Marie Curie Initial Training Networks Midterm Review
on MC-PAD Project 2:

Hybrid Pixel Detectors

(Development of Radiation Hard Pixel Detectors for Photon Science and Particle Physics)

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Under the supervision of Robert Klanner[1] and Tilman Rohe[2]

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[*]started on July 15th 2009, MC-PAD Early-Stage Researcher
from China, M. Sc in Particle and Nuclear Physics at Peking University on July 2009,
Master thesis:"Experimental Study of the $^{10}B(n,a)^{7}Li$ Reaction in the MeV Neutron Energy Region"

Outline

- Trainings and benefits from MC-PAD framework
- Achievements in the first year
- Summary and further work

Trainings and benefits from MC-PAD framework

Trainings:

- 1st MC-PAD training event on **electronics** in Krakow (Sep 2009)
- 2nd MC-PAD training event on **"Detector simulation and data analysis (Geant4, ROOT)"** in Hamburg (Jan 2010)
- 3rd MC-PAD training event on **"Radiation hardness of semiconductor detectors and detector processing"** in Ljubljana (Sep 2010)
- Operation of X-ray irradiation setup in F4 beamline at Hasylab (local training)
- Solid state measurements – CV, IV and TSC (local training)

Other benefits:

- German course from DESY
- Regular participation in the **"Joint Instrumentation Seminar"** organized by DESY and Hamburg University (every two weeks)
- Participation of Deutsche Physikalische Gesellschaft (DPG) meeting, talk on **"Characterization and spice simulation of a single-sided, p+ on n silicon microstrip sensor before and after 12 keV X-ray irradiation"** (Mar 2010)
- Experience of **test beam experiments at CERN SPS** (May - June 2010)
- PSI Zuoz summer school on **"Gearing up for LHC physics"** (Aug 2010)

Achievements in the first year

Reminder of the project 2:

- **This project aims at an optimized design of the pixel sensor that can survive in harsh radiation environment.**

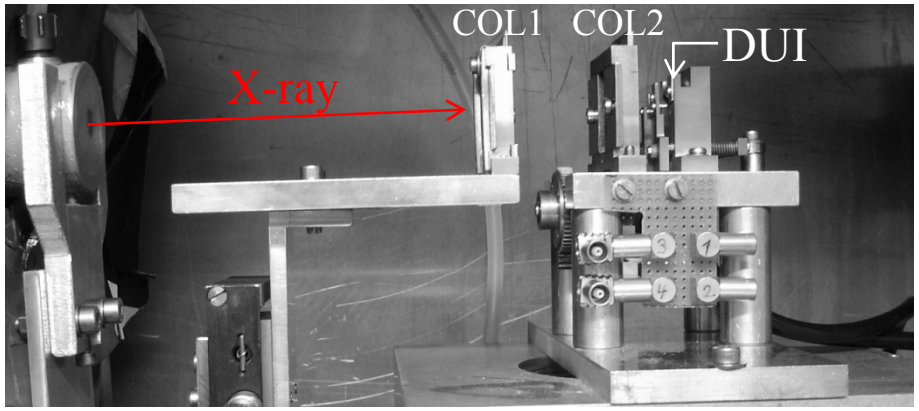
Work done in the first year:

- **Operation of irradiation setup at DORIS III beamline F4**
- **Parameters (N_{ox} and N_{it}) extraction due to X-ray irradiations**
- **Characterization of p+ on n microstrip sensors up to 10 MGy**
- Model calculation (CV and GV reconstruction) for CMOS capacitors
- SPICE simulation for unirradiated p+ on n strip sensors
- Qualitatively understanding and characterization of n+ on n CMS test pixel sensors up to 1 MGy

- *Selected topics*

Achievements in the first year

Operation of X-ray irradiation setup at DESY DORIS III beamline F4:



