Silicon sensor quality assurance for the D0 RunIIb silicon detector: Procedures and equipment

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Abstract

This documents describes in detail the quality assurance (QA) program for the D0 RunIIb silicon sensors. The scope of the QA program, the responsibilities of the participating institutions and the measurement procedures are defined.

1. Introduction

For the extended run of the Tevatron collider at Fermilab, called RunIIb, the D0 collaboration is building a new silicon tracker system. It will be a six layer device, consisting of ~2400 single sided silicon sensors located between 1.7 cm and 16 cm radius. The planned silicon detector is expected to become operational in early 2005 and continues to take data until 2007/8.
A thorough, reliable, and efficient silicon sensor probing and characterization, defined in a well-organized silicon quality assurance (QA) program, are critical for the sensor quality and hence the success of the silicon detector. This document describes the procedures, responsibilities and the organization of the silicon sensors quality control for RunIIb. In particular this includes:

- Organization and responsibility of testing
- Testing procedures and acceptance criteria
- Testing setups
- Accounting, documentation and database

The QA program as defined in this document is based on testing procedures for ATLAS SCT sensors, CMS silicon sensors and the gained experience from our D0 RunIIa SMT sensors. It is the result of many discussions within the D0 RunIIb silicon group.

2. General D0 RunIIb silicon sensor QA organization issues

Quality assurance will be a collaborative effort and is shared among different institutes. The institutes, which are participating in the QA program, provide for silicon sensor testing centers, where the quality checks of the QA program have to be carried out in a consistent manner. It will be the task of each participating institute that the QA procedures -as defined in this document- are established and the QA program is exactly followed. The responsibility for the complete QA program implementation will be the task of the local coordinator of each testing center. Before a testing center will start to take part in the silicon QA program, it has to be certified by one of the two RunIIb silicon sensor coordinators.
Presently we foresee four institutes as testing centers with the following local coordinators:

- CINVESTAV, Mexico City, Mexico. Local coordinator: Heriberto Castilla
- Fermilab, Batavia, USA. Local coordinator: Ron Lipton (?) and N.N.
- Kansas State University, Manhattan, USA. Local coordinator: Regina Demina
- State University of New York, Stony Brook, USA. Local coordinator: NN

Fermilab will serve as a central distribution and control center with dedicated testing and coordinating tasks. Its main tasks will be:

- The initial registration of the sensor
- Visual inspection on sensors
- The distribution of the sensors to the three other testing centers
- The performance of an additional sensor characterization measurement program on sensor sub-samples, as described in this document
- The shipping and handling of the rejects which are returned to the supplier
- The overall monitoring of the QA program
- The final acceptance and grading of the sensors

The last two items are also coordinating and managing tasks and their completion will be the responsibility of the two appointed Run2b silicon sensor coordinators together with the local coordinator(s) at Fermilab.
In case of testing backlogs at the testing centers, Fermilab will run the standard QA testing program as well. In addition there are two further institutes, which will serve as backup testing centers:

- Moscow State University, Moscow, Russia. Local coordinator: Michael Merkin
- University of Zurich, Zurich, Switzerland. Local coordinator: Frank Lehner

Figure 1 shows a graphical representation of the QA program with the silicon sensor flow.

