Development of an Enhanced Lateral Drift Sensor.

Anastasiia Velyka, Hendrik Jansen (DESY, Hamburg, Germany)

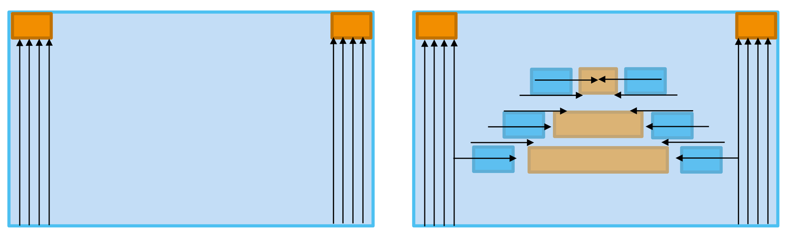
Introduction

One of the main goals in the R&D of particle sensor technology is to improve the position resolution of the particle incident.

Commonly, the size of the read-out cell is decreased, i.e. the pixel or strip pitch. But in this case, the number of channels increases, which requires an increased bandwidth for the read-out and results in less logic on chip per channel.

Another possibility to improve the position resolution of sensors is to increase the lateral size of the charge distribution already during the drift in the sensor material. In this case, it is necessary to carefully engineer the electric field in the bulk of this so-called enhanced lateral drift (ELAD) sensor.

This new concept uses implants deep inside of the bulk. Implants constitute volumes with different values of doping concentration in comparison to the concentration in the bulk. This allows for modification of the drift path of the charge carriers in the sensor.

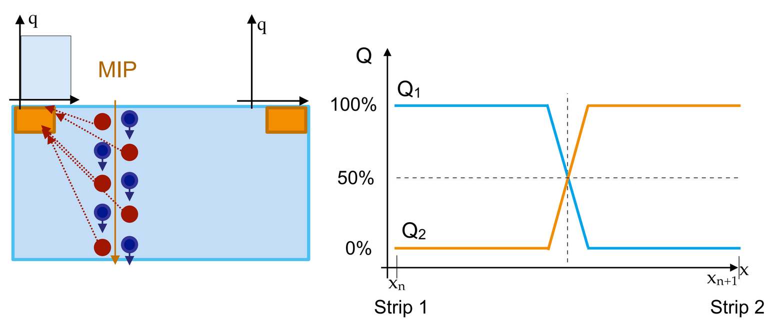


Electric field in a standard planar sensor *Electric field in an ELAD sensor*

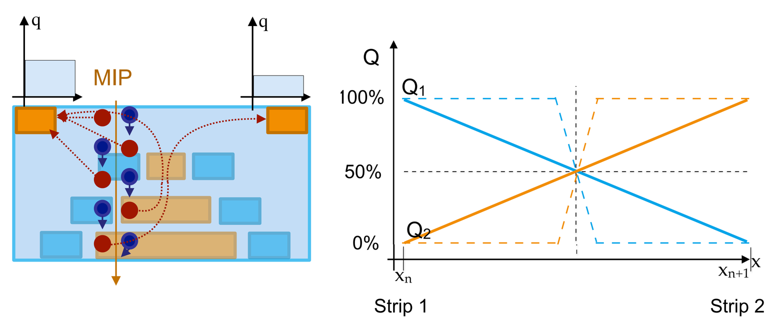
- **Lateral electric field**
- **ELAD enables position-dependent charge sharing**

