Electro Polishing of Niobium Cavities at DESY

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Abstract

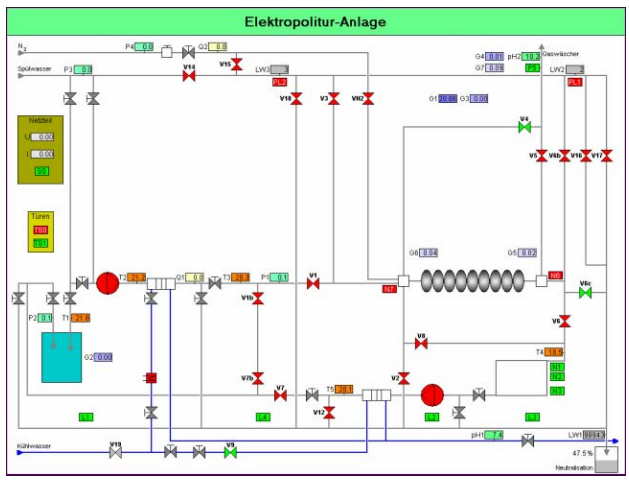
At DESY a facility for electro polishing (EP) of the super conducting (s.c.) TESLA/TTF cavities has been built and is operational since summer 2003. The EP infrastructure is capable to handle single - cell structures and the standard TESLA/ TTF nine - cell cavities.
Several electro polishing processes have been made since and acceleration voltage up to 40 MV/m have been reached in nine cell structures. We report on measurements and experiences gained since 2003 as well as on handling procedures developed for the preparation of electro polished resonators. Specific data like heat production, variation of current density and bath aging will be presented. Another important point for reproducible results is the quality control of the electro polishing process.

INTRODUCTION

At DESY an electro-polishing stand (EPS) was built in 2003 [1;2;3]. According to the good experiences gained with electro polishing (EP) at KEK and CERN, constant voltages and a mixture of 9 volume parts of sulphuric acid (96%) and 1 part fluoric acid (48%) are chosen for the baseline parameters set of the EP process [3].
A total of 14 cavities are electro polished since summer of 2003. Voltages of 14 to 18 V have been tested. The well-established handling procedures for cavities processes with buffered chemical polishing (BCP) had to be changed to meet the needs of EP resonators. On three single cell and one 9-cell resonator acceleration voltages up to 40 MV/m are reached using the DESY EP set up and adapted handling procedures. During the EP processes all relevant parameters are monitored and stored for documentation. From these data set's a first analysis is made to find system parameters, gain online analysis of the process and find parameter sets for reproducible high gradient resonator preparation.

ELECTRO POLISHING INFRASTRUCTURE

The DESY EP set-up (EPS) is designed as a closed loop acid circuit with one acid supply barrel of about 150 –180 l storage volume, the cavity rotating horizontally on the EPS bench and a heat exchanger in line [1]. The acid is pumped into the resonators via the pure aluminium cathode and is distributed homogenously into the 9 cells via holes with adopted diameters. Main parameters to determine the EP process are the acid volume sent into the resonator (Q), the temperature at the inlet of the electrode (T3), the temperature at the cavity outlet (T4), the current (I) and the current oscillation (dI).



Valve Sensor P1 0.1 Pump

Figure 1: Flow chart of the DESY electro polishing infrastructure.

All other are Sensors are mainly installed to control the safety of the system and the automated process sequences [2] (Figure 1).

PROCEDURES

The procedures in use for processing the EP cavities are close to the once, which are well established for BCP cavities [6]. For safety reasons the EPS is located outside of the DESY TTF cleanroom. To enter the cleanroom after EP, the cavities have to under go an additional cleaning procedure by rough outside surface cleaning (solvent + DI water rinse at 80 bars pressure), ultrasonic cleaning and rinsing with ultra pure water (R=>18 Mohm cm, particle filtered to <= 0,2 µm). The number of high-pressure water (HP) rinses, following the assembly procedure, is increased from 2 to 6 rinses. Assembly and RF test at 2 K as well as heat treatment at 800 C resp. 1400 C (post purification) are identical to the standard BCP treatments. Up to now no technical solution for EP of cavities dressed with the helium vessel is available. The procedures for tank welding and tuning of cavities are modified and are still under investigation and optimization. The cavities, vented to normal pressure by argon gas are sealed inside the cleanroom and stay hermetically closed during electron beam welding (Nb cone to Ti connections) as well as during tuning of the field profile and tank welding by TIG weld. Major item developed for this process is a new flange system with

integrated bead pull and the RF antennas. This equipment stays with the cavity during all processes until the final HPR rinse before installation of the RF power coupler.

PARAMETERS OF THE EP PROCESS AT DESY

Until now a total of 14 cavities in about 163 hours have been electro polished in 6 runs (1 run = 1 barrel of 145 to 180 l of EP acid). Voltages of 16 to 18 V have been applied and tested. Average removal rates of 0.4 µm/min and current densities of 5,6 A/dm^2 have been measured.
For the DESY EPS 17 V as nominal voltage and a process temperature range of 28 to 34 C^o is established. At this work point the temperature of the acid can be controlled best and the available cooling power is reasonable. An extreme high out gassing of the hydro fluoride (hf) gases, starting when the cavity is rotating, is observed. A change in hf gas absorber lay out was necessary to handle the outgasing. Continuous runtimes of up to 4 hours for removal of niobium before oven treatments and 2 hours for the final preparation are established and can be handled in one shift.
Up to 13 gram of niobium can be dissolved in one liter of acid before the oscillation reduces and the system leaves the plateau of the EP polarogram [3].

