

PROGRESS OF BEP TREATMENTS ON NB AT JLAB*

A.T. Wu^{1#}, S. JIN^{1,2}, R.A. RIMMER¹, X.Y. LU², and K. ZHAO²

¹ Thomas Jefferson National Accelerator Facility, 12000 Jefferson Avenue, Newport News, VA 23606, USA

² SRF Group, Institute of Heavy Ion Physics, School of Physics, Peking University, Beijing 100871 P. R. of China

Abstract

Recent experimental results have indicated that Buffered Electropolishing (BEP) is a promising candidate for the next generation of surface treatment technique for Nb superconducting radio frequency (SRF) cavities to be used in particle accelerators. In order to lay the foundation for using BEP as the next generation surface treatment technique for Nb SRF cavities, some fundamental aspects of BEP treatments for Nb have to be investigated. In this report, recent progress on BEP study at JLab is shown. Improvements on the existing vertical BEP are made to allow water cooling from outside of a Nb single cell cavity in addition to cooling provided by acid circulation so that the temperature of the cavity can be stable during processing. Some investigation on the electrolyte mixture was performed to check the aging effect of the electrolyte. It is shown that good polishing results can still be obtained on Nb at a current density of 171 mA/cm when the BEP electrolyte was at the stationary condition and was more than 1.5 years old.

INTRODUCTION

Surface treatment of Nb is one of the important steps in fabricating Nb superconducting radio frequency (SRF) cavities to be used in particle accelerators. One important factor in judging whether a surface treatment is successful is how smooth the obtained surface can be and how high an accelerating gradient the cavity can reach with a decent Q_0 . A smooth Nb surface is beneficial not only because it can reduce the magnetic field enhancement on Nb surfaces, but also because it can allow the contamination on Nb surfaces to be removed in a relatively easier way so that the chance for getting field emission during RF tests can be reduced. It has been shown [1] that a surface roughness of less than 2 μm is required in order to achieve an accelerating gradient higher than 30 MV/m for Nb SRF cavities.

Recent experimental results have shown that buffered electropolishing (BEP) can produce the smoothest surface finish on Nb [2-4] while providing a Nb removal rate more than 10 times faster than that of the conventional electropolishing (EP). BEP is therefore a promising candidate for the next generation of surface treatment technique for Nb SRF cavities to be used in particle

accelerators. This paper presents the recent progress on BEP at JLab regarding the basic aspects of BEP treatments on Nb.

MODIFICATIONS ON VERTICAL BEP SINGLE CELL TREATMENT SYSTEM

Recent EP treatments [5] on SNS cavities at JLab showed that external cooling to better control the temperature of vertically treated cavities is very critical in order to get a good polishing result. This inspired us to modify the existing vertical BEP single cell processing system that was reported in Ref.6. A Teflon water container was made as shown in Fig.1 to allow water cooling from the outside of a treated Nb single cell cavity. There are two water inlets at the bottom of the Teflon container so that hot and cold water cannot feed through to allow reaching a particular set temperature from 20 °C to 40 °C. The Teflon container is designed in a way for easy

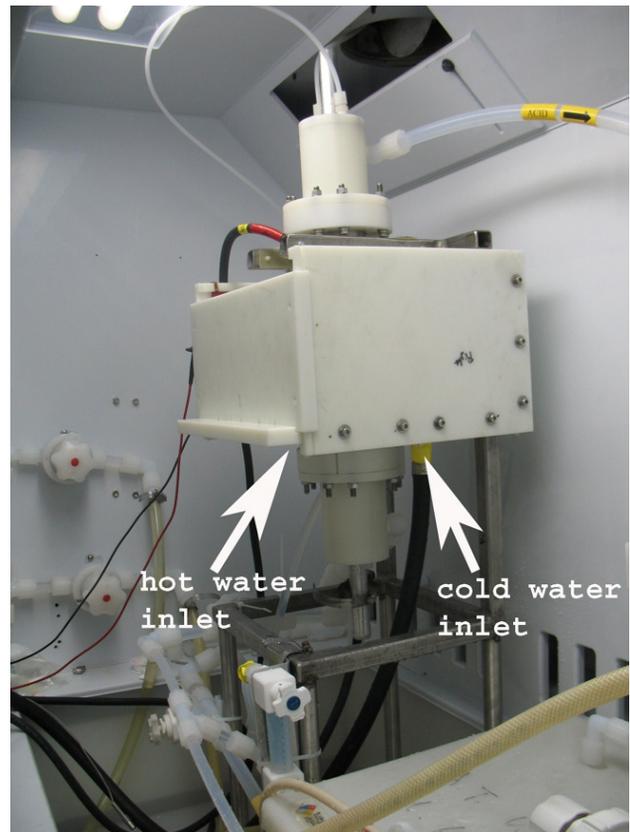


Fig.1: Modified vertical BEP single cell treatment system with water cooling from outside of the cavity.

