Exploring the novel nLGAD concept

Veronika Kraus\textsuperscript{1,3}, Marcos Fernández\textsuperscript{2}, Michael Moll\textsuperscript{3}, Sebastian Pape\textsuperscript{3,4}, Moritz Wiehe\textsuperscript{3}

Low Gain Avalanche Detectors

Semiconductor detectors with signal amplification: Gain layer creates strong electric field → avalanche multiplication → good Signal-to-Noise ratio and timing capabilities

The traditional LGAD

Implemented as \( n^{++} + p^{++} + p \)

Exemplary IV characteristic: temperature dependence of the breakdown voltage indicates dependence of impact ionization in the \( n^{++}\) gain layer

The novel nLGAD concept

Exchanging the conductivity type of all LGAD layers to \( p^{++} + n^{++} + n \)

Difference in multiplication mechanism for holes and electrons

Characteristics

- Of interest for high energy physics and R&D: \textbf{first ever tests in such a structure!}
- Impact ionization, donor removal ↔ acceptor removal (e.g.: relevant for compensated LGADs) and many more things to learn
  - Thickness 275 μm
  - Active area 1.3 mm x 1.3 mm
  - Resistivity > 1 kΩcm

TPA-TCT Measurements

Working principle \textbf{Two Photon Absorption - Transient Current Technique}:
- Laser (\( \lambda = 1550 \text{ nm} \)) induces generation of charge carriers
- 2 photons produce one electron-hole pair (\( E_{\text{photon}} < E_{\text{gap}} \))
- Point-like energy deposition in focal point
- 3D spatial resolution (1 μm x 1 μm x 10 μm)

TPA-TCT signal at the corresponding position of the charge profile (below) and nLGAD gain for two bias voltages (right):

\[
\text{Gain}[V] = \frac{CC_{\text{nLGAD}}[V]}{CC_{\text{PIN}}[V - V_{FD}]}
\]

TCT with UV Laser

- UV laser (\( \lambda = 375 \text{ nm} \)) at CERN-SSD TCT+ setup
- Single Photon Absorption (SPA-TCT): continuous energy deposition along beam (\( E_{\text{photon}} \geq E_{\text{gap}} \))
- Gain measurements of nLGADs with Gain (UV) > Gain (Infrared, \( \lambda = 1064 \text{ nm} \)) compared to traditional LGADs due to inverted conductivity type

Detection performance is optimized for low penetrating particles

Future plans:

- Proton (IRRAD, CERN) and neutron (JSI, Ljubljana) irradiation
- Study donor removal (↔ acceptor removal for HEP applications)

Outlook & Acknowledgment

Thanks to the Instituto de Microelectrónica de Barcelona (IMB-CNM) for providing the samples!