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Nb SINGLE-CELL CAVITY VERTICAL ELECTRO-POLISHING WITH NINJA CATHODE AND EVALUATION OF ITS ACCELERATING GRADIENT

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Abstract

Marui Galvanizing Co., Ltd. has been improving Vertical Electro-Polishing (VEP) technology for Nb superconducting RF cavity in collaboration with KEK. In this collaboration, we developed a unique cathode namely "Ninja cathode" for VEP treatment of Nb cavities. We have already reported that longitudinal symmetry in niobium removal and surface state of a single cell cavity were improved after VEP using the Ninja cathode. In this article, we report a result of accelerating gradient evaluation for 1.3 GHz single cell RF cavity after VEP with Ninja cathode.

INTRODUCTION

Marui Galvanizing Co., Ltd. has been developing Nb SRF cavity vertical electro-polishing (VEP) technologies for cavity mass production and manufacturing cost reduction in collaboration with KEK. Until now, construction and improvement of VEP facility and original structure cathode "i-cathode Ninja" (Ninja cathode) have been performed [1–9]. Using these items and a single cell coupon cavity whose coupon surface can be evaluated in detail after VEP, we performed VEP experiments many times and reported that surface status and removal thickness distribution were improved in comparison with conventional VEP [2, 6, 8].

Furthermore, in order to apply VEP for cavity mass production, evaluation of cavity's accelerating gradient after VEP with Ninja cathode is required. To approach this issue, single cell cavity VEP with Ninja cathode and accelerating gradient evaluation were performed in collaboration with Marui – KEK – CEA Saclay.

NINJA CATHODE AND VEP SETUP

In this experiment, CEA Saclay's single-cell cavity (C1-19, after buffered chemical polishing (BCP)) was VEPed with Marui's VEP facility and Ninja cathode. The Ninja cathode used in this experiment has 4 insulating wings and enhanced cathode area (Ninja-3). It was proved that polished surface and removal thickness distribution were improved by using this Ninja cathode for VEP. Figure 1 shows the schematic view of Ninja cathode (Ninja-3).

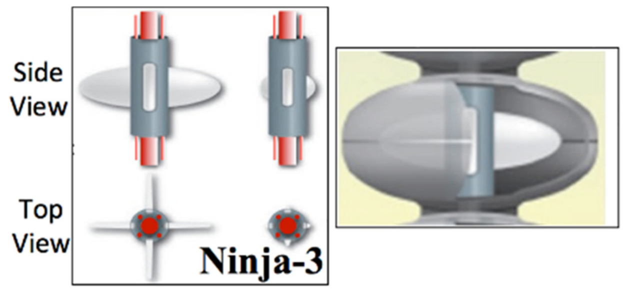

Figure 1: Schematic view of Ninja cathode (with 4 insulating wings and enhanced cathode area, Ninja-3).

The process of this experiment was bulk VEP1 (target removal 50 um) – status conformation – bulk VEP2 (target removal 50 um) – status conformation – HPR and anneal – final VEP (target removal 10 um) – HPR and vertical test (VT). HPR and anneal were performed in KEK, HPR and VT were performed in CEA Saclay. Before this VEP, inner surface was inspected with Kyoto camera and found defects were locally grinded in KEK. Figure 2 shows the VEP setup and the single-cell cavity.

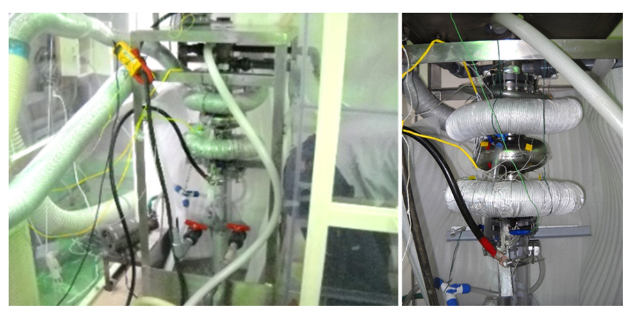

Figure 2: Photos of the VEP setup and the single-cell cavity.

VEP EXPERIMENT AND VERTICAL TEST RESULT

Table 1 shows conditions of bulk VEP1, bulk VEP2 and final VEP. The VEP parameters were selected according to previous VEP experiments that show good results. The anneal condition was 750°C, 3hours. Figure 3 shows the logged data of voltage and current density of each VEP.

