Characterization of RD53A pixel modules with passive CMOS sensors

Franz Gleasen1, Malte Backhaus1, Florencia Canelli2, Yannick Manuel Dieter2, Jochen Christian Dingfelder2, Tomasz Hemperek2, Fabian Hugening2, Arash Jofreheli2, Weiwei Jin3, Ben Kilminster3, Anna Macchiolo3, Daniel Muenstermann4, David-Leon Pohl4, Branislav Rustic5, Rainer Waltrun4, Tianyang Wang4, Norbert Wermers5, Pascal Wolf1

CMS market survey submission by LFoundry:

- The first batch of bare sensors showed a very high leakage current ($V_{dep} = 40$ V).
- Fixed by increasing the backside implant doping.

IV measurements

- Phase 2 requirements: 0.75 $\mu$A per cm$^2$ at $V_{dep} + 50$ V
- Breakdown > 300 V

Leakage current and breakdown voltage in compliance with the Phase-2 specifications.

The IV after irradiation is also well behaved.

- CMOS sensors and stitching

The characterized samples are passive planar n-in-p sensors for hybrid modules built in CMOS technology using the 150 nm production line of LFoundry and the stitching process.

Advantages of CMOS sensors:
- Reuse of CMOS libraries from the industry
- Large throughput and low cost
- Implementation of small on-pixel features

LFoundry on-sensor features:
- Metal layers on top of the sensor for signal redistribution
- DC or AC-coupled sensors
- Low and high resistivity polysilicon layers

- Crosstalk

Capacitive coupling between neighbouring pixels leads to spurious hits and can deteriorate the sensor’s resolution.

- The ratio of the lowest charge over the total charge for 2-pixel clusters showed that the cross-talk is smaller than 3%.

Resolution

Minimal resolution of 2.2 $\mu$m in the 25 $\mu$m direction around 9.5 degrees. The CMS tracker has a Lorentz angle of 11.5 degrees.

- Charge collection

- Time-over-threshold distribution from DESY testbeam runs.

Full charge collection of approximately 12000 electrons is reached for a bias voltage of 40 V.

- Next steps

- Modules irradiated up to $10^{10}$ neq cm$^{-2}$ to be tested
- New sensor submission expected this year

- 25 x 100 $\mu$m$^2$ pixel size