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Prof. dr hab. inż. Wojciech Kucewicz
AGH-University of Science and Technology
Department of Electronics
Al. Mickiewicza 30
30-059 Kraków

REVIEW

of the PhD thesis of Mohammed Imran Ahmed entitled "New pixel detectors in SOI technology for particle physic applications".

Supervisor: Prof. dr hab. inż. Marek Idzik

The review was carry out according to the order WFiIS-b.510/182/15 of the Deputy Dean of Faculty of Physics and Applied Computer Science Prof. dr hab. inż. Bartłomiej Szafran.

1. Content-related evaluation of the thesis.

Author have presented measurement results of new types Monolithic Active Pixel Sensor in SOI technology. Mainly he has concentrated on analyses of SOI detectors developed using LAPIS SOI 200 nm technology by KEK in Japan.

The SOI sensors are representatives of a novel technique for silicon position sensitive detectors with respect to other established technologies of pixel detectors. One of the main advantages of this technique is a fact that, the sensors part is integrated with readout electronics on the same wafer and there is no limit with complexity of front-end electronics which can be apply. In SOI technology the wafer is split in two part by silicon dioxide. The upper part is used to create an electronics circuit and the bottom part, normally used as a support, is exploit as a sensor part. To do the sensor in bottom part a special technology development is required. A limited availability of such technology (for today LAPIS

Semiconductor Co., Ltd is offering it) is the main disadvantage of SOI sensor development process.

The thesis is focused on validation of performance and characterization of two types of SOI detector prototypes. It consists 5 chapters in addition to Introduction and Summary.

The first chapter is dedicated to short introduction to functionality of vertex and tracking detectors in High Energy Physics. Author presents different types of applied detectors, starting from strip detectors, and then describing advantages and disadvantages of several monolithic pixel detectors.

Chapter 2 contains description of using Technology Computer Aided Design (TCAD) for simulation of the physics of semiconductor devices. There is also shown results of simulation of SOI detector. Author has mainly concentrate on studies of back gate effects of NMOS and PMOS transistors and compared them with standard electrical simulation.

Next two chapters refer to measurements and analyses of two prototypes of SOI detectors: Integration Type Pixel (INTPIX3) and Dual Mode Integration Type Pixel (DPIX2).

The measurement results include comparison of 16 different layout topologies of INTPIX3 and 3 different detectors of DPIX2. Author has prepared set-up system for tests based on SEABAS readout board including data analysis and cluster searching software. Then selected results are described. At the beginning Author was presenting some result of test structure measurements showing the main reason of Buried P-Well (BPW) applying. Afterwards is shortly explained the difference between topology of pixel configuration layout. The INPIX3 consists 8 matrixes of 32 x 64 pixels with former version (from INTPIX2) layouts and 8 matrixes the same size with new configurations of layout. The DPIX2 chip consist the pixel matrix of 256 x 256 pixels which was fabricated using different wafer types (CZ-n, FZ-n and FZ-p).

Author is presenting results of some of the performed measurements. Regarding the INTPIX3 a stability test and measurement of pedestals in function of bias voltage have been done. Then the author has analyzed performance of detectors using IR laser irradiation and gamma radiation from Am^{241} source. Functionality and performance of different type of pixel topology have been discussed. Similar measurement and analyses have been done for chip

DPIX2. In this case it was analyzed the behavior of sensor produced on different wafers. Finally in the end of chapter 4 Author presents smart method of calculation of leakage current for single pixels in the matrix.

The PhD thesis is ending with Summary. It should be also mentioned that bibliography contains 140 items, mainly published in the last years.

It should be emphasized that Ph.D. student made a great number of measurements, and in the thesis it is only showed exemplary results of tests.

2. Detail remarks

Topics of the thesis are treated with different levels of detail. A typical example is chapter 2, where for description of the TCAD tool is devoted 12 pages and results of very simple simulation is shown on 4 pages. It seems that the author didn't use fully their experience in the application of TCAD to simulate phenomena in the structure of SOI detector. For example, the TCAD application could be extremely useful for analyzing the currents propagation in pixel structure, or in the analysis of the halo effect described on page 77.

