PRAMANA
— journal of
physics

Vol. 69, No. 6
December 2007
pp. 1085–1088

Silicon detector technology development in India for the participation in international experiments

ANITA TOPKAR*, S PRAVEENKUMAR, BHARTI AGGARWAL,
S K KATARIA and M D GHODGAONKAR
Bhabha Atomic Research Centre, Trombay, Mumbai 400 080, India
*E-mail: anita@apsara.barc.ernet.in

Abstract. A specific research and development program has been carried out by BARC in India to develop the technology for large area silicon strip detectors for application in nuclear and high energy physics experiments. These strip detectors will be used as pre-shower detector in the CMS experiment at LHC, CERN for π^0/λ rejection. The fabrication technology to produce silicon strip detectors with very good uniformity over a large area of $\sim$40 cm^2, low leakage currents of the order of 10 nA/cm^2 per strip and high breakdown voltage of >500 V has been developed by BARC. The production of detectors is already under way to deliver 1000 detector modules for the CMS and 90% production is completed. In this paper, research and development work carried out to develop the detector fabrication technology is briefly described. The performance of the silicon strip detectors produced in India is presented. The present status of the detector technology is discussed.

Keywords. CMS; silicon strip detectors; silicon sensors; detector technology.

PACS Nos 29.40.W; 29.40.Gx; 29.30.Ep

1. Introduction

Silicon detectors are being used for several applications involving detection and measurement of position and energy of particles such as α particles, fission fragments, heavy ions, etc. These detectors have exceptional energy resolution, high stability and fast response time. Detectors with various geometries such as strips, microstrips and pixels are being increasingly used for detecting ionizing radiation in nuclear physics and high energy physics experiments such as LHC, CERN. BARC has carried out a specific R&D for the technology development of silicon strip detectors for applications at CMS detector, LHC, CERN. These detectors also will be used for nuclear physics experiments in India for charged particle measurements. The R&D for the development of technology has been carried out in various phases such as prototype development, pre-production and production. The silicon strip detector technology development has been targeted to produce detectors with high breakdown voltage and low leakage currents for ensuring ten years of operation in

the high radiation environment of LHC. The technology development and performance of these detectors is presented in the subsequent sections of this paper.

2. Detector design and fabrication process development

The silicon strip detectors have a geometry of 63 × 63 mm and these detectors incorporate 32 P^+ strips with width of 1.78 mm and with a pitch of 1.9 mm [1]. In view of the expected radiation damage during ten years of operation in the LHC environment, the electrical specifications of the detectors are quite stringent, i.e. low leakage currents and high breakdown voltage. Therefore, the strip detector mask has been specially designed to incorporate features such as strips with rounded corners and floating field P^+ guard rings [2]. The floating field guard rings reduce the surface electric fields and hence increase the breakdown voltages of the strips.

The detectors have been fabricated using a four-layer mask process using the standard silicon technology. The fabrication facility of Bharat Electronics Limited (BEL) has been utilized for the prototype development and subsequent production of detectors [2,3]. The 32-strip silicon detectors have been fabricated using 4″, N-type, $\langle 1\,1\,1\rangle$, 300 μm thick silicon wafers having resistivity of the order of a few kohm-cm. The front P^+ strips and the back N^+ contact have been obtained by ion implantation. The silicon surface of the strip detectors is passivated with a thick silicon dioxide layer. The detectors have an additional passivation layer over the metal layer.

The desired specifications of high breakdown voltage and low leakage currents have been achieved by strict contamination control, incorporating gettering, having a uniform and thick N^+ layer at the back for suppressing back injection [3,4]. Critical process parameters such as temperature, time, ambient for processes such as oxidation, implantation anneal and drive-in, etc. have been optimized to meet the desired electrical specifications of the strip detectors. The fabrication process has been optimized in eight batches to tune the process parameters so as to achieve the desired specifications of leakage currents and breakdown voltages.

3. Performance of strip detectors

The strip detectors are subjected to several tests involving electrical and mechanical measurements for quality control of the detector, i.e. acceptance/rejection of the detector. The breakdown voltages of strips, leakage currents and capacitance of individual strips, mechanical dimensions (thickness, length and width), dicing quality are some of the parameters which are monitored during quality control. Simultaneous measurements of leakage currents (IV) and capacitance (CV) of the 32 strips of the detectors are carried out using PC-based automated measurement set-ups. The static characteristics of the detectors are as shown in figures 1 and 2. The characteristics show that the strip leakage currents are of the order of 5–10 nA at high voltages of the order of 500 V. The CV curves are uniform for all the strips and the full depletion voltages are about 110 V.

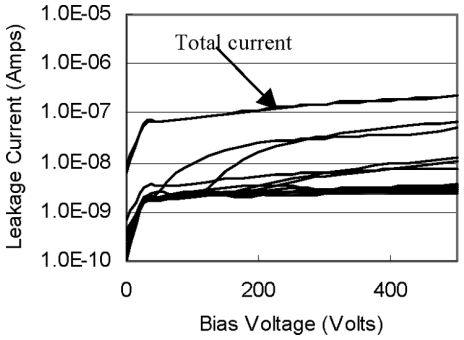

Figure 1. *IV* characteristics of the 32 strips of the strip detector.