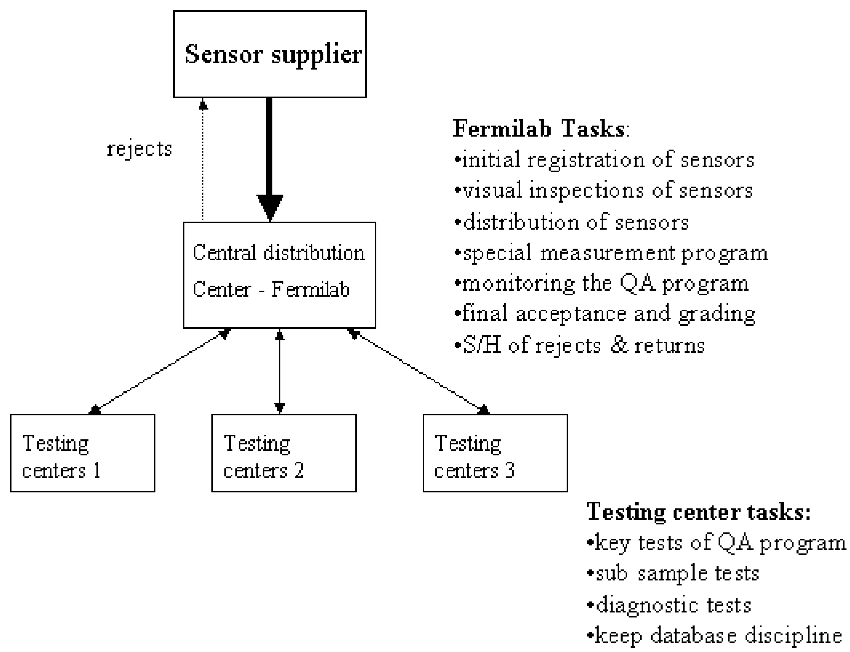

Figure 1: A graphical representation of the QA organization and silicon sensor flow.

3. Overview of sensor design, specifications and terms of acceptance

3.1. General

All silicon detectors are p+n type single sided sensors, with AC coupling and biased through polysilicon resistors. The silicon sensors will have either multi-guard structures or a single-guard ring with peripheral n-well design as designed by Hamamatsu. We envision three sensor types for RunIIb:

Layers	Active Length (mm)	Active Width (mm)	Strip pitch /readout pitch (μm)	# readout channels	# of sensors + spares
0	77.36	12.8	25/50	256	144+50%=216
1	77.36	22.272	29/58	384	144+50%=216
2-5	98.33	38.34	30/60	639	1896+20%=2280

Layer 2-5 will be entirely manufactured on 6''-wafers. Layer 0 and 1 sensors are compatible with a production on 4'', 5'' or 6'' wafers.

Detailed mechanical drawings of the sensors, on which the location of strips, fiducial marks, bonding and testing pads as well as the strip numbering definition and other features are indicated, exist on the Fermilab based NT-server d0server4.fnal.gov in the directory projects/run2b/silicon/sensors. The sensors carry a multiple-field scratchpad for unique sensor identification, vendor information and for QA pass/fail marks done by the testing centers.

3.2. Specifications

The detailed sensor specifications are attached in the appendix of this note. The following table gives an overview:

Specifications:	**Layer 0/1**	**Layer 2-5**
Wafer thickness	320±20μm, wafer warp less than 50μm	320±20μm, wafer warp less than 50μm
Depletion voltage	V<300V	V<300V
Leakage current	<100nA/cm2 at RT and FDV+10%V, total current < 4μA at 700V	<100nA/cm2 at RT and FDV+10%V, total current < 16μA at 350V
Junction breakdown	>700V	>350V
Implant width	7μm	8μm
Al width	2-3 μm overhanging metal	2-3 μm overhanging metal
Coupling capacitance	>10pF/cm	>12pF/cm
Coupling capacitor breakdown	>100V	>100V
Interstrip capacitance	<1.2pF/cm	<1.2pF/cm
Polysilicon bias resistor	0.8±0.3 MΩ	0.8±0.3 MΩ
Not working strips	<1%	<1%

3.3. Terms of acceptance

The silicon distribution and control center (Fermilab) will initially accept the silicon sensors delivered by the suppliers and preliminary qualify them as good according to the test results of the supplier, if the criteria described in the sensor specifications are fulfilled. So-called key sensor tests of the QA program will be carried out independently on every delivered sensor for verification at the testing centers. In addition and only for a sub-sample of the delivered sensors, more measurements of the QA program will be performed to confirm the specifications. Based upon the results of these measurements, the silicon distribution and control center will reject a sensor within 6 months after delivery. The manufacturer will be notified and upon request the sensors will be returned for re-measurements. Both parties – the supplier and the silicon control center together with the Run2b silicon sensor coordinators - can agree upon the acceptance of individual sensors if specifications are missed only marginally.