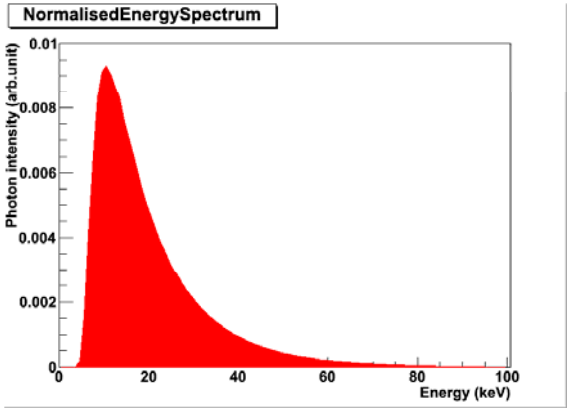


Fig.1 X-ray energy spectrum

Energy spectrum of photons:

- ***Typical energy: 12 keV***
- ***Flux density: 1.08 ×10^{14} /(s ·mm^2)***

Beam profile:

- ***Beam spot: 4 mm × 6 mm***

Dose rate:

- ***Beam centre: 200 kGy/s***
- *2D scan: 500 kGy/scan*

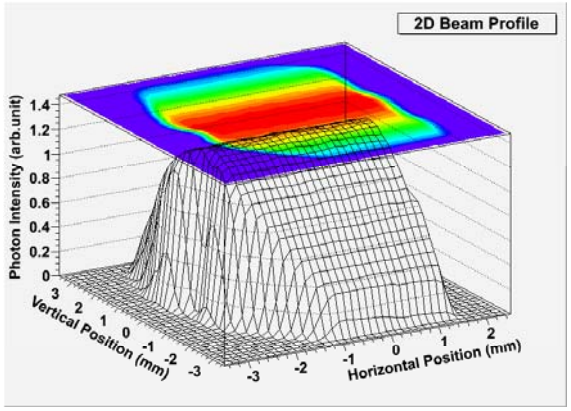
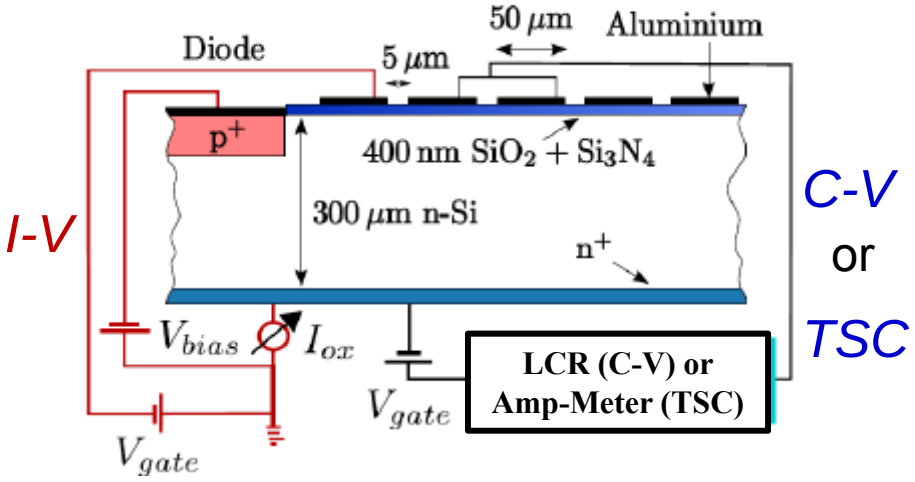


Fig.2 Beam profile at beamline F4

Basis to determine dose for the following studies

Achievements in the first year

Parameters (N_{ox} and N_{it}) extraction from MOS capacitors and gated diodes:



