Contribution ID: **106** Type: **Talk**

Study of Irradiation-Induced Defects in PINs and LGADs by DLTS

Friday, 7 November 2025 10:10 (20 minutes)

Low Gain Avalanche Detectors (LGADs) exhibit excellent properties, including ultra-fast time resolution and a high signal-to-noise ratio. They are widely used in high-energy physics experiments for precise particle detection and time-of-flight measurements. However, irradiation introduces deep-level defects and causes detector performance degradation. Therefore, improving the radiation hardness of LGADs is essential. In this work, capacitance-transient deep-level transient spectroscopy (c-DLTS) and current-transient deep-level transient spectroscopy (i-DLTS) were employed to investigate PINs and LGADs under various neutron and proton irradiation fluences. The defect parameters, including activation energies, capture cross sections, and concentrations, were analyzed. The results show that, compared with i-DLTS, c-DLTS is more sensitive to shallow-level defects. However, at high irradiation fluences, due to increased leakage current and device degradation, c-DLTS may fail to detect defects, while i-DLTS can still reveal typical deep-level defects (e.g., CiOi). Furthermore, under the same irradiation fluence, PINs can resolve both shallow- and deep-level defects, whereas shallow-level defects are hardly observable in LGADs. This phenomenon may be attributed to the gain-layer structure and electric-field effects. Therefore, PINs can serve as a reference for shallow-level defects in LGADs. With increasing irradiation fluence, the variety of observable defects increases, and the concentrations of specific defects (e.g., CiOi and BiOi) rise significantly. Both BiOi and CiOi are directly or indirectly related to the acceptor removal phenomenon, which further accelerates gain degradation in LGADs. The quantitative correlation of these defect concentrations thus provides important guidance for designing radiation-hard LGADs.

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Session Classification: Silicon Detector

Track Classification: Detector and System: 12: Silicon Detector