A Double-Metal Silicon Pad Design for the PHENIX Multiplicity/Vertex Detector

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Abstract

The two endcaps of the PHENIX Multiplicity/Vertex Detector are comprised of twenty-four wedge-shaped silicon pad detectors.. The performance of a double metal pad detector designed for these endcaps is described.

1. THE MULTIPLICITY/VERTEX DETECTOR

The PHENIX Multiplicity/Vertex Detector[1] (MVD) is a 35,000 channel device comprised of two layers of silicon strip detectors in the central barrel (112 detectors total), and 24 silicon pad detectors on two endcaps. The MVD will be installed into the PHENIX experiment at The RHIC Collider in early 1999. The main physics goals of the detector are to provide a multiplicity measurement, $dN/d\eta$, to the PHENIX Level-1 trigger and to measure fluctuations within the multiplicity distribution on an event-by-event basis. The detector has full azimuthal coverage with good granularity and is capable of reconstructing the collision vertex to better than 2 mm.

2. SILICON PAD DESIGN

Each 30 degree wedge-shaped pad detector is comprised of 252 elements which are arranged in 12 columns by 21 rows. The layout is shown in Figure 1. The individual pad elements vary in area from 2 mm x 2 mm at the inner radius of the detector, to 4.5 mm x 4.5 mm at the outer radius of the detector. The area of the pads is a function of distance from the beamline, and scales with the anticipated angular distribution of particles incident on the endcaps. The height of the detector from the inner to the outer radius is 72 mm. In a gold-on-gold central collision at RHIC, the average occupancy of the detector will be on the order of 40%.

The detectors are single-sided, ac-coupled detectors. The dielectric oxide is 200 nm thick. The biasing of the detector is through polysilicon resistors, The average value of the resistors is 5 MΩ. The bias resistors are distributed between alternate rows of pads, within a 300 μm wide gap, connecting to the pads that are located above and below the gap. The gap between pads in adjacent columns is 200 μm. There are two guard rings on the detector. The first ring is placed close to the pads, inside of the bias line. The second ring is placed between the bias line and the cut-edge of the detector.

We have prototyped the detector geometry in both a single-metal and a double-metal process. The detectors were manufactured by Micron Semiconductor Ltd[2]. The single-metal design requires an additional element, a kapton trace router, which would be glued and wire-bonded to the detector to bring the pad output signals to the outer radius of the wedge. The double-metal process incorporates this feature directly on the detector itself. It is a major advantage to avoid the extra assembly step associated with the single-metal design. The potential disadvantage of using the double-metal design is the possibility of additional crosstalk induced into a given pad by the signal trace that is running directly over it. To minimize this possibility, we have made the silicon dioxide layer that separates the two metal layers as thick as possible; 4 μm thick.

3. TEST RESULTS

The dc characteristics of the single, and double-metal detectors are very similar. Typical individual I/V characteristics show nearly ideal diode behavior. The leakage current varies from about 400 pA in the smallest pads, to about 1 nA in the largest pads. The C/V characteristic of individual pads indicate a full depletion around 30 volts. The pad capacitance at full depletion ranges from 3 pF for the small pads to 10 pF for the large ones.

The single-metal detector exhibited a problem with low interpad resistance in the center region of the detector. This region is where the polyimide environmental coating is deposited before being spun over the detector surface. We suspect that the low resistance is a result of some processing flaw associated with this polyimide deposition. In fact, we have measured very low interstrip resistance in the central region of several strip detectors which were provided by the same manufacturer, and also coated with polyimide. The double-metal design does not have this coating, as the surface of the detector has the thick isolation oxide over it. The measured interpad resistance on this design were normal.

We used a focused 1064 nm laser with automated x-y control[3], to measure the ac response of the silicon pads. In Figure 2 an output response is shown. A single MIP corresponds to about 300 mV. In the display, the upper trace is the output of the incident pad, while the lower trace is the time-coincident output from a non-adjacent pad, which is in the same column as the incident pad, and therefore has the second-metal trace from the incident pad running directly over it. The crosstalk for a 150 mV incident signal was not measurable, while for a 300, 400 and 800 mV signal, it is on order 3.5%. This number includes the crosstalk that is present from the readout cable and the amplifier chip, as well as pickup from the logic edge that fires the laser, and so, is an upper bound. We are currently implementing a radioactive source telescope for additional testing.

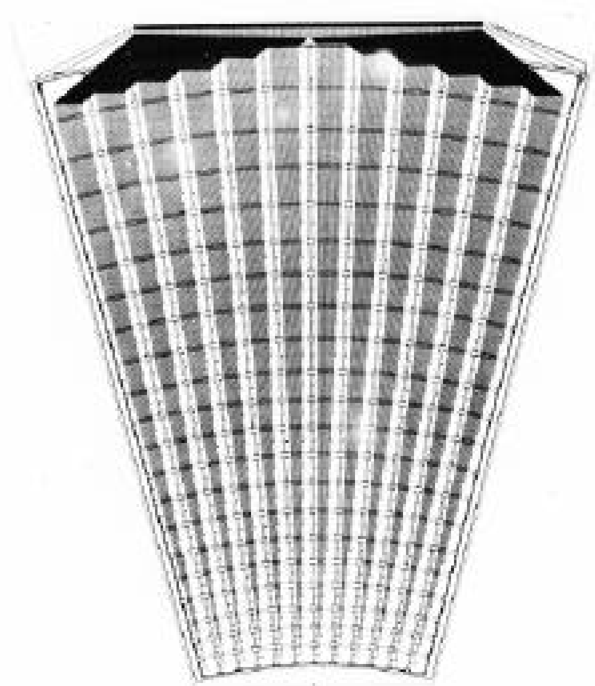

Figure 1. The double-metal pad detector layout.

4. SUMMARY

A 252 element pad detector design has been prototyped in both a single, and double-metal process. The dc characteristics of each design are similar, with the exception of some low interpad resistance measured on the single-metal detector which we suspect is caused by a processing flaw in the polyimide environmental coat. The upper bound that was measured for the crosstalk induced into a pad from a trace running over it with an active signal, is 3.5%. This level is acceptable for the performance requirements of the MVD endcaps.

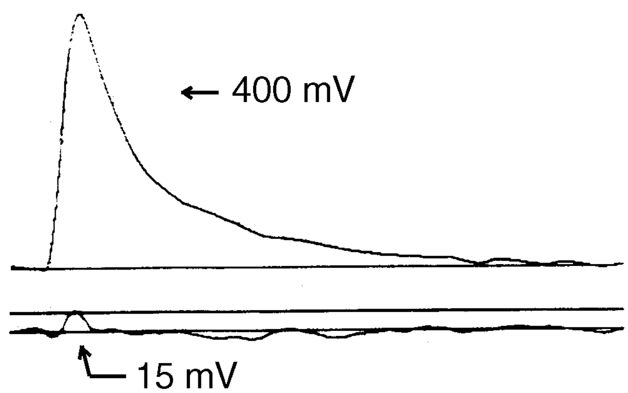

Figure 2. Detector response to a focused 1064 nm laser.

REFERENCES

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[3] "Characterization and Quality Control of Silicon Microstrip Detectors with an Infrared Diode Laser Station," S. Shaheen et. al., Nucl. Instr. and Meth. A 352 (1995), p.573.

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