Charge collection

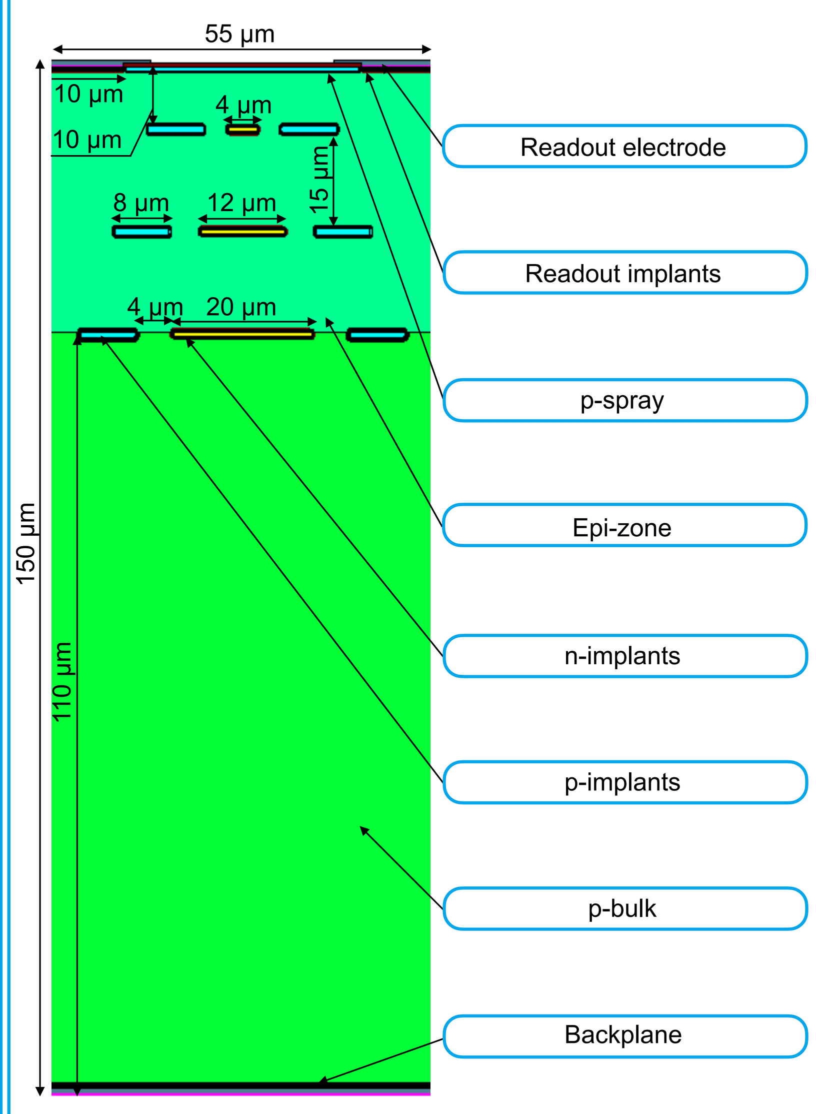
For a standard planar sensor design charges in the left (right) part of the pitch are collected by the 1st (2nd) strip. In the middle of the pitch, the ratio between the collected charge at 1st and at the 2nd strip is 50%/50%.



The theoretical optimum of a charge sharing is a linear dependence on the MIP position. In this case, at any MIP position, the charge will be collected by both strips. With a linear charge sharing, the position resolution is at the optimum.



Design



Doping concentration

Simulations

The development of such a detector requires a good understanding of the entire production process. In order to find an optimal geometry and design of the detector, it is necessary to make reliable simulations, which are conducted using SYNOPSYS TCAD.

The parameters that need to be defined are:

- Width, depth of implants;
- Distance within/to next layer;
- Position/shift to neighbouring layer;
- Number of layers;
- Optimal doping concentrations for deep implants.