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#andywu@jlab.org

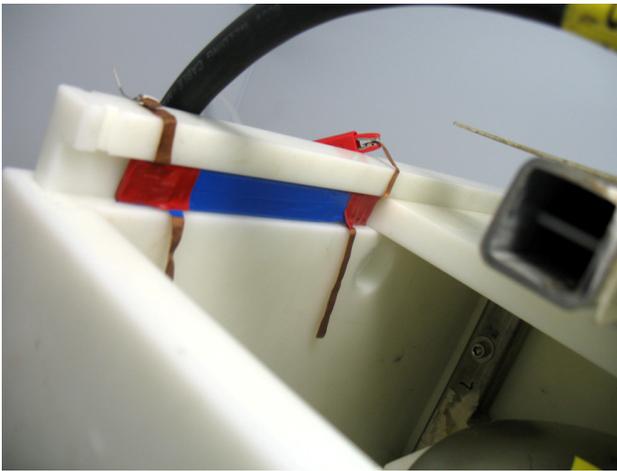


Fig.2: A simple BEP electrolyte leak detector.

assembly and disassembly.

To detect a possible leak during BEP processing when a demountable cavity is used for processing, a monitor is set up to check the resistance of the water in the water container continuously as shown in Fig.2. When BEP electrolyte and DI water ratio is 1:3000, the resistance

Table 1: Resistance and PH Value of Pure DI Water and BEP Electrolyte and DI Water Mixture

	Resistance	PH value
DI water	0.77(MΩ)	~5
BEP electrolyte :DI water=1:3000	1.1 (kΩ)	~3



Fig.3: Computer system for monitoring BEP processing.

decreases significantly from 0.77 MΩ when no BEP electrolyte is present in DI water to 1.1 kΩ when 1 in 3000 of BEP electrolyte is present as shown in Table 1. This change in resistance will trigger an alarm to signalize a possible leak.

One important aspect of the fundamental study of the BEP treatments of Nb cavities is the measurements of I-V curves and monitoring of the processing temperature during polishing. A computer program and some hardware are under construction as shown in Fig.3, so that all processing parameters can be measured accurately and stored in a computer.

STUDY OF BEP ELECTROLYTE AGING EFFECT

It was noted during the early stage of the BEP study [7] that the color of BEP electrolyte changed with time. It appeared that acid mixing order might alter the appearance of the BEP electrolyte. However, in a preliminary study presented in Ref.2 we found that the acid mixing order was not important and the color of the BEP electrolyte was the same no matter whether the HF or H₂SO₄ was added to lactic acid first. This basic study is important if we want to get a reproducible polishing result from BEP treatments.

A more systematic study was therefore planned to check this carefully. A bottle of BEP electrolyte of 300 ml with a mixing ratio of HF:H₂SO₄:lactic acid=4:5:11 was first mixed by adding H₂SO₄ first to lactic acid and then followed by adding HF while stirring during the mixture as originally adopted by JLab (called JLab mixing order). Then another bottle of 300 ml was mixed by adding HF first to lactic acid followed by adding H₂SO₄ (called PKU mixing order). This two bottles are pictured in Fig.4. As we can see, both bottles are almost colorless. During the mixing, the temperature of the electrolyte was kept below 45 °C. However, the color of the electrolyte has been progressively changing after the mixture for both bottles. After about two months from the initial mixing, the electrolyte became much darker as shown in Fig.5.



Fig.4: Two bottles of 300 ml BEP electrolyte mixed in a different order of acid addition after they were just mixed.

