11th International "Hiroshima" Symposium on the Development and Application of Semiconductor Tracking Detectors (HSTD11) in conjunction with 2nd Workshop on SOI Pixel Detectors (SOIPIX2017) at OIST, Okinawa, Japan

Contribution ID: **141** Type: **ORAL**

New 50µm thin LGAD for Tracking and Timing Applications

Thursday 14 December 2017 10:00 (20 minutes)

Low Gain Avalanche Detectors (LGAD), are customised Avalanche Photodiodes (APD) to obtain a high electric field region confined close to the reversed junction. As a consequence, only the electrons generated when an incident particle passes through the detector start the impact ionization. Thus multiply the charge collected by readout electronics without increasing the noise in the signal. Due to this increase of the signal-to-noise ratio the timing resolution of these detectors is reduced to less than 50ps [1]-[3]. LGAD detectors are based on the conventional power PiN diode fabricated in a very high resistivity P-type substrate (5-10 k), mandatory to work in a high radiation environment. Then, a deep P-type diffusion is formed at same place where the shallow N+ diffusion is implanted. Finally, the back side P+ diffusion is implanted to guarantee a good electrical contact with the Aluminium electrode. In this way, the n+-p-p- junction is reversed biased during normal operation of the detector with the extremely low doped substrate fully depleted. Incident particles create a certain density of electron-hole pairs in the depleted region and, as a consequence of the electric field, are accelerated towards the corresponding electrode. Electrons flowing towards the positive biased N+ diffusion generate new electron-hole pairs at the multiplication region with high electric field, thus enhancing the collected charge. The key point of the LGAD core cell design is the precise control of the implantation dose and energy of the multiplication P-type diffusion and also the fine tuning of the total thermal budget to get the desired profile. However, the design of the edge termination and the peripheral region of the detector are also crucial to get the desired breakdown voltage (typically in excess of 1000 V for 300µm thick detector) and to minimize the leakage current coming from the periphery that may mask the readout electronics. Deep p-type diffusions are commonly implemented to avoid surface current as a consequence of the creation of an inversion N-type layer due to the extremely low doping of the substrate.
LGAD devices have been successfully fabricated on 300 micron thick substrates and extensively characterized, before and after irradiation. However, the radiation hardness of these devices is not as good as it should be for timing applications due to the degradation of the gain and creation of traps in the bulk [4]. A way to reduce the bulk radiation effects (creation of traps in the bulk) of LGAD detectors is to reduce the substrate thickness as much as possible. Two approaches have been contemplated: the use of SOI substrates with an active silicon layer of 50 microns and the use of Silicon to Silicon bonding substrates with an active silicon layer of 50 microns. As a consequence, the distance covered by the generated electrons and holes is significantly reduced and the number of electrons trapped due to radiation bulk defects is also reduced.
Therefore, the new family of thin detectors, named High Granularity Timing Detectors (HGTD) is suitable for timing applications with time resolution less than 30 ps at -20C.
The measurement comparisons of HGTD on different substrates will be presented and discussed.
The decrease of the detector active thickness reduces the trapping but doesn't avoid the degradation of gain due to acceptor removal. As it was observed by Khan Gallium doped wafers showed a drastic reduction of the acceptor removal [5]. Therefore Gallium LGADs has been produced to reduce the gain degradation on LGADs. The first batch has been produced on 300 µm thick high resistivity p-type substrates and 50 µm thin detectors with Gallium multiplication layer are ongoing. The performance and radiation damage of Gallium LGADs will be discussed in the present work.

REFERENCES
[1] H.F.-W. Sadrozinski et al. "Ultra-Fast Silicon Detectors,"Nuclear Instruments and Methods in Physics Research A, 831 (2016) 18-23.
[2] J. Lange et al "Gain and time resolution of 45µm thin Low Gain Avalanche Detectors before and after irradiation up to a fluence of 1015 neq/cm2,"," Journal of Instrumentation, 12, P05003, 2017
[3] N. Cartaglia et al "Beam test results of a 16ps timing system based on ultra-fast silicon detectors,"Nuclear Instruments and Methods in Physics Research A, 850 (2017) 83-88.
[4] G. Kramberger et al. "Radiation Effects in Low Gain Avalanche Detectors after Hadron Irradiations," Journal of Instrumentation, 10, PO7006, 2015.
[5] A. Khan et al., "Role of the impurities in production rates of radiation-induced defects in silicon materials and solar cells", Journal of Applied Physics, 90 , 1170, (2001)

Authors: CARULLA ARESTE, Maria del Mar (Instituto de Microelectronica de Barcelona IMB-CNM); FLORES GUAL, David (Instituto de Fisica Corpuscular (ES)); PELLEGRINI, Giulio (Centro Nacional de Microelectrónica (IMB-CNM-CSIC) (ES)); Dr HIDALGO VILLENA, Salvador (Instituto de Microelectronica de Barcelona (IMB-CNM-CSIC)); QUIRION, David (IMB-CNM, CSIC); MERLOS DOMINGO, Angel (Instituto de Microelectronica de Barcelona-CNM-CSIC)

Presenter: CARULLA ARESTE, Maria del Mar (Instituto de Microelectronica de Barcelona IMB-CNM)

Session Classification: Session11

Track Classification: New ideas and future applications