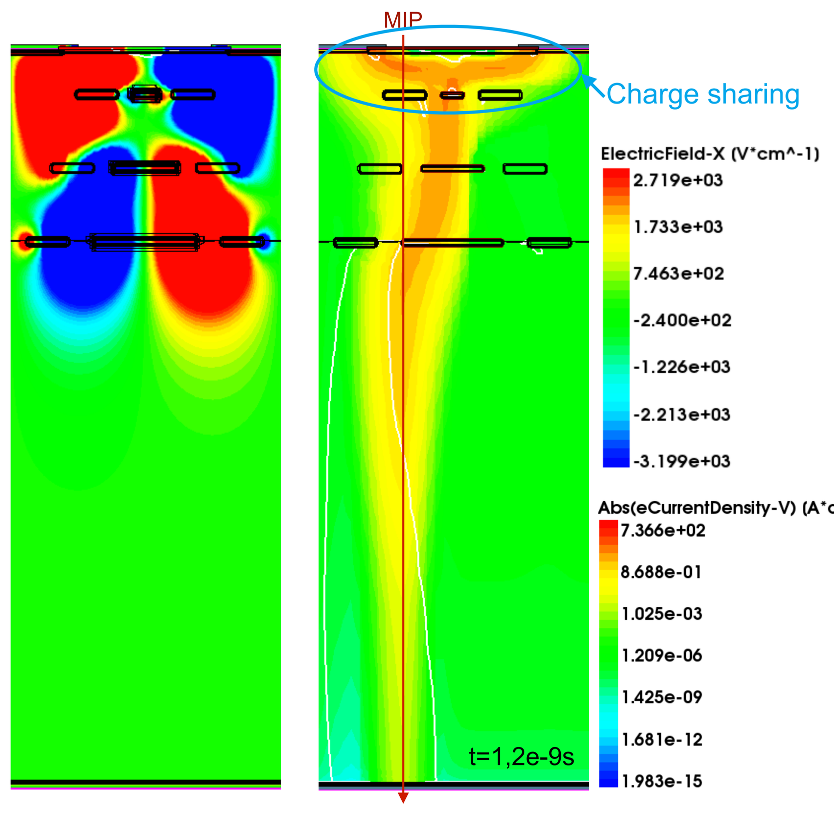
For getting an electric field profile static simulations have been done. In the transient simulations is placed a probe charge in different positions. Process simulations are used to provide input of their production-determined shapes of the sensor structures.

Defined parameters:

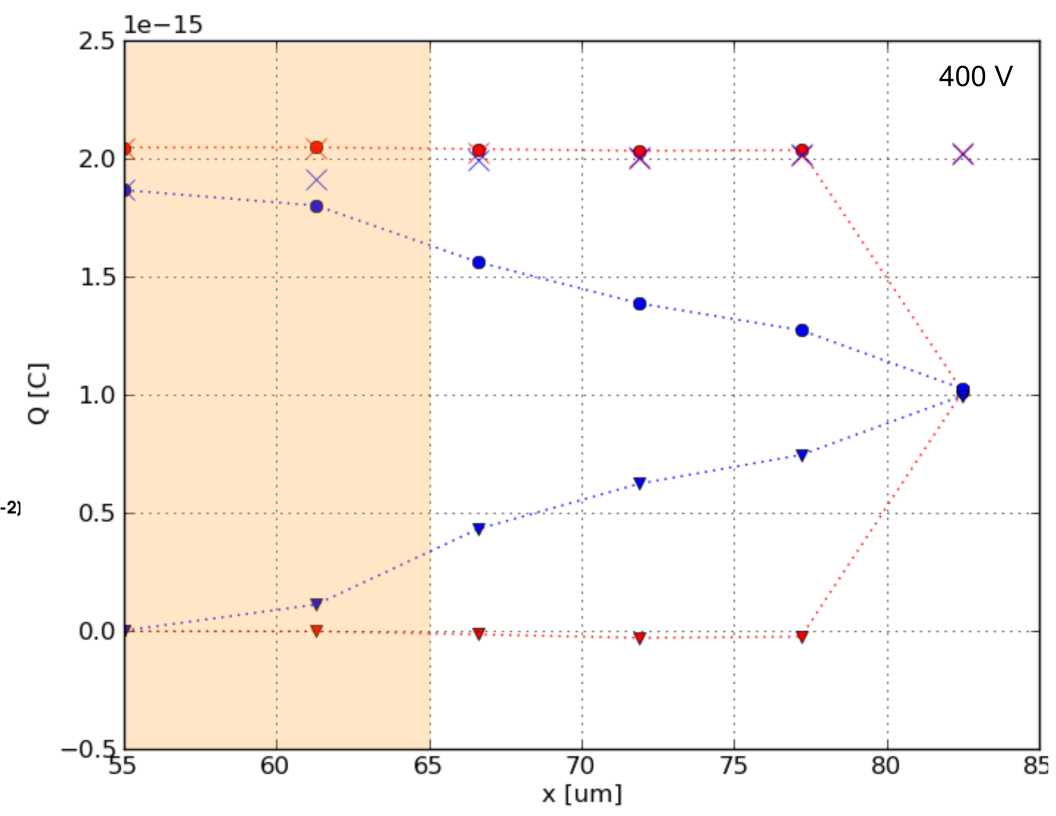
- implant concentration 3e15 cm^{-3};
- p-spray concentration 5e15 cm^{-3};
- 3 layers of p and n deep implants;
- distance to the 1st layer 10 µm, between layers 15 µm;
- epi-zone thickness 40 µm;
- V_{dep}=240 V;
- V_{bd} = 880 V;

