Alternatives to Baseline

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What Alternatives?

- Cavity Shape (talk by Rongli)
  - Low Loss (LL)
  - Re-entrant
  - Low Surface Field (LSF, LINAC 2008, paper THP038)
- Material
  - Large Grain
- Processing
  - BCP
  - ALD (Atomic Layer Deposition)

    too early, but obviously interesting with some potential

Material(1)

- It is generally accepted that the performance of cavities made from large grain niobium is comparable to those made from poly-crystalline material – at least as far as single cell cavities are concerned. This is true for both BCP and EP surface treatments.
- Several 9-cell cavities – especially those fabricated for DESY – have shown encouraging results after BCP and EP
- Whereas at Jlab and recently also at KEK high gradients in single cells have been achieved with bcp only, those results could not be reproduced at DESY, where a significant degradation of high performance, electropolished cavities has been observed.
- At DESY, gradients as high as Eacc~ 38 MV/m have been measured in a 9-cell cavity after EP

Material (2)

- Reproducibility test with single cell cavities (5 each), made from large grain material of 4 different manufacturers (CBMM, W.C.Heraeus, Ningxia and Tokyo Denkai) are underway at Jlab
- Initial test series with the Ningxia and W.C.Heraeus cavities showed some promising results (e.g. SRF 2007, paper TH102) even though a narrowing of the spread in performance is desirable
- A large grain 9-cell cavity from Ningxia niobium is being fabricated at PKU, two LL 9-cell cavities from TD and CBMM niobium are in fabrication at Jlab and DESY has received(?) six additonal 9-cell cavities from ACCEL made from W.C.Heraeus niobium

Material(3)

- The potential advantages of large grain niobium have been pointed out in the past:
  - Sheets directly cut from ingot show less vulnerability to introduction of defects, eliminating need for eddy current scanning
  - Performance of cavities comparable to poly-crystalline Nb
  - Smooth surface can be achieved with bcp only, resulting in “streamlining” of procedures
  - Material most likely less expensive because many processing steps for sheet forming (forging, rolling annealing, cutting..) are eliminated
  - Important : an inexpensive cutting method of sheets from ingot is essential
  - This has recently been developed by K.Saito with Japanese Industry: 59 sheets (not a limitation) have been simultaneously cut from an ingot with good tolerances and surface finish in 45 hrs, reducing the cutting time/sheet below 1 hr; for comparison: a single cut takes app. 20 hrs at Jlab with some remaining surface roughness

Material (4)

Large grain niobium might have some additional beneficial features:

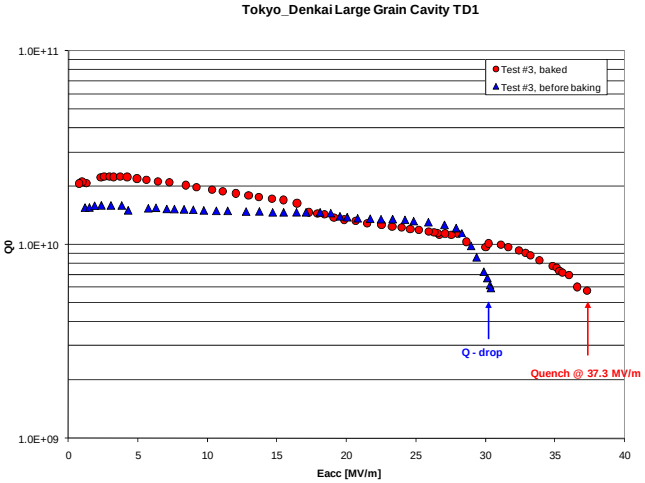
- Less grain boundaries (a 9-cell cavity from large grain niobium has ~ 7 m of grain boundaries, for poly-crystalline niobium the grain boundary length is ~ 1000 m
- Grain boundaries can be “weak links” because of preferential impurity segregation; they can also be pinning centers for vortices; both effects are not desirable
- The defect density from manufacturing might be lower because of a simplified sheet manufacturing process
- 12 hrs of “in situ” baking after bcp surface treatment seems to be sufficient to remove the “Q-drop”
- The appearance of “cat-eyes”, which are presently identified in many cases as being responsible for quenches, might be reduced, if they are caused by missing grains (small) in the heat effected zone – this is very speculative and not sufficient internal inspections have been done large grain material. However, the few inspections done at Jlab did not show cat-eyes

