Properties of Thin Polyurethane Coatings of Wire Bonds after Irradiation

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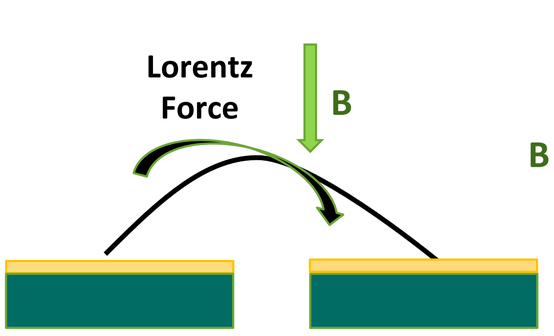
Objective

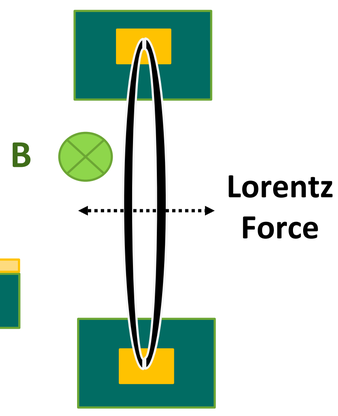
Qualify sprayed Cellpak D9201 polyurethane coatings for suppressing wire bond oscillations ($I_{P\text{-}P}$~100 mA, B=2T) at doses anticipated for the ATLAS Inner Tracker (ITk) at the High Luminosity LHC (HL-LHC).

Periodic Lorentz Force: Intermittent Current in a B Field

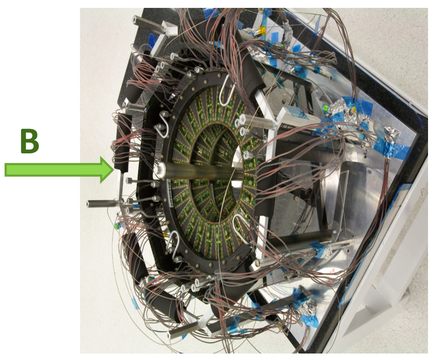
Most Vulnerable Wire Bond Geometry

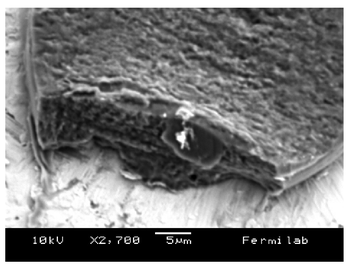
End Cap/Disk in Solenoidal Field





ATLAS Pixel Disk



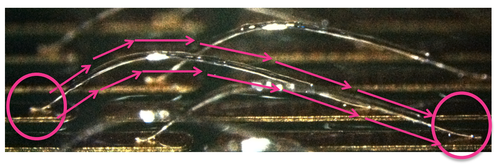


From G. Bolla et al., *Wire-bond failures induced by resonant vibrations in the CDF silicon detector, Nucl. Instr. and Methods* A518, 277 (2004).

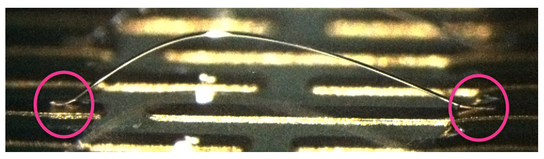
SEM pictures of a wire-bond heel broken by fatigue stress induced by resonant vibrations

