Advances in the TCAD modelling of non-irradiated and irradiated Low-Gain Avalanche Diode sensors

T. Croci(1,∗), A. Morozzi(1), P. Asenov(2,1), A. Fondacci(3,1), F. Moscatelli(2,1), L. Lanteri(5), F. Siviero(5), V. Sola(6,4), M. Ferrero(4), D. Passeri(3,1)

1) Istituto Nazionale di Fisica Nucleare (INFN), Perugia, Italy.
2) Istituto di Ingegneria e Tecnologie Avanzate “G. Marconi” (IOM) CNR, Perugia, Italy.
3) Dipartimento di Ingegneria, Università di Perugia, Perugia, Italy.
4) Istituto Nazionale di Fisica Nucleare (INFN), Torino, Italy.
5) Dipartimento di Fisica, Università di Torino, Torino, Italy.

Motivations

✓ Developing radiation-resistant silicon detectors for particle tracking in the next generation of high-energy physics experiments (e.g., HL-LHC or FCC) able to efficiently operate in extreme radiation environments, $\Phi \sim 1 \times 10^{12}$ n$_e$/cm$^2$ [1].
✓ The Low-Gain Avalanche Diode (LGAD) technology (see figure on the right) helps to mitigate the radiation damage effects by exploiting the controlled charge multiplication mechanism [2].
✓ To evaluate the impact of several design strategies and the radiation damage effects on the LGAD sensors electrical behavior:
  o high or advanced Technology CAD (TCAD) modelling before and after irradiation;
  o massive test campaign on specifically designed structures, both non-irradiated and irradiated ones.

Validation of the development framework (in this work, based on the Hamamatsu technology - HPK)
Sensor design and optimization before the large volume production.

Measurements

Pre-irradiation

Post-irradiation

Extraction of the Gain Layer doping profile

DUT & Setup

HC2S Split1 (S1) & Split2 (S2)

Current-Voltage (I-V) setup

Capacitance-Voltage (C-V) setup

TCT Setup

Beta Setup

Gain2 > Gain1

Gain2 > Gain1

S1 vs S2

S1 vs S2

if $\Phi \rightarrow \uparrow$ Gain (Gain2 $\geq$ Gain1)

if $\Phi \rightarrow \uparrow$ Gain (Gain2 $\geq$ Gain1)

Pre-irradiation

Post-irradiation

Current-Voltage @ 248 K

Gain-Voltage @ 248 K, Beta setup

Gain-Voltage @ 248 K

References


Simulations

"Perugia ModDoping"

The "Perugia Modified Doping" (PerugiaModDoping) numerical radiation damage model has been already validated by comparing the results of TCAD simulations with experimental data carried out from the measurements of sensors coming from the UFSD2 and UPS3D2 FBK productions, before and after irradiation [5].

Validation of a TCAD model for the numerical simulation of LGAD sensors.
"Perugia ModDoping" radiation damage model – physics-based approach

Traps parametrisation ("New University of Perugia" modelling scheme)

QL and bulk effective doping evolution with $\Phi$ (Tirino analytical parametrisations)

Extensive test campaign on LGAD devices from the 2nd production of the Hamamatsu technology (HPK), both non-irradiated and irradiated ones.

The behaviour of the sensors in terms of I-V and C-V characteristics, as well as their response to different stimuli (laser and beta source) under different operating conditions (i.e., T, $\Phi$ and $\rho$) have been well reproduced in simulation.

A good agreement has been already achieved with the UFSD2 and UPS3D2 FBK sensor productions [5].

General-purpose and high-predictive model within the operating region of the sensor.

Outcome

Acknowledgement

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under GA No. 101004761 and from the Italian MIUR PRIN under GA No. 2017T2XX7T3. The work is performed in collaboration with the INFN CSNS "tofu" research project.

(*) tommaso.croci@pg.infn.it