

EXPERIENCES ON IMPROVED CAVITY PREPARATION CYCLES WITH A VISION ON INDUSTRIALIZATION OF THE XFEL CAVITY PREPARATION

B.v.d.Horst, A.Matheisen, B.Petersen, M.Schmökel, N.Steinhou Kühl, H.Weitkämper
 DESY Hamburg, Hamburg, Germany

Abstract

Within the last decade the production and preparation of superconducting resonators became more and more stable at DESY. Two cycles for the final surface preparation, the final surface removal by electro polishing (EP) and the final surface removal by a short buffered chemical polishing (BCP flash) are the baseline of cavity surface preparation at DESY. Basing on the positive development overtime and in view of industrialization of the processes for the XFEL project, a proposal for a reduced number of work steps was presented on the SRF 2007 workshop in Beijing [1]. Two parallel preparation lines, the final EP and BCP flash line, are tested on 15 cavities, for each line since. The cavities were produced by two different suppliers and randomly distributed to the preparation lines. In addition two industrial suppliers started industrialized electro polishing facilities for the main surface removal by electro polishing (main EP.) We present the cavity test results for the two preparation cycles.

INTRODUCTION

For the European XFEL project [2] more than 800 superconducting (sc) resonators will be delivered to DESY by industry. In addition to the manufacturing of the cavity bodies, the industrial companies will supply the cavities ready for RF acceptance tests at 2K, including the complete surface treatment, the individual cavity helium vessels and RF probes.

In a first step of industrialization the main surface material removal by electro polishing was transferred to industry [3]. In 2007 a proposal for a reduction of preparation steps to reduce preparation cost without losing performance of the resonators was presented at the SRF 2007 workshop. This proposal was made for the short chemical etching of about 10 µm by buffered chemical polishing (BCP flash). The baseline of reduced preparation steps was transferred to the final surface removal of 40 µm by electro polishing (EP) (final EP) sequence (Table 1) as well. 30 superconducting resonators, delivered by two industrial companies have undergone the main EP in two different industrialized EP facilities. The applicability of the proposed optimized preparation step is tested on these resonators.

PREPARATION STEPS

As a base line of the optimized XFEL preparation sequence proposal for the dedicated treatments, both for BCP flash and final EP, the Helium vessels are welded on

at the earliest state possible. The 120°C bake out [Fig. 1] as well as the vertical RF test at 2 K are done with cavities already installed into their helium vessels [Fig 1].



Figure 1: **Left side:** Cavity equipped with helium tank and all accessories installed to the vertical test insert. **Right side:** Cavity dressed with helium tank installed to 120°C baking apparatus before vertical RF measurement.

Table 1: General Preparation Steps for Optimized Process Flow

BCP flash	Final EP
Main EP in Industry	
Cavity outside surface removal @ DESY by BCP	
Ethanol rinse	
800°C annealing and H2 degassing @ DESY	
Installation of FMS	End EP (40µm)
Tank welding	Ethanol rinse
Prepare for clean room	6 times HPR
Removal FMS	Installation of FMS
BCP Flash (10 µm)	Tank welding
	Prepare for clean room
	Removal of FMS
Assembly of probes in clean room ISO 4 (HOM / Pick UP / fixed high Q Antenna)	
Ethanol rinse*	
6 times HPR	
120°C annealing	
* Ethanol rinse removed from preparation steps for BCP flash	

For the final EP sequence, no additional surface preparation, other than six times high pressure rinsing (HPR) is applied after the Helium tank is welded on. The

field measurement system (FMS) [4] is installed right after the final electro polishing [Table 1] and remains inside the resonator until the accessories like HOM probes and RF input antenna are installed.

MAIN EP IN INDUSTRY

The main EP is transferred to industry before start of the preparation test sequences. During main EP 110µm Niobium are removed for the final EP sequence and 140µm for the BCP flash. To avoid the HPR preparation

