CENTRIFUGAL BARREL POLISHING OF L-BAND NIOBIUM CAVITIES

T. Higuchi[†], Grad. Univ. of Advanced Studies and Nomura Plating Co., Ltd.
K. Saito and Y. Yamazaki, KEK, Accelerator Laboratory and Grad. Univ. Advanced Studies
T. Ikeda and S. Ohgushi, Nomura Plating Co., Ltd.

Abstract

Centrifugal Barrel Polishing (CBP) was applied to L-band niobium cavities (two types: a single cell cavity and a 3-cell cavity). With the CBP, polishing speed of the inner surface of the cavity was improved to 10 times that of usual barrel polishing. High gradient performance was measured on the single cell cavity and an electric field gradient of 26.3MV/m was reached, which shows much improvement over the best result obtained before.

Niobium samples (2.5(w), 2.5(h), 147(l) mm) were set in the 3-cell cavity during the centrifugal barrel polishing for 8 hours. Concentration of hydrogen of the sample was 61 ppm. It was found out that niobium absorbs hydrogen during the centrifugal barrel polishing.

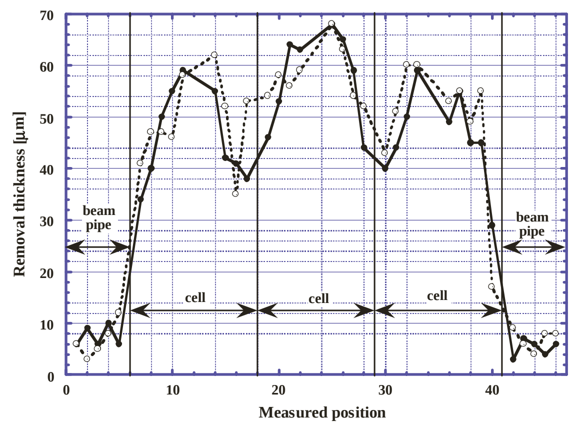

Figure 2: Distribution of polished thickness from the surface with CBP

1 PREFACE

High reliability is essential for accelerating field of the niobium superconducting cavities that would be mass-produced for accelerators of the next generation such as a superconducting linear collider. To improve the yield of the niobium accelerator cavities that satisfies required performance, it is important to apply mechanical grinding as a pre-treatment before electropolishing [1]. On the super-conducting niobium cavities of TRISTAN, buffing was employed as the mechanical polishing. Since the buffing is not suitable for mass-production, we started to look into the barrel polishing instead of employing the buffing 8 years ago and found that it takes a week to remove 30 microns from the inner surface of a niobium cavity. It was worse with a multi-cell cavity as the polishing speed became even slower. To increase the polishing speed, we did some trials (for example, swinging barrel polishing, chemical barrel polishing and intermittent barrel polishing) and got improvement of at most 20%.

Figure 1: Centrifugal barrel polishing apparatus (KEK)

To achieve faster speed on barrel polishing, we started to test the CBP and selecting a polishing media to increase its polishing speed. At the early stage, the first generation CBP apparatus was too small for a multi-cell cavity, samples of a niobium pipe and a single-cell cavity were used in this test. The result says that polishing speed was improved by ten folds from that of previous barrel polishing method. [2]

In this paper, we examine the effect of the CBP on the polishing speed and the performance of the cavity.

2 APPRICATION OF CBP TO A L-BAND NIOBIUM 3-CELL CAVITY

A CBP apparatus was made for L-band niobium single-cell and 3-cell prototype cavities (Figure 1). Using this apparatus, with 8 hours of CBP time, the surface layer of a 3-cell cavity was removed up to 43 microns deep on the first test and 44 microns for the second test (removed thickness from the surface area was measured by measuring the weight). Since it took about a week to remove 30 microns with the previous barrel polishing method, the CBP method is more than ten times faster.

The distribution of the thickness removed from the cavity (Fig.2) was measured with an ultrasonic thicknessmeter measuring the thickness of the cavity wall along the direction of its axis. We also found that:

[†]tamawo@post.kek.jp

(1) The polishing speed was the same for a multi-cell cavity (3-cell cavity) as for a single-cell cavity with this CBP. (With the old method, it was much slower for 3-cell cavity.)

(2) The polishing speed was basically the same when same sample was tried repeatedly.

With a niobium L-band 3-cell cavity, differences in polishing speed between the three cell locations were small indicating that the polishing was location independent.

