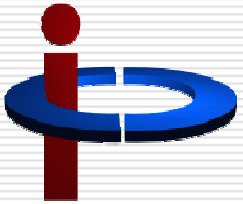

The Cockcroft Institute
Centre for Accelerator Science and Technology

LANCASTER UNIVERSITY

Proposed Investigation of High-Gradient RF Cavity Limitations

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Background

Neutrino Factory

- Novel demands on RF system
  - Low frequency, high gradient accelerating cavities
  - Operating in high magnetic field

MICE

- Current design has 8 201 MHz copper cavities
  (R.Rimmer, 2002)
- Accelerating gradient >15MV/m

Background

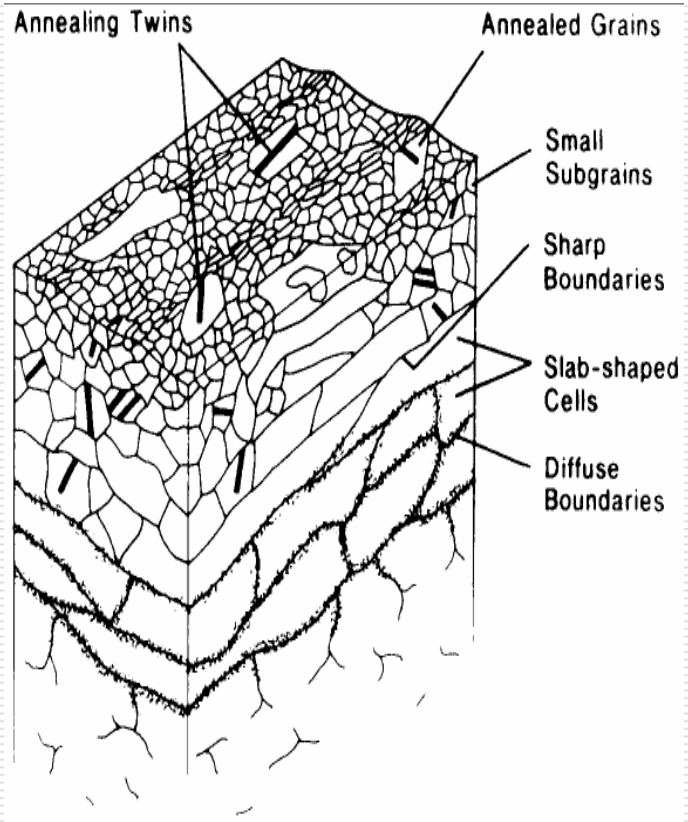
However

- Production techniques offer poor reproducibility (Laurent, 2002)
- Surface features are one of main limiting factors (Hassanein, 2006)
- Field emission not an issue when average surface roughness, $R_A < 2\ \mu m$ (Saito, 2003)
- Current Electropolishing techniques offer $R_A < 1\ \mu m$
- 'Black Art'
- Achievable gradients are poor and reproducibly low
- Surface Impurities or Defects are dominant cause of limitations in accelerating gradient ?

Background

A typical surface after mechanical polishing of OHFC copper

- Up to 1500 Angstrom
  - Small subgrains with evidence of recrystalisation (annealing twins) due to plastic stain and/or local temperature increases
- Lower
  - Slab shaped cells with sharp boundaries
- Deeper still
  - More defuse boundaries
- Virgin Copper



(after Turley and Samuels, 1957)

Background

- Damaged surface needs to be removed
  - Minimise contamination of surface
- Study showed foreign inclusions of Al, Ca, Mg
  - Even after several rinses with de-ionised water (Turley & Samuels, 1981)
- Electropolishing (EP) will be main technique investigated to remove this layer

Aim

- To investigate effects of construction processes on
  - surface characteristics
  - surface impurities

  With respect to RF performance

- Concentrating on
  - EP process, including electrolyte composition
  - Cleaning regime

- To seek answers to dominant surface characteristics and contamination elements

Proposal

- Using OHFC copper test buttons
  - Two stages with repeated steps

- Stage 1
  - Mechanically polish with finer grades of silicon carbide paper
  - Ultra Sonic Bath
  - Rinse with de-ionised water (high pressure wash)
  - Light chemical etch with phosphoric acid
  - High Pressure wash

Proposal

- Stage 2
  - Electropolish stage 1 samples with a bench-top EP setup
  - Investigate different electrolyte solutions
  - Rinse with high pressure de-ionised water
  - Examinations with Atomic Force Microscopy X-Ray Photospectroscopy& Auger Spectrometer
  - Test of RF performance in 805 MHz cavity
  - Re-examine surface with AFM, XPM & AS

