Vertically Integrated CMOS Active Pixel Sensors for Tracking Applications in HEP Experiments

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Introduction

✓ In this work we propose an innovative all-in-one detector featuring multiple, stacked, fully-functional CMOS Active Pixel Sensor layers, aiming at:
  - momentum measurement (impact point and trajectory) with a single detector;
  - low material detector (reduced multiple scattering issues).
✓ Perspective advantages for particle tracking / vertex detectors:
  - high granularity – high spatial resolution;
  - separation of sensor, analog read-out electronics, A/D conversion layers (increased fill-factor, performance).
✓ A first chip prototype has been fabricated within a multi-project run - monol, featuring a 130nm CMOS 3D Chartered/Tezzaron technology, featuring a first chip prototype has been fabricated within a multi-project run - monol, aiming at:
  - large single separation of sensor, analog read-out electronics, A/D conversion IR, UV, VIS laser with pixel, back-side detector;
  - illumination measurement (impact point and trajectory) with a detector (reduced multiple scattering issues).

Optical Workbench – Characterization with Laser

✓ IR, UV, VIS laser with μ-focusing and μ-positioning capabilities.

Significantly different responses for spots that hit the pixel sensitive area with respect to spots crossing in between pixels - potential warning for effective fill-factor / efficiency.

Characterization with X-rays (40 kV / 90 μA - Fe or Cu fluorescence)

Monolayer clusters quantified spatial differences

Conclusions

✓ First functional characterization of 3D monolithically stacked Active Pixel Sensors layers fabricated in Chartered/Tezzaron 130nm 3D technology for particle tracking purposes.
✓ Good communications between bottom and top tiers (contacts only at the periphery – PADS; redundant bondpoints scheme).
✓ Both tiers are fully functional – different test structures and matrix structures (5x5, 16x16, small vs. large photodiodes) have been characterized with focused laser.
✓ Noise analysis and X-rays calibrations with Fe and Cu fluorescence.
✓ Charged particle characterization with 3 MeV proton beam to estimate charge collection region thickness.
✓ Coincidence responses between bottom and top matrices have been obtained with laser stimuli and 3 MeV proton beams.
✓ Misalignment between top and bottom tiers has been found in both cases and it is compatible with CT chip measurements.

References

- RAPS04 3D structures: Large photodiode.signal with respect to spots crossing in between pixels - effective fill-factor / efficiency.
- Mono-hit clusters quantified spatial differences.