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# Intermediate silicon layers detector for the CDF experiment

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**Abstract**

The Intermediate Silicon Layers (ISL) detector is currently being built as part of the CDF II detector upgrade project. The ISL detector will significantly improve tracking in the central region and, together with the Silicon Vertex detector, provide stand-alone 3D track information in the forward/backward regions. In this article, we present the quality of the production sensors manufactured by Hamamatsu Photonics, which account for roughly half of the silicon sensors used in the ISL detector. © 2000 Published by Elsevier Science B.V. All rights reserved.

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## 1. Introduction

The CDF detector at Fermilab Tevatron Collider is currently being upgraded to CDF II [1] to take full advantage of 10-fold increase in luminosity. The Intermediate Silicon Layers (or ISL) detector is one of the three new silicon detectors. It is constructed from five barrels in total, one central barrel and a pair of inner and outer barrels in forward and backward regions, and covers the region $|\eta| < 2$ and $r = 20$–$29$ cm. Together with the new Silicon Vertex detector (SVX-II) installed inside it, the ISL detector will provide stand-alone 3D track information in the forward/backward regions.

The ISL silicon sensors are double-sided AC coupled microstrip detectors made from high-resistivity n-type silicon bulk material with atoll p-stops to isolate strips on the n-side. Each sensor has 512 readout strips of 112 μm pitch on either side and a small stereo angle of $\sim 1.2°$. Sensors on the central and inner barrels are fabricated by Hamamatsu Photonics KK (HPK) on 4″ wafers [2] and have an active area of $5.7 \times 6.7$ cm$^2$ per side, while those on the outer barrels are produced by Micron Semiconductors Ltd., using 6″ technology [4] and have an active area of $5.7 \times 7.5$ cm$^2$.

The ISL *half ladder* module is made of three such sensors ganged together to form a single electrical unit and is glued on a carbon fibre support. The readout hybrid is mounted off silicon and is glued on the edge of the support. Two half ladders make up a full-ladder module, and 28, 24, and 36 of these modules are mounted on each of the central, inner, and outer barrels. The numbers therefore add up to 148 ladders and 888 silicon sensors.

The overall design and some components of the ISL detector have already been described in Refs. [2–5]. In this article we review the quality of the HPK sensors. (Table 1)

Table 1
Some important electrical specifications for the HPK silicon sensors

| | |
|---|---|
| Full depletion voltage | $< 100$ V |
| Leakage current at 20°C | |
| $I$ at $V_{\text{bias}} = 140$ V | $< 4$ μA |
| $\Delta I$ ($V_{\text{bias}} = 100$–$130$ V) | $< 1$ μA |
| No. of dead channels | |
| Total | $< 2\%$ |
| Per side | $< 3\%$ |

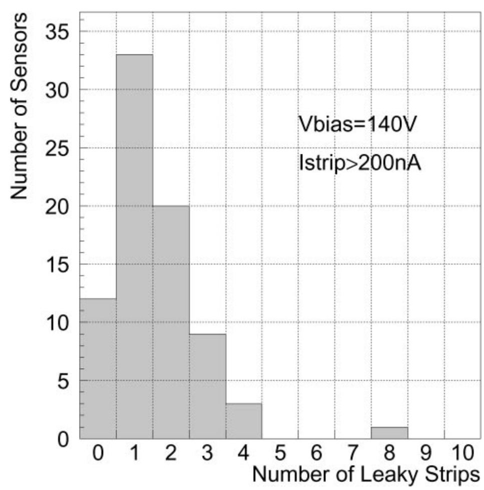


Fig. 1. Number of leaky strips in Grade B sensors.

## 2. Leakage current

While studying the prototype sensors [2] it was noted that the $I$–$V$ characteristics of sensors vary among production batches and in order to assure a wide range of stable operation voltages we require a plateau in the region above the full-depletion voltage. This is specified as the difference in leakage current $\Delta I$ between $V_{\text{bias}} = 100$ and 130 V and was initially set to 300 nA (Grade A sensors).