4. The QA program

We describe now the complete QA program for the RunIIb silicon sensor testing. The QA program consists of four main parts:

1. The so-called silicon sensor key tests have to be performed on every received sensor. The measurements/procedures belonging to this QA part are the most important ones to effectively determine the basic sensor parameters.
2. The so-called sensor subset tests will be conducted on a certain fraction of delivered sensors only. The main goal of the subset tests is to verify the specifications more in detail. The fraction of sensors, which is subject to these tests, depends on if either prototype or production type sensors are considered. The subset tests are mostly done in an automatic measurement procedure on an automatic probe station.
3. The diagnostic tests should be performed on random sensor samples as well as on sensors with observed irregularities in the key or subset sensor tests. The diagnostic tests measure in much more detail complex electrical parameters in order to get a deeper insight into the sensor qualities and to monitor the production process. The diagnostic tests should be routinely performed on 10-15% of the delivered sensors per batch with a minimum of 1-2 sensors/batch.
4. The mechanical test measurements are introduced to verify the mechanical tolerances on the wafers. They should be routinely performed on roughly a quarter of the delivered sensors (~25%) per batch.

4.1. General conditions/requirements of testing/probing

4.1.1. Clean Room conditions and handling of sensors

A clean room or a clean room housing with temperature (21 +/- 2^{o}C) and humidity (50+/-10%) control is necessary at the testing centers. The recommended test and laboratory equipment is mentioned in chapter 7 of this document.
Before handling prototype or production type sensors at the testing centers, a certain amount of practice and experience of the testing personnel is required. Protective clothes masks and gloves shall be used always near exposed silicon detectors. Vacuum tweezers should be used when lifting the sensors. The sensors should only be stored in dry storage container containers.

4.1.2. Testing conditions

All electrical tests should be carried out at a temperature and humidity controlled environment. The electrical tests are made in a light tight dark box. To contact the sensors for probing, the tip of the probes should be put on special contact pads, which are not used for production bonding during the assembly process (except bias line contact pads). Such test pads or probe pads (either AC- or DC-pads) are indicated on the mechanical sensor drawings available for each sensor type on d0server4. The chuck of the probe station can be covered with a special conductive rubber film during the measurements. It prevents any damage on the sensor's backside during the positioning of the sensor on the chuck.

4.1.3. Database usage

A general database system for parts and components as well as for production and assembly is being prepared at the University of Illinois at Chicago (UIC). The database will provide the sensor identification, tracking, location and quality information records of each silicon sensors. It is important that every testing center will get familiar with the database and its structure so that every registering of new silicon detectors, every checkout of sensors and every measured quality control information is recorded in the database. Any data base record based on mechanical or electrical measurements of the QA program should contain the following items:

- Measurement data
- Temperature/humidity
- Date
- Testing center
- Comments

A certain amount of database discipline is mandatory to make the big enterprise of building and testing a new silicon detector within a rather short time scale to a success.

4.2. Key sensor tests performed on every sensor

The key sensor test program contains the most important quality control tests of the QA program. They have to be carried out on every sensor, which arrives at the central distribution center at Fermilab shipped out by the vendors. The key sensor tests include an initial registration of the sensor in the database, a visual inspection and I-V and C-V measurements.

4.2.1 Initial registration into the database

This task is done at the central distribution center at Fermilab. The shipment of the sensor batch is checked for the content and the necessary paperwork. It has to be verified, that also the test structure pieces are available. The data provided by the supplier either in computer readable format or in written format has to be verified for completeness and consistency with the specifications. Check the paperwork for:

- serial ID-number of sensor
- batch/lot number
- wafer thickness
- leakage current values
- depletion voltage

- number of bad channels/strips as claimed by vendor
- polysilicon resistor value
- coupling capacitor breakdown
- other measurement information based on teststructures

If the supplied data by the vendor are within specs, a new entry for silicon sensor objects in the database containing serial number, arrival date and present location, has to be created. In addition, this new entry has to contain all the vendor information above. The sensors are now ready for visual inspection. In case of missing information/paperwork or in case the supplied information do not fulfill the specifications, the sensors are set in the database on a special reject list or table and, after discussion with the Run2b silicon sensor coordinators, are sent back to the vendor.

4.2.2 Visual inspection

A visual inspection on all arrived sensors is another key sensor test, which will ensure that the sensor is free from physical defects and scratches. The results of the visual inspections in case of sensor flaws should point to the strip regions or guard/bias ring regions, which look bad and doubtful, so that further electrical measurements have to be conducted. If sensor edges are bad, then the sensor should be passed to the mechanical measurements after the visual inspection.
The visual inspection is carried out at the central distribution center at Fermilab on a x-y moving table equipped with a microscope having high magnification optics (5x-50x). A video camera hooked up to the microscope as well as a video monitor and video printing possibilities are necessary.

