UPDATE ON CAVITY PREPARATION FOR HIGH GRADIENT SUPERCONDUCTING MULTICELL CAVITIES AT DESY

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Abstract

For the proposed XFEL Project at DESY about 850 Cavities will accelerate the electron beam. The resonators have to provide average acceleration gradient of 23, 6 MV/m [Ref.:1]. In order to reach that gradient reproducibly in a medium scale production, several preparations methods and surface treatments are under study at DESY. Beside the standard fine grain niobium material in use up to now, nine cell resonators made from large grain niobium are under investigation since 2006. We present the different approaches in surface preparation procedures for fine and large grain niobium and the related cavity results.

INTRODUTION

The EP (Electro Polishing) apparatus, installed in 2003 is running continuously and servers as major surface preparation equipment at DESY. More than 192 electro polishing processes have been made in the apparatus since. During the EP process sulphur is build at the aluminium electrode [Ref.:2; 3]. Sulphur is well known as origin of fieldemission and shows enhanced secondary electron emission coefficients. Sulphur can be dissolved in ethanol or ether very efficiently [Reg.2; 3]. An alcohol rinsing process is studied since end of 2006 for efficiency on sulphur removal and improvement on cavity performance.

Studies and test on single- [Ref.: 4] and multicell cavities show that below a surface removal of 10 µm the application of the well know Buffered Chemical Polishing [BCP] does not influence the performance of an electro polished surface significantly. In view of the XFEL project this BCP treatment, called flash BCP, is tested for its application in respect of cost savings due to the short treatment time of 10 minutes only.

Large- and mono grain single cell cavities show impressing results after applying BCP surface removal technique only [Ref.:5]. This large grain material bears the potential of cost and risk savings on the niobium production and cavity preparation as well. Three large grain nine cell resonators made by industry have under a standard BCP treatment since middle of 2006 at DESY.

BASE LINE TREATMENT ON FINE AND LARGE GRAIN NIOBIUM MULTI CELL CAVITIES

The cavity treatments, performed on fine grain cavities so far, are spit into two major treatment steps. Step one, a main surface removal of 160 µm, is done by electro polishing. In step two, called fine treatment, a removal of 10 µm (flash BCP) respectively 40 µm (EP) is done to prepare the cavities for vertical RF tests at 2 K.

1) Main EP

After passing the quality control and inspection tests, the damage layer is removed by electro polishing. In a heat treatment, done at 800 C in an UHV oven, the Niobium is re crystallized and degassed from Hydrogen, implanted during production and the main EP surface removal. Details of the steps of the main EP treatment are given in Table 1.

Table 1: Overview on preparation steps for main EP

Processes	Process time	Process parameter
Ultrasonic cleaning	20 Min	Oil and grease free surfaces
UP water rinse	20 Min	R> 12MOhm cm
Main EP	6-8 h	Remove 140-180 µm
Rinsing	1h	PH > 4
UP water rinsing	1 h	R >12Mohm cm
Outside BCP	20 Min	Remove 20 µm
Rinsing	1h	PH > 4
UP water rinse	20 Min	R>12 MOhm cm
drying	12 h	cl. 10000 cleanroom
1st Alcohol Rinse	15 Min	Remove sulphur
annealing	2 days	800 C UHV oven
Tuning	4 h	Field flatness>98%

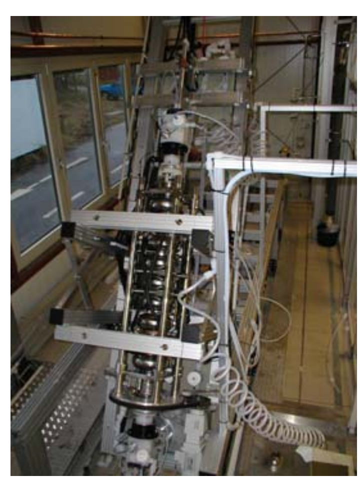

Figure 1: Cavity installed in the DESY EP bench

2) Fine EP

For preparation of a vertical test the cavities undergo a final treatment by electro polishing named fine EP. This fine EP last for 2 hour of current on condition of the EP apparatus.

To reach optimum polishing conditions a warm up of the acid to 30 C is required. This warm up phase covers the first hour of the tow hours lasting processing time Detail of the fine EP processing steps are shown in Table 2.