However, the yield of the HPK Grade A sensors was not as high as we hoped and we revised the specification in January 1999, when we had received about 10% of the production sensors from HPK. We have examined some of the production sensors using a semi-automatic probe station at the University of Tsukuba to investigate the problem and found that the large leakage current increase is due entirely to only a few bad strips that develop micro-discharge at an early stage. As Fig. 1 shows, the number of leaky strips (defined as strips drawing more than 200 nA at $V_{\text{bias}} = 140$ V) is not large – only one or two isolated strips contribute to the

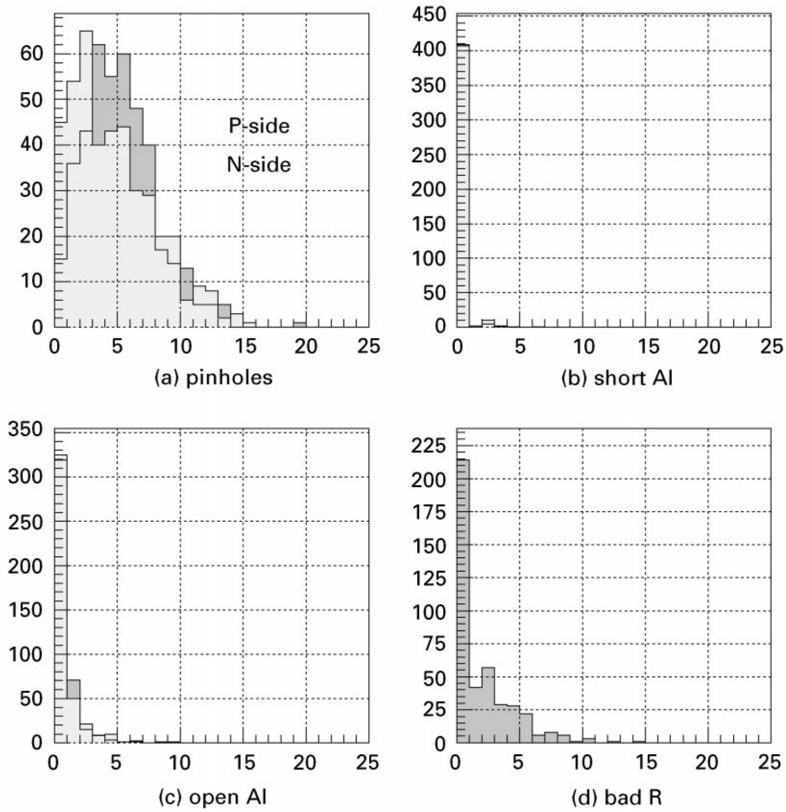


Fig. 2. Number of dead channels.

increase. We have decided to count these leaky strips as *dead* and accept sensors (as Grade B sensors) if their $\Delta I$ values are less than 1 $\mu$A, provided they pass all other specifications including the number of dead channels.

After the specification was loosened a little, the production yield went up by as much as 38% [1] and at the time of the conference 78% of the sensors had been delivered to Fermilab.

## 3. Dead channels

The statistics of dead channels (excluding leaky strips for Grade B sensors defined in Section 2) is shown in Fig. 2 in four categories: faulty coupling capacitors (i.e., pinholes), shorts on $A\ell$ traces, open $A\ell$ traces, and bad poly-Si bias resistors. Most of the dead channels are due to faulty coupling capacitors and contributions from bad $A\ell$ traces are quite small. Bad poly-Si bias resistors include both faulty resistors (large R) and bad isolation to the implant strips nearby (small R). Measurements for bias resistors are only available on the p-side where we can bias the n-strips from the p-side through a dedicated n-electrode implanted on the p-side.

## 4. $^{60}$Co$\gamma$ irradiation

Three Grade B sensors were irradiated with $\gamma$ rays from a $^{60}$Co source to 0.2 Mrad. The electrical characteristics of the sensors were measured

[1] In the end Grade B sensors came out to be about 20% of the total.

