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Characterization of Depleted Monolithic Active Pixel Sensor (DMAPS) Prototypes

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New monolithic pixel detector concepts, which integrate the front-end circuitry and the sensor on the same silicon substrate, are being explored for track reconstruction in future particle physics experiments. The innovative concept of Depleted Monolithic Active Pixel Sensors (DMAPS) is based on a high resistive silicon bulk material enabling full substrate depletion with creation of an electrical drift field for charge collection, while keeping full CMOS capability for the electronics. Due to the availability of deep p- and n-type implantations in the used technology (ESPROS), the pixel electronics can be implemented using independently isolated N- and PMOS transistors.

Summary

A novel concept of Depleted Monolithic Active Pixel Sensors (DMAPS) has been implemented in a 150 nm CMOS technology. The first matrix prototypes are implemented on an n-type silicon bulk with a resistivity of 2 kΩ•cm and a thickness of 50 µm. The full depletion voltage is expected to be ˜ 7-10V allowing the charge generated in the substrate to be collected by drift. The detector matrix is arranged in an array of 352 square pixels with a pitch of 40 µm. The frontend circuitry consists of a charge sensitive amplifier (CSA) followed by a discriminator, with an overall noise of ˜ 30 electrons and gain ˜ 100 µV/e. This study is focused mainly on sensor aspects.
For the sensor part a bias parameter optimization has been carried out. The depletion zone develops from two pn-junctions with two p-implantations forming a junction with the n-collecting electrode: At the backside there is a p-implantation for sensor depletion and at the front-side a deep p-implantation isolates the electronics. Additionally, the matrix is surrounded by an n-guard ring. All potentials can be controlled and have to be optimized for charge collection properties.
Sensor studies were performed with radioactive sources and lasers. Source spectra of Fe55 and Sr90 were recorded with a single pixel. Both the 5.9 keV and 6.5 keV lines from Fe55 can be separated. The electrons from Sr90 behave as minimum ionizing particles (MIPs) and can be used to obtain an estimate on the deposited energy which is expected to be 12 keV for 50 µm depleted silicon [Ref]. However, the Landau peak could not be observed since a few effects add a 1/x component to the spectrum of Sr90, namely charge sharing, multiple scattering and the fact that the electrons are impinging under various angles. The reasons will be explained.
In order to determine the charge collection homogeneity and for in-pixel studies, the sensor was illuminated from the back with a scanning laser system (680 nm wavelength) with a 5µm spot size. The measurements show that charge created close to the backside (the laser penetration depth is ˜ 4 µm) can be detected with appropriate voltage settings, biasing the device either from the front or the backside. With a typical scan a response is observed at every laser position albeit the fact that the layout fill factor (i.e. the ratio of the area of the collecting electrode to the pixels area) is < 25 %. Preliminary results of homogeneity studies show local signal variations of the order of 20 % although further investigations are ongoing.
After detailed characterizations of the current prototype, a new iteration has been submitted. A new collection diode layout, testing ability of all analog outputs using an integrated multiplexer and a larger input transistor are expected to improve the performance of the device.

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