DEVELOPMENT OF HORIZONTAL CHEMICAL POLISHING FOR SUPERCONDUCTING NIOBIUM CAVITIES

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Abstract

In a previous chemical polishing method for niobium superconducting RF cavities, where the cavity is chemically polished in a vertical position, a distribution of removal thickness is not uniform. The material removal is the most at upside of the cell. So, we have to turn the cavity in the middle of the process. A new method, in which a cavity is set horizontally and chemically polished (HCP), was developed under the collaboration of KEK and Nomura Plating Co., Ltd. in order to solve this problem. A uniform distribution of removal thickness was obtained with HCP using a virgin 1300 MHz niobium cavity. In addition, the polishing speed of HCP is 20 times as fast as that of EP. Therefore, there is a probability that the HCP is used as a pre-treatment of the EP. HCP was applied to 1300 MHz niobium cavities and its performance were measured. This paper presents these results.

1 INTRODUCTION

Recently the superiority of electropolishing (EP) over CP was confirmed on high gradient of the niobium superconducting RF cavities [1]. However, CP has still merit in the speed of the material removal. But in the previous CP, the distribution of the material removal is not uniform.

In order to eliminate this problem, a new method, in which a cavity is set horizontally and chemically polished (HCP), was developed by a collaboration of KEK and Nomura Plating Co., Ltd. We tested the cavity at the material removal steps by 30-40 μm up to 130μm, then 100μm totally up to 230μm. In each step, the distribution of the material removal and the cavity performance were measured. Especially we concerned with the Hydrogen Q-disease in this measurement. In this paper, results of these experiments are reported.

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2 HCP SYSTEM

A system of HCP is shown in Figure 1. A single cell and a 3–cell niobium cavity of 1300 MHz were treated with this HCP system. In the HCP method, the cavity is set horizontally and rotated continuously (20 r.p.m.). The acid is loaded into the cavity at a half of level through a tube set in the center of the cavity. During the polishing, the acid temperature in the cavity is monitored with a thermocouple. The cavity is cooled by water shower from the outside. In addition the acid is cooled by a heat exchanger, however, it was not used in this experiment. When the polishing process is over, the valves for circulation of acid is closed and the cavity is cooled with flashing water during it is turning to vertical position. After that, inside of the cavity is quickly rinsed with demineralized water through the tube.

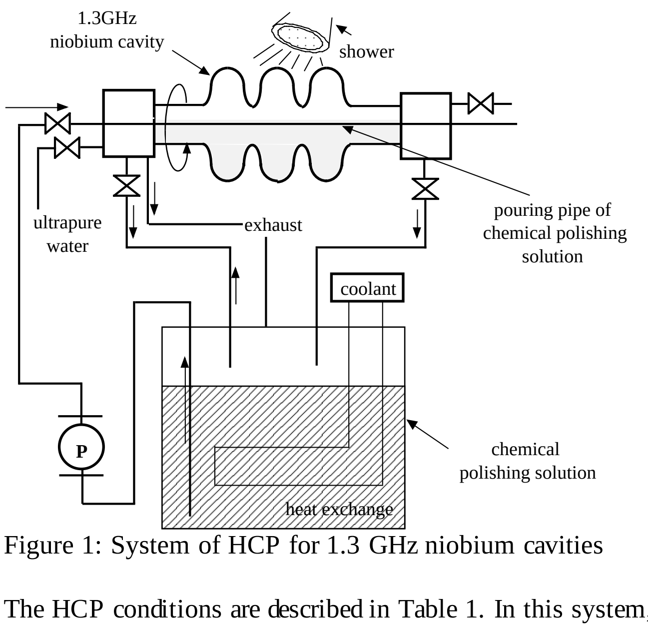

Figure 1: System of HCP for 1.3 GHz niobium cavities

The HCP conditions are described in Table 1. In this system, we used the same BCP acid as has been used at KEK; 1:1:1=nitric acid: phosphoric acid: hydrofluoric acid v/v. During HCP, the acid temperature in the cavity was kept under 45ºC. This temperature was the same as the previous vertical BCP method. The rotation speed was 20 r.p.m. The removal speed was 8μm per minute.