Procedure for visual inspection:
1. Ensure that the x-y table is completely clean and clear of any debris.
2. Remove sensor from its envelope/shipping container.
3. Search for any signs of silicon debris in the sensor envelope or within the shipping box. If debris is present, be sure to remove it before eventually returning the sensor to the envelope, and identify the source of the debris during the visual scans of the sensor.
4. Examine the back surface by eye. Take note of any blemishes or scratches.
5. If there are indications of edge chipping, place the sensor on the probe station chuck (with the sensor still strip-side down on the card) and measure the width of the chipping. Take a picture if appropriate.
6. Remove the sensor from the chuck.
7. Place the sensor on to the probe station chuck again, with the strip side facing upwards.
8. Check that the serial number scratched on the identification pads matches the serial number on the sensor envelope.
9. At high magnification, scan along all four edges, searching for edge chipping, scratching or other damage.
10. Check the visibility and quality of the fiducial marks
11. With the same high magnification, scan along the bias resistors, searching for breaks, signs of processing defects or non-uniformity.

12. Scan along the AC-bonding pads (the ones which will be used for hybrid bonds) and verify that they are clean and not probed.
13. At lower magnification, scan the full area of the sensor, taking note (and taking pictures where appropriate) of blemishes, scratches or other non-standard features.
13. Update the database, that visual inspection has been done and type in your comments and findings.

Acceptance:

The sensor should be flagged as having failed in the database, if any edge chipping (front or back) exceeds 50µm, or if there is severe scratching or other gross defects, or there are signs of a processing abnormality. If in doubt, select the sensor for a full strip test to confirm any defects electrically.

4.2.3. C-V Curve and Sensor depletion voltage determination

This measurement is done at the testing centers on every arrived sensor and requires an LCR-meter with an external bias adapter and a voltage source. Place the sensor with the backside on the chuck of a probe station and contact the bias rail with a probe needle. Connect the probe needle to the GND of voltage source and to L-output of the LCR-meter through the external adapter. Connect the chuck to the high voltage output of voltage source and to H-output of LCR-meter through the external adapter. Measure and record the capacitance in 10V steps up to 350V (for L0&L1) or up to 200V (for L2-L5), with a 10 second delay between steps. Use 1 kHz or 10kHz with CR in SERIES mode. See the schematics of this measurement in Fig.2. In order to determine the full depletion voltage (FDV), we recommend plotting $1/C^2$ versus bias voltage. The depletion voltage is then determined as the intersection of two straight lines.

The obtained depletion voltage value together with the date of the measurement and the measuring testing center has to be recorded into the database. Moreover, the raw data file, containing the measurement values, should be uploaded into the database.

Acceptance criteria:

- Full Depletion Voltage (FDV) is in the region 40÷150V for L2.
- FDV is in the region 60÷300V for L0&L1.

