DESIGN AND DEVELOPMENT OF A TWO COORDINATE POSITION SENSITIVE PHOTODETECTOR

Ricardo Cunha Gonçalves da Silva and Henri Ivanov Boudinov

Laboratório de Microeletrônica – Instituto de Física – UFRGS - Brazil

ABSTRACT

Position sensitive photodetectors (PSDs) utilize the lateral photovoltaic effect to produce an electrical output that varies linearly with the position of a light spot incident on a semiconductor junction. The design, fabrication and characterization of newly developed silicon PSD which employ the planar technology and double ion implantation with diferent doses are described. Shallow and low-doped p-n junction is formed by boron implantation in n-type silicon substrate. The position characteristics of PSD are symetric to the central position and linear in the 80% of the active area. For a higher resistivity top layer (lower implanted dose) the sensitivity grows up and the linearity gets improved. The influence of the substrate is not substantial for the characteristics. The response of the sensor, measured by pulsed 15ns laser, was determined to be about 100ns. The characterization of the PSD prepared by above presented technology shows that these devices can be successfully employed for measuring purposes in practice.

1. INTRODUCTION

Its well known that sufficiently energetic radiation normaly incident on a p-n junction produces a photovoltage across the junction. If the junction is nonuniformly irradiated, the photovoltage will, in general, vary with position, producing an addictional signal parallel to the junction plane [1]. One may use this effect to build a position sensitive photocell. This was first investigated and demonstrated by Wallmark [2]. Based on this effect, several kinds of optical sensor devices have been built. Such devices are able to determine precisely the location of an incident spot light on their surface and have been used for applications in different areas, like mecanical alignment, robotic vision, etc. The main advantage of these devices over arrayed detectors is that there is no discontinuity on the signal. Two features are best considered to determine the good functionality of the device, the linearity of the transfer function and sensibility [3]. In this work, we present fabrication and caracterization of double implanted position sensitive photodetector (PSD). The PSD proposed here is a p-n junction built-up in a silicon substrate with metallic contacts deposited on the surface to pick up the formed signal. A simplified sensor design is shown on fig. 1. Sensors with different active areas were built, with intercontact distance of 4, 5, 6 and 7 mm. Al and In were

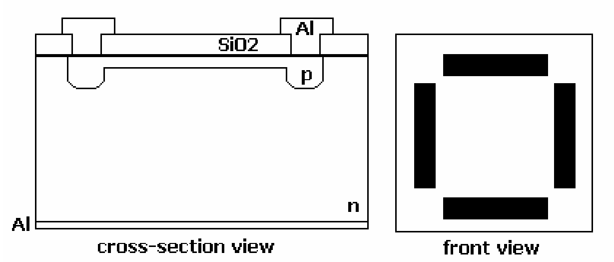

Fig. 1: Sensor design

used as contact metals. The substrate was (100) Si n-type with a resistance of 2-4 Ohm-cm. The influence of parameters like, junction depth, impurity concentration, contacts and light intensity on the device response was investigated in this work. Sensitivity, accuracy, response time and linearity were studied.

Static features can be measured applying a constant spot light in different positions on the device surface. Dinamic features are investigated applying pulsed laser light. Transients were measured using a fast osciloscope.

2. FABRICATION PROCEDURES

The devices were fabricated using the same planar tecnology of integrated circuits fabrication. Processes like implantation, oxidation, difusion, etching and photolitography were used. Like a first step, a 4200Å silicon oxide was termally grown on the silicon surface. This oxide was removed in specific regions (where the contacts were placed later) by a photolitographic process followed by etching of the oxide. Two boron implantation were performed, the first one with a relatively high dose and low energy. This implant is used to make a p+ region under the contacts and the low energy doesn´t let the dopants to cross the oxide in the device active region. The second one, with a high energy is used to control de resistivity of the p-side of the junction in the active region. In a second litographic process, the sensors are prepared for a phosphorous difusion to achieve an electric separation between active region of one sensor and the others on the wafer. Next step is to etch the oxide until it reaches 1500Å thickness serving as anti reflective coating. Metal is then deposited and annealed.

