Extended Abstracts of the 1995 International Conference on Solid State Devices and Materials, Osaka, 1995, pp. 641-643

Effects of Dielectrics on the Characteristics of Large-Area Silicon Microstrip Sensors

Wen-Chin Tsay, Yen-Ann Chen and Jyh-Wong Hong
Department of Electrical Engineering
A. Chen, Willis T. Lin, Y.H. Chang, S.R. Hou, S.L. Hsu and C.R. Li
Department of Physics
National Central University, Chung-Li, 32054, Taiwan, R.O.C.
and
Hsien-Jen Ting and Song-Tsang Chiang
Electronics Research & Service Organization
ITRI, Chu-Tung, Hsin-Chu, 30050, Taiwan, R.O.C.

The ONO films have been chosen to replace the usual oxide layer as the dielectric of coupling capacitor used in silicon microstrip sensors. In conjunction with a reordering of sequence for layer formation, the proposed process could be used to produce sensors with self-moisture-protection and free from the effect of pinholes. The side-wall leakage current of sensor was found to be caused by the dielectric stress and implantation damage. A boron solid source predeposition process was employed to reduce this leakage current. From the results of electrical measurement and beam test, the proposed process has been shown to have very good performance.

1. Introduction

Many existing and future high-energy experiments have proposed the construction of large-area silicon trackers based on microstrip sensors[1][2]. Also, the AC-coupling readout scheme is often chosen to cope with amplifier saturation due to the leakage current. Usually, the coupling capacitor is made by separating the p+ strip from the readout metal strip with a thin layer of silicon dioxide. Production yield and breakdown voltage of the large-area coupling capacitor is still a major problem in recent studies[3]. In addition, to improve the S/N (signal-to-noise) ratio of sensor, the leakage current of sensor was also a major concern recently. This report presents results of our studies related to the above mentioned points.

2. Design

We have designed and processed the silicon microstrip sensor on a 4 inches 4KΩ-cm n-type (111) silicon wafer of 320± 15um thickness, as shown in Fig. 1. This sensor is single-sided, single-metal, with direct-bias and AC-coupling readout, and needed 4 masks[4]. The size of this sensor is 8cm long and 4cm wide. This microstrip sensor consisted of diode strips with 25um pitch, in which the readout pitch was 50um. A 10MΩ polysilion resistor was attached to each readout pads for direct bias. The polysilicon resistors were designed to let all strips have the same resistance.

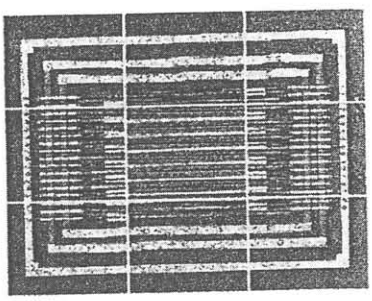

Fig. 1. The top view of silicon micro-strip sensor.(divided into 9 parts)

3. Measurements

3.1. Dielectrics of capacitors

A multilayer dielectric -- ONO(Oxide-Nitride-Oxide) had been chosen to replace the oxide layer in the coupling capacitor. This multilayer dielectric consisted of an 100nm oxide and a 200nm nitride giving an equivalent capacitance of a 200nm oxide. A second oxidation was used to anneal the interface between the oxide and nitride layers. Because of the nearly pinhole free characteristics, the breakdown voltage and production yield of ONO capacitor were much higher than those of the usual oxide layer.

The advantages of using the ONO dielectric were not only higher breakdown voltage and production yield[4], but also good moisture protection.Sensors fabricated with the ONO process and sensors fabricated with the identical process except ONO being replaced by oxide were prepared to compare their performances. There was no additional passivation process for all sensors. All sensors were placed in an 85% relative humidity and 85°C environment for 240 hours. Their leakage currents and polysilicon resistances after such a stress were compared in Table 1. The leakage current and poly-resistance of sensors fabricated with ONO process were found to be essentially the same after the stress. For the sensors fabricated with oxide process, the leakage currents increased by a factor of 40 and the poly-resistances dropped by a factor of 20. This could be ascribed to the moisture which was absorbed and penetrated into the oxide layer,and hence formed a new leakage path,since, when these sensors were baked-out at 120°C for 30 min, their characteristics were restored.

3.2. Leakage Current

To improve the signal-to-noise ratio of sensor, the other concern is leakage current. From results of several batches of test run, we found the leakage currents of silicon mircostrip sensors with ONO capacitors seemed to be unstable and varied from 80nA/cm^2 to 900nA/cm^2. Those of sensors with TEOS oxide capacitors seemed to be more stable and varied from 100nA/cm^2 to 300nA/cm^2,as shown in Table 2.

To find the dominant component of leakage current, several p-n junction test structures were designed. The large area square diode was designed to monitor the leakage due to the bulk junction, and the long-perimeter finger diode was designed to measure those due to the side-wall junction. By comparing the leakages of these two p-n junction diodes, we found the side-wall one dominated, as shown in Fig. 2. From the TEM photograph, we found there were stacking faults near the edges of microstrips with ONO capacitors(Fig. 3a). But, for those of microstrips with oxide capacitors,there was no stacking fault found (Fig. 3b). The stacking faults were caused by implantation damages. The damages would be enhanced and may caused slips by temperature difference if there was a significant stress of dielectric films.