The depletion voltage in ELAD sensor is tuned to be the same as in a standard sensor design with an epitaxial layer.

Static and transient simulations in TCAD



Electric field *Electron current density*



- collected charge at 1st strip in a standard sensor;
- collected charge at 2nd strip in a standard sensor;
- sum of charges from 1st and 2nd strip in a standard sensor.
- collected charge at 1st strip in ELAD;
- collected charge at 2nd strip in ELAD;
- sum of charges from 1st and 2nd strip in ELAD.

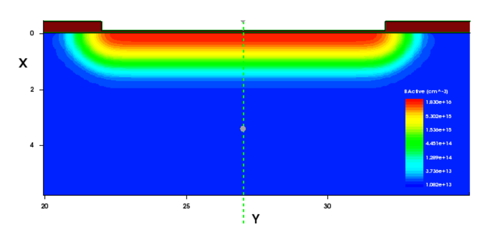
TCAD simulation is a highly versatile tool used in the development of semiconducting sensors. TCAD SYNOPSYS follows the standard finite element analysis scheme.

A simulation process starts from the definition of a sensor structure, which is afterwards meshed. Subsequently, the device simulation is executed. In this type of simulations, a transient simulation is performed to assess the response of the ELAD device to a traversing particle at defined time and position. The electron current density is presented.

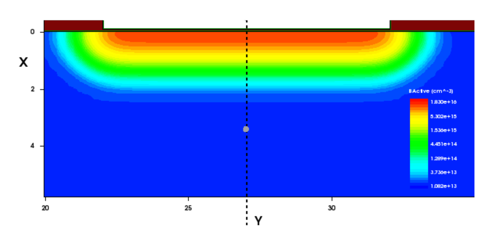
The collected charge as a function of the MIP incident position is shown. The x-axis is incident position of the MIP [µm], the y-axis is the collected charge [C].

The results are shown for MIP positions in the range from 55µm to 82,5µm. The plot shows that the ELAD detectors have better charge sharing (blue) than the standard planar design detectors (red).

