XFEL
X-Ray Free-Electron Laser

Update on the experiences of electro polishing of multi-cell resonators at DESY

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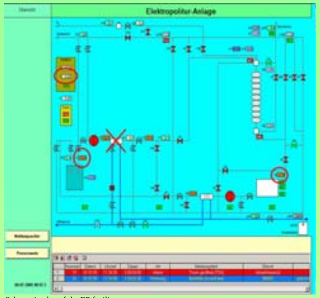
Abstract

At DESY electro polishing (EP) is applied on superconducting cavities for about two years now. Acceleration gradients of up to 39 MV/m have been achieved on nine cell resonators. The EP infrastructure is running continuously since 2004 and serves as major surface preparation tool now. Data, basing on the statistic gained so far, are available for parameters like current density, removal rate, live time of components and process temperature. We report on the latest data as well as on ongoing studies on material stability and sulphur segregation that was found recently during maintenance of the EP infrastructure.

Change of the control parameter

To keep the current as stable as possible the temperature inside the cavity should be nearly constant. The first EP`s were steered to keep the cavity outlet temperature (T4) at 30°C with the heat exchanger in the return pipe (see Fig.1). This method is not very stable because T4 is affected by the current (see Diagram). Steer the heat exchanger to stabilize the temperature inside the storage barrel (T1) is more efficient (see Fig.2/3).

Fig.1: Current curve: Old method



Schematic plan of the EP facility

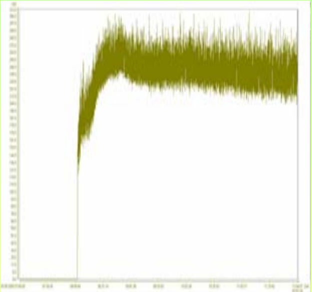


Fig.2: Current curve: New method

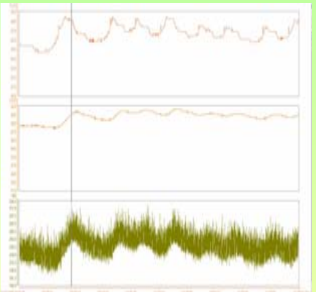
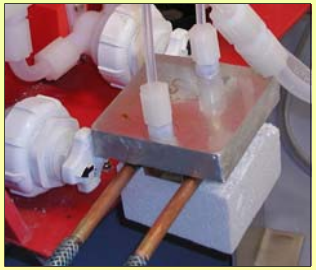


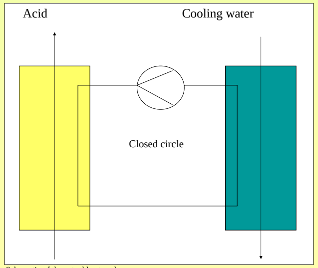
Fig.3: Temporal dependence between T1, T4 and I

Consequences from the new control parameter

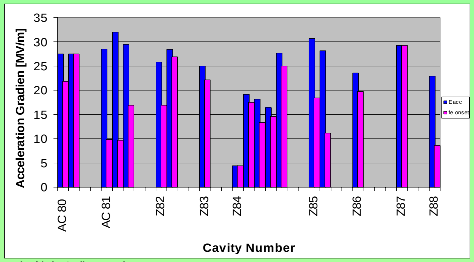
As a result of the change of the control parameter another structure arises for an optimal plant. Actually only the heat exchanger in the return pipe is functional. We are working on a new, more efficient heat exchanger made of pure alumina. We plan to have an additional head exchanger in the feeding pipe to stabilize the temperature of the acid more exactly. Another way to stabilize the temperature of the acid before it reaches the cavity is a storage barrel with an integrated heat exchanger. This is not possible for the DESY EP facility because of limited space.



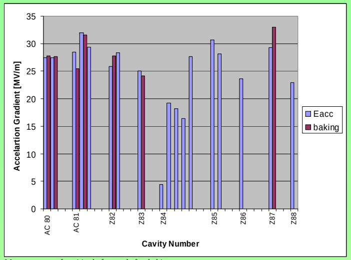
Experimental heat exchanger (Al)



Schematic of the actual heat exchanger

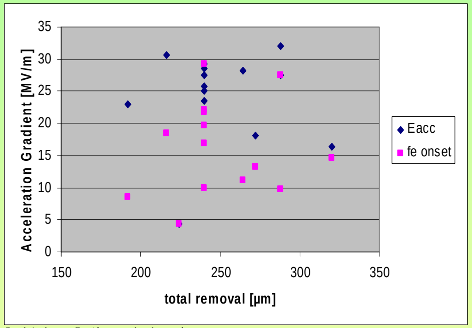


Results of the last 9-cell cavity production



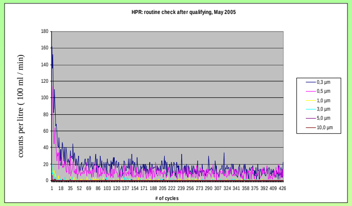
Measurements of cavities before and after baking

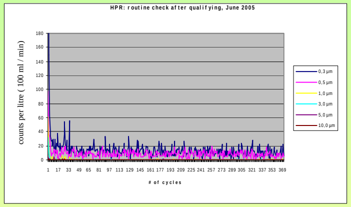
No correlation between the removal rate and acceleration gradient is to be found.