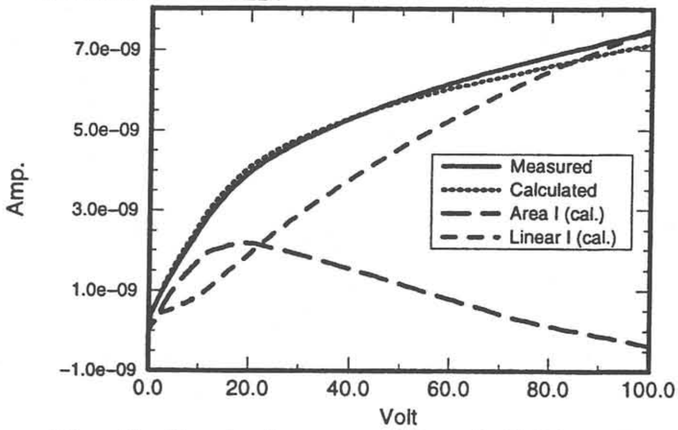

Fig. 2. The Leakge currents of different p-n junction test structures.

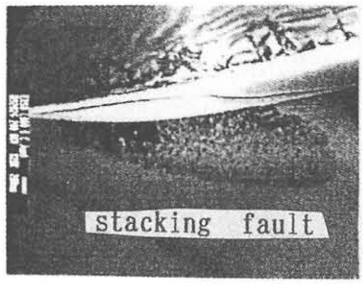

Fig. 3a. TEM cross section view of microstrip with ONO capacitor.

Fig. 3b. TEM cross section view of microstrip with TEOS oxide capacitor.

In order to obtain higher breakdown voltage and production yield of capacitor, the ONO dielectric should be used. To prevent the implantation damages, a boron solid source predposition was used to replace the p+ strip implantation process. A significant improvement of leakage current had been obtained, as shown in Fig. 4.

3.3. Beam Test

These sensors were bonded with SVX-D readout chips [5] and tested at CERN. An average S/N ratio of 23 and an efficiency above 97% were obtained in conjunction with an intrinsic spatial resolution of 3.5±1um [6][7]. This was the best spatial resolution for silicon microstrip sensors ever reported.

Table 1. The moisture test results for sensors with oxide capacitor and ONO capacitor

	oxide capacitor			ONO Capacitor	
	Before test	After test	After baking	Before test	After test
Leakage current(uA)	1.25±0.31	48.6±8.8	1.37±0.43	1.25±0.31	48.6±8.8
Poly resistance(MΩ)	11.3±1.14	0.37±3.6	10.9±0.98	11.3±1.14	0.37±3.6

Table 2. The thermal stresses and leakage currents of sensors with different dielectrics

	Thermal oxide	TEOS oxide	LPCVD nitride	ONO
Thermal stress(dyne/cm^2)	comp. -1.99E10	comp. -1.2E8	tensile,5.1E9	tensile,1.8E9
Leakage current density (nA/cm^2)	800-1000	100-300	------	80-900

4.Conclusion

An improved process of ONO coupling capacitor had been demonstrated to have the higher breakdown voltage and production yield of capacitor than those of oxide coupling capacitor.Sensors with ONO coupling capacitor passed IEC standard environment test, while sensors with oxide capacitor showed deterioration. Special p-n junction test structures were employed to monitor the leakge currents of silicon microstrip sensors. The measurement results of those test stuctures indicated that the leakage current dominated by the side-wall one and caused by the implantation damages. The damages would be ehanced by temperature differences if there was a significant stress of dielectric films. A boron solid source predeposition process had been developed to reduce the side-wall leakage. From the results of beam test at CERN, we found that sensors made by the proposed process had high S/N ratio, efficiency and spatial resolution.

Acknowledgment

The authors would like to thank ERSO /ITRI and National Central University for their continus supports. This work was partially supported by National Science Council of the Republic of China under the contracts NSC 82-0212-M-008-114 and NSC 83-0208-M-008-047.

References

(1) J. Kemmer, Nucl. Instrum. & Methods A288(1990)282.
(2) L. Evensen et al., IEEE Trans. on Nucl. Sci., NS-35(1988)428.
(3) T. Ohsugi et al., Nucl. Instrum. & Methods, A342(1994)22.
(4) W.C. Tsay et al.,Nucl. Instrum. & Methods, A351(1994)463.
(5) S.A. Kleinfelder et al., IEEE Trans. on Nucl. Sci., NS-35(1988)171
(6) W.C. Tsay et al.,"Studies of Large Area Silicon Microstrip Sensors", to be appeared in IEEE Trans. on Nucl. Sci. 1995 August.
(7) S.R. Hou et al., "Clustering and Spatial Resolution of Silicon Microstrip Detector", L3 Note 1559(1994)

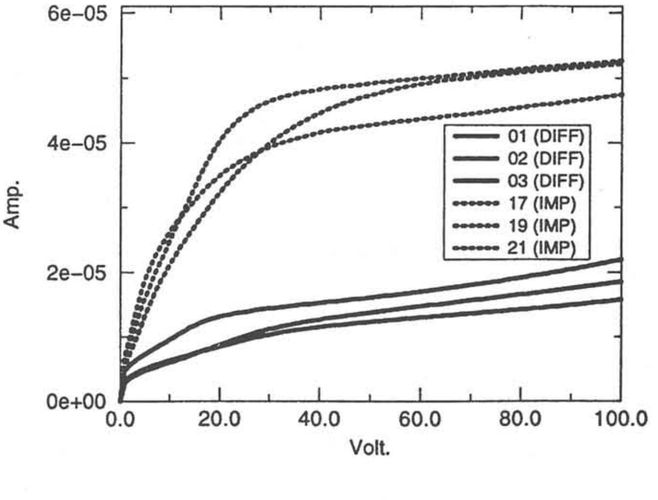

Fig.4.Leakge currents of sensors made by boron diffusion and p+ implant process.