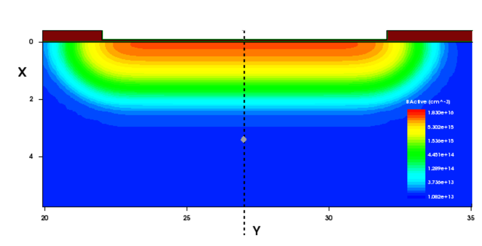
Process simulations in TCAD



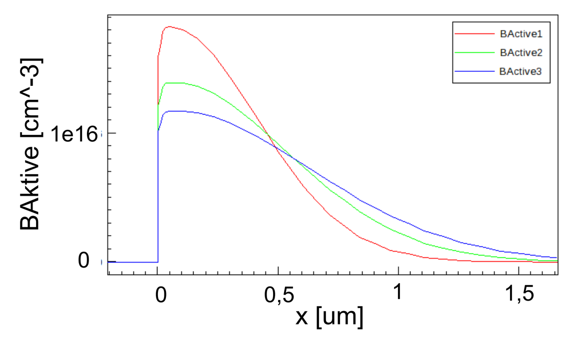
Boron implant, 1st temperature cycle



Boron implant, 2nd temperature cycle



Boron implant, 3rd temperature cycle

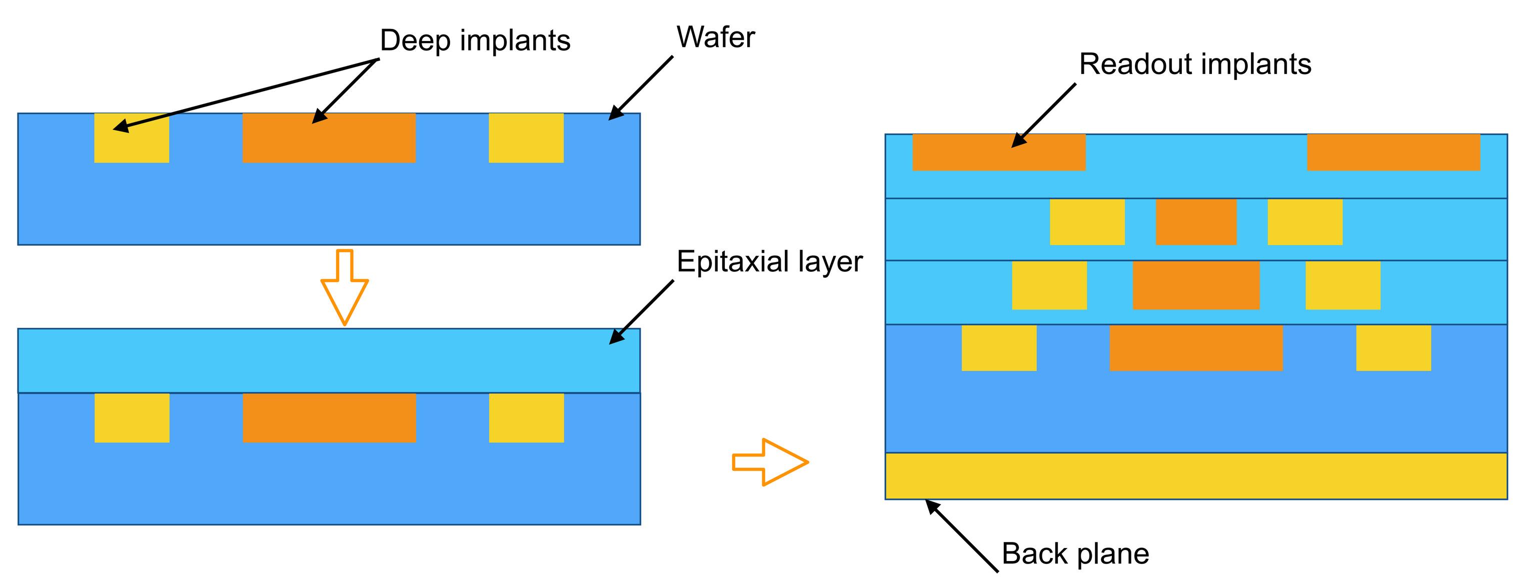


Active Boron concentration after 1st, 2nd and 3d temperature cycles as a function of depth

The process simulation results for 3 temperature cycles 1150°C for 20 minutes are presented. Each temperature cycle corresponds to one step of an epitaxial grows.

The difference between implants size after heating is less than 1 µm. The difference in sizes of deep implants from layer to layer has a negligible effect on a charge sharing between strips.

