CONTINUOUS CURRENT OSCILLATION ELECTROPOLISHING AND APPLICATIONS TO HALF-CELLS*

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Abstract

A method to electropolish niobium with continuous current oscillation is introduced. The current continuously oscillates for as long as 3 hours. The key is to maintain continuous agitation of the acid mixture. A niobium surface treated by this method has suppressed grain boundaries and a lower hydrogen content. The method has been used to electropolish L-band half-cells. The test results of a 1500 MHz cavity made of electropolished half-cells are presented.

INTRODUCTION

Electropolishing (EP) of niobium leads to the realization of record accelerating gradients in single- and multiple- cell SRF cavities. Niobium EP can be done differently. First application of EP to SRF cavities at Siemens was done with the current oscillation method [1]. More recent Saito method obtains good results by controlling the current density and acid temperature [2]. In the latter case, the current does not oscillate.

The current oscillation in Siemens method lasts only for 2-3 minutes. The EP process has to be interrupted when oscillation dies away and the acid needs to be agitated for several minutes to re-establish current oscillation. In contrast, the Saito method is a continuous process and is suited for cavities requiring heavy surface material removal.

CONTINUOUS CURRENT OSCILLATION ELECTROPOLISHING

A continuous current oscillation EP method was recently established at Cornell. In this method, current oscillation lasts for 2-3 hours continuously. This is achieve by maintaining a stable acid temperature and a continuous acid agitation, which is provided by a magnetically driven spin bar placed in the acid. Fig. 1 shows a typical 10-minute time slice out of a 3-hour of continuous current oscillation.

The acid mixture is made up with H_2SO_4(96%) and HF(48%) in a volume ratio of 10:1. A constant voltage in the range of 10-15 V is applied across the niobium part and an aluminum cathode. The current density is in the neighborhood of 30 mA/cm^2. The nominal oscillation frequency is 0.1-0.3 Hz. The oscillation amplitude and frequency can be tuned by changing the cell voltage, the acid temperature or the acid agitation speed.

* Work supported by NSF

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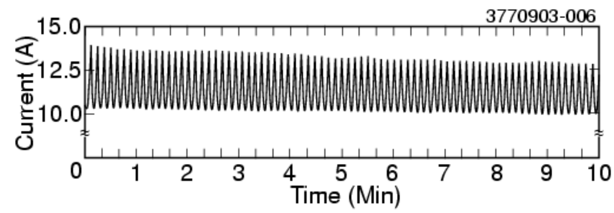

Figure 1: Continuous current oscillation EP.

GRAIN BOUNDARY FREE SURFACE

Like non-current-oscillation EP, the continuous current oscillation EP also gives a better surface smoothness as compared to a BCP treated surface. Furthermore, the grain boundaries are suppressed progressively when the niobium surface is treated step by step with the presented method. In the following example, a niobium surface was first etched for 120 μm with BCP. As a result, niobium grains were clearly exposed. Additional surface removal at a ∼15 μm step was obtained by continuous current oscillation EP. The microscopic picture of the surface after a 30 μm removal by EP is given in Fig. 2. As can be seen, some grain boundaries have already disappeared, although some still remain. After sufficient EP was given to the sample, all grain boundaries disappeared.

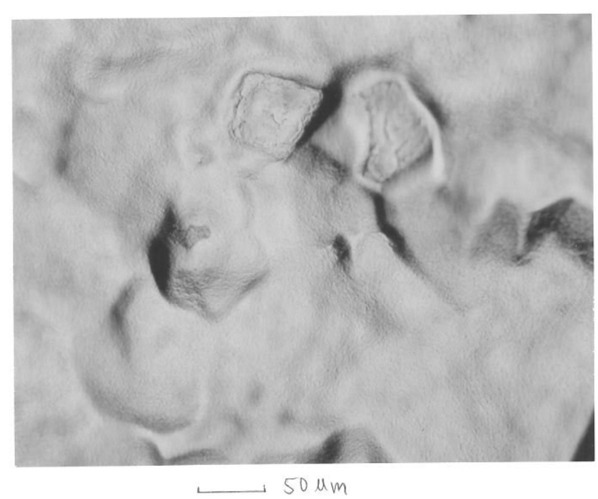

Figure 2: Niobium surface after a 30 μm surface removal with continuous current oscillation EP. Niobium grain boundaries are suppressed. The surface was previously etched for 120 μm with BCP exposing niobium grains.