Table 2: Overview on major reparation steps during fine EP treatment

Processes	Process time	Process parameter
Ultrasonic cleaning	20 Min	Oil and grease free
UPW rinsing	20 Min	R >12MOhm cm
fine EP	2 h	Remove 35-40 µm
Fine rinse	20 Min	R>18 MOhm cm
High pressure rinse	2 h	P= 100 bar
Drying	12	Cl 10 ASTM
Assemble cavity	40 min	CL 10 ASTM
NEW 2nd Alcohol Rinse	10 min	Remove sulphur
6 times High Pressure Rinse	6*2h	P= 100 bar
Assemble variable antenna	30 min	CL 10 ASTM
120°C Heating	2 days	

3) Flash-BCP

The 800 C heat treatment and the handling during tuning are origin of pollutions on the surface. A short (<=10µm) surface etching by a 1:1:2 (HF/HNO3/H3PO4) BCP acid mixture, named flash BCP, leads to a minimum of grain boundary etching and cleans the surface sufficiently.

Table 3: Overview on major reparation steps during flash BCP EP treatment

Processes	Process time	Process parameter
Ultrasonic cleaning	20 Min	Oil and grease free
UPW rinsing	20 Min	R >12Mohm cm
Flash BCP	5-10 min	5-10 µm
Fine rinse	20 Min	R>18 Mohm cm
High pressure rinse	2 h	P= 100 bar
Drying	12 h	CL 4 (ISO)
Assemble cavity	40 min	CL 4 (ISO)
6 times High Pressure Rinse	6*2h	P= 100 bar
Assemble variable antenna	30 min	CL 4 (ISO
120°C baking	2 days	

During flash BCP the acid, pre cooled to 5 C, is filled into the cavity and circulates with a minimum of acid velocity after filling up the cavity. This low circulation enforces a homogenous surface removal on all areas of the cavity body, without reaching the maximum allowed acid temperature of 15 to 18 C.

4) Large grain Niobium cavities preparation

Impressing results were reached on large grain (LG) single cell cavities, applying BCP surface etching [Ref.:5]. Basing on these results buffed chemical polishing (acid mixture 1/1/2) is chosen to study a cost optimized cavity preparation. Three nine cell LG resonators have undergone a treatment shown in Table 4. The total removal prior RF test was fixed to 120 µm. Two cavities got additional BCP treatment of 20 µm each after the first vertical test, to ensure that the 120 µm etching is sufficient to reach the maximum acceleration gradient.

Table 4: Preparation sequences on main BCP treatment of large grain multicell cavities

Processes	Process time	Process parameter
Ultrasonic cleaning	20 Min	Oil and grease free
UP water rinse	20 Min	R> 12MOhm cm
Main BCP	1 h 40 Min	Remove 100 µm/
Rinsing	1 h	R >12MOhm cm
Outside BCP	20 Min	Remove 20 µm
Drying	12h	Cl 10000
Rinsing	1h	PH > 4
Annealing	2 days	800 C UHV oven
Tuning	4 h	Field flatness >98%
Ultrasonic cleaning	20 Min	Oil and grease free
UPW rinsing	20 Min	R> 12Mohm cm
BCP treatment	20 Min	Remove 20 µm
Fine rinse	20 Min	R>18 MOhm
High pressure rinse	2h	Cl 10 ASTM
Drying	12 h	Cl 10 ASTM
Assemble cavity	40 min	CL 10 ASTM
NEW 2nd Alcohol rinse	10 min	Remove Sulphur
6 times High Pressure Rinse	6*2h	P= 100 bar
Assemble variable antenna	30 min	CL 4 (ISO)
120°C Heating	2 days	

Alcohol Rinse

Sulphur origins from a chemical reaction of the EP acid and the Aluminium electrode in use for the electro polishing [Ref.:3]. Sulphur is able to settle and stick on the cavity surface and is well know as a source of field emission. Studies made on samples show that sulphur removal by High Pressure Rinsing or ultrasonic treatments with ultra pure water is not very efficient while pure ethanol removes the sulphur segregations on the samples efficiently. Before the 800°C annealing and prior to the final HPR, taking place after assembly of flanges for vertical test in Cl 4 cleanroom, alcohol rinsing (Table 5;6) is introduced into the preparation line. For reproducible processes and to full fill safety regulations in handling of flammable liquid the alcohol is stored inside a reservoir (Fig.:2) which is pressurized by nitrogen to feed the ethanol via a filter unit into the cavity.

