

APPLICATION OF ELECTRO CHEMICAL BUFFING ONTO NIOBIUM SRF CAVITY SURFACE

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Abstract

Niobium electropolishing for SRF cavities are generally considered to be the best technology today. However, hydrofluoric and sulfuric acid mixture usually used in the EP process is harmful and requires us carefully controlled handling of it and the many additional facilities. In this article, we propose a new application of electrochemical buffing (ECB) to niobium SRF cavity. In the method of ECB, a rotating disk with abrasive fine particles where electrolyte is supplied is pressed against the workpiece. The disk and the work function as a cathode and an anode, respectively and an aqueous solution of sodium nitrate is used for the electrolyte. This technology brings us a couple of remarkable advantages like high etching rate, ultra small surface roughness, cost-effective and environment-compatible polishing.

INTRODUCTION

Today's electropolishing (EP) is generally considered to be the best technology for niobium SRF cavities. Recently it has been demonstrated that a remarkable number of EPed 9-cell cavities showed field-emission free performance in a range of 35-40 MV/m [1]. However, hydrofluoric and sulfuric acid mixture usually used in the EP process is harmful and requires us carefully controlled handling of it and the many additional facilities.

A quite good number of production cost is able to be reduced when any other technology which is further simpler with highly efficiency and with a smaller number of main and peripheral facilities of polishing, bringing us equivalent or better performance compared with EP. Electrochemical buffing (ECB) has one of possibilities to realize this idea.

The electrolyte for ECB is an around 20 wt% of aqueous solution of sodium nitrate which is quite environment-compatible. This electrolyte allows us to be released from many constraints of niobium surface polishing as listed in Table 1. The sodium nitrate solution does not age at all even after one year storage unless it is used. This is because any volatile component such as hydrogen fluoride of EP solution is not included in it. That type of solution also enables us frequent usage of the same electrolyte. The rough usage efficiency would be an area of 100m² per 1 m³ solution since most of etched metallic component becomes its hydroxide which is solid and be able to be filtered during the solution circulation. The electrolyte temperature does not affect the polishing performance practically since electropolishing just assists

mechanical buffing. Therefore a heat exchanger is needless in the ECB facility. This is another big advantage of ECB against EP which need somehow sensitive temperature control of EP solution.

Table 1: Comparison of EP and ECB treatments

	EP	ECB
Electrolyte	HF+H ₂ SO ₄	NaNO ₃
Aging of electrolyte	Quick	Very slow
Heat exchanger	Required	Unnecessary
Usage efficiency of electrolyte	Low	High
Strong acid compatibility of facility materials	Required	Unnecessary
Draft chamber	Required	Unnecessary
Alarm and safety systems	Required	Unnecessary
Safety zone and safety wear	Required	Unnecessary
Facility of liquid-waste treatment	Complicated	Simple

Since the sodium nitrate solution is harmless and obviously safer than EP solution, the whole polishing facility becomes simple. Strong-acid compatible plumbing and components such as flanges, gaskets made of PTFE, PFA, or HDPE are not necessary in ECB technology at all. Furthermore it is considerable that one does not need to care the all costly facilities and systems to protect humans such as a draft chamber, alarm and safety systems, safety zones, safety wear including boots and goggles. While both EP and ECB require their facilities of liquid waste treatment, the ECB also offers longer life time of the solution, simple procedures and cheap facility for the liquid waste. Hence, ECB can be considered to be a green technology to protect our environment in production of SRF cavities.

The ECB technology has been utilized for many kinds of metals of steel, stainless steel, aluminum, copper,

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titanium, molybdenum and so on for many years in order to reduce outgassing rate and micro dust particles from those materials in applications to semiconductor system, UHV and XHV chambers and components, space chambers, gas cylinders, plant plumbing and the others. Examples of ECBed products are shown in Fig. 1. The ECB would be able to realize removal of altered surface of materials, achievement of ultra flat surface without contaminants and micro dust particles, and generation of thin passive layer on the surface through the controlled anodic oxidation [2].

