Sensors for the Run IIb CDF Silicon Detector

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We describe the characteristics of Hamamatsu silicon sensors prototyped for CDF Run IIb silicon detector. In the prototype program, 116 micro-strip sensors have been fabricated. Five sensors were irradiated with neutrons up to 1.4×10^{14} cm^{-2}. The sensors have shown superior electrical characteristics in all the aspects, fulfilling our specifications.

1. Introduction

The CDF collaboration is building a new silicon tracker system for Tevatron Collider Run IIb, replacing the present L00 and SVXII detectors. The new silicon system will be a six-layer device located between 2.1 cm and 16 cm radius, consisting of 2300 single sided silicon microstrip sensors[1].

The main specifications are; (1) Sensors should be operational up to 500V, (2) Full depletion voltage should be in the range from 120 to 250V; (3) Dead channel fraction should be less than 1%; (4) Sensors should be uniform in coupling capacitance (>12pF/cm); bias resistance ($1.5 \pm 0.5 M\Omega$), interstrip resistance (< 1.2pF/cm), and other electrical properties. We have employed single sided p^+-on-n sensors with dimensions of 96.4 mm length and 40.6 mm width for axial and 41.1 mm width for 1.2° stereo sensors, so that two sensors can be taken from a 6" wafer. The readout pitch is 75 (80) μm for axial (stereo) sensors. Single intermediate strip is implemented to improve the position resolution.

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Prototypes of 63 axial and 53 stereo types were fabricated by Hamamatsu Photonics (HPK). We have performed detailed electrical characterization of 18 sensors for each type along with other more general tests such as I-V and C-V. The innermost sensor will receive radiation corresponding to 1.4×10^{14} 1-MeV eq neutrons/cm^2 in 30 fb^{-1} of data taking period. We have irradiated five sensors up to this fluence. The performance results of irradiated sensors are also reported.

2. Initial electrical characteristics

The I-V measurement results are summarized in Fig.1. The leakage currents are normalized to 20°C. Most of the sensors do not exceed 0.2 μA even at 950 V. Only two sensors out of 116 showed noticeable micro-discharge.

Scanning the individual strip current for the two leaky sensors, we found only one strip for each sensor is contributing to the large leakage. The micro-discharge onset voltage showed to shift higher as we repeat the I-V measurements.

HPK reported in total 21 defective strips for 14 sensors out of 116. Our full characterization for 36 sensors, including these 14 sensors, recognized all the defects reported by HPK. In addition, we found 5 implant opens and a pair of low bias resistors. The new 5 implant opens are due to that HPK testing is not sensitive to detect them. The low bias resistor pair is obviously due to a discharge caused probably at probing. The estimated dead channel fraction is 0.08% including these defects altogether.

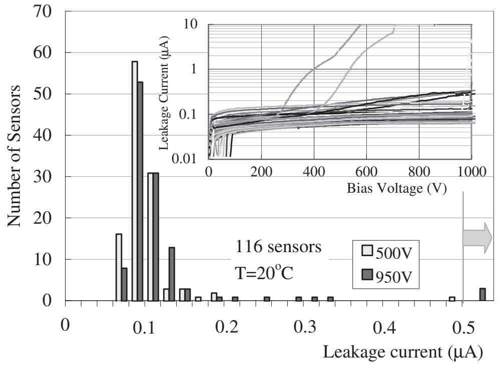

Figure 1. Leakage current distributions of 116 prototype sensors at 500 and 950V. The overflows are histogrammed on the extreme right. The inset is the I-V curves of all the sensors.

3. Electrical characteristics of irradiated sensors

The irradiation took place at MNRC Irradiation Facility at UC Davis. Three sensors were irradiated to 1.4×10^{14} /cm^2 and two to 0.7×10^{14} /cm^2.

The damage constant evaluated from five sensors is $(2–3)\times10^{-14}$ A/cm, being consistent with previously known value[2]. The I-V curves are good to 1000 V without showing significant micro-discharge.

The full depletion voltage was evaluated when the initial beneficial annealing is almost completed. It resulted to 100 V (40–50 V) for the sensors irradiated to 1.4 (0.7)$\times$ 10^{14} /cm^2, whereas 90 V (40 V) is an expectation from Rose parameterization[2] .

The capacitance between two neighboring readout strips is plotted in Fig.2. The data is for the two sensors irradiated to 1.4×10^{14} /cm^2. The curves show shoulders around 130 V corresponding to the full depletion voltages (note: these were measured at annealing conditions different to the above), then decrease gradually with the bias voltage. Though the asymptotic value is consistent with non-irradiated sensors, an excess bias of 200–250 V is required to reach the minimum. The interstrip resistance of >1 GΩ is achieved for a bias of 300 V.

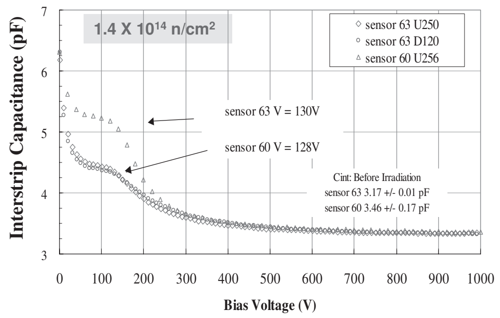

Figure 2. Interstrip capacitance of two irradiated sensors: one pair and two pairs for each.

4. Summary

We have evaluated the performance of prototype sensors for CDF Run IIb silicon detector. The electrical characteristics are superior in every aspects. The irradiated sensors also performed as expected. An excess bias of 200–250 V is required to recover the electrical performance.

REFERENCES

1. B. Flaugher (CDF Run IIb Silicon Group), These proceedings.
2. G. Lindstrom *et. al. (Rose Collaboration), Nucl. Instrum. and Methods A466 (2001) 308.*