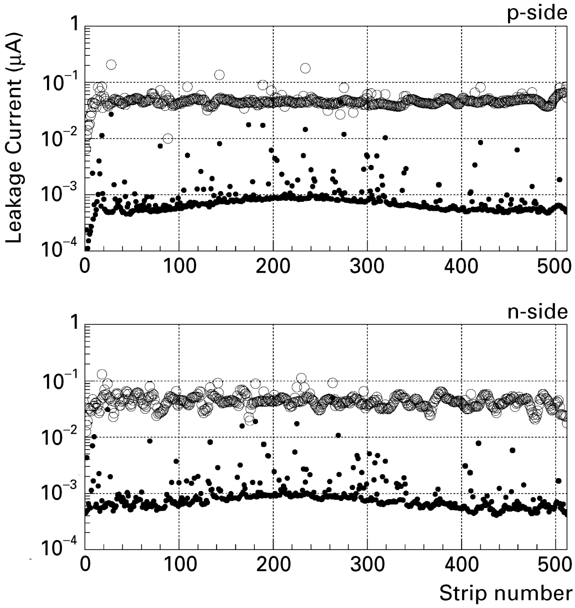


Fig. 3. Leakage current at $V_{\text{bias}} = 140$ V before (●) and after (○) 0.2 Mrad $^{60}$Co $\gamma$ irradiation.

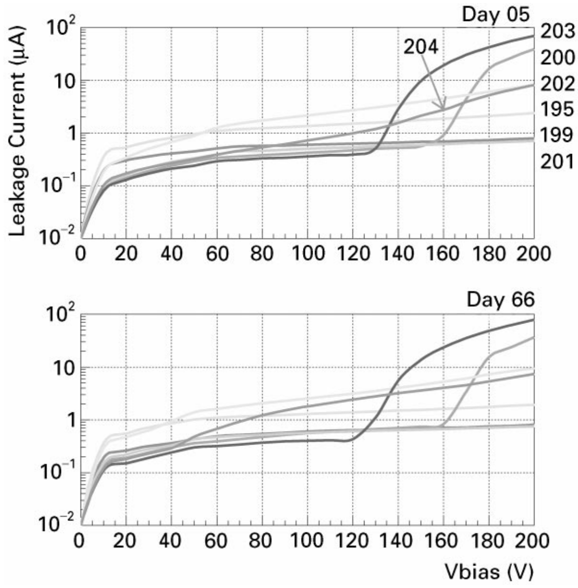


Fig. 4. $I$–$V$ on day 5 (top) and day 66 (bottom).

before and after the irradiation. Fig. 3 shows the leakage current of one of the sensors for each strip before and after the irradiation. The current of good strips increased from 1 to 50 nA and that of leaky strips remained leaky but no additional radiation-induced increase was observed. Moreover, there was no obvious effect on neighbouring strips.

The ISL sensors will not receive more than 0.1 Mrad of radiation for an integrated Tevatron luminosity of 10 $\text{fb}^{-1}$, so we do not expect them to undergo type inversion throughout their lifetime.

## 5. Long-term stability

A total of seven sensors of varying $I$–$V$ characteristics were burned at 120 V for 3 months at 20°C to see the long-term stability of these sensors as well as the possible differences between them. These sensors all fail the criteria on the number of dead channels but sensors 199, 200, and 201 are otherwise good to be Grade A while sensors 195 and 202 are good to be Grade B. Even sensors 203 and 204, which failed the $\Delta I$ criteria on day 0, are quite stable after a few days of burn-in.

Fig. 4 shows the $I$–$V$ curves of these seven sensors measured on day 5 and day 66. Both Grades A and B sensors show no noticeable difference between the two measurements.

## 6. Detector assembly

At the time of the conference, ladder assemblies had just been started at the two sites, Fermilab for the HPK sensors and Pisa for the Micron sensors. Right now, we have more than 100 half-ladders assembled and both half- and full-ladders productions are very well on schedule.

## 7. Conclusion

ISL silicon sensors are fabricated by Hamamatsu Photonics using 4″ technology and Micron Semiconductors using 6″ technology. We have examined the quality of the HPK production sensors. Using Grade B sensors we have evaluated the performance of the sensors under radiation environment as well as their long-term stability.

ISL detector should be ready for SVX installation in June 2000, and for physics run in March 2001.

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