OPEN 120°C BAKE IN ARGON ATMOSPHERE: A SIMPLIFIED APPROACH FOR Q-DROP REMOVAL

D. Reschke[#], J. Ziegler, Deutsches Elektronen-Synchrotron DESY, 22603 Hamburg, Germany

Abstract

The removal of the Q-drop without field emission by a low temperature bake procedure (app. 120°C) is essential in order to achieve the full performance in both electropolished (EP) and chemically etched (BCP) high gradient SCRF Nb cavities. A simplified procedure applying an open 120°C bake in an Argon atmosphere is presented. The first successful cavity results are compared to the well-established bake procedure under ultra-high vacuum (UHV) conditions.

INTRODUCTION

The low temperature annealing ("bake") at 100°C – 130°C is an essential preparation step following a chemical or electrochemical surface treatment in order to achieve high gradients (> 30 MV/m) at high Q-values [1, 2]. The standard bake procedure in UHV conditions is applied to the fully assembled cavity ready for its rf test (Fig. 1). The cavity itself is kept under vacuum during the bake, while the outside is an inert gas atmosphere in order to prevent oxidation (Fig. 1 shows the bake stand without its outer hood, which can be partially seen at the right-most of the picture). Typical parameters applied at DESY are (120 – 129)°C for 48 h. On single-cell cavities a modified process with (130 – 138)°C for 12 h has been applied successfully.

Figure 1: DESY bake stand for UHV bake.

In order to adapt the bake procedure for a large scale cavity production two alternatives have been proposed:

- a higher temperature (130 – 160)°C , but shorter time of (1 – 12) h [3, 4, 5]
- open bake in inert gas atmosphere or air with 110 – 120 °C for 12 h – 60 h or 145°C for 3 h

The latter using an inert gas atmosphere has been developed also at CEA Saclay [6].

NEW BAKE PROCEDURE

Single-Cell Apparatus+ Procedure

For the single-cell tests described below a commercial lab vacuum drying cabinet was used successfully (Fig. 2). The vacuum drying cabinet has a programmable temperature control unit with a stability of ± 3°C and excess temperature protection. The vacuum and venting installation is integrated, which allows an adjustable, permanent Argon flow with overpressure protection. A dry, oil-free diaphragm pump is used for the initial pump-and-purge cycles. Applied parameters are a temperature of 120°C for 24 h with an Ar flow of app. 250 l/h. The purity of the Ar gas is better than 99,999%. Typically, warm-up takes 2 h; cool-down takes 16 h.

Figure 2: Vacuum drying cabinet for single-cell cavities.

detlef.reschke@desy.de

For the start-up experiments the vacuum drying cabinet could not be placed inside the cleanroom. It is located in a “grey” area close-by in order to avoid unnecessary contamination of the cavity. After the bake process the cavity is transported immediately back in the cleanroom, rinsed with ultrapure high pressure water (UHPW), assembled, again UHPW rinsed, finally assembled and evacuated.

Nine-Cell Apparatus+ Procedure

The final technical design of a nine-cell bake cabinet is in preparation. It will be placed inside a cleanroom annex in order to allow the loading of cavities without contamination. Typical parameters and procedures will be based on the successful single-cell results, but matched to nine-cells, where necessary.

CAVITY TESTS AFTER OPEN AR BAKE

Final Electropolishing

One single-cell cavity fabricated of large grain Niobium was prepared and tested after a final electropolishing. The standard EP procedure at Henkel Co. consists of a 100 µm EP, high pressure rinse with demineralised water, hot ultra-pure water rinse, drying with pure nitrogen and final packing. After transportation to DESY, the cavity is stored until the final cleanroom UHPW rinse and assembly takes place. Open Ar bake was done with the procedure described above.

In Fig. 3 the Q(E)-performance of an earlier EP treatment followed by standard UHV-bake is compared to the recent EP + open Ar-bake. All Q(E)-curves are taken at 2 K. Both processes result in gradients around 40 MV/m at high Q-values limited by quench. The Q(E)-curve after open Ar-bake suffers from some field emission degrading the Q-value at gradients > 34 MV/m. This level of field emission occurs from time to time, and is most probably not related to the open Ar-bake process. The Q(E)-curve after UHV-bake shows no detectable x-rays until the quench field, which allows a Q-value of $1{,}4 \cdot 10^{10}$ at $E_{acc,max}$ = 40,5 MV/m.

Open Ar-bake removes the Q-drop of electropolished cavities as well as standard UHV-bake.

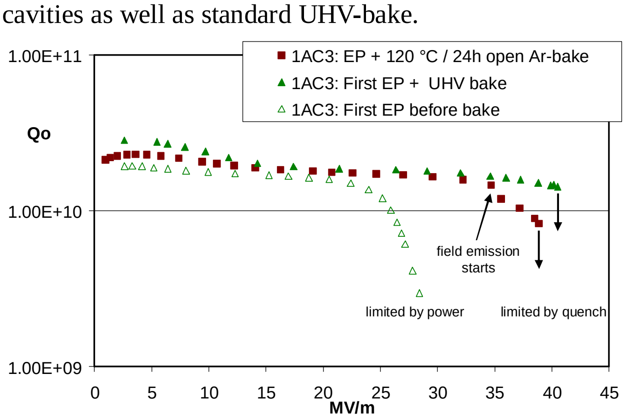

Figure 3: Effect of open Ar-bake and UHV-bake on an electropolished single-cell cavity made of large grain niobium (1AC3).

