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Geometry optimization of AC-coupled LGADs for high precision 4D tracking

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Low Gain Avalanche Detectors (LGADs) are thin silicon detectors capable of providing measurements of minimum-ionizing particles with time resolution as good as 17 ps. These properties make LGADs the prime candidate technology for achieving 4D tracking in future experiments. Furthermore the fast rise time and short full charge collection time (as low as 1 ns) of LGADs are suitable for high repetition rate measurements in photon science and other fields. Granularity in traditional DC-LGADs is limited to the mm scale due to protection structures preventing breakdown caused by high electric fields at the edge of the segmented implants. The structure, called Junction Termination Extension (JTE), causes a region of 50-100 µm of inactive space in between electrodes.

In this contribution, a set of measurements on AC-coupled LGADs (AC-LGADs, also named Resistive Silicon Detectors, RSD) will be presented. AC-LGADs overcome the granularity limitation of traditional LGADs and have been shown to provide spatial resolution of the order of 10s of µm. This remarkable feature is achieved with an un-segmented (p-type) gain layer and a resistive (n-type) N-layer. An insulating di-electric layer separates the metal readout pads from the N+ resistive layer. Because of the AC-coupled nature of AC-LGADs the pulse is bipolar with a theoretical zero area. The high spatial precision is achieved by using the information from multiple metal pads, exploiting the intrinsic charge sharing capabilities of the AC-LGAD provided by the common resistive N-layer. The following detector parameters have been investigated: sheet resistance (resistivity of the N+ layer), oxide thickness, doping profile of the gain layer, pitch, size and shape of the readout metal pads. The response of non-conventional metal structures in AC-LGADs such as crosses and microstrips was also evaluated. AC-LGADs fabricated at the Fondazione Bruno Kessler (FBK) and at Brookhaven National Laboratories (BNL) were studied extensively with a focused IR-Laser and the result of the studies will be reported in this contribution. Sensors were mounted on fast analog electronic boards (with 1 GHz of bandwidth) and digitized by a fast oscilloscope. Sensors mounted on boards are measured in a laser TCT system using an infrared (IR) 1064 nm laser with a penetration length in silicon of several mm. The IR laser produces linear ionization across its path mimicking the behavior of a minimum ionizing particle (MIP). The laser beam is focused by a lens system that can produce a laser spot of 20-30 µm. The board is placed on micrometer motorized stages to allow to study the response of the sensor as a function of laser position.

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