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Table 1: Conditions of Each VEP Experiment

Parameters	Bulk VEP 1	Bulk VEP 2	Final VEP
Electrolyte	H_2SO_4 (98wt%):HF(55wt%)=9:1 (v/v)		
Voltage	12 – 14 V	12 – 14 V	12 – 14 V
Current density	10 – 20 mA/cm^2	20 – 30 mA/cm^2	15 – 25 mA/cm^2
Cavity surface temperature	14 – 17 degC	21 – 24 degC	21 – 24 degC
Cathode rotation speed	30 rpm	30 rpm	30 rpm
Acid flow rate (Bottom to top)	3 – 5 L/min	2 – 4 L/min	2 – 4 L/min
EP time	~2.5 hours	~2.5 hours	~40 min
Average removal thickness	~31um (Weight loss)	~55um (Weight loss)	~12um (Weight loss)

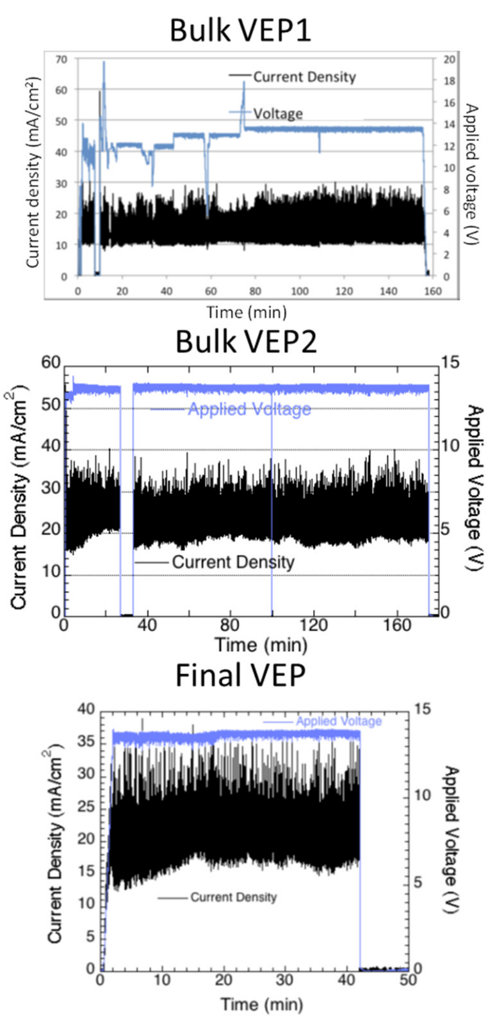

Figure 3: Logged data of voltage and current density of each VEP (Upper: bulk VEP1, Middle: bulk VEP2, Lower: final VEP).

However current density of bulk VEP1 was some smaller because of low cavity temperature during VEP, overall current density was around 10 – 30 mA/cm^2, this value is almost the same as previous VEP experiments [2, 6, 8]. Figure 4 shows removal thickness distribution after bulk VEP1 and bulk VEP2 measured with an ultrasonic thickness gauge. Average removal thickness calculated from weight loss is seen in Table 1.

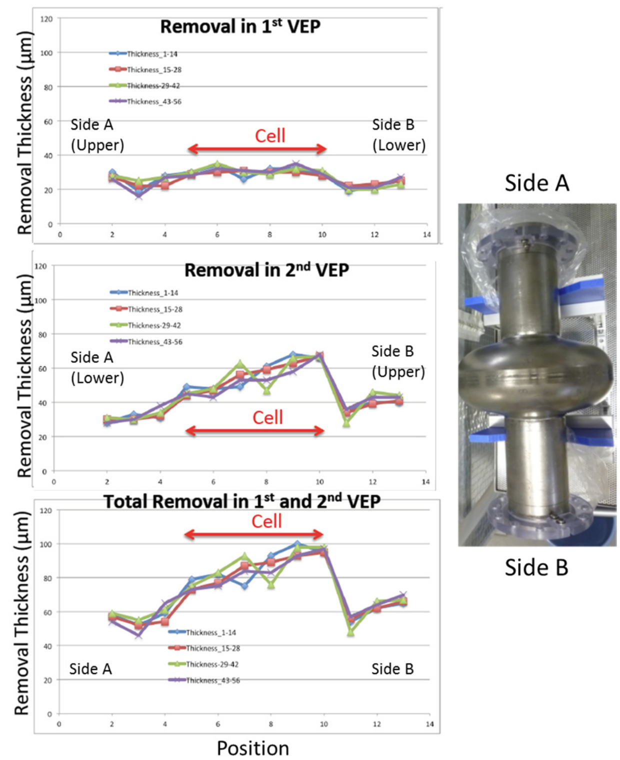

Figure 4: Removal thickness distribution after each VEP (Upper: after bulk VEP1, Middle: after bulk VEP2, Lower: total of bulk VEP1 and bulk VEP2).

