TEST RESULTS OF THE L-BAND SUPERCONDUCTING CAVITY MADE FROM TWICE MELTED NIOBIUM

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Abstract

An L-band single-cell cavity was fabricated with niobium sheets made from twice melted ingot, which had a low RRR of 130. The accelerating gradient (Eacc) was limited by quench at about 20MV/m with a preparation by CP (Chemical Polishing) and HPR (High Pressure Rinsing). On the other hand, the Eacc of 40MV/m was achieved by applying EP (Electro Polishing) and HPR in spite of a low RRR material. Neither mechanical polishing nor heat treatment was carried out in this cavity.

1 INTRODUCTION

For a large application of superconducting cavity such as TESLA (TeV Energy Superconducting Linear Accelerator), it is important to achieve high accelerating gradient (Eacc) reliably. The performance of superconducting cavity is governed by many factors such as thermal quench, field emission, multipacting. In case of thermal quench, the quench field is able to shift up by raising an RRR (Residual Resistivity Ratio) of niobium material, because the RRR is proportional to λ (thermal conductivity) [1]. For a higher RRR, heat generated at defective spots is flow out to liquid helium more effectively. This is one reason why superconducting cavities have been made from a high purity niobium material. At KEK, the RRR of more than 200 has been usually employed. However, cost of such material is expensive, because more than three times refinement by Electron Beam Melting (EBM) is necessary. Therefore, in case of a large project like TESLA, it is important to reduce the cost of niobium material. An L-band single-cell cavity named K-22 was fabricated with niobium sheets made from twice melted ingot, and the cavity performances were tested. The test results are quite promising for getting high gradient if the surface treatments are processed properly by electropolishing.

2 CAVITY AND SURFACE TREATMENT

The parameters of the K-22 cavity are shown in Table 1. Many cavities, which have been tested at KEK, were made from a high purity niobium of more than 200 RRR supplied from Tokyo-Denkai Co., Ltd.. Such material can be obtained from repeating EBM more than three times to a niobium ingot [2]. However, the K-22 cavity was made from twice melted niobium ingot, which has an RRR of 130 (in sample). The niobium sheets were supplied from Tokyo-Denkai Co., Ltd.. Figure 1 shows a relationship between RRR and the number of melting [2].

Table 1: The parameters in K-22 cavity

R/Q [Ω]	102.
Γ (geometrical factor)	274.
Ep/Eacc	1.78
Hp/Eacc [Oe/MV/m]	43.8
Eacc/√(PQ)	87.35
Diameter of beam tube [mm]	80.
Area of inner surface [cm2]	1664.
Weight [g] per material removal of 1 μm	1.42
Resonant frequency [MHz] at 4.2K	1297.0

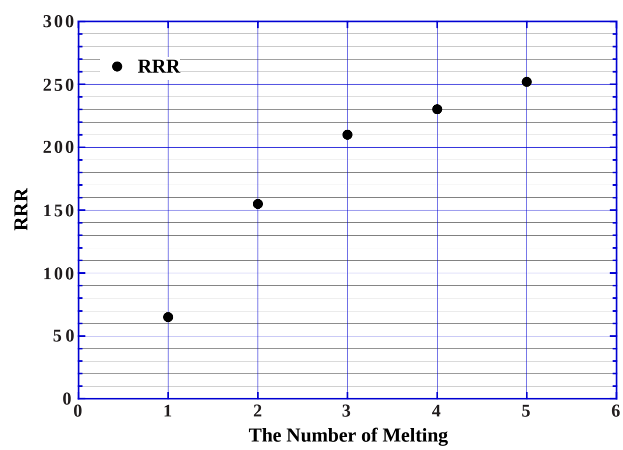

Figure 1: RRR vs. The Number of Melting
: reprinted from ref. [2]

A process of a cavity fabrication produces residual stress that may make RRR lower. Therefore, in the usual cavity fabrication, heat treatment at 800°C in a vacuum furnace is carried out for eliminating residual stress and for hydrogen degassing.

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Neither mechanical polishing nor heat treatment was carried out in the K-22 cavity. The sequential test followed after each surface treatment was carried out systematically, such as chemical polishing (CP) series and electropolishing (EP) series. The removal thickness was 30-50 µm at each treatment, and high pressure rinsing (HPR) was always followed. The surface treatment of each test is summarized in Table 2. Water pressure of HPR was about 90 kgf/cm^2.