Table 1: Comparison the conditions between the previous CP and HCP

Method	Previous CP	HCP
Setting of cavity	Vertical	Horizontal
Flow late	0 (no circulation)	5 l/min
Polishing solution	HF:HNO3:H3PO4 = 1:1:1 (v/v) (HF; 46%, HNO3; 60%, H3PO4; 85%)	same as the solution of previous CP
Rotation of cavity	0	20 r.p.m.
Contact surface aria with the solution	100%	65%

3 DISTRIBUTION OF REMOVAL THICKNESS BY HCP

The distribution of removal thickness by the HCP is compared with that of previous CP or EP. Along the direction of beam pipe, the thickness of the cavity wall was measured with using an ultrasonic thickness meter. A comparison of material removal between HCP and privious CP is presented in Figure 2, in which the target material removal was 30 μm. The uniform removal thickness was observed in the HCP. However, in the previous CP, a larger material removal at upper half-cell was seen, in which the cavity was not turned during the process.

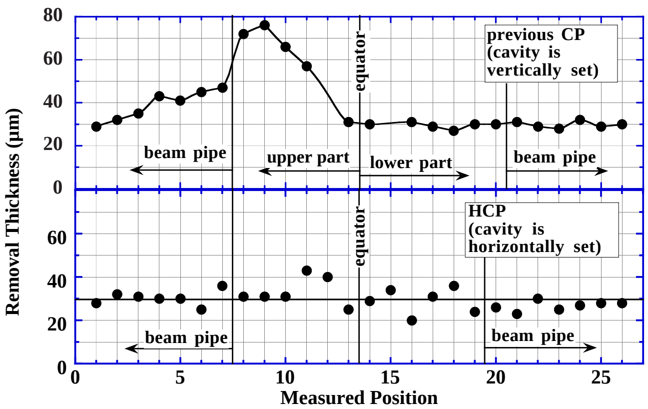

Figure 2: Comparison of the distribution of removal thickness between vertical CP and HCP

A comparison of HCP and EP with the material removal is presented in Figure 3. The beam tubes are removed much in EP.

The uniformity of material removal by HCP was also obtained in a three-cell structure as shown in Figure 4, in which the target removal was a 100μm.

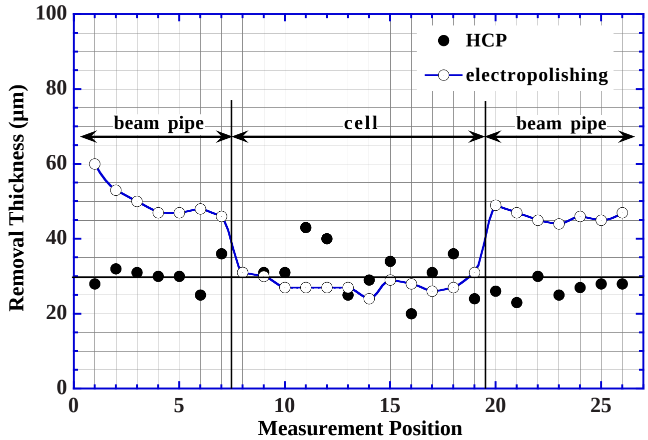

Figure 3: Comparison of the removal thickness between HCP and EP

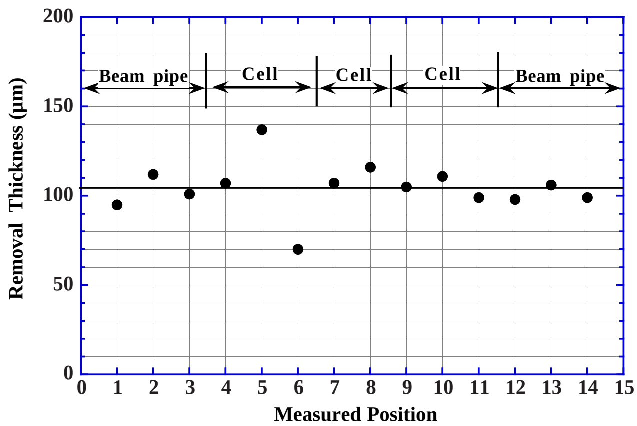

Figure 4: Distribution of removal thickness of 3-cell cavity (target material removal: 100μm)

