Sensors for the CDF Run IIb Silicon Detector

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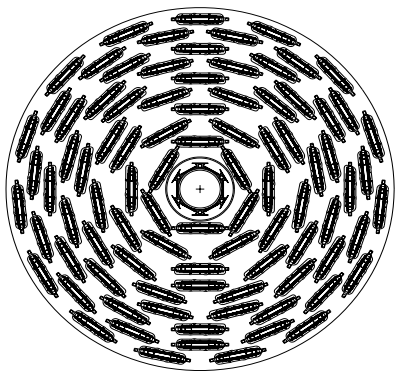
The CDF collaboration is building a new silicon tracker system for Tevatron Collider Run IIb, replacing the present L00 and SVXII detectors.

The lifetime of the present Run IIa detector is estimated to 4 fb^{-1}, while the expected luminosity for Run IIb is 5-15 fb^{-1}.

The new silicon system will be a six-layer device located between 2.1 cm and 16.6 cm radius, consisting of ~2300 single sided silicon microstrip sensors. The cross-sectional view of the new system is shown below. Each rectangular piece, called “stave”, is a self-supported 4cm wide and 60cm long object where cooling tubing is incorporated. Inner most is L0, where sensors are glued on a carbon fiber shell supported by the beam-pipe.



The whole silicon detector is 120cm long, consisting of two sets of such stave systems, or 180 staves in total.

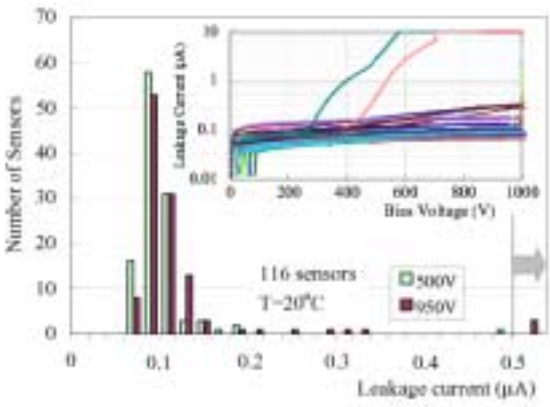
Three types of silicon sensors are used as listed in the Table. 93% are for the outer staves, where six sensors are glued on each side of the stave. L1 and L5 staves have axial strip sensors on both sides, while L2-L4 have axial and 1.2° stereo sensors.

*RO is double of these

Sensor type	dimensions	strip pitch	number
Outer (axial)	41×96 mm^2	37.5 μm*	1512
Outer (1.2°)	43×96 mm^2	40 μm*	648
L0 (axial)	15×78 mm^2	25 μm*	144

Prototype 63 outer axial and 53 stereo sensors were fabricated by Hamamatsu Photonics. The sensors are p^+-in-n single-sided processed on 6” wafers. Each sensor has 512 readout strips at a pitch of 75 or 80 μm. Single intermediate strip improves the spatial resolution with use of SVX4 chips.

We have carried out detailed quality assurance measurements on the prototype sensors. The test includes neutron irradiation up to $1.4x10^{14}$ 1-MeV eq/cm^2, corresponding to the fluence L0 sensors receive in 30 $fb^{-1}$of data taking period.



The quality assurance measurements have covered various electrical and mechanical properties. As an example, I-V results are summarized in the left plot: The leakage currents at 500V and 950V are histogrammed for all the sensors (current normalized at 20°C, over flows are shown in the right most). As can be seen also from the I-V curves, most of the sensors do not show significant leakage increase up to 1000V. Probing individual strips showed that only one strip is leaky for each of the two sensors showing micro-dishcarge.

C-V curves have shown that the full depletion voltages distribute from 115-142V for our specification of 120-200V.

Other electrical properties such as I-V curve stability, interstrip capacitance/resistance, and mechanical properties such as cutting-edge precision (<5μm), wafer thickness (320+/–5μm) are superior. The sensor is bowed by maximum of 100μm, which is also acceptable.

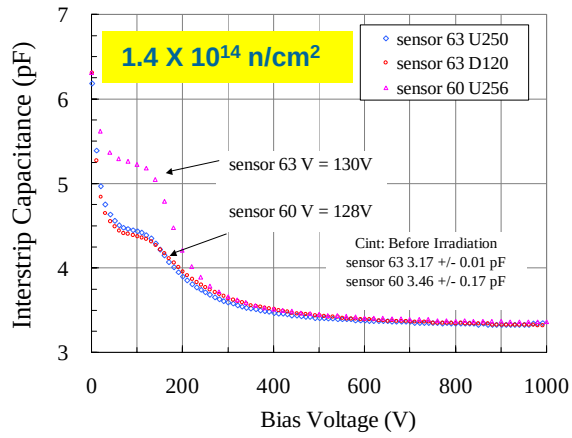
Intensive strip probing was carried out to check the manufacturer datasheet. 18 sensors were fully probed for each type of the sensors. The sample included all the sensors where Hamamatsu has found any defective strips. An LCR meter measured Cs-Rs between the AC pad and bias, providing the oxide capacitance and sum of bias and implant resistances. Also oxide leakage current was measured when 100V was applied for 1 sec.

HPK reported in total 21 defective strips for 14 sensors. Our strip probing 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 our probing. The estimated dead channel fraction is 0.08%.

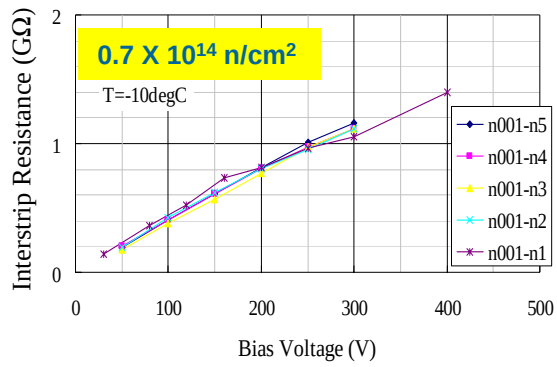
The radiation hardness is studied intensively by various groups such as for LHC experiments. We have irradiated three (two) sensors with neutrons to1.4 (0.7)x10^{14} 1-MeV eq/cm^2 to see if our sensors behave as expected.

The full depletion voltage evolution and leakage current increase turned out to be as expected: The full depletion voltage will be around 50V and the strip current be 0.2 μA at T=–5°C after 15 fb^{-1}.

The bias voltage dependences of the interstrip capacitance/ resistance and bias resistance were also measured. The left plot shows the interstrip capacitance measured for the samples irradiated to 1.4x10^{14} n/cm^2.
The shoulders at around 130V are due to full depletion. Then the interstrip capacitance decreases gradually with the bias, reaching the value consistent with the pre-irradiation value. An excess voltage of 200V is required to reach the asymptotic value.



The bias resistance was also found to require a similar bias voltage to recover to the asymptotic value. The interstrip resistance is also voltage dependent and a bias of 300V is required to become 1GΩ (see the plot below).



Conclusions:

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

We will also report new results for the production sensors which will be delivered from June.