Preliminary analysis of Red TCT measurements on LGAD's produced at CNM-Barcelona Focus on Gain and uniformity

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Join us for the 22nd RD50 Workshop at the University of New Mexico, Albuquerque, New Mexico, USA

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Chaired by Michael Moll, (CERN) and Sally Seidel (University of New Mexico)

Abstract deadline extended to: May 13, 2013



Wafer 9, f9, g9 [PiN diode]

	Wafer Number	P-layer Implant (E = 100 keV)	Substrate features
	1	1.0 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	2	1.1 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	3	1.2 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	4	1.3 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	5	1.4 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
Low doping	6	1.5 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	7	1.6 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
High doping	8	2.0 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
No doping	9	(PIN wafer)	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	10	1.1 × 1013 cm-2	HRP OXG (DOFZ; ρ = 5-15 KΩ·cm; <100>; T = 285±25 μm)
	11	1.3 × 1013 cm-2	HRP OXG (DOFZ; ρ = 5-15 KΩ·cm; <100>; T = 285±25 μm)



Wafer 9, f9 (PiN) [no amplification built-in]

CCE [a.u.]

-50

-100

-150

25 ns



Vbias%50==0 && Vbias>-1000



-200 -250 -300 -1000 -800 -600 -400 -200 Vbias [V] Sum\$((volt-BlineMean)*(time>9.701493 &&time<34.701493)):Vbias {Vbias>-980.000000} CCE [a.u.] -50 25 ns Bottom TCT, 50% intensity -100 -150 -200 -250 -300 -350 -800 -600 -400 -200 -1000Vbias [V]

Top TCT, 100% intensity



Sum\$((volt-BlineMean)*(time>10.519151 &&time<35.519151));Vbias {Vbias>-980.000000}

0



Wafer 6, g11, h11 [1.5×10¹³cm⁻²]

	Wafer Number	P-layer Implant (E = 100 keV)	Substrate features
Low doping	1	1.0 × 1013 cm-2	HRP 300 (FZ; p>10 KΩ·cm; <100>; T = 300±10 μm)
	2	1.1 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	3	1.2 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	4	1.3 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	5	1.4 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	6	1.5 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	7	1.6 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	8	2.0 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	9	(PIN wafer)	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	10	1.1 × 1013 cm-2	HRP OXG (DOFZ; ρ = 5-15 KΩ·cm; <100>; T = 285±25 μm)
	11	1.3 × 1013 cm-2	HRP OXG (DOFZ; ρ = 5-15 KΩ·cm; <100>; T = 285±25 μm)



Wafer 6, h11 [1.5×10¹³cm⁻²]



Vbias%50==0 && Vbias>-950



Sum\$((volt-BlineMean)*(time>10.835782 &&time<35.835782)):Vbias {Vbias>-950.000000}



Sum\$((volt-BlineMean)*(time>11.029765 &&time<36.029765)):Vbias {Vbias>-950.000000}



Amplification observed

Ad-hoc simulation (qualitative interpretation of data):



Input: P-bulk, Cend=10 pF, Vdep=50 V Gain(950V)=2.8 Gain(200)=2





Electrons injected from the back → travelling to n+ strips. Multiplication occurs, then equivalent to holes "injected" from top.

Gain definition

For instance, **in back injection:** Reference diode: we inject 50 pC, we **read** 50 pC DUT: we (assumed) injected 50 pC, we **read** 150 pC



I will assume gain=multiplication factor+1

Wafer 6, h11 [1.5×10¹³cm⁻²], gain





Wafer 6, h11 top illumination Low multiplication factor

Wafer 6, h11, bottom illumination Higher multiplication factor



Interpretation for lower gain seen in top injection: Maybe eh pairs generated inside P+ region do not see all the E-field \rightarrow produce less ionizations.

Estimation of gain without reference diode at V>>V dep







Uniformity scan, rear side illumination, w6 h11 tune 34



Outliers are likely misalignment of the laser grid wrt the sensor window

Uniformity scan, junction side, w6 h11 tune 34





Possible misalignment.

In any case, compared to former slide, we can say that the junction side is less uniform than the ohmic side.

To be studied: effect of 2x400 nm layers of passivation (SiO₂/Si₃N₄)



Wafer 7, f11, k9 [1.6×10¹³cm⁻²]

	Wafer Number	P-layer Implant (E = 100 keV)	Substrate features
Slightly higher doping	1	1.0 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	2	1.1 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	3	1.2 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	4	1.3 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	5	1.4 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	6	1.5 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	7	1.6 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	8	2.0 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	9	(PIN wafer)	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
	10	1.1 × 1013 cm-2	HRP OXG (DOFZ; ρ = 5-15 KΩ·cm; <100>; T = 285±25 μm)
	11	1.3 × 1013 cm-2	HRP OXG (DOFZ; ρ = 5-15 KΩ·cm; <100>; T = 285±25 μm)



Wafer 7, k9 [1.6×10¹³cm⁻²], same tune (34)



Vbias>-450 && Vbias%20==0





Top illumination, breaks at -450V, before the bump due to h overcomes the e peak Multiplication observed

Wafer 7, k9 [1.6×10¹³cm⁻²], gain



Gain calculated comparing diode to reference PIN diode, measured at the same power



Wafer 7, K9, top illumination

Wafer 7, K9, bottom illumination

>×3 mult. factor for Vbias>100 V ×4 at Vbias~400V

Summary

- First look at the red-TCT data on LGAPDs
- PiN diode taken as reference to calculate the gain
- Wafer 6, lower doping: MF: ~1.5 (top), ~2.5 (bottom) Uniformity: 30% (top), ~2% (bottom)
- Wafer 7: slightly higher doping MF: ~3.5 (top and bottom) Uniformity no data yet
- Wafer 8: results need to be understood (see backup)

Wafer 8 ?



Wafer 8, k4, k8 [2×10¹³cm⁻²]

Wafer Number	P-layer Implant (E = 100 keV)	Substrate features
1	1.0 × 1013 cm-2	HRP 300 (FZ; p>10 KΩ·cm; <100>; T = 300±10 μm)
2	1.1 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
3	1.2 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
4	1.3 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
5	1.4 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
6	1.5 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
7	1.6 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
8	2.0 × 1013 cm-2	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
9	(PIN wafer)	HRP 300 (FZ; ρ>10 KΩ·cm; <100>; T = 300±10 μm)
10	1.1 × 1013 cm-2	HRP OXG (DOFZ; ρ = 5-15 KΩ·cm; <100>; T = 285±25 μm)
11	1.3 × 1013 cm-2	HRP OXG (DOFZ; ρ = 5-15 KΩ·cm; <100>; T = 285±25 μm)



Wafer 8, k8 [2×10¹³cm⁻²]

Vbias%50==0 && Vbias>-1000



Breaks at -250V



Sum\$((volt-BlineMean)*(time>4.859497 &&time<54.859497)):Vbias {Vbias>-980.000000}





0 Vbias [V]

Sum\$((volt-BlineMean)*(time>9.585904 &&time<59.585904)):Vbias {Vbias>-980.000000}

Wafer 8, k8 [2×10¹³cm⁻²]



Sum\$((volt-BlineMean)*(time>9.553926 &&time<59.553926)):Vbias {Vbias>-980.000000}



Sum\$((volt-BlineMean)*(time>5.025387 &&time<55.025387)):Vbias {Vbias>-980.000000}





0 V

- -50 V --100 V

-150 V -200 V -250 V

> -300 V -350 V -400 V -450 V

-500 V -550 V -600 V

-650 V

-700 V -750 V

-800 V -850 V

-900 V -950 V

