# Preparation Sequences for Electro-Polished High Gradient Multi-Cell Cavities at DESY

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*Abstract*

During the last years encouraging results on improvements of acceleration gradients on TESLA TTF cavities were gained. Within the collaboration of DESY and KEK in 2001 as well as treatments made in the DESY electro-polishing facility, acceleration gradients are pushed towards 40 MV/m by electro polishing. Beside the new surface preparation technique the subsequent handling- and preparation steps had to be adjusted to the need of the electro-polished high gradient resonators. We report on the major differences in the treatment sequence of BCP and EP cavity handling. Changes on the infrastructure and tooling as well as processing sequences, adapted to the need of electro-polished resonators, will be described in detail.

## INTRODUCTION

AT DESY Hamburg an electro polishing apparatus (EPA) was installed in 2003 and serves as major surface preparation tool for the TTF /XFEL accelerator structures [1,2]. More than 54 electro polishing (EP) runs have been made. Several resonators reached acceleration gradients (Eacc) of up to 39 MV/m [3] . These Cavities have been welded into their individual helium containers. One resonator is installed into the TTF linac and showed the acceleration gradient of with 35 MV/m under full beam load in the TTF 2 [3] linac.

The DESY electro polishing apparatus (EPA) [4,5] is located outside of the DESY/TTF clean-room in normal air. During the EP process the resonator is connected to a handling frame and current leads made from copper. The current is guided to the cavity via sliding contacts made from copper carbon alloy and the electrode made from pure alumina. These contacts as well as the mechanics of the EPA could not be designed for clean-room application. Therefore the cavity exterior has to be cleaned for class 10 clean-rooms after the polishing process.

Actually there is no post processing treatment for EP cavities that are dressed with helium tank available. New preparation procedures are developed for post treatments of dressed cavities. Well established sequences for cavity with surface preparation by Buffered Chemical Polishing (BCP) processing as well as the tank welding procedure are adapted to the new infrastructure and needs of the EP processed surface.

## PROCEDURES FOR TEST PREPARATION

Independent on the preparation technique by BCP or EP, each resonator has to under go five major steps in preparation (table 1)

| | |
|---|---|
| A | Removal of damage layer<br>Annealing / post purification |
| B<br><br>C<br>D | Final surface treatment / assembly for vertical test<br>RF test at 2K<br>Welding of connection to He vessel / He vessel welding |
| E | Final cleaning and assembly for module / horizontal test |

Table 1: List of major preparation steps applied for preparation of s.c. resonators at DESY

### *Removal of damage layer*

In the KEK/ DESY collaboration the removal of damage layers was done by BCP. After electro-polishing at KEK two resonators where no post purification by Titanium getter material was applied and two cavities with post purification of the Niobium, showed gradients of more than 35 MV/m [6].

Since 2003 the damage layer is removed by EP only to study the influence of surface roughness on cavity performance. No post-purification at 1400 C is applied to these cavities since to get statistical numbers for this treatment that reduces costs in a large scale production.

### *Removal of damage layer by EP*

After installation of the cavity into the handling frame and ultrasonic cleaning inside the clean-room class 10000 the cavity is connected the cavity to the EP apparatus. Current leads and EP end heats are installed in a normal air atmosphere. The removal of 190 µm of damage layer is done in two polishing sequences of four hours length each with a constant voltage of 17V applied. A 2h rinse with ultra pure water finalizes the EP process before the cavity is removed from the EP apparatus. The limited height of the DESY clean-room does not allow removing the electrode inside the clean-room. It is removed in the EP stand while the resonator is filled with UP water. A protecting beam pipe flange made from PVDF covers the top cavity beam pipe end afterwards.

| | TTF | XFEL | ILC |
|---|---|---|---|
| Treatments | BCP /EP | EP | EP |
| Installation to frame | X | X | X |
| Ultrasonic cleaning | X | X | X |
| Installation of | Tubes | Current leads | Current leads |
| Removal of X µm (by) | 80 (BCP) | 160 (EP) | 160 (EP) |
| remove from apparatus | X | | |
| Outside chemistry µm | 40 (BCP) | 20 (BCP) | 20 (BCP) |
| 800 C annealing | 3 h | 3 h | 3h |
| 1400 C post purification | 3,5h | No | No |
| tuning | X | X | X |
| Ultrasonic cleaning | X | X | X |
| Installation to apparatus | X | X | X |
| Removal of µm | 20(BCP) | 45 µm EP | 45 µm EP |
| Cleaning for clean-room (USE) | No | Yes | Yes |
| Exchange of flanges | X | X | X |
| Low pressure rinsing to | 18 Mohm/cm | 18 | 18 |
| High pressure rinsing | 1time | 1 time | 1 time |
| Drying in class 10 | X | X | X |
| Assembly of components | X | X | X |
| High pressure rinsing | 2 time | 6 times | 6times |
| Assembly of antenna | X | X | X |
| Rf test at 2K | X | X | X |

Table 2: Comparison of preparation sequences applied at DESY for s.c. cavities with BCP or EP surface treatment

| **USE** | |
|---|---|
| Carwash | Detergent 5 min 80bar<br>DI water rinse 10 min 80 bar |
| Ultrasonic | 50 C 20 Minutes |
| UP water rinse | R >= 12 Mohm /cm |
| Removal of EP heat short side | |
| Removal of EP flanges | |
| Low pressure Rinse | 4 bar R>= 18 Mohm cm |

Table 3: sequence of cleaning steps to reenter the clean-room after electro polishing.

