Development of radiation hard CMOS Active Pixel Sensors for ATLAS ITK
Heinz Pernegger / CERN on behalf of the ATLAS CMOS collaboration

Develop depleted radiation hard CMOS Sensors for ATLAS ITK
• ATLAS ITK upgrade for Phase II Pixel detector requires radiation hard sensors, which present CMOS MAPS cannot do (not radiation hard & too slow)
• Started RD to develop commercial CMOS processes to radiation hard sensors through optimized designs, high voltage processes (>100V on chip) and higher resistivity (100Ohm*cm to kOhm*cm)

Monolithic solutions benefits:
• Thin & light detector modules
• Simplified assembly and cost advantage for large areas

Hybrid solution benefits:
• Fast and complex readout in separate digital chip to cope with highest hit rates at smallest radii
• CMOS sensor + analog stages

AMS H18 180nm HV2FEI4 Version 2 & 4
• Matched to ATLAS FEI4 readout chip (50x250µm pixel size) and includes sub-pixel encoding
• Sub-pixel (size 33x125µm) includes Preamp + Shaper + Discriminator

Produced in AMS H18 process:
• p+100cm with bias 60–100V
• Depletion depth ~10 µm
• Q (theoretical) ~1000 e– by drift
• capacitively coupled to FEI4

Results on AMS 180nm CCPD
• Lab characterization before and after irradiation : Edge Transient Current Technique

Results on AMS 180nm CCPD
• Charge Collection Studies
• Drift and diffusion are distinguished by timing cut at 2.5ns
• In-time signal fraction increases with irradiation
• Acceptor removal due to irradiation may lead to increased substrate resistivity & depleted area

Beam test results on AMS 180nm
• Unirradiated and irradiated HV2FEI4 CCPD Version 4 (neutrons 1x10^15 neq/cm²)

Overall efficiency (time-integrated):
• Unirradiated 99.7% at -12V bias, irradiated 96.2% at -30V
• Signal after irradiation ~ 1500 e– (SNR ~25) but in-time efficiency not yet met

Results on AMS 180nm CCPD
• HV2FEI4 CCPD Version 2:
  • Three pixel types
  • Voltage based sub pixel encoding
  • First to work after 850 Mrad

HV2FEI4 CCPD Version 4:
• Lower noise
• Pulse length or voltage based sub-pixel encoding

Capacitive coupling to FEI4
• Capacitive readout AMS CMOS sensor to input of ATLAS FEI4 pixel readout chip
• “Capacitive Coupled Pixel Detector” (CCPD)
• Flip chip on SET FC150

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