Current Status of Centrifugal Barrel Polishing(Tumbling) at Fermilab

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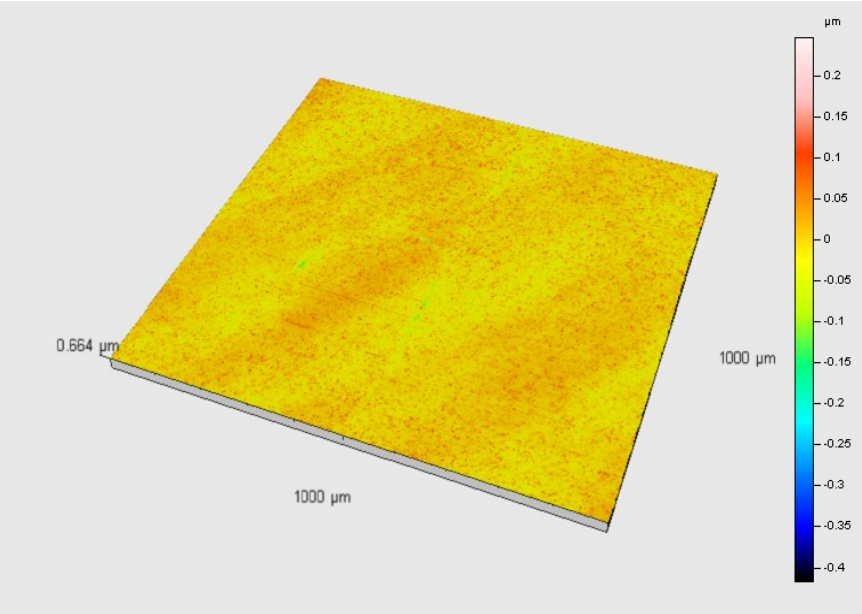
Objectives

- Objective: Polish cavities to mirror-smooth finish
  - This could increase Q and Eacc
- Finding: Mirror-smooth finish is not yet optimum
  - Smearing necessitates10-40 μm EP to improve results, even though finish is degraded by EP
  - This result is related to the transition between intermediate and fine polishing regimes
- Evaluate requirements for acid use
  - Can this be zero?
    - Results suggest that the acid requirement may be linked to polishing stage

Why seek a Mirror Finish?

- Both 4-step tumbling and EP processing can produce > 40 MV/m* for TESLA shape
  - *TE1ACC004 reported at TTC meeting, Fermilab, Aug. 2010
  - 4-step tumbling is smoother than EP with less acid use
  - Surface roughness ≤ 0.1 μm appears to be sufficient.
- Nanometer roughness (mirror) adds benefits
  - *Minimize or eliminate acid use*. Residues removed by chemistry scales with polishing stage.
  - *Process alternate shapes*. Re-entrant cavities, operate with higher electric field – 0.1 μm then may not be sufficient.
    - World-record Cornell re-entrant cavity was mechanically polished.
  - *Deposition of thin films*. Mirror finish could enable the deposition of thin films.

Results- Mirror Like Surface after 5th step



Single Cell Polished to Mirror Finish

Ra = 0.0139 µm +/- 0.00216 µm
Rz = 0.139 µm +/- 0.0242 µm

Typical finish achieved by fine polishing.