Lorentz Force can break wire bonds

Protection mechanisms: Coating vs Potting



Entire Wire Bond Coated

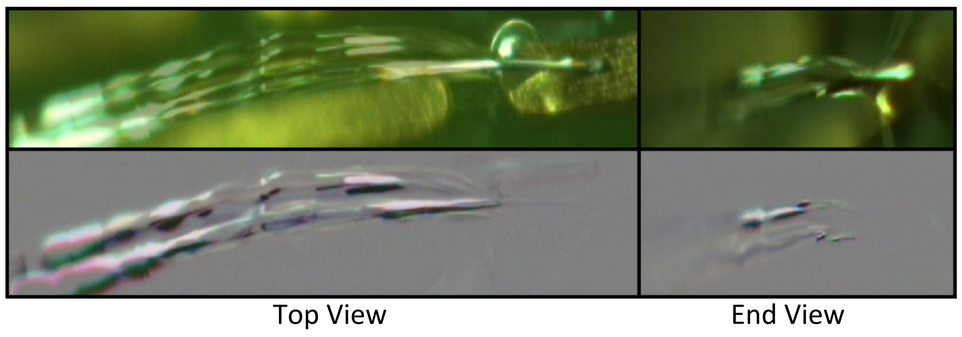


Wire Bond Heel Potted

- Immobilized wire bond heel
- Resonance amplitude ~ F_0/m
- Resonance amplitude ~ Q

- Immobilized wire bond heel

Coating increases oscillator mass and reduces oscillator Q value



Top View End View

Video frames of coated wire bond summed (top) and subtracted (bottom) to show regions of movement (light and dark) and motionless regions (gray).

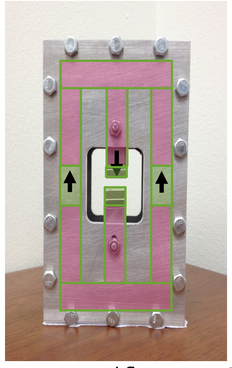
Destructive Tests of Protected Bond Wires

Al wire bonds: 2.8 mm long, 25μ OD B =1.7 T Room temperature
Coating and potting material: Cellpak D9201 Pre-irradiation

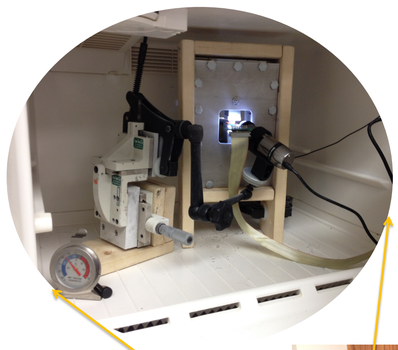
Sample	f_{res} [kHz] mean, (range)	Q mean, (range)	$I_{p\text{-}p}$ [mA] to break at f_{res}
Uncoated N_{wires}=17	11.78 (11.68 -11.97)	92 (69 - 117)	4 one wire tested
Coated 55μ – 60μ OD N_{wires} = 15	9.28 (8.88 - 9.76)	36 (26 - 46)	32 - 40 one wire
Coated 100μ – 110μ OD N_{wires}= 8	(8.1 - 14.1)	(7 - 14)	f_{res} = 10.4 kHz: breaks @ 180 mA p-p f_{res} = 13.3 kHz: 38.5 hours @ 180 mA p-p

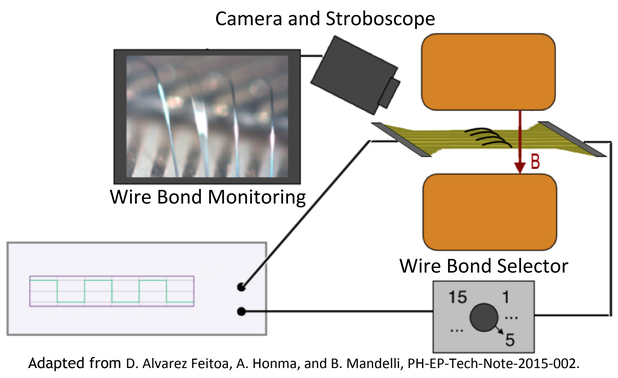
Sample	f_{res} [kHz] mean, (range)	Q mean, (range)	$I_{p\text{-}p}$ [mA] to break
Potted N_{wires}= 8	14.95 (13.80 - 16.17)	68 (60 - 77)	12 - 15 one wire

Measurement of Lorentz Force-Induced Vibrations at -20C



Neodymium magnets and flux return, B=1.0 T





Adapted from D. Alvarez Feitoa, A. Honma, and B. Mandelli, PH-EP-Tech-Note-2015-002.