RF TEST RESULTS

Three single- and 8 TTF multi-cell cavities have been EP processed and tested at 2 K in vertical tests (Table 1). The single cell cavities, pre-tested in the single-cell test program [4], reached acceleration gradients of 35 to 40 MV/m (Figure 2).

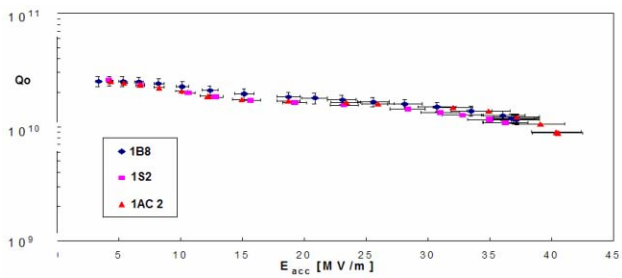


Figure 2: Test results (Qo vs. Eacc) of single cell cavities EP processed at DESY.

Four nine cell cavities (AC 70;71;74;78) that did not meet the high gradient goal of 35 MV/m in the KEK / DESY EP test sequences and were re-polished at DESY. Most cavities showed high quality factors and acceleration voltage improvement's. AC 71 and 74 were limited by field emission, origin from a defect filter cartridge in the HP rinse line. AC 71 improved its gradient from 19 MV/m (field emission loaded) to 38 MV/m after 23 µm EP and 120 C baking (Figure 3). This cavity was successfully welded into the He vessel and showed 38 MV/m acceleration gradient without field emission limitation in the horizontal test as well [5].

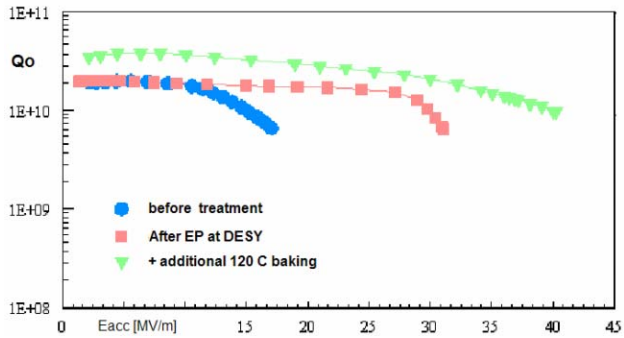


Figure 3: RF test results (Qo vs. Eacc) of AC 70.

Even after removal of about 40 µm the resonator AC 78 did not recover from a surface damage appearing during handling for tank welding. The resonator AC 80, made from hang over material of the last cavity production showed 28 MV/m acceleration gradient and is limited by quench. The prototype resonator p-1, in use since 10 years now, was recovered to 25 MV/m by electro polishing at DESY.

Table 1: RF test results of cavities EP processes at DESY

Cavity	Eacc [MV/m] before EP	Eacc [MV/m] after EP	+120 C baking	Q0 @23,5 mV/m	Limit
1b8	28	33,59	38	1,7E10	Breakdown
1s2	31,5	31,5	36,6	1,5E10	Breakdown
1ac 2	34,8	31,5	40,5	1,7 E10	Breakdown
ac 78	15,3	-	23,7	2,9E10	Breakdown
ac 78	20,7	15	-	1,7E10	Breakdown
p-1	0,5	10,6	-	7,6E8	Power
p-1	10,6	25,3	-	1,4E10	Breakdown
ac 70	19	30	39,4	1,7E10	Breakdown
ac 80	0,5	27,5	-	1,7E10	Breakdown
ac 80	27,5	28	-	1,6E10	Breakdown
ac 71	31,5	29		1,2E10	Field emission
ac 74	28	19,8		6E9	Field emission

OBSERVATIONS

The data analyzed from the EP data logging so far show a stronger relation ship between the current (I), establishing at the given voltage, the acid volume (Q) passing the cavity and the temperature measured at the cavity outlet

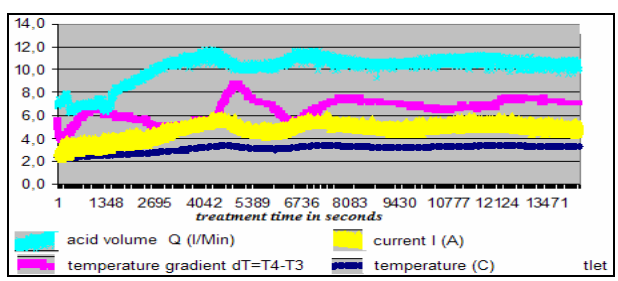


Figure 4: Example for correlation of I;T4; dT and Q.

