Development of Radiation tolerant Silicon microstrip sensors of n- and p-single-sided readout on n-bulk Silicon waters

Y. Unno\textsuperscript{a}, T. Kohriki\textsuperscript{a}, T. Kondo\textsuperscript{a}, S. Terada\textsuperscript{a}, Y. Ikegami\textsuperscript{a}, T. Ohsugi\textsuperscript{b}, Y. Iwata\textsuperscript{b}, R. Takashima\textsuperscript{c}, I. Nakano\textsuperscript{d}, K. Hara\textsuperscript{e}, Y. Hayama\textsuperscript{f}, K. Yamamura\textsuperscript{f}, K. Yamamoto\textsuperscript{f}

\textsuperscript{a}Institute of Particle and Nuclear Studies, High Energy Accelerator Research Organization (KEK), Tsukuba 305-0801, Japan

\textsuperscript{b}Physics department, Hiroshima University, Higashi-Hiroshima 739-8526, Japan

\textsuperscript{c}Education department, Kyoto University of Education, Kyoto 612-0863, Japan

\textsuperscript{d}Physics department, Okayama University, Okayama 700-8530, Japan

\textsuperscript{e}Physics department, Univ. of Tsukuba, Tsukuba 305-8571

\textsuperscript{f}Semiconductor division, Hamamatsu Photonics Co. Ltd., Hamamatsu 435-8558, Japan
n-strip readout single-sided sensor

- N-side microdischarge breakdown

  n-side requires an isolation structure between n⁺ readout strips: p-stop structure

  Bulk is p-type, after heavy irradiation

  Main p-n junction in the n⁺ strips

  After irradiation, accumulation of positive oxide charge creates conductive accumulation layer in Silicon

  Edge of p-stop is where the electric field concentrate and defect initiates microdischarge

**Passivation with Oxide over the surface is not drawn in the figures**
Microdischarge at the p-stop edge

Individual (atoll) p-stop

Red: Hot spot viewed with a highly sensitive IR camera
• Novel p-stop structure

Extended Polysilicon dc-coupled plate over the p-stop structure

![Image of p-stop structure and polysilicon dc-coupled plate]

Polysilicon - high resistivity not to deteriorate the interstrip capacitance
p-strip readout single-sided sensors

- p-in-n sensors after irradiation

Main p-n junction moved to the backside -- still work
p-side, after heavy irradiation, is the ohmic contact
Positive oxide charge keeps the Silicon in n-type
No need of an isolation structure between p⁺ strips
Large bias voltage creates high electric field at the edge of p⁺ strips, and hence, microdischarge
ATLAS98 p-in-n Silicon microstrip sensor

- 6.36 x 6.40 mm², 80 µm pitch, AC-coupled

Strip marks (10 µm height)) and strip numbers (25 µm height)
(o: every 10, +: every 100)

Unit: µm

Fiducial marks
Mark A
Mark B
Mark C
Mark D

DC contact pads
Edge contact pads
Bias pads
Bias ring
Labeling pad
Identification pads

Note:
1. Pad sizes: a = 56 µm x 200 µm, b = 80 µm x 550 µm, c = 50 µm x 60 µm
2. Fiducial marks A & B are "metal-in-opening"
3. Fiducial marks C & D are either "hole-in-metal" or "metal-in-opening"
4. Bonding pads of strip 0 and 769 are required if the metal is not connected to the bias ring permanently
5. Use "Row C" pads for probing
6. Dicing tolerance: ±25 µm to fiducial marks and ±25 µm overall
ATLAS98 variants

- ATLAS SCT uses the AC-coupled p-in-n sensors in the configuration that the p-implant and the readout metal are in the same potential, namely ground

This allows to use the readout metal to move the electric field concentration from the edge of the implant to the edge of the metal in the oxide

4 variants: narrow metal, narrow Polysilicon, wide metal, wide polysilicon

Note: All dimensions are of finish
Passivation layer is excluded
Irradiation

- Narrow metal or narrow Polysilicon

![Leakage Current Characterization graph](image1)

- 3x10^{14} p/cm^2

![Leakage Current Characterization graph](image2)

- 1.5x10^{13} p/cm^2
Irradiation (cont’d)

- Wide metal

![Graph showing leak current vs bias voltage for wide metal detectors.]

![Graph showing leak current vs bias voltage for specific detectors labeled 837, 334, 948, 836, 843.]

- After irradiation and anneal, leak current increases with bias voltage.

- Detectors in metal boxes show higher leak current.

- Temperatures range from -10°C to 10°C.
Summary

• We have succeeded to suppress microdischarges in the n-in-n and p-in-n Silicon microstrip sensors, after the irradiation of $3 \times 10^{14}$ protons/cm$^2$

• Our key concept is to have an extended electrode over the edge of the implant in the Silicon, where the electric field gets strong enough to generate the microdischarge, specially the early ones associated with defects, so that the strongest field is inside oxide

• In the n-in-n sensors, DC-coupled Polysilicon over the p-stop structure

• In the AC-coupled p-in-n sensors, when the potential of the implant and the metal is the same, wide AC metal over the p-implant strip