Table 2: Surface Treatment of Each Measurement

1st	CP(50µm)+HPR (upw -> pw) 1hour
2nd	CP(30µm)+HPR (pw) 1 hour
3rd	CP(30µm)+HPR (pw) 1 hour
4th	CP(50µm)+HPR (pw) 1 hour
5th	CP(50µm)+HPR (pw) 1 hour
6th	CP(50µm)+HPR (pw) 1 hour
7th	CP(40µm)+HPR (pw) 1 hour
8th	EP(30µm)+HPR (upw) 1 hour
9th	EP(30µm)+HPR (upw) 1 hour
10th	Keep at 100K for 4hours, and re-cooling
11th	EP(30µm)+HPR (upw) 1 hour
12th	EP(30µm)+HPR (upw) 1 hour

upw : ultra pure water
pw : pure water passed through 0.2µm filter

3 EXPERIMENTAL RESULTS

A surface resistances (Rs) of a cavity is expressed by a following equation:

$$Rs = A/T \exp[-(\Delta/kT)] + Rres \quad (2)$$

where the first term represent the BCS resistance and the Rres is the residual resistance independent on temperature. The parameters calculated from this equation in each test are shown in Figure 2. Almost constant parameters in each test may indicate that all in tests were carried out property, and the bulk properties in the cavity were not changed. An observed tendency of the cavity performances in each test may be the resultant in each surface treatment. In these tests, 16 carbon thermometers were attached at the equator (except 12th test). No effect was observed at least on these parameters. Influence of the residual magnetic field is estimated about 5nΩ in the Rres. The test results in CP-series and EP-series are shown in Figure 3 and Figure 4, respectively. The maximum accelerating gradient (Eacc,max) as a function of a removal thickness are shown in Figure 5. The Eacc,max in the CP-series were limited by thermal quench, and they are saturated at 20MV/m, in spite of the removal of 300µm.

On the other hand, the first EP of 30µm (8th test in Table 2) the Eacc,max was remarkably improved by and 32MV/m was achieved. A superiority of EP [3] was again