3. MEASUREMENTS AND RESULTS

In order to characterize the devices, static and dinamic features were tested under constant and pulsed light sources respectively. The static measurements gave us mainly the transfer function of the devices and all information related, whereas in dinamic tests, we obtained information about how the electrical output behaves under lights turn-on and turn-off, e.g., the device transient.

3.1. Static measurements

PSDs were tested using a broad-band focused white light to ensure the diversity of device response. A light spot of ~0.05mW/cm^2 with a diameter of ~1mm is used to illuminate the sensor surface, and the lateral photovoltage is measured. The light spot position is varied over the active region and a transfer function relating the position with the electrical output is obtained. PSDs with 4,5,6 and 7 mm of intercontact distance were measured and the transfer functions are shown on fig.2.

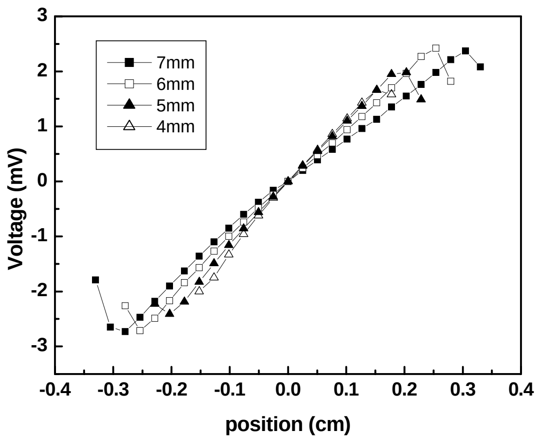

Fig.2: The transfer function of four PSDs with different intercontact distances.

PSDs have good linearity in 80% of the active region. The light spot is partially reflected or absorbed by the contact metal in the peripheral regions of the device, so that the output signal has a significant decrease. We have been measured sensitivities of 12.1, 11.4, 10.1 and 9.5 mV/cm for 4,5,6 and 7 mm sensors respectively. Symmetric curves were obtained for all sensors with Al. This is due to the uniformity of the metal deposition deposition and good ohmic contacts with the silicon. Resolution better than 10µm was verified for all sensors.

3.2. Dynamic measurements

To measure dynamic features, pulsed laser of 15ns was used as light source. The rise time of sensors was

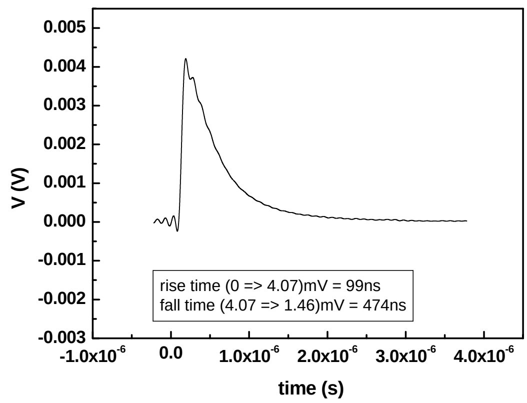

Fig.3: Evolution in time of the photovoltage under incidence of a 15ns-pulsed laser

measured to be about 100ns. The fall time is strongly dependent on light intensity. It can vary from less than 1µs for low intensity illumination to several microseconds for power illuminations. Fig.3 shows the time evolution of the sensor signal for a non-centered illumination on a 5mm sensor. The signal maximum has a non-linear relation with the light intensity, reaching saturation in the free carrier photogeneration process, due to high laser power (2kW/cm^2).

4. CONCLUSION

Double implanted two coordinate position sensitive photodetectors were fabricated and characterized under static and dynamic regimes and showed good linearity and fast response in the output signal. The good repeatability, accuracy and resolution make these PSDs a good choice for practical applications.

5. REFERENCES

[1] Lucowsky, G, "Photoeffects in nonuniformly irradiated p-n junctions", Journal of Applied Physics, vol. 30, pp 1088-1095, 1960.

[2] J. Wallmark, "A new semiconductor photocell using lateral photoeffect", Proc. Inst. Elect. Eng.., vol. 45, pp. 474-483, 1957.

[3] J. Henry and J. Livinsgtone, IEEE Sensors Journal, vol. 2, no.4, pp. 372-376, 2002.