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TCAD Simulation of Complementary P- and N-type Silicon Low Gain Avalanche Detectors

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Due to internal charge multiplication, Low Gain Avalanche Detectors (LGAD) enable to produce rather thin (˜ 50 μm) silicon sensors with a relatively low operating voltage. A typical P-type LGAD consists of n+-p-p–p+ layers with p-well formed by deep diffusion of boron into p–layer. Another way of p-well formation by using an epitaxial process may lead to lower sensitivity of the breakdown voltage on n+ layer thickness (M.Carulla at al., 29th RD50 Workshop). Possible boron compensation by radiation defects would cause gain degradation in P-type LGAD structures. This effect may be reduced by using N-type (p+n-n–n+) structure with a phosphorus doped n-well epitaxial layer. In this investigation we compared complementary P-type and N-type LGAD sensors.
The static and dynamic characteristics of the silicon LGAD structures have been simulated using a drift-diffusion approach implemented in the software package Synopsys TCAD Sentaurus. The total width of the diode was 50 μm. Only a 5 μm wide central part of the diode was simulated. The equal thickness of p-well and n-well layers (3.2 μm) leads to quite different breakdown voltage of complementary diodes due to the difference of the electron and hole ionization coefficients in silicon. The breakdown voltage is about two times lower in N-type diodes at the same current level. As a result, the electric field in the n–-layer is much lower than the carrier velocity saturation field. TCT calculations show that in such a case the carrier extraction is too long and the charge collection is much lower due to the recombination via deep levels in the irradiated diode. It is necessary to reduce the n-well thickness by 70 nm in order to obtain an equal charge collection in both types of diodes.
Particle detection was emulated through photo-excitation of a 2x50 μmˆ2 excess carrier domain at the center of the active volume in a diode. Shockley-Read-Hall (SRH), Auger and recombination through two deep levels was taken into account. The detailed investigation of the carrier and the electric field distribution dynamics during transient processes has been performed.

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