Sources of Quench Producing Defects
Low and High Fields

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Jefferson Lab
International Linear Collider (ILC)
16000 cavities, each 1 square-meter surface area
Operation temperature 2 Kelvin
Electropolished 9-cell cavities
JLab/DESY (combined 4th and 5th generation) successful test of cavities from established vendors

Yield

ILC goal

Gradient

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<tr>
<td>&gt;10</td>
<td>95 ± 2</td>
<td>94 ± 3</td>
<td>93 ± 4</td>
<td>92 ± 5</td>
<td>91 ± 6</td>
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<tr>
<td>&gt;15</td>
<td>90 ± 3</td>
<td>89 ± 4</td>
<td>88 ± 5</td>
<td>87 ± 6</td>
<td>86 ± 7</td>
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<tr>
<td>&gt;20</td>
<td>85 ± 5</td>
<td>84 ± 6</td>
<td>83 ± 7</td>
<td>82 ± 8</td>
<td>81 ± 9</td>
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<tr>
<td>&gt;25</td>
<td>80 ± 6</td>
<td>79 ± 7</td>
<td>78 ± 8</td>
<td>77 ± 9</td>
<td>76 ± 10</td>
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<td>&gt;30</td>
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<td>74 ± 8</td>
<td>73 ± 9</td>
<td>72 ± 10</td>
<td>71 ± 11</td>
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<tr>
<td>&gt;35</td>
<td>70 ± 8</td>
<td>69 ± 9</td>
<td>68 ± 10</td>
<td>67 ± 11</td>
<td>66 ± 12</td>
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<tr>
<td>&gt;40</td>
<td>65 ± 9</td>
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<td>63 ± 11</td>
<td>62 ± 12</td>
<td>61 ± 13</td>
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Gradient Scatter (up to 2nd-pass proc.)

16 9-cell cavities (10 built by ACCEL/RI and 6 by AES) processed and tested at JLab since July 2008.

Each of the 3 failed cavities is limited by one defect in one cell.

Hpk 75-90 mT

Hpk 160-180 mT
Two Types of Quench (Defect)

• Type-I
  – Hpk 75-90 mT
  – Defect from fabrication
    • Near or in EBW joint
    • Geometric defects
    • Sum-mm in size
      – Observable with “high-resolution” optical inspection machine
  • Little effect by repeated surface processing
  • Mechanical (local or global) polishing effective
Two Types of Quench

• Type-II
  – $H_{pk} > 1100$ Oe
  – Nature of defect not well understood
    • Still near EBW weld (high magnetic field region)
    • Size unknown
      – Not observable with “high-resolution” optical inspection machine
    • Re-EP is found often times effective
      – Raise limit to $> H_{pk} 1500$ Oe
Fine grain EP
twin defects causing quench 17 MV/m. Cavity by a new vendor
Fine grain EP defect causing quench 19 MV/m.

Cavity by experience vendor
Fine grain EP defect causing Quench 20 MV/m.

Cavity by then new vendor
Fine grain EP defect causing Quench 15 MV/m.
Cavity by then new vendor
Large grain BCP
Fine grain BCP (IA15, cavity built for CEBAF project in the 80’s)
Type I Defect

- Sub-mm sized geometrical defect at or near EBW joint
  - Independent of manufacturer
    - Experienced or new
  - Independent of surface processing
    - BCP or EP
  - Independent of material
    - Fine-grain or large-grain
Sources of Type I Defect

• Fabrication (Electron Beam Welding)
  – Surface defects
    • Optical inspection
    • Mechanical polishing
  – Under-surface defects
    • Pocket/porosity
    • Ultrasonic/X-ray inspection
    • Re-melting

• Material?
• Quench is primarily a magnetic field effect
  – High magnetic field region (arrow) in cavity is critical

Elliptical cavity (TM-class)  
Half-wave cavity (TEM-class)
Facility for Rare Isotope Beams (FRIB)
Four cavity types, total 350 cavities
operation temperature 2 Kelvin
Sources of Type II Defect

• Nature is not clear
  – Size is probably sub-micron
  – Probably has to do with surface composition irregularity
  – Probably has to do with processing
  – Probably has to do with material inhomogeneity
  – ...

R.L. Geng, 7/25/2011
Observation

• Type I defect is an issue of common interest
  – for $\beta=1$ elliptical cavities (ILC)
  – for $\beta<1$ elliptical cavities (Px, ESS)
  – for $\beta<1$ cavities HWR, QWR cavities (FRIB)
• Quench study in elliptical cavities (for ILC)
  improved understanding of type I defect
• Quench study in $\beta<1$ QWR, HWR, spoke?
• Fabrication improvement is needed
  – Fabrication is and will be done in industry
  – Feedback between lab and industry
Observation (continued)

• Type II defect is a unique challenge for very high gradient application such as ILC
• Deeper understanding requires high-resolution localization of quench location and microscopic surface material studies of the quench site
• Understanding is necessary toward the ultimate gradient determined by the RF critical field
Additional Slides
Achieved Peak Surface Electric Field in L-band SRF Niobium Cavities
(Circle: Single-Cell Cavity; Triangle: Multi-Cell Cavity)

- CEBAF 4 GeV
- CEBAF 12 GeV
- XFEL
- ILC 500 GeV
- ILC 1 TeV
- Cornell LR1-3
- KEK ICHIRO7
- Best QWR, HWR

FRIB QWR, HWR

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Seamless cell BCP