At bulk VEP1, a cavity was set that side A was upper side and side B was lower side. At bulk VEP2, a cavity was set upside down. Removal thickness distribution after bulk VEP1 was almost symmetric, but average removal thickness was smaller than the target value. This is because of low cavity temperature during VEP. In contrast, average removal thickness after bulk VEP2 was almost on-target, but removal thickness distribution was asymmetric (upper side was larger). So total removal thickness distribution became one side larger. And total average removal thickness became some smaller than the target. Removal thickness distribution after final VEP was not measured because VT was preceded.

Figure 5 shows the results of surface inspection before and after VEP with a digital camera and Kyoto camera.

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Figure 5: Surface inspection results before and after each VEP (Upper: digital camera, Lower: Kyoto camera).

The surface after VEP was brighter than that before VEP, this indicate that satisfactory EP was processed. From Kyoto camera inspection, no rough surface was inspected except for crystal grains. After final VEP, Kyoto camera inspection was not performed because VT was preceded.

Figure 6 shows the VT result before and after this VEP.

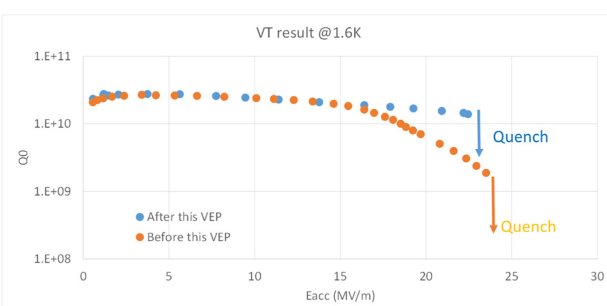

Figure 6: Vertical test result before and after this VEP (Blue dots: after this VEP, Orange dots: before this VEP)

After this VEP, accelerating gradient was 22.5MV/m, Q value was 1.3E10 (@1.6K), and finally quench occurred. Before this VEP (after BCP), accelerating gradient was 23.5MV/m, Q value was 1.9E9 (@1.6K), and finally quench occurred. Q value was improved and Q slope was disappeared after this VEP, however quench occurred at almost same accelerating gradient before and after this VEP. It is thought that totally surface status is improved, there are some defects which become the cause of heat generation and they remain after this VEP.

In order to investigate the cause of quench, T-map measurement was performed. Figure 7 shows the result.

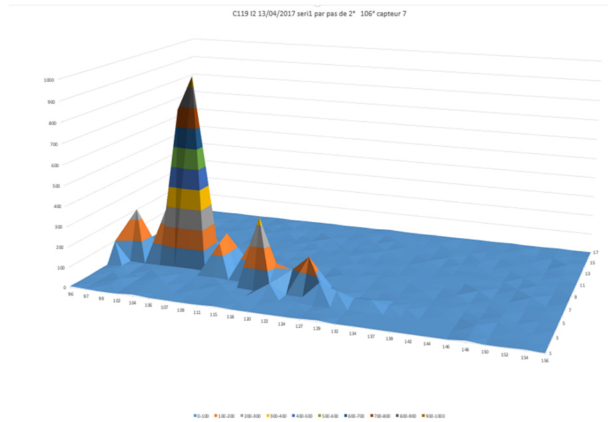

Figure 7: T-map measurement result.

A remarkable heat generation point was found near the equator. After this, the surface status of this point will be checked with Kyoto camera, the cause (maybe defect) will be removed, and final VEP and VT will be performed again.

And now, single cell cavity VEP experiments with CEA saclay's VEP facility and Ninja cathode is being planned. In this experiment, we will perform VT, and show that it is possible to construct good performance cavities using VEP with Ninja cathode.

SUMMARY

In order to evaluate Nb SRF cavity accelerating gradient after VEP with Ninja cathode, single cell cavity VEP experiments were performed in collaboration with Marui – KEK – CEA Saclay. The VEP parameters were selected according to previous VEP experiments that show good results. Current density during VEP was almost the same as previous VEP experiments. Removal thickness distribution of bulk VEP1 was symmetric, however bulk VEP2 was asymmetric, upper side was larger. Polished surface was shiny and crystal grains were observed from Kyoto camera inspection. From VT result, accelerating gradient was 22.5MV/m, Q value was 1.3E10 (@1.6K), and finally quench occurred. From T-map measurement, a remarkable heat generation point was found. After this, observation of heat generation point surface and removal of the cause (maybe defect) will be performed. And now, single cell cavity VEP experiments with CEA saclay's VEP facility and Ninja cathode is being planned. From these experiments, we would like to show that it is possible to construct good performance cavity using VEP with Ninja cathode.

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