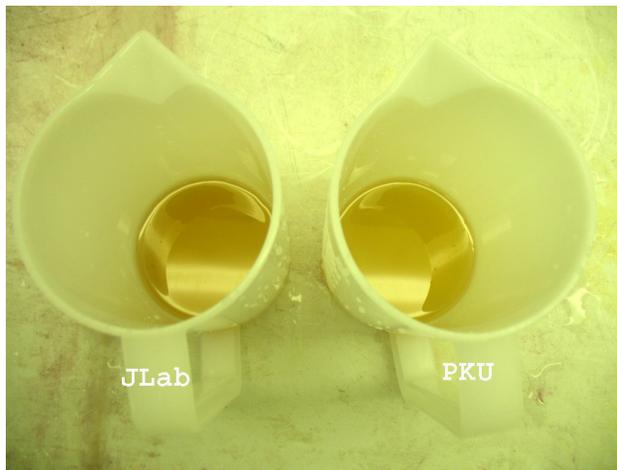


Fig.5: The appearance of the two bottles of BEP electrolyte two months after they were mixed (see text for details).

One strange observation was on a commercially mixed BEP electrolyte. We found that some bottles of the electrolyte had quite some precipitations on the bottom of the bottle as shown typically in Fig.6a while other bottles from the same company do not show any precipitation as typically shown in Fig.6b. The reason for causing this is currently under investigation. It is noted however that the melting temperature of lactic acid is 16.8 °C that is relatively high [8]. If stirring is not done sufficiently, a laminar structure will appear after mixing due to the weight differences between acids. Once the temperature is dropped below 16.8 °C, the lactic acid will start to solidify. Furthermore, lactic acid should be stored in dark bottles to avoid exposure to direct light. If layer separation takes place, the lactic acid may start to decompose due to the light. It requires more study to understand this topic.

We believe that the variation in acid quality from the commercial BEP electrolyte provider may explain why our results of vertical BEP treatments on Nb SRF cavities scattered a lot [2,4,6].

We also used the commercially mixed BEP electrolyte to do polishing on small Nb samples. In one case, the polished surface was dull and rough as shown in Fig.7a. However, in another case when a bottle of BEP electrolyte that was the same as the one shown in Fig.6b



Fig.6: Commercially mixed BEP electrolyte a) a typical bottle that shows precipitation, b) a typical bottle that does not show precipitation.

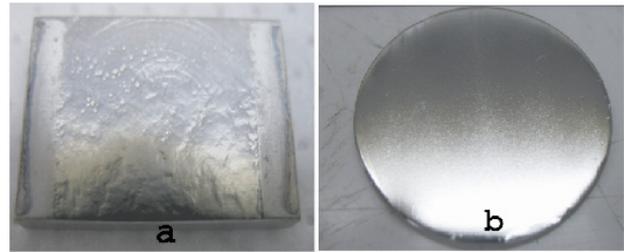


Fig.7: Two different surface finished for BEP treated Nb samples employing two different bottles of the commercially mixed BEP electrolyte.

was used for polishing, a shining and good finish was obtained as shown in Fig.7b. It is noted here that the electrolyte used for polishing the sample shown in Fig.7b has been stored in an acid storage cabinet for more than 1.5 years and has the so-called “coke” color. The polishing was done when the electrolyte was stationary. The Nb removal rate in this case reached 1.5 $\mu\text{m}/\text{min}$ with a decent root mean square (RMS) of 241 nm over an area of 200X208 μm^2 as shown in Fig.8. This removal rate is much higher than 0.65 $\mu\text{m}/\text{min}$ reported in Ref.7. This result indicates that it is highly plausible the bottle used for treating the sample shown in Fig.7a was bad. Therefore, in principal electrolyte aging should not affect the results of BEP treatments if the electrolyte is mixed in an appropriate way.

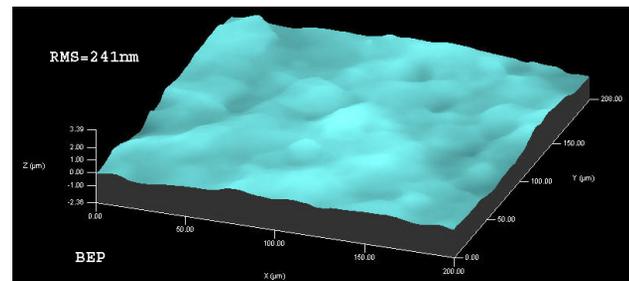


Fig.8: Profilometer measurements on the surface of the sample shown in Fig.7b.

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