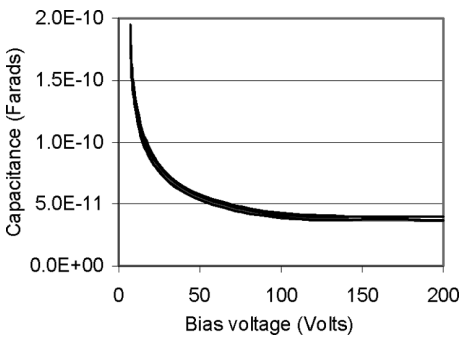

Figure 2. *CV* characteristics of all the 32 strips of the strip detector.

The radiation hardness of the detectors has been tested by irradiating them to neutrons in a reactor (at BARC, India and at Dubna, Russia) and using a 24 GeV proton beam at CERN. The increase of leakage current, breakdown voltage and full depletion voltage were monitored after irradiation. The detectors have been found to meet the specifications and show a stable behavior without showing early breakdown of strips after irradiation to a total neutron fluence of 1.36×10^{14} n/cm^2.

4. Production of strip detectors and quality control

Detectors with very good uniformity and at a production yield of 40% are being produced at BEL to deliver 1000 detector modules to CERN and 90% of the production has been completed. During production, the quality control is being carried out as per the qualification procedures specified by the CMS Preshower Group, CERN. The quality control involves electrical measurements to check leakage currents and breakdown voltages and full depletion voltages of strips. Geometrical measurements are carried out to check the tolerance of 100 microns over detector length and width and measurement of the thickness (within 300–340 μm). All the tests are being carried out in a class 10,000 environment with controlled humidity and temperature.

Figures 3 and 4 show the statistical distribution of breakdown voltage and total leakage current at 300 V for about 800 sensors. As can be seen, the breakdown voltage exceeds 500 V for a majority of the detectors. The total leakage current of the detector is less than 1.0 μA for most of the detectors though this tolerance is 10.0 μA.

The silicon strip detectors are assembled in the form of detector modules so as to integrate the front end electronics hybrid to the detector. The assembly of detectors involves very precise mechanical alignment and gluing of the detectors to the ceramic tile which carries the hybrid and the ceramic is glued to the aluminum tile. Prototype modules have been made in India and the detector performance has been observed to be stable during assembly.

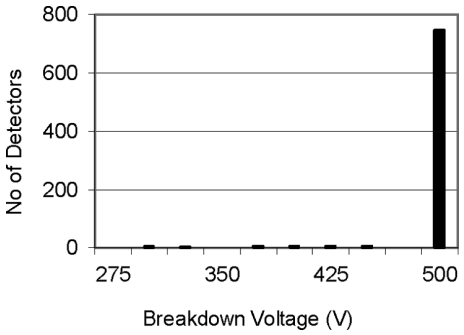

Figure 3. Distribution of the breakdown voltage for 800 detectors.

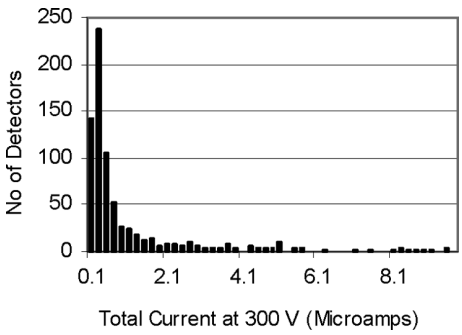

Figure 4. Distribution of the total leakage current at 300 V for 800 detectors.

5. Summary

BARC has developed the demanding technology for fabrication of strip detectors with good uniformity, low leakage currents and high breakdown voltage. The detectors also meet the radiation hardness requirements for operation at LHC. Subsequent to the development of technology, the full scale production of the detectors has been started in India so as to produce 1000 detector modules for the pre-shower of CMS and more than 90% of the production has been completed.

Acknowledgement

This work has been carried out under India-CMS collaboration and has been funded by DAE and DST. The authors are grateful to Dr Anna Peisert, CERN EP Division for her valuable suggestions during this development work. Contribution of Prof. R K Shivpuri and his team from Delhi University for carrying out the detector measurements is acknowledged.

References

[1] Ph Bloch *et al*, *Nucl. Instrum. Methods* **A479**, 265 (2002)
[2] S K Kataria *et al*, *Proceedings of the DAE-BRNS Symposium on Intelligent Nuclear Instrumentation* (2001) p. 3
[3] Anita Topkar *et al*, *Proceedings of the 9th International Conference on Advanced Technology and Particle Physics (ICATPP)*, Coma, Italy, Oct. 17–21, 2005, Published by World Scientific, 411 (2005)
[4] Ph Bloch *et al*, *IEEE Trans. Nucl. Sci.* **NS-49**, 321 (2001)