### *Cleaning process after electro polishing*

Residues from assembly procedures, contamination of acid and abrasives of the current contacts on the cavity exterior permit the entry to the clean-room. A cleaning procedure called ultrasonic clean after EP (USE) is applied before entering the clean-room for further treatment [Table 3]. During this USE treatment the resonator remains filled with UP water. After exchange of all flanges and pipes to special ones, which are only applied for UPW rinses, a low pressure rinse at 4 bars is applied with

### *800 C annealing*

For annealing of the Niobium and removal of Hydrogen from the Niobium lattice, an 800 Co annealing in an UHV oven is applied. To prevent contamination of the Niobium and the UHV oven during the annealing process, the cavities exterior is cleaned by a 20-40 µm BCP treatment. This process step is unchanged in respect to the BCP cavity preparation sequence.

### *Preparation for vertical test*

The DESY EP apparatus needs about 1 h to reach the set point of 30 to 35C$^{o}$ for EP treatments. The time for final EP is set to 2 hours to reach reasonable removal at that temperature [7]. A total of 45 µm of Niobium is removed during this 2 hours electro-polishing process for preparation of the vertical test.

After entering the clean-room by applying the USE procedure, all pipes and flanges are exchanged and the cavity is rinsed by low pressure rinse until the draining water shows 18Mohm cm conductivity [Table 2]. Residues of the EP process and particulates are washed away by high pressure rinsing at 100 bar. After drying in class 10 area for about 12 hours, the assembly of flanges, pick up probes and the variable antenna takes place. This procedure is applied to EP and BCP resonators identically. The number of high pressure rinses at 100 bar after assembly and before installation of the variable antenna is increased from 2 to 6 rinses for the EP resonators (Table 2).

## PROCEDURES FOR TANK WELDING

For the actual design of cavities dressed with their individual helium containers the current lead can only be connected to the beam pipes. Experiments on multicell resonators showed a strong polishing at the beam pipe tubes and no visual polishing effect in the middle cells. Actually there is no set up available to apply electro-polishing after the Helium containers is welded.

For electron beam welding of the interconnections of cavity and helium vessel intermediate rings are welded to the “bordscheibe” by electron beam welding at an outside facility. Inside the class 10 area of the clean-room, the cavities are hermetically sealed and filled with argon for this welding procedure. Before TIG welding of the tank tube to the interconnections, the cavities have to be tuned to field flatness of >= 98 % and a frequency of 1.3 GHz. The tuning machine is located outside of the clean-room. A complicated sequence of installation of antennas for mode spectrum measurement and bead pulls for field profile adjustment has to be applied to preserve the cleanliness of the cavity interior (Table 4). Three out of six resonators lost gradient during this procedure [8].

For large scale production this sequence is too complicated and bears too many risks. A bead pull equipment is developed that can be installed inside class 10 and remains inside the resonator for the whole procedure of tank welding (Fig.: 1). This on line field

| SEQUENCES FOR TANK WELDING | |
|---|---|
| 1) Remove variable antenna | 13) Install mode spec. antenna |
| 2) Exchange power coupler port to High Q antenna | 14) Tuning |
| 3) Exchange Pick up probe | 15) Cleaning for clean-room |
| 4) HP Rinse | 16) Removal mode spec antenna |
| 5) Leak check and venting with Argon | 17) Installation of antennas |
| 6) EB welding of tank interconnection | 18) HP rinse |
| 7) control of mode spectrum | 19) Leak check and venting with Argon |
| 8) Cleaning for clean-room | 20) Tank tube welding |
| 9) Removal of Pick Up | 21) Cleaning for clean-room |
| 10) Removal of high Q antenna | 22) Check filed profile Installation / remove bead pull |
| 11) HP rinse | 23) Installation of pick Up and HOM probes |
| 12) Installation of bead pull | 24) 6 times High pressure rinsing |

Table 4: List of operations necessary for the tank welding procedure applied to TTF cavities before qualification of an integrated bead pull equipment for tank welding

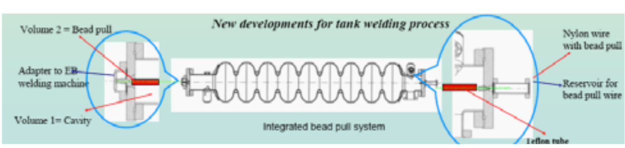


Fig.:1 Cross section of the integrated bead-pull measurement devise for tank welding

profile measurement system separates the cavity volume in two independent volumes by a teflon tube. The interconnection of this tube and flanges is designed particle tight. Antennas and feed threw for the RF measurements are fixed to the beam pipe flanges. Two valves allow to pump and to purge both volumes in parallel or independently. The bead pull remains inside the Teflon tubes during the whole tank welding process. A field profile check and tuning can be done at any time without entering the clean-room or exposing the cavity interior to a non particle free atmosphere. EB welding is done at a vacuum of $1*10^{-5}$ mbar. Measurements show that during welding procedures the cavities reach temperatures of up to 60 $C^{o}$. A desorbtion measurement is done to make sure that no contamination of resonators appears due to degassing of the teflon tube. At a vacuum of $10^{-8}$mbar and 60 C environment temperature no out-gassing was seen by the mass spectrometer analysis [9]. The bead pull equipment is removed right before installation of HOM antennas and the final HP rinses inside the class 10 clean-room area. A cavity equipped with this bead pull device incorporated during the welding treatment did not show degradation in performance afterwards.

## CONCLUSION

The DESY EP apparatus is running continuously since more than 100 hours and serves as a major preparation facility now. An adaptation of preparation steps to the needs of resonators prepared by electro-polishing surface removal is done. The EP apparatus and the tuning machine for field profile adjustment are not located inside a clean-room. New sequences to re enter the clean-room after EP treatment and tuning are developed. For better reproducibility of cavity performance after the tank welding procedure an bead pull equipment is developed. This system is installed in the class 10 clean-room and is in cooperated inside the resonator during these preparation steps.

## ACKNOWLEDGMENTS

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