

Comparison of the performance of irradiated n-in-p planar pixel sensors of different active thickness

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n-in-p pixels for the ATLAS upgrade

Pixel Layout



Work in progress!

4 layers of pixels at larger radius than now → Outer layer at r~ 20-25 cm 7-10 m² of pixel area Need for cost-effective modules!

n-in-p pixels represent an optimal solution in the outer layers



First n-in-p pixel production at CiS

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First CiS n-in-p pixel production

Common PPS ATLAS -CMS pixel production within RD50





- FZ p-type material, 300 μm thick
- Inter-pixel isolation:
 - moderated p-spray
 - homogenous p-spray
- Bump bonding to the FE-I3 chips (present ATLAS pixel read-out) performed by IZM-Berlin

 BCB layer deposited on the sensor front side as an isolation to prevent sparks between sensor and chip



CiS module characterization before irradiation





Charge collection summary of neutron irradiated CiS n-in-p modules, ⁹⁰Sr scan

Updated with the 10¹⁶ n_{eq} / cm² results!



Results of the irradiated modules up to 5e15 summarized in a new paper

C. Gallrapp et al., "Performance of novel silicon n-in-p planar Pixel Sensors ", arXiv:1112.5395



N-in-p FE-I3 @ 10¹⁶ n_{eq}/cm²



N-in-p FE-I3 @ 10¹⁶ n_{eq}/cm²

Charge collection with 90 Sr, V_{bias}=600V, Threshold=2000 e Hit Map Row 400 150 30000 Vbias 600V 300 100 MPV 4.4 ke⁻ 20000 200 50 10000 100 10 20 15 10 Charge in ke Column Charge/Threshold>2 Noise occupancy at 600V The conditions for a good tracking 10⁻⁷ with 1% masked channels efficiency are fulfilled \rightarrow to be demonstrated with the DESY/CERN 10⁻⁶ with 0.5% masked channels beam test analysis.

 $\Delta p \cdot \Delta q \ge \frac{1}{2} \hbar$



Test-beam results

■ 5x10¹⁵ n_{eq}/cm²





MPI-HLL n-in-p 150 um thin pixel sensors interconnected to FE-I4 chips

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Thin pixel technology at MPP-HLL



In-in-p 6" wafers with ATLAS FE-I3 compatible sensors

- $\hfill 75~\mu m$ thick sensors interconnected to FE-I3 chips with SLID at EMFT
- n-in-p 6" wafers with ATLAS FE-I4 sensors (pitch 50 um x250 um)
- \square IBL compatible GR \rightarrow 450 μm dead edge
- Interconnected to FE-I4 chips with bump-bonding at IZM



MPP-HLL SOI2 production: FE-I4 150 μ m thick





- 6 SCM FE-I4 with IBL guard-rings
- 2 SCM FE-I4 with full guard-rings
- 7 DCM FE-I4 with IBL guard-rings
 - 11 SCM modules available
- 1 irradiated at 2x10¹⁵ n_{eq/} cm² at KIT with 26 MeV p.
- 3 irradiated at 4x10¹⁵ n_{eq/} cm² in Los Alamos with 800 MeV protons



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MPP-HLL SOI2 production: ⁹⁰Sr scan before and after irradiation

⁹⁰Sr Scan with Threshold=1000 e, V_{bias}=90V



4-bit resolution ToT, MPV compatible with the value expected with a thickness of 150 um (12 ke)



Comparison of CC for n-in-p pixels of different thickness





 Φ = 4-5x10¹⁵ n_{eq}/ cm²





New productions of n-in-p pixels at CiS



New production of n-in-p FE-I4 sensors at CiS – 4"

RD50 common project

 Production on 4" FZ p-type wafers of 200 and 300 um thickness (150 um thick wafers broke during production).

Processing completed two weeks ago

 Interconnection with bump-bonding foreseen to be performed at IZM-Berlin

Distance between two FE-I4 DCM diced as a quad module





 2 neighboring 2-chip sensors can be used as 4-chip sensors



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Preliminary measurements and yield (200 μ m thickness)

- Measurements carried out at CiS wafers just arrived at MPP
- Yield following IBL prescriptions on 200 um thick wafers:

Double FE-I4 sensors I(VdepI+30V)<2 uA = 97% Single FE-I4 sensors I(VdepI+30V)<1 uA = 95%

 3 different guard-ring versions implemented for the FE-I4 Single Chip Modules



T5 FE-I4 SCM, Full GR

10 GR, 450 um inactive width



DCM, 450 um inactive width



11 GR, 450 um inactive width





Production of n-in-p FE-I4 sensors at CiS – 4"

Different devices will allow to test new features as:

Pixel biasing through poly-silicon resistors.

•FE-I4 SCM with a new GR that has shown a better performance on diodes.

 Omegapix sensors (chip designed by LAL) with a reduced r-phi pitch of 35 μm.



OmegaPix sensor





Proposal for a new production of n-in-p diodes and pixels at CiS as common RD50 project

Proponents: M. Bruzzi, A. Macchiolo



- CiS will upgrade in 2012 its production line from 4" to 6" wafers, with the possibility to start a test production on 6" wafers in second half of 2012.
- Plan for a first production of 25 wafers on high resistivity FZ p-type material
- FE-I4 compatible sensors to be interconnected with bump-bonding at IZM and with SLID at EMFT.
- Test inactive edges down to 250 um (now 450 um) and pixel pitch of 25 um x
 250 um (foreseen for the inner layers of upgraded ATLAS pixel detectors).







n-in-p diodes with multi-guard rings (active side 2.5 mm or 5.0 mm)

• Characterization of trap parameters of main radiation induced defects with spectroscopic methods as DLTS, TSC, HRPITS (High Resolution Photo Induced Spectroscopy), EPR (Electron Paramagnetic resonance), FTIR (Fourier Transform InfraRed), PL (PhotoLuminescence).

 Understanding of their charge state under operation as well as on electric field profile with TCT (Transient Current Technique), Edge TCT, Photoconductivity decay.

•Cross-correlation of results got with different techniques and cross-links with simulation to get a detailed knowledge on radiation hardness of n-on-p devices and understanding of charge multiplication effects.





- Excellent performance of n-in-p modules demonstrated up to $10^{16} n_{eq}$ /cm² with lab and beam tests!

Future Plans

- CIS FE-I3 modules (300 µm thick):
 - Irradiation in LUB and characterization up to 2x10¹⁶ n_{eq} cm⁻²
- FE-I4 modules (HLL 150 μm thick, CiS 200 μm thick):
 - Bump-bonding interconnection at IZM-Berlin of the new CiS production with FE-I4A chips
 - Irradiation at Los Alamos up to 2x10¹⁶

 Launch a first production run on the new 6" line at CiS with FE-I4 sensors to be interconnected with SLID and bump-bonding.