Figure 2: Set up of alcohol cleaning apparatus at DESY

Table 5: Test set up and applied sequences for alcohol rinse on EP fine grain niobium cavities

Alcohol in use:	Ethanol 98%
Ethanol Volume:	12 l
Filtration:	0, 2 µm filters
Cavity set up	All flanges for test installed
Application	Before 800C annealing Before final 6 times HPR
equipment	Fill in /out flange on beam pipe
Mech. impact:	Cavity shaking during treatment
Treatment time:	10 min

Table 6 Handling sequence for ethanol rinse

Connect fill in flange to beam tube (Quick connect
Fill in 12 l Alcohol via particle filter of the fill in line
Disconnect reservoir
"Shake" cavity for 10 minutes
Connect Nitrogen purge line to fill in flange
Backfill alcohol to reservoir
Disconnect fill in flange from cavity
Continue with HPR sequences

RF TEST RESULTS

At DESY several attempts on improvement and optimization of the 120 C baking process are on going. For analysis of the test results in respect to the cavity preparation sequences applied, only the first power rise of a resonator after leaving the cleanroom before baking is selected to study the preparation sequences. Fieldemission of cavities results in dark current which can limit the experiments done with the beam. For acceptance of a cavity, to be installed in modules for FLASH, the maximum gamma loading, measured in the DESY vertical test set up, is limited to 2*exp $^{-2}$ mGy /min. The data displayed as "fe limit" are the gradients of the resonator at which that X ray level limit is reached.

1) RF Test results after flash BCP treatment

Ten cavities have undergone the flash BCP treatment for studies. One of theses resonators showed gradient limitation at low field, origin from a defect inside an equator weld. One resonator reached the radiation level (fe limit) below the acceptance voltage of 25 MV/m, while all other resonators pass the acceptance levels.

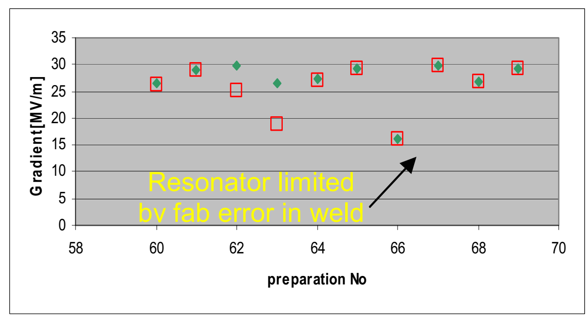

Figure 3: Rf test results after flash BCP [no 120 C bake]; [fe limit = Eacc@1*exp-2 mGy/min]
[Green stars = maximum gradient; Red square= fe limit gradient]

2) RF test results of large grain cavities

After removal of 120 µm gradients up to 30 MV/m are measured on the three large grain cavities.

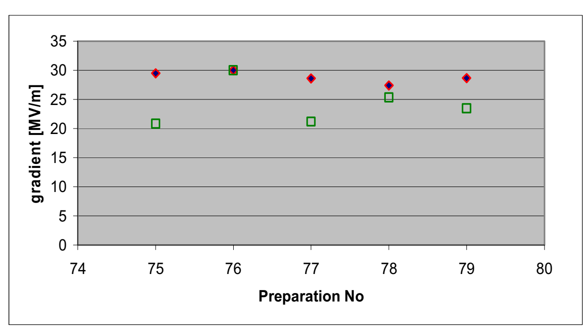

Figure 4: Rf test results of large grain cavities after BCP treatment ([no 120 C bake]; [fe limit = Eacc @ 1*exp-2 mGy/min]
[Red stars= maximum gradient; green square= fe limit gradient]

Two resonators have been re processed with an additional 20 µm removal by BCP. No significant improvements are measured after this additional material removal.

3) RF test results after fine ep treatment

Figure 5 displays the RF test results since beginning of 2005 of resonators, undergone the EP treatment right after fabrication. To visualize the impact of alcohol rinse during cavity preparation, the test results are displayed in one overview graph in order of the preparation nomenclature (Fig.: 5). One of the cavities alcohol rinsed is limited at an equator weld due to fabrication errors. With exception of one resonator, all cavities of these test sequence of alcohol rinse are no more limited by field emission.