(T4). The temperature gradient dT = T4 – T3 (T3= Temperature at Cavity inlet) seems to be of secondary order for the process (Figure 4). The linear relation

$$Y = \frac{I}{Q * T4} \qquad (1)$$

seems to be a good indicator for parameter settings of the EPS (Figures 5a-c). Wrong parameter setting and irregularities during the process show a non-linear behavior (Figure 5b). New acid shows higher temperatures

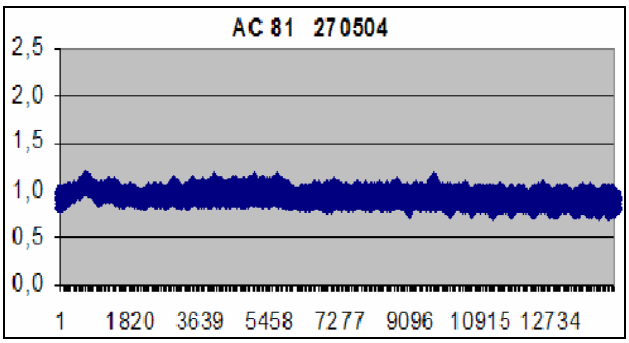


Figure 5a: Y parameter vs. time with correct settings.

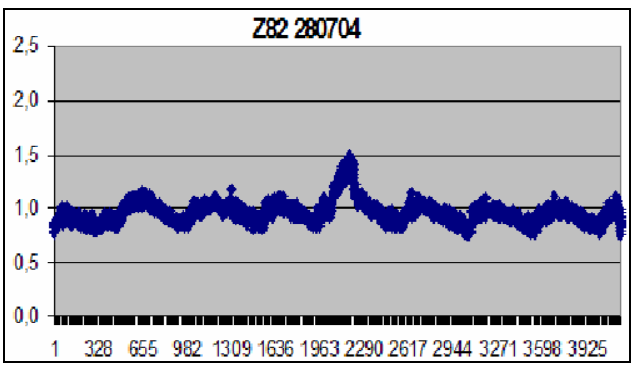


Figure 5b: Y parameter vs. time for wrong setting of N2 overflow.

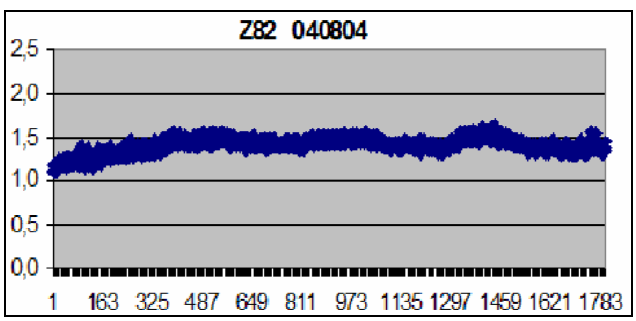


Figure 5c: Y parameter vs. time for correct setting and new acid.

resulting in a scaling factor Y of 1.2 to 1,5 (Figure 5c), while used acid shows, with same parameter setting, Y value of 0,8. The process parameters chosen for the EP are related to a plateau in the PE polarogram where current oscillation establishes [3]. Aging effects in the acid mixture may be indicated by the relation of the average current (I aver.[A]), the average of maximum current amplitude (Imax aver.[A]) and average of minimum current amplitude (Imin aver.[A]) during oscillation in a given time interval. This parameters show

$$Z\max(t1-t2) = \frac{I(\max.aver.)}{I(aver.)} \quad (2)$$

$$Z\min(t1-t2) = \frac{I(\min.aver.)}{I(aver.)} \quad (3)$$

a reduced oscillation with increasing use time and increasing amount of niobium dissolved in the acid (Figures 6a;b).

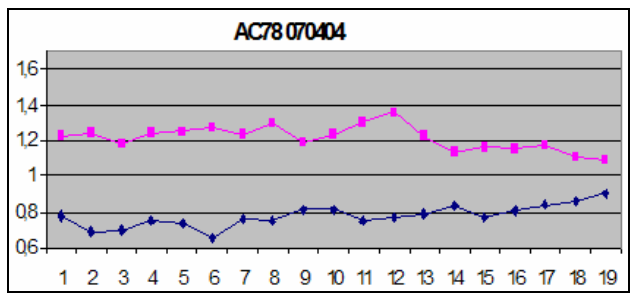


Figure 6a: Z max (red) and Z min (blue) parameter vs. time interval for new acid.

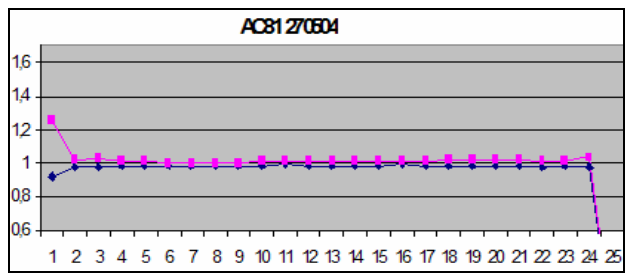


Figure 6b: Z max (red) and Z min (blue) parameter vs. time interval for used acid (10 gr. Nb dissolved per l acid).

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