Superconducting Cavities

Preparation & Testing – Draft for BCD

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- Description of Cavity Preparation
  - Basic steps
- BCD proposal for Cavity Preparation Process

General Requirements - Overview

- The preparation of the cavities should finally result in fully assembled cavities (incl. power coupler to) which are ready for string assembly.
- After delivery from the welder, several things are to be done:
  - a Mechanical checks, inspection
  - b Frequency tuning
  - c Cleaning
  - d Damage layer removal
  - e Furnace treatments
  - f Final frequency tuning
  - g Final surface preparation
  - h Final cleaning
  - i Bake-out at 120-130°C
  - j Low-power acceptance test
  - k Tank-welding
  - l Assembly for high power operation
  - m High-power test
- Although all these steps need improvements in QA/QC for a mass production, the most challenging one is to define final (electro-)chemical surface preparation to deliver a reliable and reproducible performance.
- The overall workflow needs optimization.

4. a) Mechanical checks, optical inspection

- Options under consideration
  - Mechanical measurements (Eccentricity, etc.), Optical inspection (EB welds etc.)
  - Integration of mechanical measurements (Eccentricity, etc.), optical inspection (EB welds etc.) into the cleanroom area
- BCD choice
  - Mechanical measurements (Eccentricity, etc.), Optical inspection (EB welds etc.)
- Pros & Cons of BCD (technical, cost, reliability/risk)
- Pros
- Concept exists.
- Cons
- Potential cost impact
- R&D necessary (at different levels)
  - Is a roughness measurement of the inner cavity surface needed? If so: At which steps in the preparation process?
  - Mass production issues.

4. a) Mechanical checks, optical inspection

- ACDs choices prioritized
  - Priority 1 ACD
    - Integration of mechanical measurements (Eccentricity, etc.), optical inspection (EB welds etc.) into the cleanroom area
  - Pros
    - Reduction of contaminations of inner cavity surface
  - Cons
  - Technical advantages, increased tech potential
  - Potential cost impacts
    - Enlargement of cleanroom facility
- Risk and Reliability impacts
- R&D necessary (at different levels)
- Time scales for R&D

4. b) +f) Frequency tuning

- Principle clear.
- *R&D necessary (at different levels)*
  - Mass production issues need to be solved.
  - Integration into clean room seems desirable (see above).

4. c) Cleaning

- Principle clear.
  - Ultrasound cleaning of components
  - Resistivity rinse with ultra-pure water
  - ionized nitrogen blowing of components (e.g. screws).
- *R&D necessary (at different levels)*
  – Mass production issues need to be solved.
  – Is an outside etching of the full cavity required (etching cups before welding might be sufficient) ?
  – Is hot ultra-pure water rinsing desirable?
  – Improved quality control at all levels seems desirable.

4. d) Damage layer removal (100-150 um)

- *Options under consideration*
  1. Electropolishing (EP)
  2. Tumbling / Barrel polishing + small (electro-)chemistry
  3. Etching (BCP)
- ***BCD choice***
  - Electropolishing
- *Pros & Cons of BCD (technical, cost, reliability/risk)*
- *Pros*
  - Only preparation method that has proven gradients of more than 35 MV/m.
- *Cons*
  - Potential of hydrogen contamination of the niobium material.
  - Slower material removal rate than BCP. Up to now process seems to be more manpower intensive than BCP or tumbling (more sophisticated assembly to setup). Safety issues related to strong acids.
- *Potential cost impact*
- *Potential Mods to BCD with impact (tech, cost, difficulty/time scale).*
  - Change of acid mixture to avoid hydrogen contamination.
  - Is recycling of the acid possible (and cost saving)?.
- *R&D necessary (at different levels)*
  - Reproducibility of the process needs improvement.
  - Mass production issues.
  - Fundamental R&D: Is the smoothness the important parameter for good performance ?
    - If not: Is a long EP (100 um) needed for damage layer removal?
    - If yes: What is the best way to avoid hydrogen contamination?

4 d) Damage layer removal (100-150 um)

- ***ACDs choices prioritized***
  - <u>Priority 1 ACD</u>
    - Tumbling / Barrel polishing + small (electro-)chemistry
    - *Pros*
      - Simple process. Less evironmental impact.
    - *Cons*
      - Proven for high gradients only for single-cells.
    - *Technical advantages, increased tech potential*
    - *Potential cost impacts*
      - Cost reduction compared to EP seems likely.
    - *Risk and Reliability impacts*
    - *R&D necessary (at different levels)*
      - Removal of abrasive material: BCP or EP?
      - Multi-cell issues need to be solved.
    - *Time scales for R&D*

4 d) Damage layer removal (100-150 um)

– <u>Priority 2 ACD</u>
- BCP
- *Pros*
  – Simpler than EP.
- *Cons*
  – High gradient performance not shown on multi-cells.
  – Long EP might be needed to gurantee performance.
- *Technical advantages, increased tech potential*
- *Potential cost impacts*
  – Cost reduction compared to EP seems likely.
- *Risk and Reliability impacts*
- *R&D necessary (at different levels)*
  – Does surface roughness play a role in the final cavity performance?
- *Time scales for R&D*