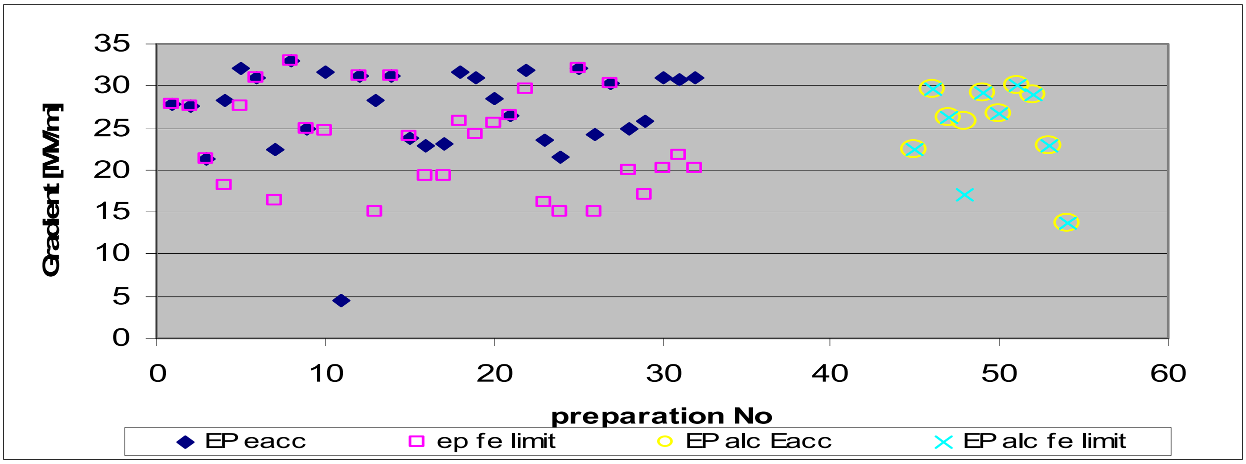

Figure 5: Rf test results after fine EP treatment [no 120 C bake] [fe limit = Eacc @ 1*exp-2 mGy/min]

PROPOSAL FOR A COST OPTIMIZED CAVITY PREPARATION

Actually no EP process for application on resonators, dressed with its Helium container (tank) is published. The BCP treatment successfully applied was for repair of dressed cavities installed in module 5 showed gradients above 25 MV/m [Ref.:6]. Actually the tank welding for EP treated cavities can only be applied after the vertical acceptance test. Here special care must be taken in order to conserve the surface on the as measured status. For the XFEL accelerator average gradient of 23, 6 MV/m in modules and above 25 MV/m during the vertical test are proposed. Basing in the test results of the cavity preparations presented above and the experiences gained during tank welding, a proposal for a cost minimum cavity preparation usable for the XFEL is presented in table 6.

Table 6: Proposal for a cost optimized preparation process applicable for the XFEL cavity production

1) main EP (Table 1)	9) HP rinse
2) outside BCP (Table 1)	10) Assemble of all probes
3) 800 C annealing	11) optional alcohol rinse
4) Install FMS	12) Six times HP rinse
5) Tank welding	13) 120 C Bake
6) Remove FMS	14) RF test with HE tank
7) Clean for cleanroom	15) Clean for cleanroom
8) Flash BCP with tank	16) Install power coupler

CONCLUSION

Several cavity preparation sequences are under test at DESY. These methods are capable to serve for the XEL Cavity preparation where an average acceleration gradient of 25 MV/m in vertical acceptance test is requested. Three TTF resonators made from large grain material are tested and reached well above the XFEL specification, right after a buffered chemical polishing with a total removal of a 100 to 120µm. Alcohol rising of electro polished resonators is capable to remove sulphur, origin from the electro polishing process. Significant reduction on field emission is observed on resonators which have undergone the alcohol rinsing procedure installed into the cavity preparation.

REFERENCES

[1] TDR of European XFEL DESY 2006-047 July 2007

[2] Electro polishing surface preparation for high gradient cavities at DESY; A.Matheisen, et al PAC 2005

[3] IMPURETES Aluminium et Soufre Dans Les Bains d'Electropolissage, A.Aspart et al CARE-Pub-05-004

[4] D Reschke private communications

[5] Progress on Large Grain and Single Grain Niobium. P Kneisel this conference

[6] D Kostin private communication