4 CAVITY PERFORMANCE TESTS

Using a 1300 MHz virgin single-cell niobium cavity, effect of material removal by HCP on the cavity performance was evaluated. The cavity performance tests were carried out at the steps of material removal: 28μm, 55μm, 99μm, 132μm and 232μm totally from the initial surface. After the HCP, the cavity was treated with hot rinsing (60°C) in an ultrasonic agitator bath and high pressure rinsing ($80kg/cm^2$). In this experiment, we have a special concern to Hydrogen Q-disease. The measurements were done twice for every material removal. At first, the cavity was measured after fast cooling down within one hour from room temperature to 4.2 K. Lowering the liquid helium temperature from 4.2 K to 1.5 K, the temperature dependence of surface resistance was carefully measured, and the residual surface resistant was evaluated by the data fitting. Then the Eacc-Qo curve was measured at the lowest temperature. After that, the cavity was warmed up to 100K in which hydrogen Q-disease most pronounces [2], and exposed to the temperature for one night. Then, the same cold test was repeated again.

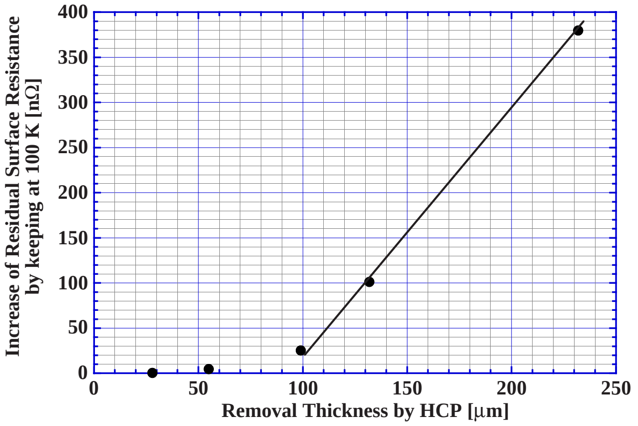

Figure 5: Effect of material removal of HCP on the difference of surface residual resistance between before and after keeping at 100 K for one night

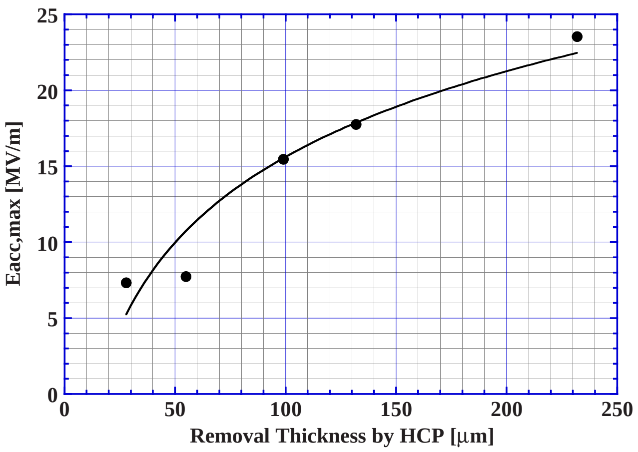

Figure 6: Effect of material removal of HCP on the cavity performance

The measurement results are presented in Figure 5 on the residual surface resistance which was measured after exposing to 100 K. By the exposing to 100K, a remarkable increase in the residual surface resistance was observed, which increases proportionally to the amount of removed thickness. Thus, the hydrogen Q-disease was clearly observed by HCP.

