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Effect of Carbon co-implantation on radiation hardness of LGAD

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The Low Gain Avalanche Detectors (LGAD) are silicon sensors with a state-of-the-art timing performance specifically tailored for the High Granularity Timing Detector (HGTD) programme in the ATLAS detector to answer the unprecedentedly complex pile-up in the High-Luminosity Large Hadron Collider (HL-LHC). In virtue of thin epitaxial layer and moderate internal gain, the time resolution of IHEP-IMEv2 LGADs reaches 35 ps before irradiation. A major challenge to these sensors is to maintain time resolution at low bias after withstanding 1 MeV neutron equivalent fluence up to $2.5\times10^{15}\ n_{eq}cm^{-2}$ during their operating life in HGTD , given that high energy particles passing through the sensor deactivate gain layer acceptors (acceptor removal), leading to a deterioration of time performance.
IHEP-IMEv2 LGADs are designed aiming at improving device radiation hardness as well as discovering the dependence of c factor values to carbon distribution in the critical region of devices. 12 designs vary in carbon implantation dose and carbon thermal load are included in this version. Carbon distributions in critical region of LGADs are analyzed in detail based on SIMS. In an effort to explain the mechanism of implanted carbon to alleviate acceptor removal induced by radiation, the acceptor removal coefficients (c factors) of LGADs are modeled based on SIMS data. The modeled values are in good agreement with measurements. This model is povital to the design of next version IHEP LGAD and will help bring to light the acceptor removal mechanism.

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