3 CAVITY PERFORMANCE

As mentioned above, we succeeded in achieving faster speed in barrel polishing with CBP. We checked the cavity performance of the niobium L-band single cavity which was treated in the same way earlier. The cavity went through the CBP (145 microns removed), annealing, electropolishing (30 microns removed), high pressure rinsing and baking. A high electric field gradient of 26.3MV/m was achieved, which is much higher from the previous best result on the cavity. Figure 3 shows performance of the cavity measured at various stage of treatment.

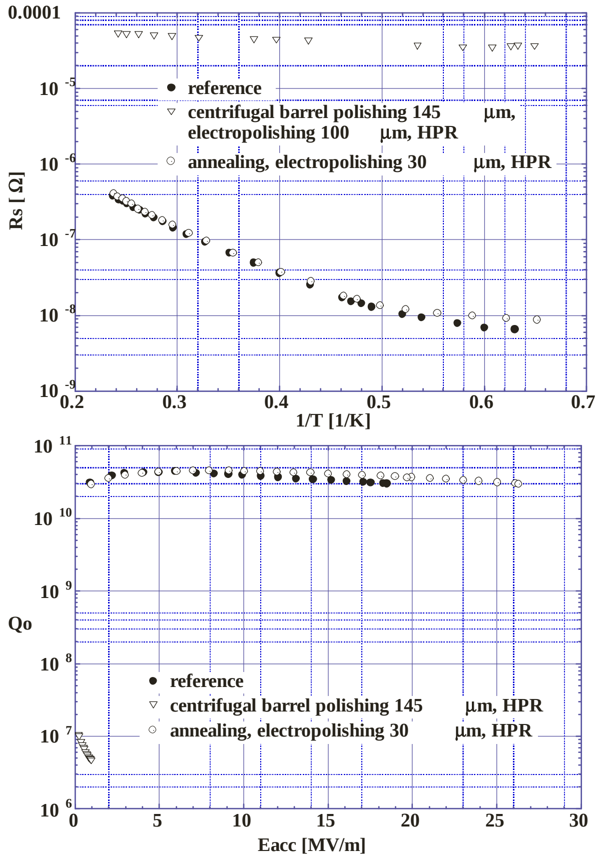

Figure 3: Performance of the cavity that was treated with CBP (pre-treatment) and electropolishing

4 HYDROGEN ABSORPTION WITH CBP

To check if hydrogen is absorbed in the niobium during CBP, niobium samples were also CBP'ed along with the 3-cell cavity for 8 hours. The samples were treated as below; the sample pieces were cut with electric discharge machine (2.5(t), 2.5(w), 147(l) mm), slight chemical polishing to remove oxidized surface, and annealing at 750 °C for 3 hours to remove hydrogen that could be absorbed in the cutting process. After CBP, concentration of the hydrogen was 61 ppm per volume, which was under 1 ppm before the CBP. Here, this value is an average of 10 measurements over the sample piece. Hydrogen absorption into niobium was prominent with the CBP.

5 SUMMARY

1) single-cell cavity but also for a multi-cell cavity (3-cell cavity), barrel polishing speed was improved 10 times with the CBP (40 microns/8 hours).
2) With a niobium L-band 3-cell cavity, location dependence of polishing speed was insignificant.
3) A single-cell cavity treated with CBP was measured and a good result was obtained.
4) During the CBP, hydrogen was absorbed into niobium.

6 ACKNOWLEDGEMENT

This work was supported by Cryogenics Science Center in KEK that supplied liquid helium and by Mechanical Engineering Center that cut out and annealed the niobium samples. Mr. Fujino, Mr. Abe and Mr. Shishido helped us for the tests. Mr. Morimoto (TKX Co., Ltd.) helped us to realise high-speed polishing by his valuable advises and tests. Authors greatly appreciate their support.

7 REFERENCES

[1] K.Saito et al., "A Role of Mechanical Polishing in the Surface Treatment of Superconducting Niobium RF Cavities", Proceedings of the 21st Linear Accelerator Meeting in Japan, 1996, p.225-227 (Japanese)

[2] T.Higuchi, K. Saito et al., "Application of Centrifugal Barrel Polishing to a Niobium Superconducting Cavity", Proceedings of the 25th Linear Accelerator Meeting in Japan, July 12-14, 2000, p.329 and p330 (Japanese)