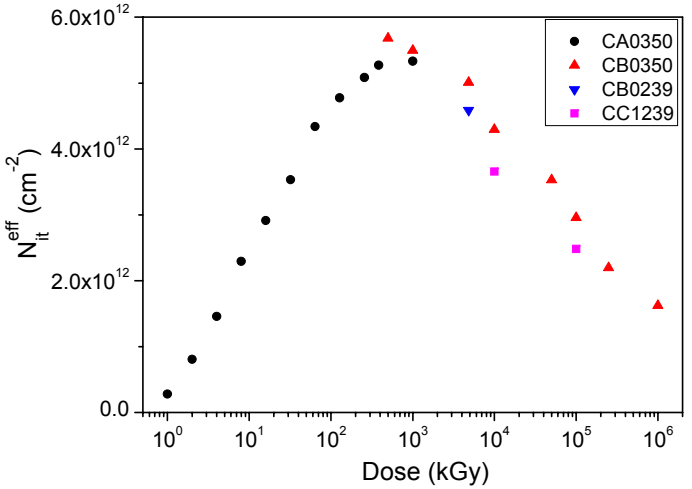


Fig.3 Dose dependence of N_{it}

TSC → interface trap density N_{it}
C-V → oxide charge density N_{ox}
I-V → surface current (macroscopic)

Extracted parameters were used in TCAD simulation to confirm performance of segmented sensors

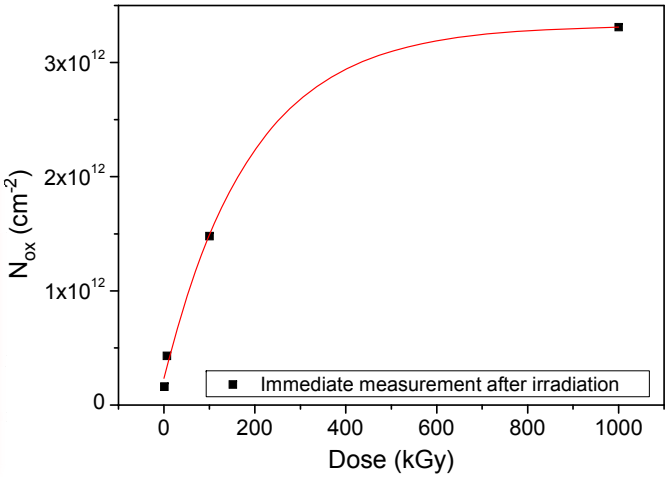
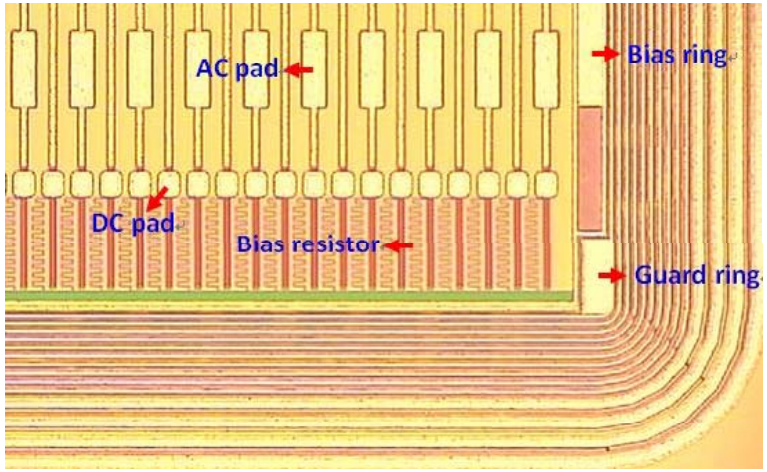