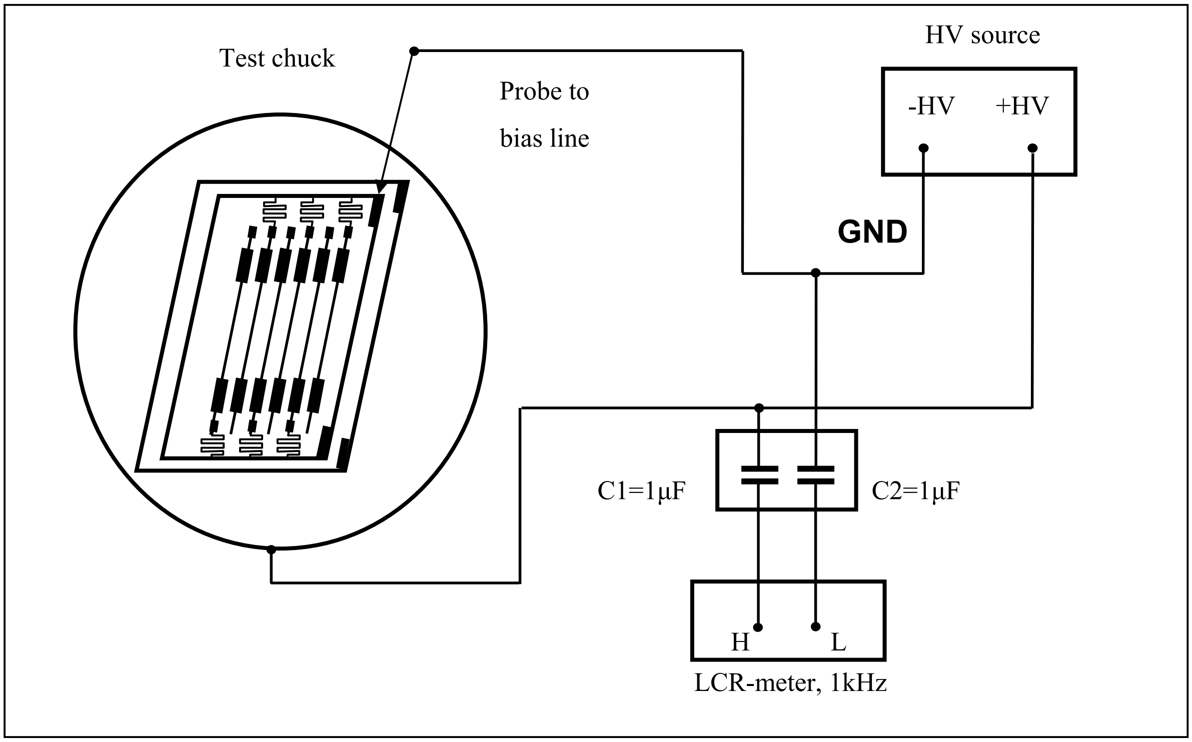

Fig.2: The setup for the depletion voltage measurement with the C-V method.

4.2.4. I-V Curve and leakage current determination

This key-measurement is carried out at the testing centers for every sensor as well. The test requires a power supply and a pico-Amperemeter. The best choice is a source measurement unit (SMU) such as a Keithley-487/237. The sensor backside is placed on the chuck of a probe station and probe needle is put on the bias line contact pad. The I-V characteristic between the bias rail and the backside is measured using the SMU. The current is measured every 10V step up to 800V (for L0&L1 sensors) or up to 500V (for L2-L5 sensors), with a 5 second delay between steps. A current limit of 50µA is imposed throughout the measurement. The temperature of the probe station environment should be recorded as well. The measurement schematic is sketched in Figure 3.

The obtained leakage current values at the following 5 voltage values

- 100V, 200V, 300V, 400V, 500V for L2-L5
- 100V, 250V, 400V, 650V, 800V for L0&L1

have to be stored in the database.

Acceptance:

- bias current is generally below 100 nA/cm^2 at 1.1×FDV and R.T. (for L0,L1,L2-L5)

- L0: 1 μA at FDV+10%FDV
- L1: 1.7 μA at FDV+10%FDV
- L2-L5: 3.8 μA at FDV+10%FDV

➢ bias current is below 4 μA at 700V (for L0, L1) or below 16 μA at 350V (for L2-L5).

