WP1.4: Radiation damage studies: Defect spectroscopy studies on LGADs

Low Gain Avalanche Detectors (LGADs) operating in a high radiation environment undergo a degradation in performance that is liked with defects formed during the particle-device interaction. Those defects (like the BiOi) result in a deactivation of active boron in the gain-layer region. However, the B-deactivation in LGADs cannot fully be understood using the common defect kinetic model that assumes BiOi being the main responsible defect that induces acceptor deactivation [1]. In this context the question of additional boron-related defects formed in the highly boron doped gain layer region of a LGAD came up. To get information about those boron-related defects the applicability of defects spectroscopy methods on LGADs was examined. In this context Deep-level-transient spectroscopy (DLTS) and Transient Current Technique (TSC) measurements were performed on irradiated and non-irradiated LGADs from different foundries (FBK, CNM, HPK).

DLTS is a technique that measures capacitance transients (measurement frequency 1 MHz) at low temperatures (up to 20 K). During our studies, it could be shown, that due to a strong frequency and temperature dependence of the gain-layer capacitance (see Fig. 1) data obtained by DLTS are not completely reliable. However, TSC could successfully be used to identify radiation induced defects in LGAD devices, while the discrimination between gain-layer and high-resistivity Si-bulk defect contributions remains challenging. Fig.2 shows TSC spectra of two LGADs, irradiated at different fluencies, in comparison to a corresponding PiN-diode. Radiation induced defects in the temperature range of 20K to 120K can nicely be seen. However, it must be noted that due to the gain layer of the LGADs the detected current signals are amplified. That becomes obvious e.g. in the increase of the background leakage current, that starts for the lower irradiated LGAD (less gain damage) already at temperatures > 100K. This amplification effect, that shows a dependence on the applied reverse bias, hinders the exact determination of defect concentrations which are usually used to deviate defect introduction rates. Another effect that affects the measurements is, that internal defect induced polarization fields can be formed in the device and influence the TSC signal leading even to a sign inversion of the current. Therefore, in a next step one purpose will be to investigate highly irradiated, highly B-doped pad-diodes that mimic the gain of an LGAD. Those investigations together with simulations of TSC spectra could deliver further profound insight into the defect formation in LGADs.

Fig.1) Gain-layer capacitance values of a neutron irradiated LGAD (fluence: 1E+14 n_{eq}/cm^2) in dependency of the measurement frequency and temperature. With decreasing temperature and increasing frequency the capacitance drops.
Fig. 2) TSC spectra of two neutron irradiated LGADs with $1 \times 10^{14}$ n$_{eq}$/cm$^2$ (blue) and $1 \times 10^{15}$ n$_{eq}$/cm$^2$ (green) in comparison to a PiN-diode (black).

Publications and contributions to conferences and workshops


References