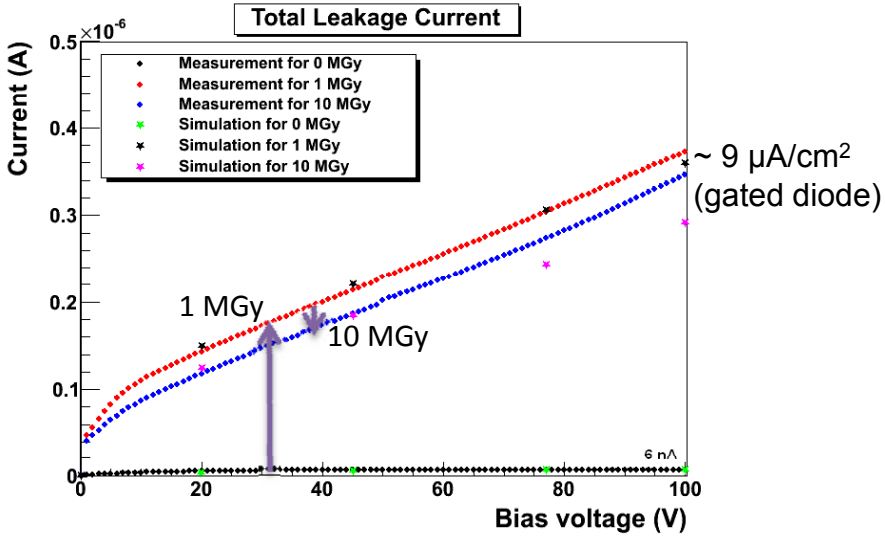
Fig.4 Dose dependence of N_{ox}

Achievements in the first year

Characterization of p+ on n strip sensor up to 10 MGy:

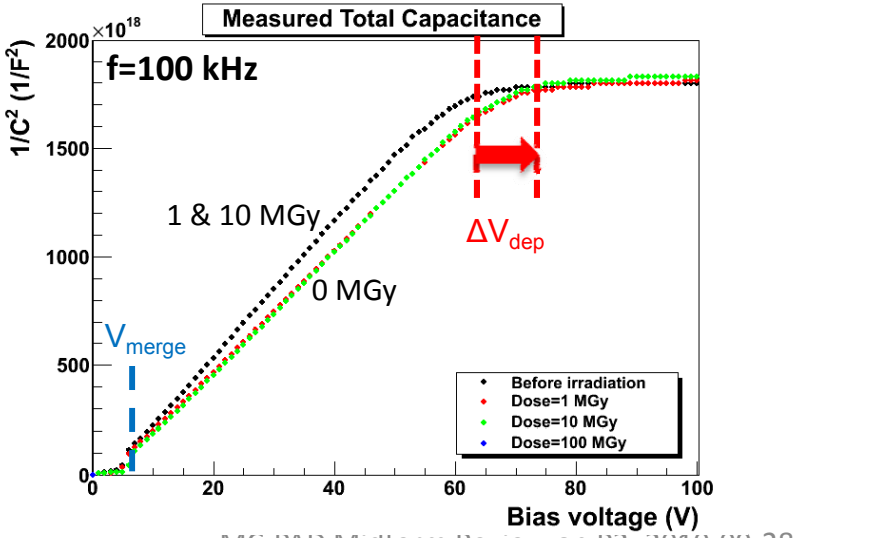


Irradiated p+ on n strip sensor



Do we really understand the results?

- Non-saturated leakage current
  → **surface depleted area S_{dep}**
- Change of full depletion voltage
  → **electron accumulation layer at the Si-SiO_2 interface**



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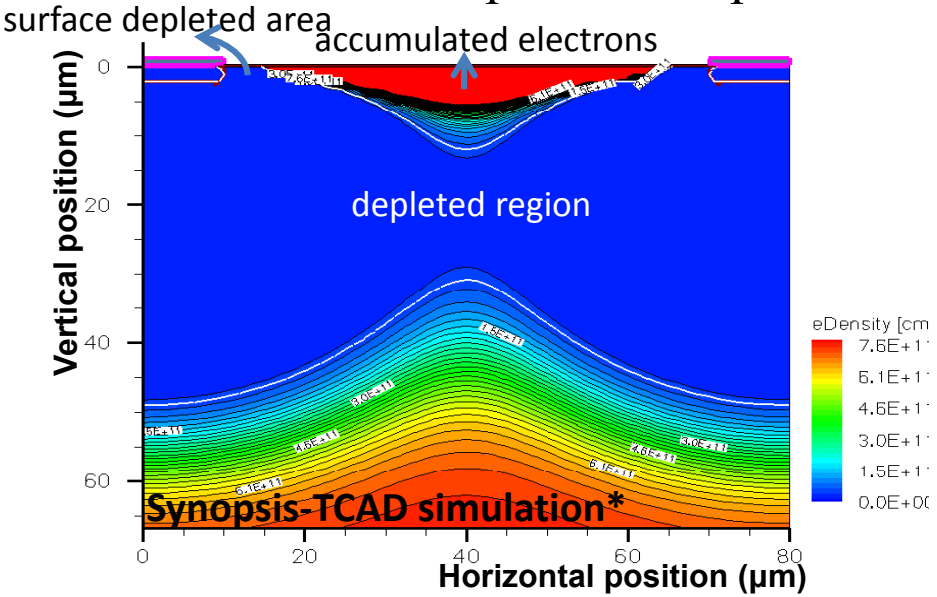

