TuP05

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First Results on « Fast Baking »

Baking Optimization for the Mass Production of Nb Superconducting Cavities

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Summary

Whatever the chemical surface treatment of bulk niobium cavities, high gradient performances go through a low-temperature baking (110 °C / 60 hours) due to the removal of the high field Q-slope.

Baking under ultra high vacuum conditions (UHV-Baking) has been first applied. We report here on similar results at high fields achieved with the "Fast Baking" method (145 °C / 3 hours).

Through this result:

- The oxygen diffusion appears as the main reason to explain the high field Q-slope improvement and opens a new way towards the Q-slope understanding,
- A better procedure for the large-scale cavity preparation can be suggest due to the reduction in baking time.

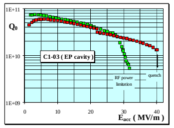
Baking ≡ Recipe for High Gradients

Whatever the Niobium Structure ... Single Crystal or Multi Grains

Whatever the Fabrication Method ... EB Welding or Hydroforming, bulk Nb or clad Nb/Cu

Whatever the Purification Thermal Treatment ... nothing, 800°C or 1300°C/Ti

Whatever the Chemical Treatment ... Electropolishing or Buffered Chemical Polishing



TTF 1.3 GHz - Saclay / KEK - SRF'03

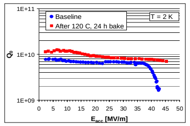
Multi grains
EB Welding - Bulk Nb
No Thermal Treatment
Electropolishing

final treatment :

« In-Situ Baking »
Ultra High Vacuum

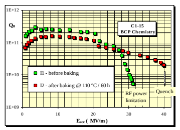
Temperature
110 – 120 °C

Time
1 – 2 days



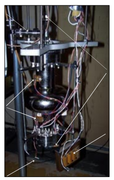
Low Loss 2.2 GHz - JLab - PAC'05

Single Crystal
EB Welding - Bulk Nb
800°C - 1250°C / Ti
Chemical Etching BCP 1:1:1

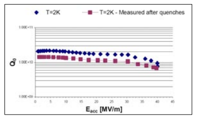


TTF 1.3 GHz - Saclay - EPAC'02

Multi grains
EB Welding - Bulk Nb
1300°C / Ti
Chemical Etching BCP 1:1:2



In-Situ Baking



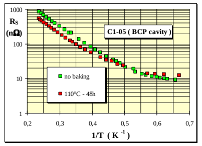
TTF 1.3 GHz - DESY / JLab - SRF'01

Multi grains
Hydroforming - Clad Nb/Cu
800 °C + baking (140 °C/30h)
Chemical Etching BCP 1:1:1

Unknown Origin for the « High Field Q-Slope »

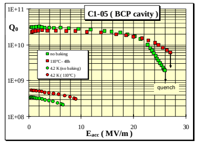
No Physical Explanation for the « Baking Effect »

High Field Q-Slope ⇔ Oxygen Diffusion



After Baking, surface resistance R_S is modified by O diffusion trough $R_{BCS}(\ell)$

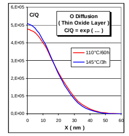
$$R_S = R_{res} + A(\lambda_L, \xi_F, \ell)\frac{\omega^2}{T}e^{-\Delta/kT}$$



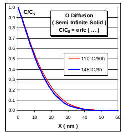
Hypothesis: O diffusion is involved too in the High Field Q-Slope improvement

Oxygen Diffusion Parameters (T , t)

2nd Fick's law $\frac{\partial C}{\partial t} = D_0 e^{E_A/RT}\frac{\partial^2 C}{\partial x^2}$ → analytic solutions



110 °C / 60 hours ↔ 145 °C / 3 hours



« Fast Baking » & High Field Q-Slope ?

thin oxide layer : C(x,0) = Q δ(x)

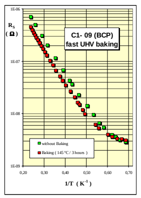
$$C(x,t) = \frac{Q}{\sqrt{\pi D t}}e^{-x^2/4Dt}$$

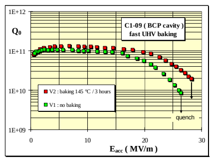
semi infinite solid : C(0,t) = C_S

$$C(x,t)/C_S = erfc\frac{x}{2\sqrt{D(T)t}}$$

« Fast UHV - Baking »

- Cavity under Ultra High Vacuum
- Infra-Red emitters (2kW) : short T rise time (few mn)





145 °C - 3 hours → Q-slope improvement

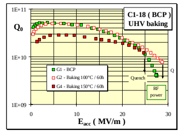
Right Hypothesis about O diffusion

Fast Baking at Room Atmosphere

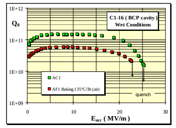
Oven - Wet Cavity after HPR

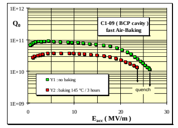
145°C / 3h Bad Results (R_S, quench)
Active interaction between atmosphere and Nb surface

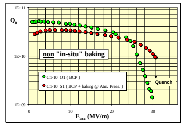
IR heater - Dry Cavity
Clean Room hygrometry 60%



Similar degradations with standard in-situ baking (UHV / 60h) @ 150 °C







Improvement @ 110 °C / 60h

O concentration in excess provided from surface (wet atmosphere)

Fast Air-Baking @ 145°C : 3 h too long

XPS analysis on Nb Samples :

- to confirm this hypothesis
- to find the right Baking Time

Consequence : Optimization of the Baking Process

ILC — *Cavity Mass Production* — XFEL

International **L**inear **C**ollider

linear accelerators e⁻ e⁺

30 km - 500 GeV → 1 TeV

niobium cavities : 20 000 – E_{acc} : 35 MV/m

X-ray **F**ree **E**lectron **L**aser

linear accelerator e⁻ (2.1 km - 20 GeV)

SASE X-rays (λ: 0.1 → 6.4 nm - 100 fs)

niobium cavities : 936 – E_{acc} : 23.5 MV/m

Standard Preparation

- Heat Treatment 800°C (H) / 1300°C+Ti (O-K_T)
- Ultrasonic Cleaning (TFD4 - 50 °C)
- Chemical Etching (BCP) – FNP (1:1:2) / Electropolishing (EP)
- Ultra pure Water Rinse
- High Pressure Rinse - 85 bars (FE)
- Air-Drying : RT - 3 hours
- Assembly + Helium Test
- Optional RF Test
- « In-Situ » Baking : 110°C - 2 days
- Final RF Test

Clean Room (Class 100)

Test Stand (Vertical Cryostat)

Modified Process

- Heat Treatment 800°C (H) / 1300°C+Ti (O-K_T)
- Ultrasonic Cleaning (TFD4 - 50 °C)
- Chemical Etching (BCP) – FNP (1:1:2) / Electropolishing (EP)
- Ultra pure Water Rinse
- High Pressure Rinse - 85 bars (FE)
- Hot Air-Drying : 145°C - 3 hours
- Assembly + Helium Test
- RF Test

Hot Air - Drying

Advantages

- Save time : 3 hours instead 2 days
- Save step : combine drying and baking
- Avoid risk of leaks : baking before assembly

Fast Air-Baking on Wet cavity under Laminar Flow (FE)

OK — t < 3hours — turbulences