The high gradient performance by HCP is presented in Figure 6, in which the measurement was carried out by the fast cool down measurements. As reported in the reference [3], upgrading of the high gradient performance with the material removal was observed. The maximum field gradient of 23.5 MV/m was achieved after 130μm was removed totally. With the cavity that was treated with HCP, Hydrogen Q-disease occurs. But there is no difference between HCP and the previous CP in the high gradient performance of the first fast cool down (Figure 7). With the hydrogen Q-disease, there seems to be still room for further development: control of acid temperature, chemical composition of the CP acid and so on.

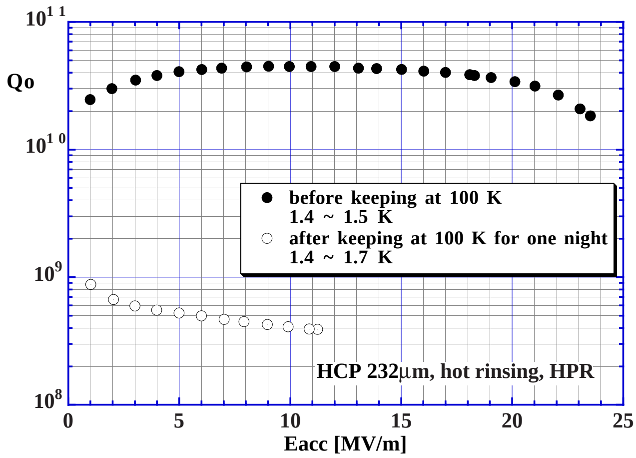

Figure 7: Q-disease of the cavity that was removed the 232 μm of the inner surface with HCP

5 RELATIONSHIP BETWEEN THE MATERIAL REMOVAL AND CAVITY RESONANT FREQUENCY

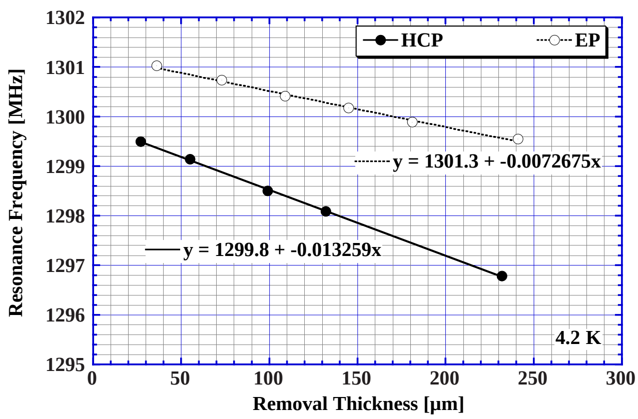

Figure 8: Relation between resonance frequency and removal thickness of HCP and EP

The relationship between a resonance frequency and a removal thickness is an important information for the cavity fabrication. The resonance frequency at 4.25 K was plotted as a function of a material removal for both HCP and EP in Figure 8. The following results were obtained;

- 13.3 kHz/μm for HCP (1)
- 7.3 kHz/μm for EP (2)

The frequency change with the material removal of the HCP is twice as much as that of EP.

4 CONCLUSION

1) By HCP, a more uniform distribution of the material removal is obtained compared with the previous CP or EP.
2) The uniform distribution of removal thickness is obtained with a multi-cell structure also.
3) Q-disease was occurred by HCP after material removal became more than 100 μm.
4) To cure the hydrogen Q-disease, a further R&D is needed.

5 ACKNOWLEDGEMENT

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6 REFERENCES

[1] K. Saito, E. Kako, T. Fujino, S. Noguchi, M. Ono and T. Shishido, "SUPERIORITY OF ELECTROPOLISHING OVER CHEMICAL POLISHING ON HIGH GRADIENTS", Particle Accelerators, Vol. 60, pp. 193-217

[2] K. Saito and P. Kneisel, "Qo-DEGRADATION IN HIGH PURITY NIOBIUM CAVITIES – DEPENDENCE ON TEMPERETURE AND RRR VALUE", Proc. of the 3rd EPAC conf. 1992

[3] P. Kneisel, "A Selection of higher gradient cavity experiments", Proc. of 8th Workshop on superconductivity, Italy, 1997, pp. 830-842