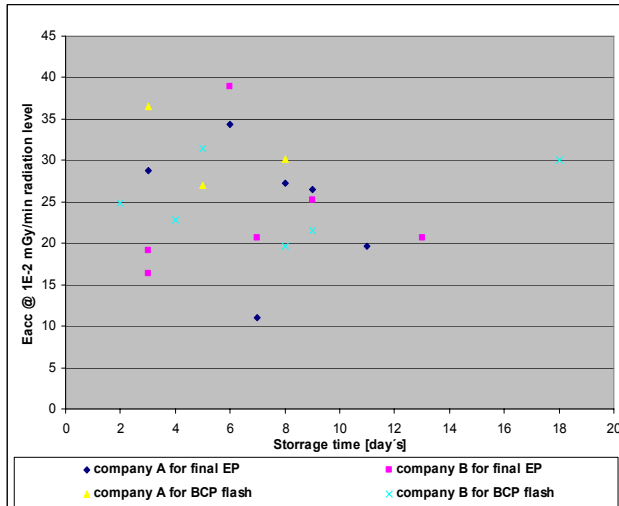


Figure 2: Correlation of storage time of cavities in Ultra Pure Water and acceptance gradient @ first RF test.

step in industry, the main EP cycle was modified, compared to the former preparation cycle at DESY [R5]. For transport to DESY and storage, the cavities are filled with water of a conductance below < 0.14 µS/cm. in between main EP and the final rinse including HPR.

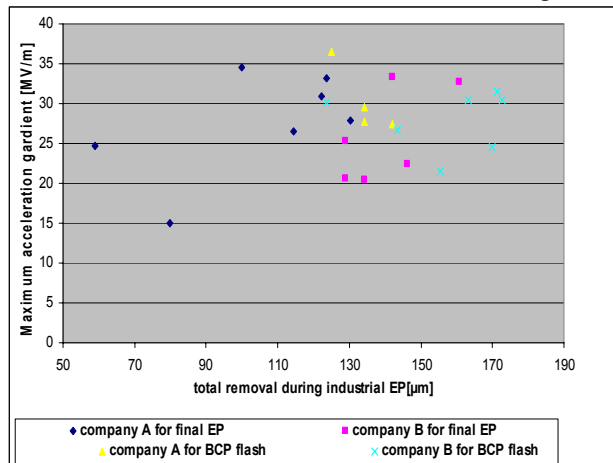


Figure 3: Comparison of maximum acceleration gradient and removal of material during main EP treatment in industry.

For storage times of less then one week after the main EP no significant influence on resonator performance is observed. (Fig.2). One company makes use of applying constant voltage, the second company of constant current

for EP process steering. No differences in cavity performance of resonators are observed between this two process steering.

A comparison of the data like gradient yield on removal of Niobium during main EP at industrial EP facilities (Fig.3) and the main EP at DESY does not show significant differences [6;7].

RF RESONATORS

Cavities Available for Test

Beside the preparation sequences, the main EP in industry had to be tested in parallel. Thirty cavities from production lot number six, fabricated by two different suppliers were available for the test sequence. In a first batch a random distributed set of two times ten resonators, five from suppliers one (CVS1) and five from supplier two (CVS2) was chosen and sent to the industrial EP facility (A+B) for main EP treatments (Table 2).

Table 2: Distribution of Resonators for Main EP in Industry

Batch No 1	Main EP @ Company A	Main EP @ Company B
For final EP (110 µm removal)	2 * CVS1	2 * CVS1
	3 * CVS2	3 * CVS2
For BCP flash (140µm removal)	3 * CVS1	3 * CVS1
	2 * CVS2	2 * CVS2
Batch No 2		
For final EP (110 µm removal)	4*CVS1	4* CVS2
For BCP flash (140µm removal)	----	2* CVS1

During the test of these first twenty resonators, three cavities showed low maximum gradient. Two of these cavities were removed from their helium vessels and further investigated. As a result these cavities were limited at equator welds or bad spots close to the equator. One cavity showed a Q switch, not related to preparation sequence. One cavity showed a leakage to the helium reservoir during test and the re-test is not finished yet. These resonators are excluded from the analysis relevant for the proof of preparation sequences.

Due to strong heating of the HOM coupler antennas three cavities were limited in the first power rise. For these cavities additional HPR was applied after the removal of the HOM probes and the tests were repeated. The final test results for these cavities were included in the statistics of the different preparation sequences.

Accessory, Couplers and Antennas

To minimize preparation steps following the vertical acceptance test, all accessories like higher order mode pick up antennas (HOM), RF signal pick up probe (RFP) and a high Q power coupler antenna (POW) should be installed already and tested during the vertical test at 2K. A variable high quality antenna (hQ), which is presently in use for the tests does not allow transportation over long distances. As a consequence, new designs of fixed hQ antennas and HOM coupler probes were installed and tested [8].

