Radiation
Radiation damage in silicon detectors
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Radiation damage in silicon detectors: DEAL WITH IT
Outline

• Introduction

• Radiation damage
  • How do we study it
  • Effects

• Conclusions
Introduction

• High demanding radiation environment

• Need to understand how radiation damage affects detector performance
Displacement damage

- Displacements of atoms
- Defects in the lattice
  - Creates energy levels in the band gap
- The new levels can act as traps
How do we study it

• Irradiation up to very high radiation fluence
  • Protons and neutrons

• Measurements of parameters as leakage current, depletion depth, etc
Effects of displacement damage

- Increased leakage current, due to levels in the band gap
  - Increased noise
- Acceptor removal
  - Effective doping concentration of the substrate decreases
  - Depletion region increases
Ionizing damage

- Defects in the silicon oxide
  - Fixed positive charge near the interface
- Changes the functionality of components
How do we study it

• Gamma ray irradiation of test-chips
  • Photons of different energy and dose specification

• Measurement of electrical parameters:
  • Leakage current
  • Transistors characteristics
  • Capacitance
  • Cross-talk
Effects of ionizing damage

- Due to fixed positive charge in the oxide layer, electrons are accumulating on the interface
  - Increase in the leakage current
  - Change of transistor threshold voltage
Conclusion

Design

Simulate
Conclusion

Design

Measure

Simulate
Conclusion

Design  
Measure  
Simulate

9
Silicon detectors basics

• **P-N junction is the basic element of a particle detector:**
  - Charge carriers move into the junction and recombine
  - Electric field induced inside this **depleted region**

• **Distinguish 2 energy bands:**
  - Valence band: electrons bounded in the Si atom
  - Conduction band: electrons moving freely through the sensor ➡️ **Noise!**

• Electrons can be thermally excited from the valence to the conduction band ➡️ **Leakage current**

• Leakage current highly reduced in the depletion region due to absence of charge carriers