Correlation between Eacc/ fe onset and total removal rate

The field emission does not depend on the HPR.





Results of Cavity RF Measurement

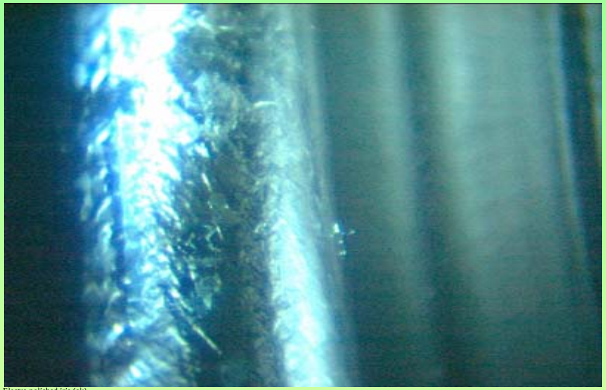
	before baking				gradient in cell [MV/m]					After baking				gradient in cell [MV/m]				
	Eacc [MV/m]	fe onset [MV/m]	Limitation	Origin	1 / 9	2 / 8	3 / 7	4 / 6	5	Eacc [MV/m]	fe onset [MV/m]	limitation	Origin	1 / 9	2 / 8	3 / 7	4 / 6	5
AC 80	27,50	21,80	bd	Quench+ Q desease						27,80	24,00							
	27,50	27,50	bd	Quench location not detected	37	34	37	38	33	27,70	27,70	bd		31	35	33	41	29
AC 81	28,50	9,87	bd	Quench +fieldemission						25,40	13,20	pwr	fieldemission					
	32,00	9,70	pwr	Q drop at high field						31,55	22,90	bd	Quench origin not detected					
	29,38	16,90	bd	Quench origin not detected	29	35	30	40	31	---	---							
Z82	25,80	16,90	bd	Quench on Equator weld						27,80	25,90	bd	Quench on Equator weld	28	41	31	36	41
	28,90	26,90	bd	Quench on Equator weld	26	38	29	35	39	---	---							
Z83	25,00	22,20	bd	Quench on Equator weld	29	34	36	27	36	24,10	24,10	bd	Quench on Equator weld					
Z84	4,41	4,41	pwr	Q desease						---	---							
	19,20	17,50	pwr	Q desease						---	---							
	18,20	13,30	pwr	RF cable						---	---							
	16,40	14,60	pwr	qdesease						---	---							
	27,70	25,00	bd	Quench on Equator weld	32	33	38	41	43	---	---							
Z85	30,70	18,45	pwr	field emission	41	40	38	37	41	---	---							
	28,20	11,20	pwr	RF cable						---	---							
Z86	24,00	19,75	bd	quench location under investigation	29	32	32	32	34	---	---							
Z87	29,50	29,50	pwr	Q drop NO fieldemission	36	33	34	38	40	33,00	33,00	bd	quench location under investigation	41	35	40	40	44
Z88	22,90	8,60	bd	Quench+ strong fieldemission	27	31	27	34	36	---	---							

Field Emission

The main problem of the electro polished cavities seems to be the field emission. After EP the most cavities show a field emission onset between 15 and 20 MeV. There are two principal reasons for field emission, mechanical defects like scratches or holes and chemical impurities at the surface like i.e. dust or impurities inside the niobium surface.

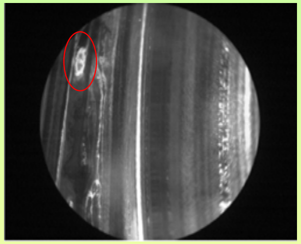
Mechanical Defects

The EP process removes small mechanical defects from the surface of the cavity. Lager defects as in Z88 can't be repaired with EP only. To remove this defect, it has to be grounded before the next EP.



Electro polished iris (ok)

AC75: scratch at the iris



Z88: mechanical defect

Sulphur

During the EP process crystalline sulphur segregates out of the acid. After a few hours a thin film of sulphur was found on tubing surface. Sulfur is water insoluble, and it's not to be excluded that the sulfur is also on the cavity surface after the HPR. To remove this sulfur we are planning to rinse the cavity with ethanol. The solubility of sulfur in ethanol at 20°C amounts to 1,14g S / 100g C_2H_5OH. A small test shows that it's possible to remove the sulphur layer with ethanol (see the pictures).

Tube with a thin sulphur layer

Tube before and after ethanol rinsing