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FUSION-9635; No. of Pages 10

ARTICLE IN PRESS

Fusion Engineering and Design xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Laser test studies on the single-sided dual-column 3D stripixelsilicon detector

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ARTICLE INFO

Article history:
Received 28 October 2016
Received in revised form 1 June 2017
Accepted 2 June 2017
Available online xxx

Keywords:
Stripixel silicon detector
Alibava DAQ system
Laser irradiation

ABSTRACT

The single-sided full-3D stripixel detector and the laser test system were introduced in this paper. The detector responses to different conditions (including detector bias voltage, laser illumination position, pulse generator parameters setting for driving laser device, etc) were measured and analyzed. Main detector parameters, including the depletion voltage, 2D position sensitivity response, charge collection characteristics with different bias voltages, noise distribution characteristics influenced by the different coupling modes of n^+-strips and p^+-strips electrodes to the readout chip channels, were obtained with 1060 nm laser irradiation tests. The measurement results showed that the detector was position sensitive. Its depletion voltage was about 5 V. The measured equivalent noise charge(ENC) of the detector system was about 730 ± 10e.

1. Introduction

The stripixel detector concept was first proposed at Brookhaven National Laboratory (BNL) in 2000 [1]. Subsequently, various prototypes aimed toward optimizing simulation techniques and fabrication technologies were successfully developed [2–6]. In order to decrease the detector's charge collection time, depletion voltage, and charge sharing, and to improve its irradiation hardness, a new single-side full-3D stripixel silicon detector was recently proposed and developed by the collaboration between BNL and Institute of Microelectronics of Barcelona IMB-CNM [6]. The new prototype of the single-sided stripixel detector used in the present work was designed by D. Bassignana and fabricated at IMB-CNM in Barcelona [6]. Based on the works of Ref. [6], further electronic characteristics of the detector were measured in this work using an Alibava DAQ System[8]with 1060 nm laser irradiations at different conditions. The results offered some valuable information for future applications and development of this type of detector.

2. Experimental system of the stripixel detector

A block diagram of the experimental system for the single sided dual-column 3D stripixel detector in this work is shown in Fig. 1.The structure of the experimental system was divided into three parts which were described as follows.

2.1. 3D stripixel detector structureand detector signal output mechanisms

The 3D stripixel detector has dual-column (n^+-type and p^+-type) electrodes arranged in a quincunx configuration, fabricated by single-sided process on *n*-type Si wafer with 5–7 kΩ cm resistivity (Fig. 2). The surface area of the detector is about 1×1 cm^2,while the thickness of the substrate with crystal orientation ⟨100⟩ is about 300 μm. The radius of the n^+- or p^+-type columns is 5 μm. It is doped by phosphorus (n^+-type) or boron (p^+-type) with constant concentration of $\sim 1 \times 10^{19}$ cm^{-3}. The n^+-type columns are isolated with a *p*-type ring around each column on the top surface with inner (outer) radius of 15(20)μm. The boron doping of the p^+-type ring has a Gaussian profile with peak concentration of $\sim 1 \times 10^{17}$ cm^{-3}. The distance between columns of the same type is 80 μm. Two sets of perpendicular strips, X-strips for p^+-type columns and Y-strips for n^+-type columns (with X-pitch = Y-pitch = 80 μm) are processed on the surface by two metal layers, directly connecting the cor-

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http://dx.doi.org/10.1016/j.fusengdes.2017.06.004
0920-3796/

Please cite this article in press as: S. Liu, et al., Laser test studies on the single-sided dual-column 3D stripixelsilicon detector, Fusion Eng. Des. (2017), http://dx.doi.org/10.1016/j.fusengdes.2017.06.004

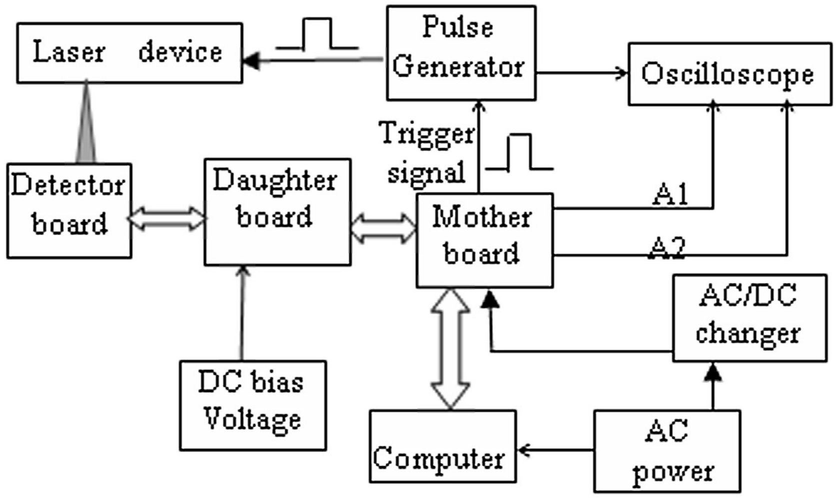

Fig. 1. Block diagram of the stripixel detector experimental system (A1 and A2 were output analogue signals from readout chip1 and chip2, respectively).

