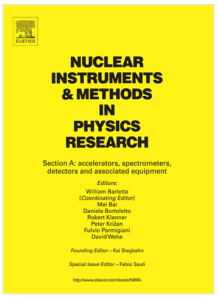
Accepted Manuscript



A process modification for CMOS monolithic active pixel sensors for enhanced depletion, timing performance and radiation tolerance

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PII: S0168-9002(17)30791-X
DOI: http://dx.doi.org/10.1016/j.nima.2017.07.046
Reference: NIMA 59995

To appear in: *Nuclear Inst. and Methods in Physics Research, A*

Received date : 10 March 2017
Revised date : 26 June 2017
Accepted date : 21 July 2017

Please cite this article as: W. Snoeys, G. Aglieri Rinella, H. Hillemanns, T. Kugathasan, M. Mager, L. Musa, P. Riedler, F. Reidt, J. Van Hoorne, A. Fenigstein, T. Leitner, A process modification for CMOS monolithic active pixel sensors for enhanced depletion, timing performance and radiation tolerance, *Nuclear Inst. and Methods in Physics Research, A* (2017), http://dx.doi.org/10.1016/j.nima.2017.07.046

A process modification for CMOS Monolithic Active Pixel Sensors for enhanced depletion, timing performance and radiation tolerance

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Abstract

For the upgrade of its Inner Tracking System, the ALICE experiment plans to install a new tracker fully constructed with monolithic active pixel sensors implemented in a standard 180 nm CMOS imaging sensor process, with a deep pwell allowing full CMOS within the pixel. Reverse substrate bias increases the tolerance to non-ionizing energy loss (NIEL) well beyond 10^{13} 1MeV n_{eq}/cm^2, but does not allow full depletion of the sensitive layer and hence full charge collection by drift, mandatory for more extreme radiation tolerance. This paper describes a process modification to fully deplete the epitaxial layer even with a small charge collection electrode. It uses a low dose blanket deep high energy n-type implant in the pixel array and does not require significant circuit or layout changes so that the same design can be fabricated both in the standard and modified process. When exposed to a ^{55}Fe source at a reverse substrate bias of -6 V, pixels implemented in the standard and the modified process in a low and high dose variant for the deep n-type implant respectively yield a signal of about 115 mV, 110 mV and 90 mV at the output of a follower circuit. Signal rise times heavily affected by the speed of this circuit are 27.8 +/- 5 ns, 23.2 +/- 4.2 ns, and 22.2 +/- 3.7 ns rms, respectively. In a different setup, the single pixel signal from a ^{90}Sr source only degrades by less than 20 % for the modified process after a 10^{15} 1MeV n_{eq}/cm^2 irradiation, while the signal rise time only degrades by about 16 +/- 2 ns to 19 +/- 2.8 ns rms. From sensors implemented in the standard process no useful signal could be extracted after the same exposure. These first results indicate the process modification maintains low sensor capacitance, improves timing performance and increases NIEL tolerance by at least an order of magnitude.

1 The standard process for the ALPIDE sensor in the ITS upgrade

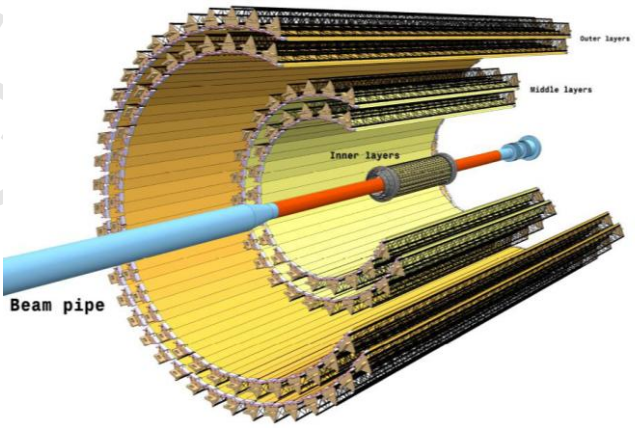

Figure 1 Layout of the new ALICE ITS with 3 inner, 2 middle and 2 outer layers spanning a range in radius of 22 to 400 mm[1].