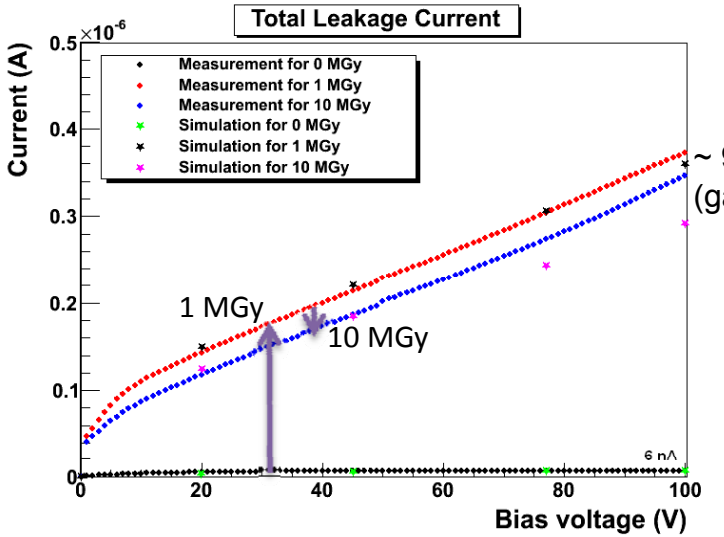

~ 9 μA/cm² (gated diode)

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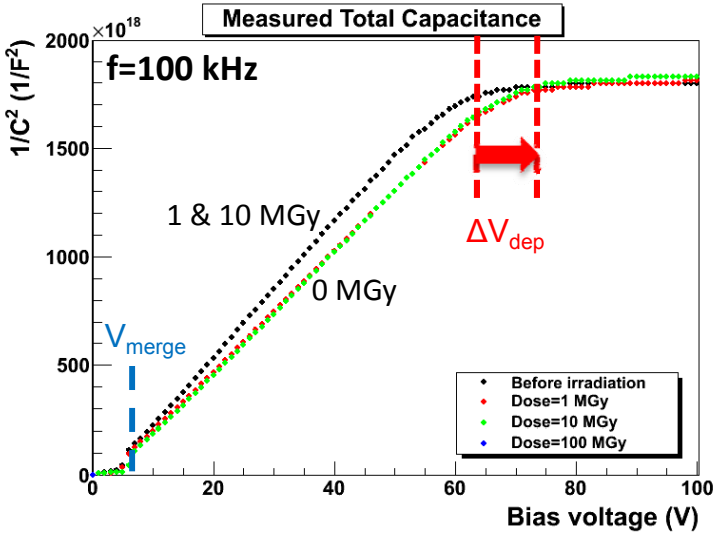

*) Simulation work done by a post doctor

Summary

- Benefit a lot from MC-PAD network
- Scheduled milestones and deliverables:

P2-M1	Definition of specifications	m6	done!
P2-M2	Layout of sensor prototypes	m21	in progress
P2-D1	Simulation of sensor response	m18	done!
P2-D2	Characterization of prototype sensors	m36	in progress

- Further works (second year):
  - i. Dead layer study for irradiated p+ on n sensors
  - ii. Annealing study for irradiated sensors
  - iii. Sensor layout design with Cadence (P2-M2)

Thanks for your attention!