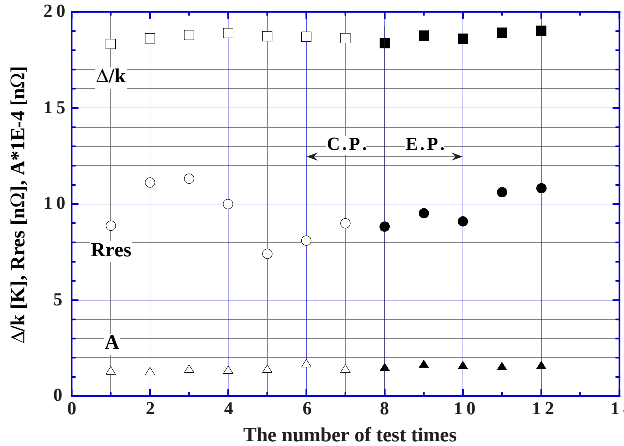

Figure 2: The obtained parameters in each test

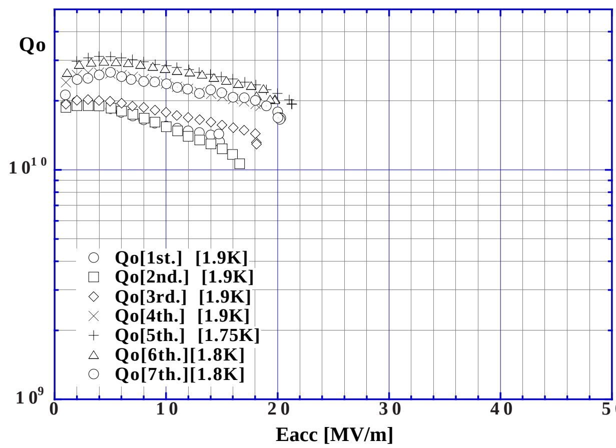

Figure 3: Cavity performances with CP and HPR

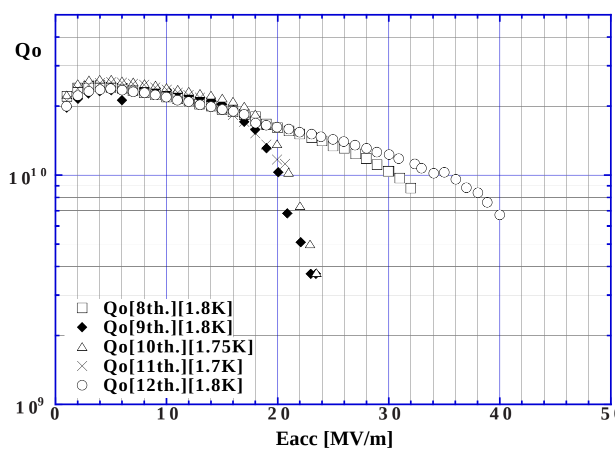

Figure 4: Cavity performances with EP and HPR

confirmed in this test. In the 9th test, field emission was observed. The causes might be due to contamination of the EP solution. An aim of the 10th test was to investigate hydrogen Q_0-disease after keeping around 100K for a few hours [4]. Consequently, no Q_0-disease was observed in spite of no heat treatment in the cavity.

The Eacc,max was limited by thermal quench at 21MV/m in the 11th test after additional 30µm removal @by EP.

Field emission was also observed, and the 30µm EP seems to be enough to remove the cause of field emission.

The 12th test was carried out further 30µm removal by EP with using new chemical solution. Processing level (multipacting) was observed between 18 and 23MV/m. After processed out these levels, the Eacc,max of 40MV/m was attained. Only weak X-rays were observed around Eacc,max, and the obtained Q_0-Eacc curve shows the similar tendency of the previously attained 40MV/m Q-E curve [5]; the slight Q-degradation at higher gradient was observed.

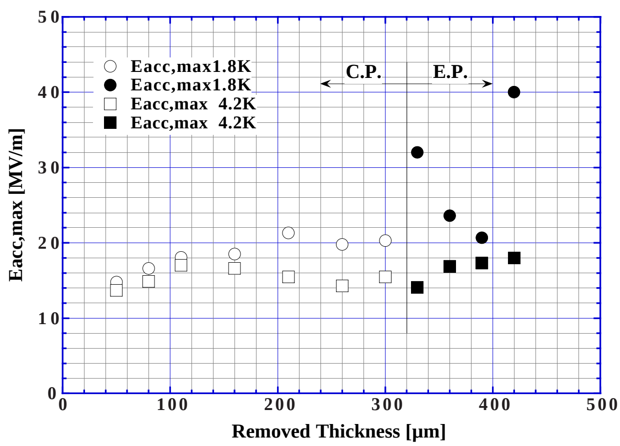

Figure 5: Eacc,max vs. removed thickness

4 SUMMARY

The K-22 cavity was fabricated with niobium sheets made from twice melted ingot (RRR=130). This cavity showed the excellent performances with the Eacc,max of 40 MV/m, even though the low RRR material was used, and neither mechanical polishing nor heat treatment was carried out. In CP-series (removal thickness of 300µm in total), the Eacc,max was limited at 20MV/m. Just only the 30µm EP and the Eacc,max of 32MV/m was achieved. The superiority of EP is again confirmed even for the low RRR material.

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Table III: Summary of K-22 Performances

	~1.8K		~4.2K	
Run#	Eacc,max[MV/m]	Qo at Eacc,max	Eacc,max[MV/m]	Qo at Eacc,max
1	14.8	1.33e10	13.7	2.97e8
2	16.6	1.06e10	14.9	3.11e8
3	18.1	1.34e10	17.0	2.68e8
4	18.5	1.98e10	16.6	2.78e8
5	21.3	1.93e10	15.5	2.67e8
6	19.8	2.04e10	14.3	2.36e8
7	20.3	1.68e10	15.5	2.67e8
8	**32.0**	8.79e9	14.1	2.55e8
9	23.5	3.71e9	16.1	2.72e8
10	23.5	3.76e9	16.0	2.75e8
11	20.7	1.12e10	17.3	2.80e8
12	**40.0**	6.71e9	18.0	2.80e8