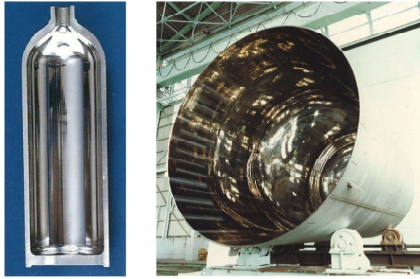


Figure 1: ECBed gas cylinder (left) and ECBed gas reverser tank for semiconductor industry (right).

This technique are applicable to almost any size of parts or components from a thin tube of several mm in a diameter to a huge tank of 5 m in a diameter with a maximum surface roughness of 100 nm homogeneously over all the surface. This flexibility of this technique allows us to apply ECB to niobium cavity cells and end groups which have complicated structures.

A new application of ECB onto niobium SRF cavity surface is described in this article to show results of sample coupons which were observed with surface analytical tools.

ELECTROCHEMICAL BUFFING (ECB)

Fig. 2 shows a principle of ECB schematically. The details of this method were described elsewhere [3, 4]. In the method of ECB, a rotating disk with abrasive fine particles where the electrolyte is supplied is pressed against the workpiece. The disk and the work function as a cathode and an anode, respectively and an aqueous solution of sodium nitrate is used for the electrolyte. The practical situation is shown in Fig. 3 where a rotating ECB head with 100 mm in a diameter gradually moves on a work which is larger than the head.

ECB conditions used for preparation of niobium sample coupons with a size of 14x20x2.8 mm³ are the following: a 20 wt% of aqueous solution of sodium nitrate, alumina micropowder of 5μm for coarse polish and silica fine particle of 60 nm for finishing. In this experiment, two different coupons were prepared. A current density during the ECB was controlled from a few of mA/cm² to a few of 10mA/cm² depending on the polishing steps. One sort of sample labelled R2 was prepared with surfactant in finishing process while another sort of sample labelled A2 was done without surfactant. Caustic soda cleaning

followed by ultrasonic water rinsing for half a hour was carried out.

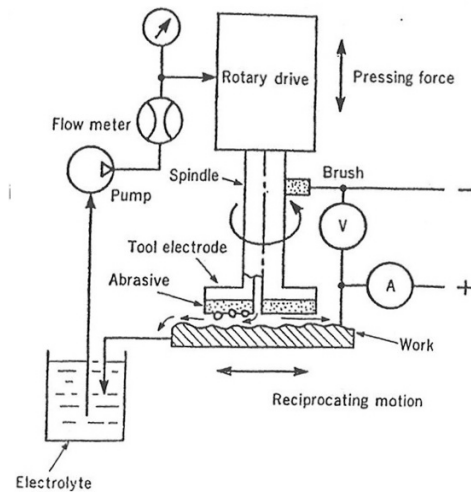


Figure 2: Principle of ECB treatment.



Figure 3: An rotating ECB head gradually moves on a work.

RESULTS AND DISCUSSIONS

Fig. 4(a) and (b) show SEM images of two coupons of R2 and A2. Based on silicon polishing technology in semiconductor industry, we attempted to obtain smoother surface with surfactant during the finishing process since the surfactant might have functioned as a sort of lubricant between silica particles and niobium surface. What was found is different from our expectation, showing rougher surface at the R2 sample ECBed with surfactant. Surface roughness of these coupons was also measured with a mechanical surface profile meter, showing consistent results with SEM; an average surface roughness of 61nm and 31nm for the R2 and A2 coupons, respectively. The R2 SEM image revealed clear scratches and microstructure probably made by silica nanoparticles. The A2 sample shows a smaller number of scratches. White spots were also rarely found on both of samples.