Production

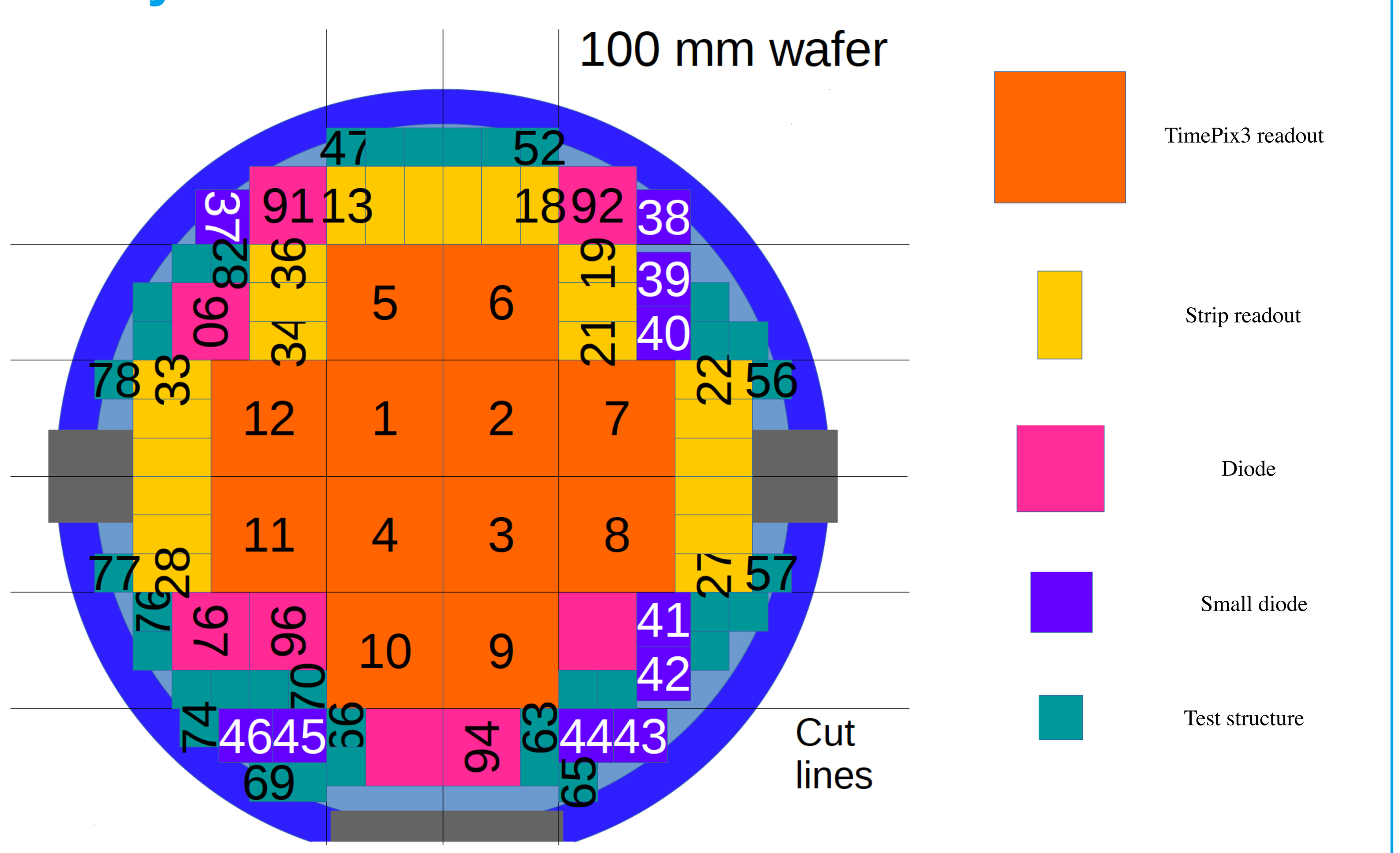


The first stage of production is Boron (p) and Phosphorus (n) surface implantation in base material. Implantation is done by bombarding the wafer with an ion beam of defined energy.

In the epitaxial growth process, a thin layer is grown on the wafer surface. In the course of the growth process, the layer adopts the orientation of the substrate crystal. The selected growth method is the chemical vapor deposition (CVD), in which at approximately 1200°C, a gaseous silicon compound is decomposed with the resulting silicon growing on the crystal substrate.

The combination of implantation and epitaxial growth is repeated three times. After the last epitaxial growth the surface implantation is performed for readout strips and backside implantation.

Wafer layout



For the submission 3 types of readout have been selected: TimePix3 pixel readout (pitch 55 µm), strip readout (pitch 55 µm) and diode. Different types of deep implant concentrations and p-spray concentrations will be produced. For comparison, wafers including the epitaxial layers but excluding the deep implants will be produced.

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

DESY