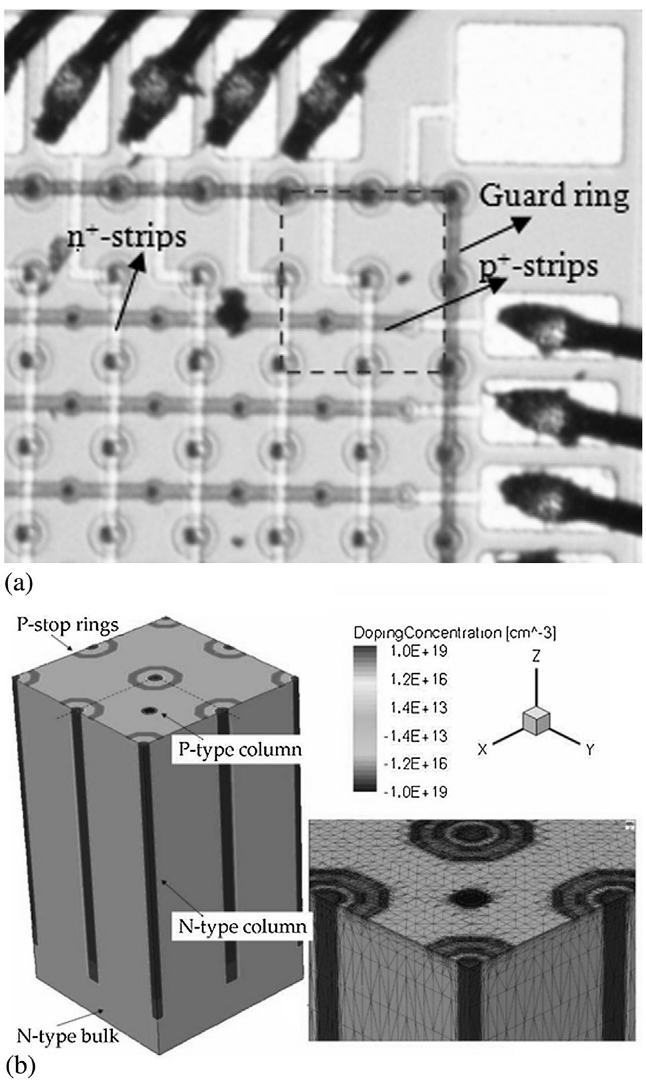

Fig. 2. The 3D stripixel detector. (a) Partial photo of the detector and (b) 3D simulation structure of the detector shown as the dash rectangle in (a).

responding electrodes. The total number of X-strips for p^+-type columns is 127 and that of Y-strips for n^+-type columns is 128. The width of each X-strip or Y-strip is 10 μm. X-strips or Y-strips are separated by a 500 nm thick SiO_2 layer via double-metal process. The active area is surrounded by a guard structure of n^+-type columns connected by a metal ring in the first metal layer. The front and back side of the detector are both passivated by a 1 μm thick layer of silicon dioxide. The detector's fabrication process and basic electrical characteristics measurement results were offered in Ref. [6].

The detector output signal comes from drift currents of electrons and holes generated by the illumination of a laser. The laser device is driven by a pulse generator output voltage signal. The pulse generator is triggered by a control signal from the mother board as shown in Fig. 1. The electrons and holes generated by the laser optical excitation in the detector sensitive region are collected by the detector electrodes of n^+-strips and p^+-strips, respectively. The detector initial output signal will be produced during the charge collecting procedure. The initial signals from detector electrodes are acquired and processed by the multi-channel readout electronic system to be described in details in next section. Finally, the detector's work performance and other properties can be determined by analyzing the characteristics of the detector signal.

(a) Partial photo of the stripixel detector
(b) 3D structure of the detector simulated with Sentaurus TCAD [6].

2.2. Detector signal readout electronic system

The readout electronic system used in this test is the Alibava data acquisition system [7,8]. It is a dual-board (named mother board and daughter board) based system connected by flat cables. The daughter board(Fig. 3) contains two front-end Beetle readout chips [8] (named chip1 and chip2, each chip has 128 readout channels) to acquire output analogue signals from detector electrodes. It also has some necessary control circuits to connect the readout chips with the mother board for further signal processing and communication. The designed functions of the mother board include processing the analogue data from the daughter board, generating a trigger output signal offering to a pulse generator for driving the laser device, controlling the whole system, and communicating with a PC software system via a USB.

Please cite this article in press as: S. Liu, et al., Laser test studies on the single-sided dual-column 3D stripixelsilicon detector, Fusion Eng. Des. (2017), http://dx.doi.org/10.1016/j.fusengdes.2017.06.004