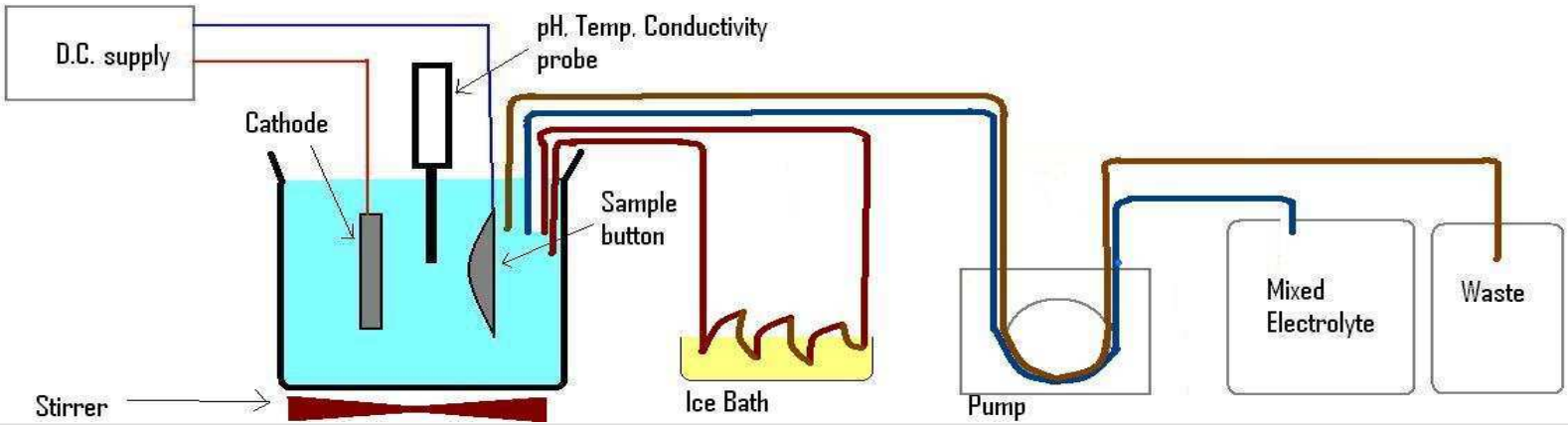
Leading to

- A systematic study to determine the effects of EP and cleaning regime on mechanically polished copper and develop 'best practice'.

Current Interest and Agreements

- From Imperial College to supply test buttons
- From Fermilab to perform RF tests
- From ---------- for use of AFM, XPS & AS

Suggested Bench-top EP setup



Electrolyte carefully mixed and circulated to keep cool

Simulating closely existing techniques at JLab

Test button to be raised and lowered

Measurements of

pH, conductivity, temp of electrolyte, surface resistance on test button, current density

Waste pumped out

Proposed cleaning regime

From EP bath

- Initial rinse with de-ionised water
- High pressure wash in sealed container (minimise operator contact)

Sealed in foil bag and pumped with nitrogen for transport to Fermilab for RF testing

Equipment required

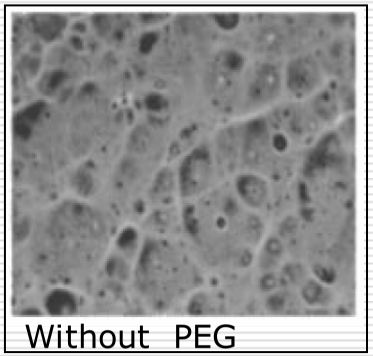
- Monitoring
  - pH, Temp, Conductivity meter £ 650
  - Current, Volt meter £ 165
- Power Source £140
- Agitation
  - Magnetic stirrer £ 85
  - Moveable stand £ 30
- Cleaning
  - Pressure washer £ 75
  - De-ionised water system £160
  - Sealed vessel £ 20
  - Ultra sonic bath £ 100
- Storage
  - Nitrogen £ 10
  - Foil bags and sealer £ 50
- Polishing
  - Pump Head £ 104
  - Pump Drive £ 330
  - Pump Tubing £ 60
  - 3 litre vessel £ 20
  - Clamps, stands £ 150
  - Waste storage £ 50
- Chemicals ~ £ 1000
- Safety equipment
  - Lab coats £ 60
  - Gloves £ 15
  - Goggles £ 10

Total approx **£3100**

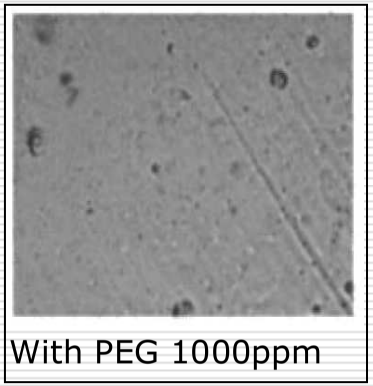
Use of technical equipment £ ??

Electrolyte Composition

- Important to understand influence of 'ingredients' in
  - Overall EP effect
  - Surface contamination
- Jefferson Lab use
  - 85% Phosphoric acid, 15 % Butanol
  - Oxygen formation and pitting
  - Use of Polyethylene Glycol (PEG) to reduce oxygen formation
- Use of Citric acid used to increase surface planarization by 35%
  - An important characteristic description of surface to compliment average roughness



Without PEG



With PEG 1000ppm

(Shih-Chieh Chang et al, 2003)

Expected Difficulties

- Replication of full scale JLab EP process in a Bench top study
- Mimic rotation of 201 MHz cavity by timed raising and lowering of test sample into electrolyte
- Determining sample areas for AFM and AS
- Made difficult by button shape

Conclusions

- Current poor reproducibility of high accelerating gradient, low frequency cavities needs fuller attention
  - Especially for demanding requirements of Neutrino Factory and MICE
- Proposed study investigating effects of Electropolishing during MICE cavity production with aim to suggest improvements in process
- Propose a full cavity EP process to address bench top findings

References

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