For the vertical acceptance test for the XFEL it is foreseen to test the cavities in continuous mode operation (CW) at 2 K. The HOM probe design in use so far is designed for pulsed mode operation and capable to run in pulsed mode operation. An improved design of HOM probes for CW operation is under investigation [8] and was tested in our test sequences as well. Some resonators were limited in performance by these antennas. An optimization of the design, the preparation antennas for test and the test procedure of fully equipped cavities is on going.

RF TEST RESULTS

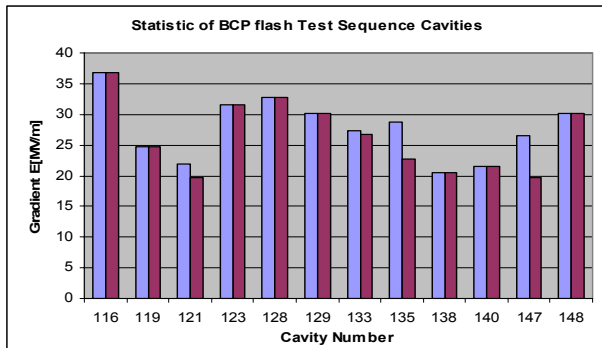


Figure 4: Test results of cavities prepared for test according to the “BCP flash” treatments cycle. [Blue: maximum acceleration gradient Eacc/Red: acceptance gradient for FLASH Eacpt]

To limit the dark current level of the FLASH accelerator, cavities to be installed in to FLASH should not exceed radiation level (Acceptance gradient = Eacpt) of $\leq 1 \cdot 10^{-2}$ mGy/min in the vertical test step up at DESY. The statistical proof of the proposed sequences bases on the test result of twenty four resonators.

Cavities passing the final EP sequence show average maximum acceleration gradient of Eacc max = 29 MV/m and acceptance gradient of Eacpt = 26,1MV/m in the first RF test after preparation. A spread of maximum gradient from 20.6 up to 34,3 MV/m is observed (Fig.5).For the BCP flash cycle the average gradient of Eacc max = 27,7 MV/m and an average value of acceptance gradient of Eacpt = 26,4 MV/m is calculated (Fig 4). The maximum acceleration gradients of this preparation spread from 20,5 up to 36,7 MV/m.

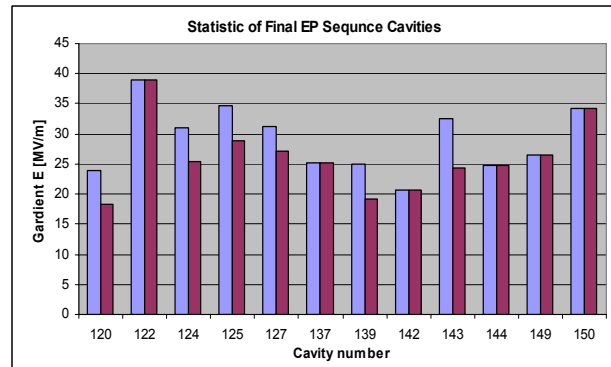


Figure 5: Test results of cavities prepared for test according to the final EP treatments cycle.[Blue: maximum acceleration gradient Eacc/Red: acceptance gradient Eacpt]

SUMMARY

Test results of cavities, undergoing the main EP in industrial company facilities, show no differences to the once treated in the EP DESY facilities. The process of industrial main EP is running stable and reproducible. For the optimized cavity preparation the helium tank is installed at a very early state of preparation. The vertical RF test as well as 120°C baking is done on cavities dressed with tank and ready for module installation. The RF test results show that the cavity preparation proposed results in the same statistical distribution of cavity performance as it was found before. It is shown that the average gradients of cavities undergoing surface preparation on either way, final EP or BCP flash, can serve for the XFEL project. More investigations have to be made for the integration of accessories installed during vertical acceptance test.

REFERENCES

- [1] Proceedings of the SRF 2007 TUP workshop Beijing China B.v.d.Horst TUP 30 B.v.d.Horst et al.
- [2] TDR of European XFEL DESY 2006-047 July 2007
- [3] D.Proch Annual CARE meeting 2008 HT-1: Electropolishing: Industrialization and Ionic liquid as replacement of hazard acid CARE 08;
- [4] FMS system A. Schmidt et al., THPPO 040 this conference
- [5] Proceedings of the SRF 2005 workshop Ithaca NY USA; ThP008 A Matheisen et al.
- [6] Proceedings of the SRF 2007 TUP workshop Beijing TUP 31 M.Schmökel et al.
- [7] D. Reschke TUPPO051 this conference
- [8] W.D.Möller; Sekutowicz DESY Hamburg, private communication