SUPIX-2: Beam Telescope Oriented MAPs based on SMIC 0.18μm process @SDU

L. LI1, M. WANG*1

1.Institute of Frontier and Interdisciplinary Science Key Laboratory of Particle Physics and Particle Irradiation, Shandong University, Qingdao, China

Introduction

Since more and more high precision devices are being applied to high energy physics experiment, such as micro channel plate(MCP), charge coupled device(CCD), silicon drift chamber(SDC), silicon strip detector pixel detector and so on, the development of the beam telescope in China is under required. A beam telescope oriented project was set up by Shandong University(SDU) pixel group in 2018 and SUPIX-2 is the first beam telescope oriented monolithic active pixel sensor developed at SDU.

In order to achieve high spatial resolution and high performance of the detector, the geometry of the pixel sensor should be simulated in advance via TCAD for instance, the pixel pitch, the diode size, gap width etc.

Keywords: MAPs, pixel detector, beam telescope, TCAD, simulation

Sensor optimization via TCAD

About TCAD
Technology Computer Aided Design(TCAD) is a branch of electronic design automation that models semiconductor fabrication and semiconductor device operation. The simulation tool we use is Sentaurus owned by SYNOPSYS Inc[1].

Characteristics of SMIC 0.18 μm process[2]

Tri-well: Nwell, Pwell, Dwell
NO Epi-layer and 10 μm substrate

d = √(VTH − VDD)

SMIC 0.18 μm process→ 15V
Circuits are realized mainly by NMOS Transistors
PMOS is counted with collection electrodes

Two Schemes of sensor geometry

There are two diode geometry design based on 50μm × 50μm pixel pitch as Fig.2 shows: 1) small diode with 8μm × 8μm Nwell, 3μm × 3μm Dwell and Pwell lays between diodes; 2) large diode with 33μm × 33μm Nwell, 30μm × 30μm Dwell, 16μm × 16μm Pwell.

AC & DC coupled results

The diode capacitance of the sensor which partially dominates the detector noise also be simulated in advance with AC coupled and the leakage current for sensor at work comes to charge sharing, problems shows. Fig. 6 shows the procedure of charge sharing simulation result for small diode(left) large diode(right)

MIPs model simulation results

The charge collection efficiency(CCE) could also be simulated via MIPs model. In this work, 2000 electrons was produced via MIPs model just as Fig. 4 shows, in which case the central pixel would be the hit pixel and seed pixel. The charge collection process could be illustrated in Fig. 5, and the total collected charge by small diode sensor was 1063 e− and 1637 e− for large diode sensor. And another property for sensor which is 90% collection time are 26.8 ns and 43.3 ns respectively.

Charge sharing simulation results

It seems that each sensor design is reasonable: high CCE and short collection time, but when it comes to charge sharing, problems shows. Fig. 6 shows the procedure of charge sharing simulation. Problem is that when you get higher single point resolution, the threshold would be lower to achieve pitch×2×2 resolution, for small diode sensor 56 e− would be hard to achieve considering the extra noise from the front end electronics, and 118 e− is available for large diode sensor.

Test system for SUPIX-2 prototype

In order to measure the performance of SUPIX-2 prototype, a chip test system was developed at SDU which based on commercial xilinx[3] ip core called “supix”, illustrated in Fig.7 And Fig.8 gives a typical noise distribution of SUPIX-1 prototype.

Acknowledgements

The authors acknowledge the Institute of Frontier and Interdisciplinary Science Key Laboratory of Particle Physics and Particle Irradiation of Shandong University and thanks to the support by SDU for 5th INFIERI Summer School. Besides, many thanks to the 5th INFIERI Summer School committee for the excellent platform for sharing and communication.

References


E-mail: longli@mail.sdu.edu.cn