The chapter 3.4.2. is dedicated to checking stability behavior of the detector. Author has found that output signal is slowly increased in time. As example he presented two pixel layouts measurements, called 3ar6 and 3br6. What about other topology configurations? It would be worth to check if moderation of reset time has influence on that behavior. May be it would be useful to apply the TCAD simulation to better understand the problem.

For evaluation of pixel detector a pulse laser (660nm and 1060 nm) set-up was used. Author presents the results of his measurement in the chapter 3.4.4. Fig. 3.17 shows the laser spot size in function of distance from detector plane. How the size of the spot was calculated with micron precision? Fig. 3.19 present results of detector surface scanning. How the weighted mean of the signal was calculated? Why along the X-axis it is decreasing and along Y-one increasing?

Chapter 3.4.5 is dedicated to analysis response of the detector to Am241 source. Author has described the method of pedestal, common mode noise calculations and cluster search and full procedure for data analysis has been performed. The results allow to evaluate

parameters, mainly gain and noise of different pixels topologies. Finally he has found the best pixel topology. Using pixels from the region 3br8 it can be seen quite clearly all energy peak of the radiation source. Author has calculated the clusters of 1 to 4 pixels. I my opinion, better results can be get using larger clusters - taking into account the nearest pixels surrounding the hit pixels.

Next generation of SOI detectors is presented in the chapter 4. Detector DPIX2 is tested in similar way like INTPIX3 detector. The DPIX2 pixel circuit architecture allow to work with both N-type and P-type detectors and it is equipped with CDS circuit. Author has analyzed detectors with three different type of detector layers: CZ-n, FZ-n and FZ-p. Half of the pixels are equipped with an extra layer: Buried N-Well (BPN) or Buried P-Well (BPN) depends on the type of detector layer. He has measured stability, response of the detectors to IR laser and he did a measurement with Am241 source. The energy spectrum collected using CZ-n and FZ-p detector are presented on the figures 4.18 and 4.20 respectively. He has found that CZ-n detectors noise is increasing in function of bias voltage, while in other two detectors noise increased is neglected. He has also observed increase of noise in function of integration time. Using laser sources he has analyzed signals and the S/N ratio in function of depletion voltage.

In chapter 4.4.2 author has presented the way to measured current and noise of each pixel independently .

The author didn't avoid some minor mistakes in the thesis.

Sometimes he confused wafer with chip (for example on page 55).

Many times is missed an axes description on presented graphs, for example on the figures 3.18, 3.20, 3.22, 3.24-3.26, 4.8, 4.11.

It's really difficult to understand results of measurements presented on the fig. 4.15. How is it possible that the leakage current of the FZ-p detector jumps from 500 to 2300 nA when the temperature change from 5 to 6 degree?

Why on the figures 3.18 and 4.11 the chart bar size does not fit the units on the axes?

In the chapter 4.2.2 it has been presented noisy peaks occurring every 22 or 23 readout frames, but author didn't try to investigate the problem.

On the page 81 he wrote that "the laser intensity was chosen to get realistic signal amplitudes corresponding to ionization of a MIP". How it was calculated?

Generally, an electron sources (like Sr96 one) are used to estimate response of the detector to MIP and an Am241 for calibration. Author didn't mention about measurements with electron source in the thesis.

As it was written on the page 81, the detector was illuminated by laser from the "top side (junction side)". It means from readout electronics side or from detector side?

3. Final conclusion

The goal of this thesis was functionality evaluation of new type of silicon detectors fabricated in SOI technology. Author has analyzed 22 different type of detectors, what required a huge number of time-consuming measurements. Only selected part of them are presented in the thesis.

The main achievements of the author are following:

1. Validation the performance and characterization of the front-end pixel topologies of the INTPIX3 architecture.
2. Validation the performance characterization of the detectors using different type of wafers as sensor part of the SOI detector.

The analysis and tests performed by author and described within the thesis are essential contribution to the development of SOI detectors.

Recapitulating, I would like to say that reviewed PhD thesis of Mr. Mohammed Imran Ahmed meets the requirements of the Act form the 14 March of 2003 of academic degrees and academic titles and degrees and title in art and I make proposal to assume it and admit it to the public defense.

Wojciech Kucewicz