Notice reflection of graph paper and writing

Current Media

Step 1

Cutting, Time as needed

+ Soap & Ultrapure Water

Removal: 11 μm/hr

Step 2

Intermediate Polishing, 12 hours

+ Soap & Ultrapure Water

3 μm/hr

Step 3

Intermediate Polishing, 15 hours

Water + 400 Mesh Alumina

Step 4

Intermediate Polishing, 20 hours

Water + 800 Mesh Alumina

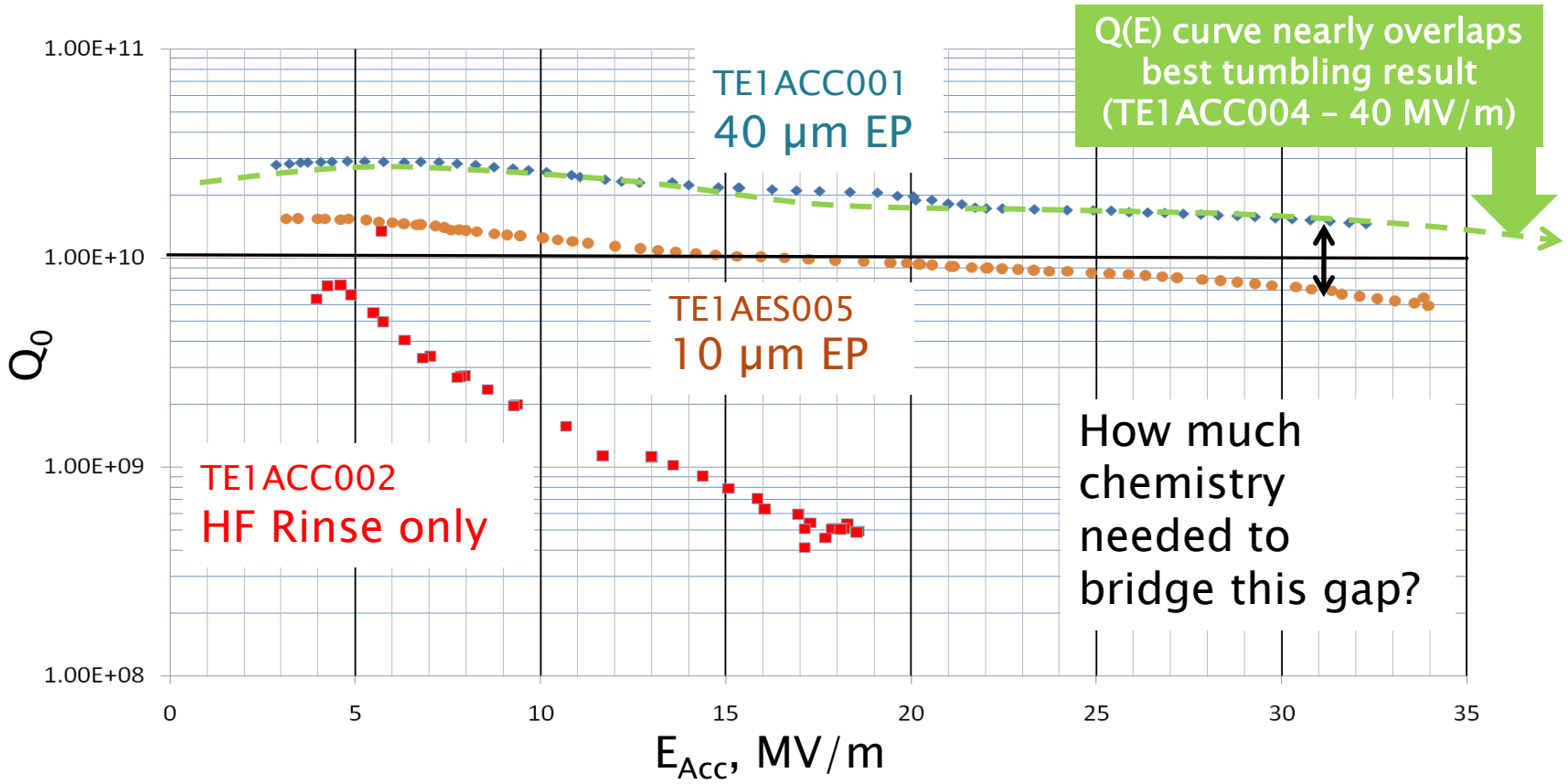
Step 5

Final Polishing, 40 hours

Colloidal Silica

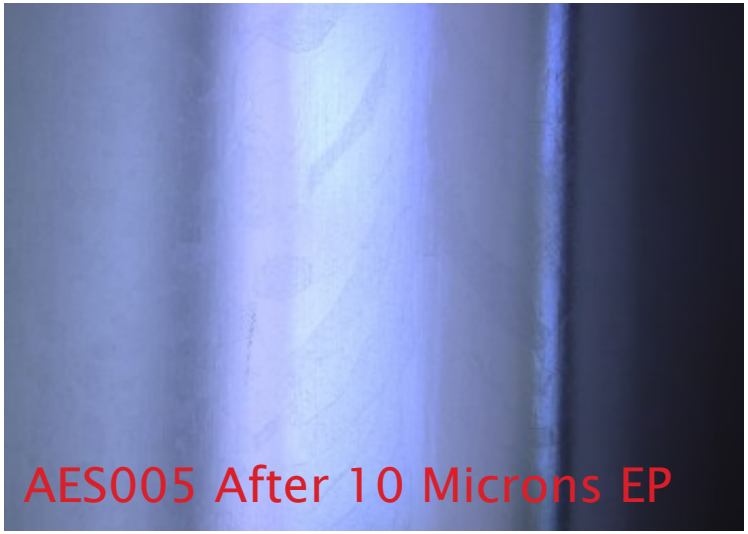
Polishing time is being optimized. Present values based on optical inspection.