Material (5): Manufacturing

- It was recently reported at the TTC meeting (H.Weise) that ACCEL encountered big manufacturing problems with the latest batch of large grain cavities. The reason reportedly was a different grain orientations in the sheets (W.C. Heraeus can not guarantee a specified grain orientation when melting an ingot), which did not lent itself to proper forming
- However, as personally confirmed in a phone call with an ACCEL representative, the problems could be solved by changing the tooling
- At Jlab we have fabricated at least 50 single cell and probably 8 multi-cell cavities from a total of 10 different ingots/sheets supplied by 4 different niobium suppliers

Material (6): Manufacturing

- Only in one case did we ran into forming problems, because the material was very hard. By annealing the discs at 600C for several hours we could solve this problem
- Also- in contrast to DESY – Jlab is not insisting on material with a large center grain. Actually, most material used for cavity fabrication at Jlab has no center grain. This is not a show stopper – see below the Tokyo Denkai cavity as an example



Material (7): Manufacturing/Procedure

- Based on Jlab's experience over the past years, we want to apply the following steps to the manufacturing and testing of our next cavities (two 7-cell LL cavities for the Jlab FEL and two 9-cell Ichiro/LL cavities):
  - Deep drawing of half cells
  - Cleaning ,bcp ~ 30 micron
  - Stress relieving at 600C for 10 hrs
  - Re-stamping
  - Trimming for EBW with a butt weld joint
  - Bcp 10 micron , welding of dumbbells
  - Mechanical grinding to remove blemishes and grain boundary steps
  - 10 micron bcp for welding of equators
  - Bulk bcp ~ 60 micron
  - Hydrogen degassing at 600C, 10 hrs
  - Tuning
  - Final bcp , ~ 50 micron, HPR, drying

Material (7): Costs

This is difficult and various cost estimates have floated around in the past. But it seems obvious that the material has to be cheaper because of the elimination of the whole sheet forming process. The big break through came with the development of the multi-wire cutting process (K.Saito), which basically reduces the cutting costs to a small percentage of the material costs. Tokyo Denkai apparently is acquiring such a machine in the near future and will be able to supply sheets from ingots.

K.Saito presented a paper at the Japanese Linac conference with contributors from Tokyo Denkai about ingot slicing (paperTP 082); his conclusion was a reduction of the waste niobium from 45% to 15% and because of a simplified production process the costs will be half of the present costs.

Material (8): Costs

- Further cost savings could obviously be realized by “streamlined” procedures:
  - No sheet inspection necessary (for the first three 9-cell cavities fabricated for DESY only the material for one was eddy current scanned)
  - Possibly BCP instead of EP : this would reduce the costs significantly because of a less “involved” process; no need for e.g. alkohol rinsing or flash bcp or flash ep
  - Shorter baking times for “in situ” baking (unless baking in argon will replace the 48 hrs presently used.
  - Generally, a significant amount of “man hrs” would be saved, maybe as much as 30 -50 % .

Processing

This is an open question and as discussed above the experiences in different labs are different.

- For a project such as the X-FEL BCP might be sufficient at the more modest/reasonable requirements
- If the Ichiro/LL cavity shape would get a “fair” evaluation (35 MV/m), bcp might also be feasible here.
- There is obviously not sufficient information available especially on multi-cell cavities
- One can get such information only, if possible cost advantages are taken seriously and the present cavity program for the ILC is modified including some efforts to evaluate the combination of Ichiro/large grain/BCP