The ECBed coupons were analyzed with X-ray photoelectron spectroscopy. The top surfaces mainly consisted of oxygen, carbon and niobium with atomic compositions of 60, 20 and 17.7 % for the R2 coupon and

61, 18.7 and 18.1 % for the A2 coupon, respectively. Fig. 5 shows typical XPS spectra of the A2 coupon. These main compositions and chemical state are very similar to those of EPed samples with fresh EP solution [5]. However contaminants which were found on the ECBed surface were obviously different from those on the EPed surface. Contaminative trace elements generally found on EPed surface are aluminum, sulfur and fluorine. In case of ECBed surfaces, sodium (R2;0.9at%, A2;0.9), aluminum (R2;0.2, A2;0.5), silicon (R2;0.7, A2;0.7), and zinc (R2;0.1, A2;0.1) were found. The sources of three elements except zinc can be assigned to be caustic soda solution in the first rinsing process and abrasive particles in the coarse polishing process. The rinsing with caustic soda for removing hydrocarbon could have been skipped as ECB is enough to remove hydrocarbon. The origin of aluminum and silicon were confirmed to be alumina and silica from chemical shifts in the XPS spectra. Further study and optimization of ECB for niobium should be done in order to reduce the trace elements. ECB was also applied to several components of a niobium single cell cavity. Fig.6 shows an example of the half cell ECBed.

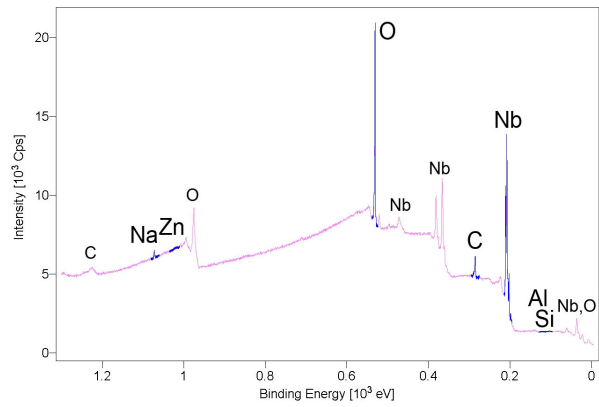


Figure 5: XPS spectra of the as-received A2 coupon



Figure 6: ECBed niobium half cell.

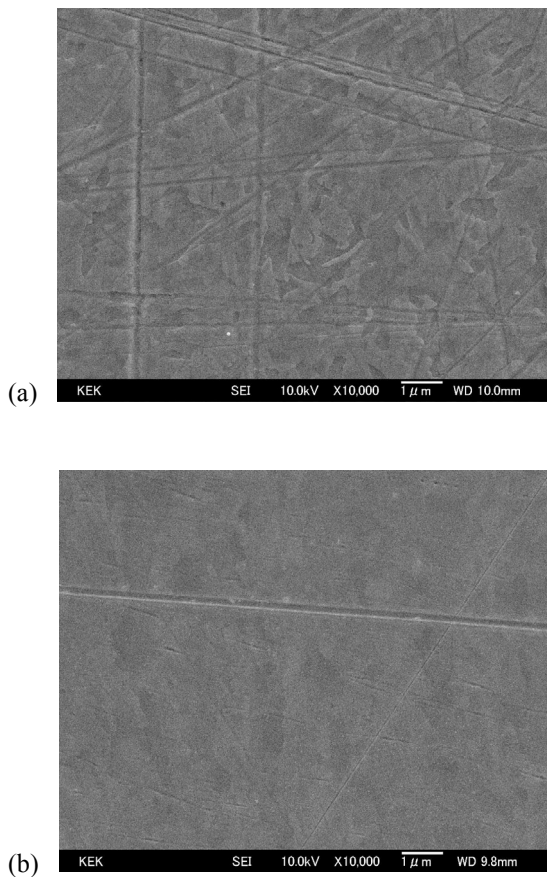


Figure 4: SEM images of ECBed R2 coupon with surfactant (a) and ECBed A2 coupon with surfactant (b).

CONCLUSIONS

Investigation of a possibility of ECB application to niobium SRF cavity was first made with an approach using surface analysis. ECB can be fundamentally considered to be a highly efficient or cost-effective green technology in production of SRF cavities. The application study of this promising technology has just started. One single cell cavity newly manufactured is waiting for the ECB application and its vertical test. An under assembly field emission scanner will allow to find field emission points with a lateral resolution of sub-micron should enhance improvement of ECB technology.

ACKNOWLEDGEMENTS

The authors acknowledge with pleasure the technical assistance of T. Noguchi at KEK.

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