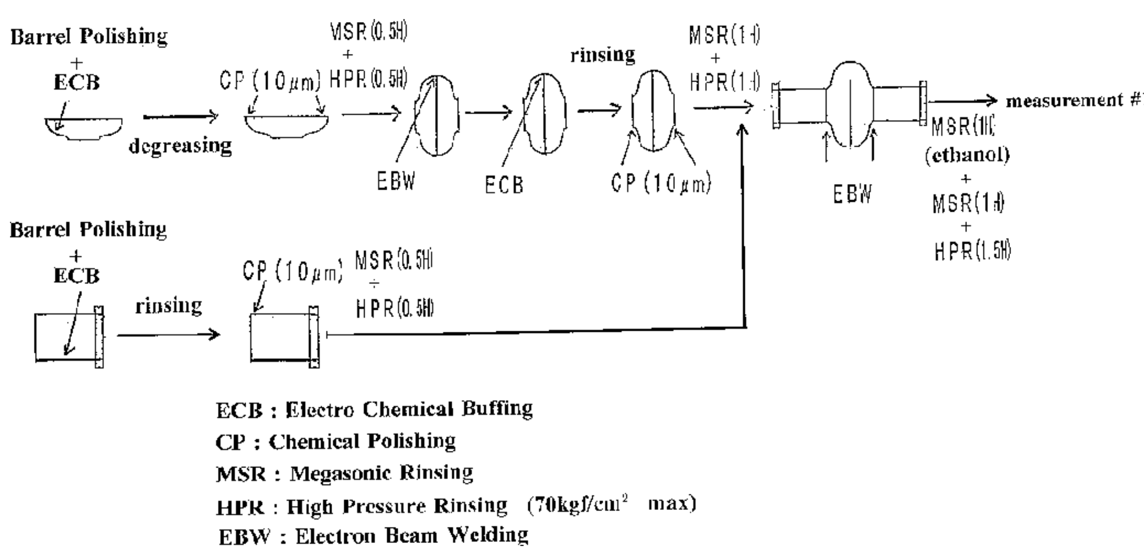


Figure 6 Fabrication procedure of L-band superconducting cavity

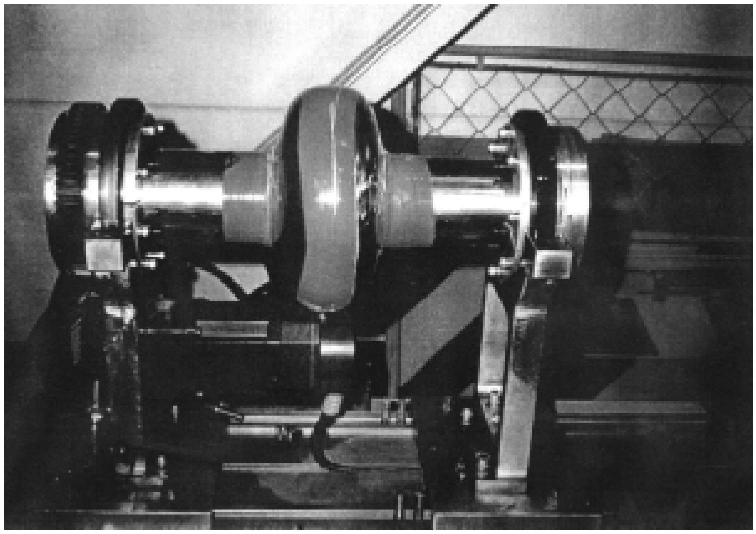


Figure 7 Barrel polishing of the L-band cavity

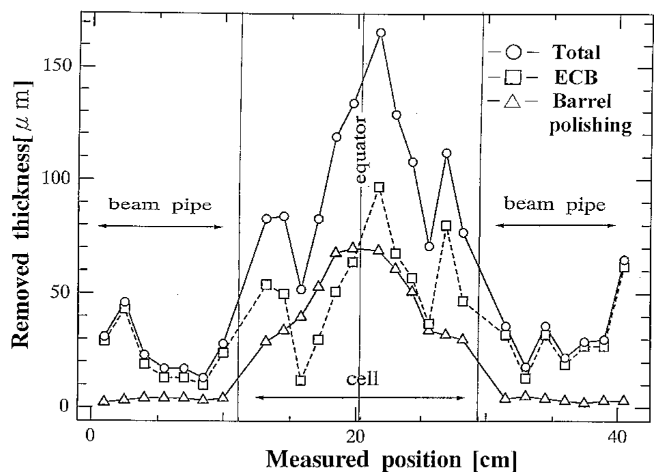


Figure 8 Removed thickness by barrel polishing and electro chemical buffing

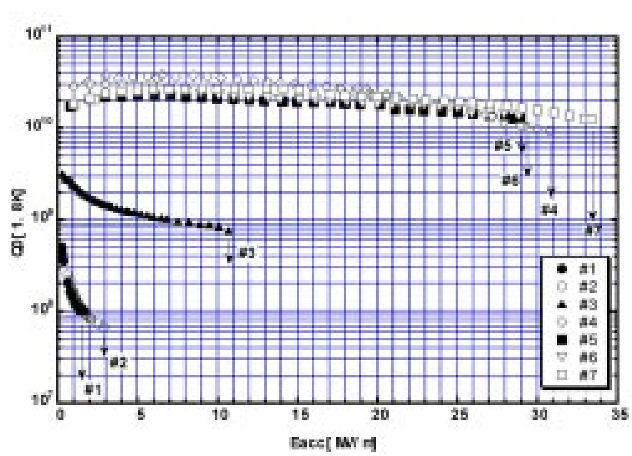


Figure 9 Result of cold test