Final Short BCP

For the European XFEL project [7, 8] a final short BCP of app. 10 µm followed by the usual UHPW rinse, assembly and evacuation procedure is proposed as an alternative to a final EP treatment [9]. For two single-cell cavities fabricated of fine grain Nb a final short BCP of 8 µm was applied followed by the handling procedure described above.

Figure 4 shows the Q(E)-results at 2 K of both cavities before and after open Ar-bake. After Ar-bake both cavities are limited by quench and show no detectable x-rays indicating field emission. The Q-drop is significantly reduced and shifted towards higher fields. In addition, the Q-value at low and medium fields is higher. This is due to the typical reduction of the BCS the surface resistance after a low temperature bake procedure [2].

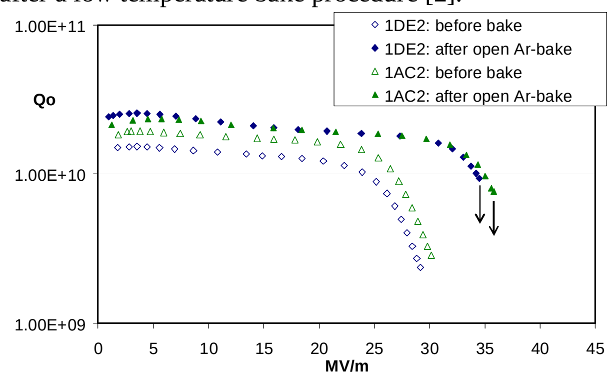

Figure 4: Effect of open Ar-bake after final short BCP on two single-cell cavities fabricated of fine-grain Nb.

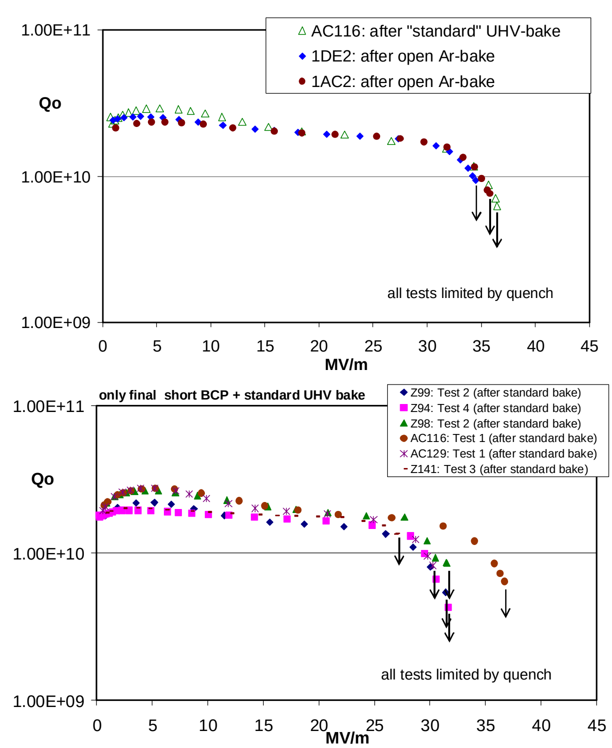

Figure 5 a+b: Comparison of open Ar-bake with standard UHV-bake after final short BCP (top); typical Q(E)-curves after final short BCP and UHV-bake (bottom).

In order to investigate the remaining Q-drop, Fig. 5a shows the comparison of the two single-cells (1AC2, 1DE2) with a nine-cell cavity (AC116) after comparable surface treatment (10 µm + UHPW rinse), but UHV bake applied. In addition, Fig. 5b gives typical Q(E)-performances of nine-cell cavities after final short BCP followed by standard UHV-bake.

Obviously, open Ar-bake is as effective as standard UHV removing the Q-drop for final short BCP surface treatment. The remaining Q-drop is a general effect of low temperature baked cavities after a final short BCP and not a specific negative impact of open Ar-bake. Moreover, it is reported in general for BCP treated cavities fabricated of fine grain Nb, that the Q-drop cannot be cured in all cases. An overview is given in [10].

CONCLUSION

The new simplified open Argon bake procedure cures the Q-drop without field emission for final EP and final short BCP surface treatment. After final short BCP a remaining Q-drop is still present at gradients E_{acc} > (25 – 30) MV/m, independent of the type of bake procedure.

Open Ar-bake is advantageous to standard UHV bake:

- The bake process can be simply implemented in the cavity preparation sequence before the final ultra-pure high pressure water rinse.
- No additional vacuum handling of the fully assembled cavity is necessary. There is no additional thermal stress of the cavity flange gaskets during bake.
- No additional UHV vacuum pump station necessary.
- The vacuum drying cabinet is commercially available instead of a special designed UHV-bake stand.

Open Ar-bake is a simplified practical solution for a mass preparation of cavities as e.g. for the upcoming European XFEL project with more than 800 nine-cell cavities.

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