LOW SURFACE HYDROGEN CONTENT

Niobium surfaces treated with continuous current oscillation EP have a lower hydrogen content as compared to those treated with BCP. It has been shown in Ref. [3] that a BCP treated niobium surface has about the same level of surface hydrogen content and depth distribution as the virgin niobium surface. In contrast, as shown in Fig. 3, the surface of samples treated by our EP method shows consistently a lower peak content and a shorter profile depth as compared to the virgin surface.

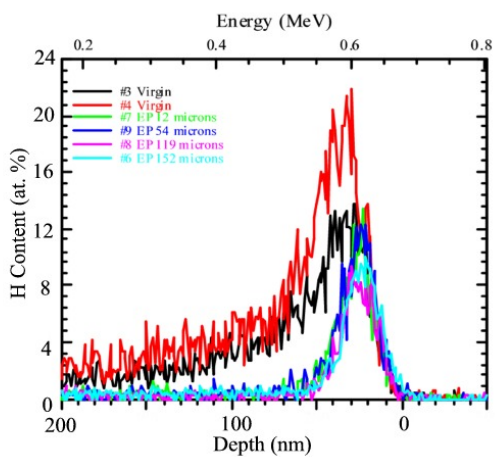

Figure 3: Depth profile of the hydrogen content for virgin samples and samples prepared by continuous current oscillation EP.

APPLICATIONS TO NIOBIUM HALF-CELLS

The continuous current oscillation EP method have been applied to several L-band half-cells, including 1500 MHz half-cells and 1300 MHz re-entrant cavity half-cells. Fig. 4 depicts the apparatus schematically.

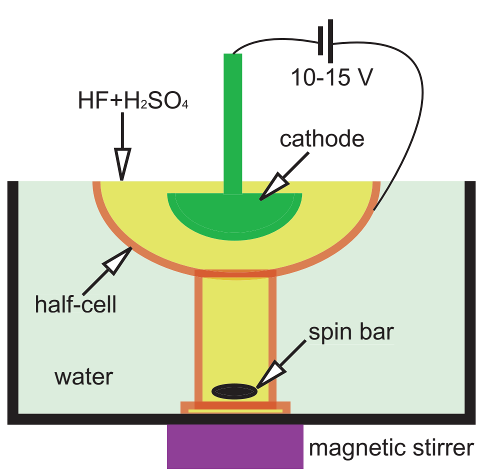

Figure 4: Half-cell electropolishing with continuous current oscillation.

The 1500 MHz cavity made by two half-cells prepared by continuous current oscillation EP has been tested. The half-cells were heat treated before EBW to improve RRR of the material. The cavity was etched with BCP and high pressure water rinsed before RF tests. A low-field Q_0 of 6×10^{10} was obtained after the RF surface was removed for 13 μm. This Q value is 3 times higher as compared to previous results obtained with cavities of the same shape and tested the same way. Details of test results can be found in Ref. [4].

DISCUSSION

It is believed that the current oscillation reflects the balance of two competing processes, i.e. the building up and dissolution of an oxide film between the acid and the niobium substrate. The film appears to be a brown or sometimes a milky white substance as observed during continuous current oscillation EP. In the Siemens method, the acid is static. The thickness of the film tends to increase and results in a decaying oscillation. In the present method, a laminar acid flow is maintained continuously. This promotes the dissolution process and a dynamically stable balance is achieved between the building up and dissolution processes. This healthy balance seems to be responsible for suppressing grain boundaries. Because grain boundaries are prone to precipitation of chemical residuals, it is anticipated that a grain boundary free niobium surface has less contamination. The measured high Q of the 1500 MHz cavity may be attributed to a less contaminated surface. A lower surface hydrogen content reflects that a grain boundary free surface also prevents up-taking of gases.

CONCLUDING REMARKS

The continuous current oscillation EP method is introduced. This method is suitable for cavity treatments requiring heavy material removal. A niobium surface treated by the continuous current oscillation method is free of grain boundaries and has a lower surface hydrogen content. A higher Q can be expected. The continuous current oscillation EP method has been successfully applied to L-band half-cells. Preliminary test results show a higher Q, confirming the expectation. This method may be extended to treat single- and multiple-cell niobium cavities.

ACKNOWLEDGMENT

Dr. Tajima of LANL is highly appreciated for providing us the surface hydrogen results.

REFERENCES

[1] H. Diepers et al., Phys. Lett., 37A (1971) p. 139-140.

[2] K. Saito, Proc. of PAC2003, Portland, OR, USA.

[3] T. Tajima et al., these proceedings.

[4] R.L. Geng et al., Proc. of PAC2003, Portland, OR, USA.