Mirror-smooth cavities so far require post-tumbling acid to improve performance



All cavities:
Mirror finish + 800 C bake + HPR + 120 C bake
before the indicated final EP was applied

Cavity appearance degrades after acid



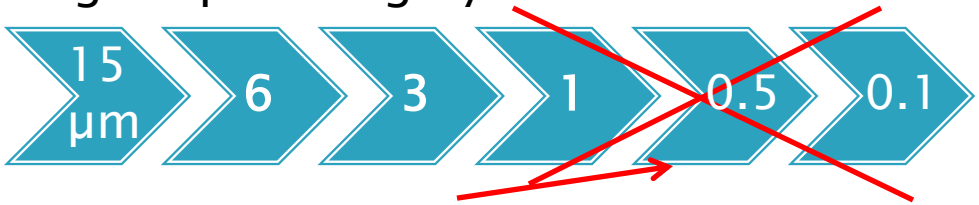
Pictures taken of cavity equator weld beads on Kyoto Camera System at Fermilab. Scale is roughly 12 mm by 9 mm.

Transition from intermediate to fine polishing is key.

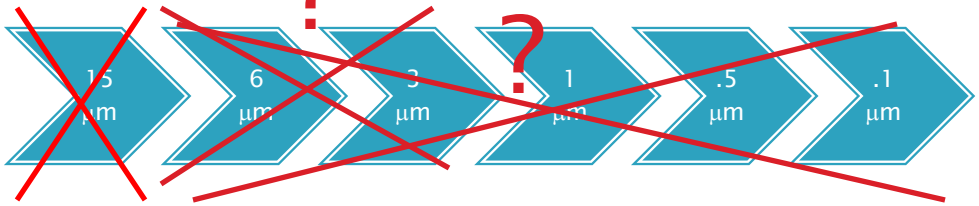
Step 4 (15 μm)
Intermediate Polishing, 20 hours

Water + 800 Mesh Alumina

Samuels' textbook: Intermediate stage is polishing by micro-machining. Fine stage is polishing by delamination.



Metallography polishing in this range is not successful for flat niobium samples because regions smear or are pulled out (large-scale delamination)



Tumbling niobium with the hardwood blocks and 1200 grit (10 μm) media pulled grains out.

Step 5 (.04 μm)
Final Polishing, 40 hours

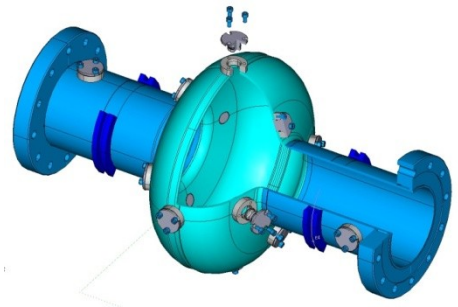
Colloidal Silica

Methods to Reduce Amount of Post-Tumbling Chemistry Needed

- Problem: Avoid smear and pull-out.
- Pull-out tendency is a function of particle size, shape, and force against cavity surface.
- Ideas for solution:
  - Increase the amount of tumbling time for step 5.
  - Try particle shapes that favor machining over laminating at particle sizes below 15 μm.
  - Try other carriers with different density & aspect ratio to change force on the cavity surface.
  - Adjust rotation speed to change force.
  - Modify pH to favor micro-machining below 15 μm.

Summary & Future Work

- Present focus is on improving the transition between steps 4 and 5
  - More light EP will be done to the current cavities to evaluate acid needs for current process.
  - Increasing the length of the final tumbling step will be examined (easiest from R&D standpoint).
  - Coupon cavities will accelerate understanding on effects of tumbling
    - New media, different applied force, different pH



- 4-step process followed by final EP can give high gradients with less acid use
  - Final EP of 40 μm is matched well to final grit size

Acknowledgments

- LD Cooley – Presentation
- J. Ozeliz – Testing
- D. Burk & G. Steuer – Tumbling
- D. Bice, B. Stone, J. Folkie – Processing
- E. Toropov – Imaging
- T. Higuchi & K. Saito