Temperature Dependence

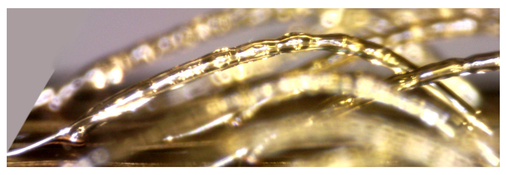
Bond length [mm]	N wires	Mean OD [μ]	Room temp avg. values Res. Freq. [kHz]	Q	Cold (-20C) avg. values Res. Freq. [kHz]	Q	% change (cold/warm) Res. Freq. [kHz]	Q
2.8	9	57 thin	9.9	59	10.3	86	+4%	+47%
2.8	13	73 med	11.0	30	12.3	42	+12%	+40%
2.8	13	112 thick	14.8	18	17.2	27	+16%	+52%
4.0	9	44 thin	7.6	66	8.0	87	+6%	+32%
4.0	11	82 med	9.9	19	11.4	32	+15%	+67%

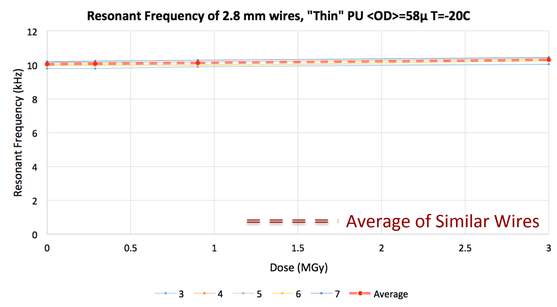
>100μ OD coatings at -20C protect ITk end cap equivalent: B=2T, $I_{p\text{-}p}$<100 mA

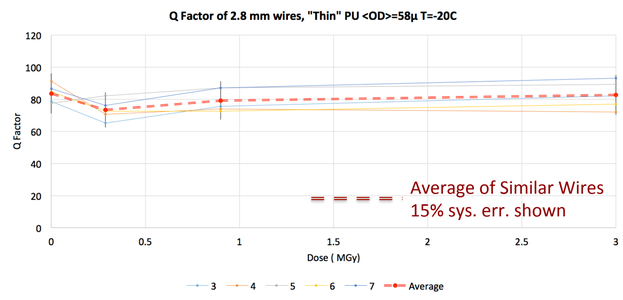
Irradiation to 3 MGy

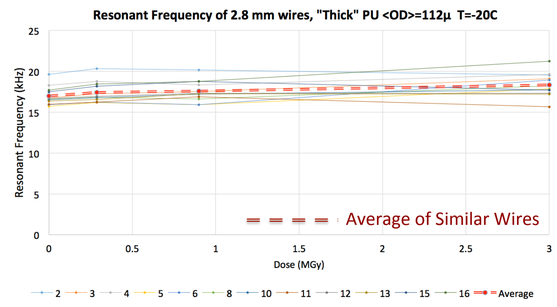
Co^{60} Irradiation at Sandia Nat. Lab Gamma Irradiation Facility.

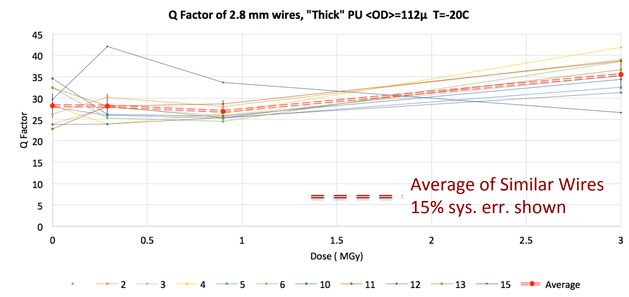
Yellowing of irradiated organic polymers is typical.











Q and f_{res} of coated wires stable to at least 3 MGy

Conclusions and Future Work

Cellpack D9201 coatings demonstrated to protect 2.8 mm, 25μ OD Al wire bonds at HL-LHC lifetime (3000 fb^{-1}) radiation dose anticipated for ITk Pixel end cap and ITk Strip barrel and end cap.
Irradiation continuing to ITk Pixel barrel dose and beyond to failure.

Acknowledgements

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