4 e) Furnace treatment

- *Options under consideration*
  1. 800°C
  2. 1400 °C
  3. No furnace
- ***BCD choice***
  – 800°C
  – *Pros & Cons of BCD (technical, cost, reliability/risk)*
  – *Pros*
    - 35 MV/m cavity performance has been demonstrated.
    - Stress annealing of the material.
  – *Cons*
    - Cavity results are not yet as reproducible as desired.
  – *Potential cost impact*
    - Should be evaluated
  – *Potential Mods to BCD with impact (tech, cost, difficulity/time scale).*
  – *R&D necessary (at different levels)*

4 e) Furnace treatment

- ***ACDs choices prioritized***
- Priority 1 ACD
  - 1400° C
  - *Pros*
    - Higher thermal conductivity of niobium material might improve reproducibility.
  - *Cons*
    - Cavities become mechanically soft.
    - More difficult handling (assembly and cryo operation).
    - More sophisticated furnaces needed.
  - *Technical advantages, increased tech potential*
  - *Potential cost impacts*
    - More sophisticated (expansive) furnaces needed. Process is longer.
  - *Risk and Reliability impacts*
  - *R&D necessary (at different levels)*
  - *Time scales for R&D*
- No Priority ACD
  - No furnace treatment.
  - *Pros*
  - *Cons*
    - Increased risk of hydrogen contamination.
  - *R&D necessary (at different levels)*
    - Is the cost saving worth the risk?

4 g) Final surface preparation (20-30um)

- *Options under consideration*
  - Electropolishing (EP)
- ***BCD choice***
  - Electropolishing
- *Pros & Cons of BCD (technical, cost, reliability/risk)*
- *Pros*
  - Only preparation method that has proven gradients of more than 35 MV/m.
- *Cons*
  - Potential of hydrogen contamination of the niobium material.
- *Potential cost impact*
- *Potential Mods to BCD with impact (tech, cost, difficulity/time scale).*
  - Change of acid mixture to avoid hydrogen contamination.
- *R&D necessary (at different levels)*
  - Reproducibility of the process needs improvement.
  - Mass production issues.
  - Fundamental R&D: What is the best way to avoid hydrogen contamination?

4 h) Final cleaning

- *Options under consideration*
  - High pressure rinsing with ultra-pure water.
  - Dry-ice cleaning
  - Megasonic rinsing
- ***BCD choice***
  - High pressure rinsing with ultra-pure water.
  - *Pros & Cons of BCD (technical, cost, reliability/risk)*
  - *Pros*
    - Only preparation method that has proven gradients of more than 35 MV/m.
  - *Cons*
    - Reproducibility for multi-cell cavities needs improvement.
  - *Potential cost impact*
  - *Potential Mods to BCD with impact (tech, cost, difficulity/time scale).*
  - *R&D necessary (at different levels)*
    - Reproducibility of the process needs improvement: Which pressure? Which volume flow? Measurement of the surface forces needed.
    - Online monitoring of cleaning process desirable.
    - Is HPR with coupler feasible?
    - Mass production issues.
    - Fundamental research to avoid field emission

4 h) Final cleaning

- ***ACDs choices prioritized***
- <u>Priority 1 ACD</u>
  - Dry-ice cleaning
  - *Pros*
    - Could be applied in horizontal position with power coupler assembled
  - *Cons*
    - More sophisticated setup. Very preliminary results available
  - *Technical advantages, increased tech potential*
  - *Potential cost impacts*
  - *Risk and Reliability impacts*
  - *R&D necessary (at different levels)*
    - Multi-cell issues need to be solved.
  - *Time scales for R&D*

4 h) Final cleaning

- ***ACDs choices prioritized***
- <u>Priority 1 ACD</u>
  - Megasonic rinsing
  - *Pros*
    - Simple process, could be used in addition to HPR
  - *Cons*
  - *Technical advantages, increased tech potential*
  - *Potential cost impacts*
  - *Risk and Reliability impacts*
  - *R&D necessary (at different levels)*
    - Multi-cell issues need to be solved.
  - *Time scales for R&D*

4 i) Bake-out at 120 - 130°C

- *Options under consideration*
  - ‘In-situ’ bakeout of the evacuated cavity
  - Air bakeout as part of drying process
- ***BCD choice***
  - ‘In-situ’ bakeout of the evacuated cavity
  - *Pros & Cons of BCD (technical, cost, reliability/risk)*
  - *Pros*
    - Process has shown up to 40 MV/m in multi-cell cavities.
  - *Cons*
  - *Potential cost impact*
  - *Potential Mods to BCD with impact (tech, cost, difficulity/time scale).*
  - *R&D necessary (at different levels)*
    - Optimum bakeout parameters (time, temperature etc.) needs investigation.
    - Basic understanding of the effect is needed.
    - Mass production issues.

4 i) Bake-out at 120 - 130°C

- ***ACDs choices prioritized***
- Priority 1 ACD
  - Air bakeout as part of drying process
  - *Pros*
    - Could significantly simplify process.
    - Less risk of leaks.
  - *Cons*
    - Not proven yet.
  - *Technical advantages, increased tech potential*
  - *Potential cost impacts*
  - *Risk and Reliability impacts*
  - *R&D necessary (at different levels)*
    - Single-cell R&D necessary. Multi-cell issues need work.
  - *Time scales for R&D*