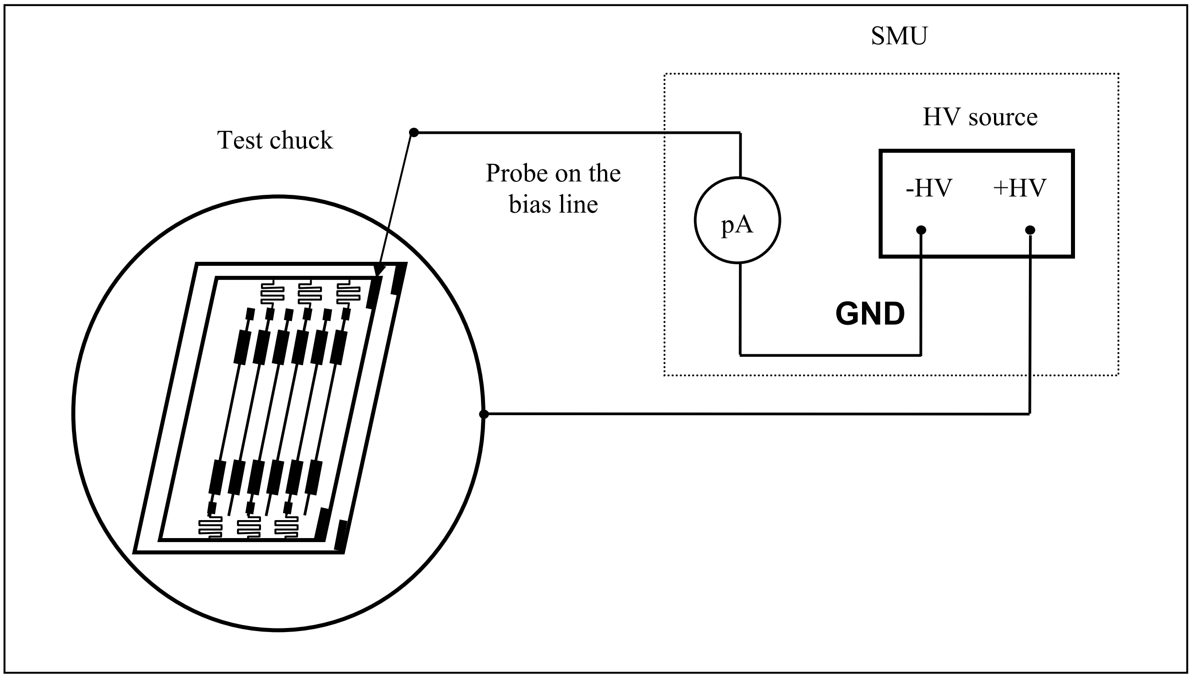

Fig.3: The setup for the leakage current measurement (I-V).

4.3. Tests on sensor subsets

The sensor subset tests are conducted on a sample of sensors only. The tests should allow us to better evaluate the general quality of the sensor batches and to verify the sensor specifications on such samples in much more detail. The tests should also be carried out on particular sensors, if there are significant deviations between the electrical parameters measured by the manufacturer and results from the testing centers for example in the leakage currents. The local coordinators decide about which sensors are being considered and used for the sample tests. A good reason to carry out these tests may be non-critical visible defects of sensors, which have been found by visual inspection (see 4.2.2.).
A general recommendation is, that after each "sensor subset test" the I-V measurement as listed in Section 4.2.3, should be repeated.

4.3.1. Definition of the subsets

A high sampling rate is important to draw firm conclusions from the QA tests. We hence define the subset samples, i.e. the number of sensors, which are subject to the sensor subset tests, as following:

- During prototype phase of any L0, L1 or L2-L5 detector type: the subset sample should consist of a minimum of 80% of all delivered prototypes.
- During pre- or pilot-production phase of any L0, L1 or L2-L5 detector type: the subset sample is ~50% of all delivered sensors
- During production phase of any L0, L1 or L2-L5 detector type, the subset sample is ~25% with a later reduction to 10%, if the measurement results are consistent and stable over the time.

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4.3.2. Leakage Current Stability - I(t) Curve

This I(t) stability test should verify that any variation in sensor leakage currents over a 24-hour period is within accepted limits. This stability test will be centrally carried out at the central distribution center and Fermilab personnel will provide the necessary hardware. A rack, which is covered in a light-tight enclosure, housing several sensors, could be a potential setup. The test requires further a multi-channel power supply, pico-Amperemeter(s) and a temperature monitor. The sensors may be placed in holders and biased through wire lead. The bias voltage is ramped to max(1.1×FDV, FDV+20V) or another initial operation voltage. Then the bias currents and temperatures are measured every 15 min. during 24 hours. A current limit of 50μA is imposed throughout the measurement. The schematic of this measurement is the same as for Fig.3. A good selection of sensors for such a test is to pick from each delivered batch one representative sensor and/or a sensor with relatively high but acceptable leakage currents.

The sensors, which are subject to this leakage current stability test, should be marked in the database. The resulting raw data file of the long-term test, as well as the maximum deviation after 24 hours have to be stored in the database.

Acceptance:
We do not have explicitly specified the HV stability of the sensor. However, we expect a variation in leakage current during 24 hours of less than 20% after correction of the temperature variation.

4.3.3 Full Strip Test (AC scan)

This test (AC scan) probes every (readout) strip of the sensor, in order to determine the coupling capacitance of the readout strip, to check the capacitor dielectric for pinholes, and finally to look for strip metal shorts and opens. The AC-scan is a crucial sensor subset test and every testing center having an automatic probe station should be able to perform it.

Procedure:
The test requires that all readout strips have to be probed while the sensor is partially depleted via contacts to the bias rail and backside. The test requires a separate "bias" voltage source to deplete the sensor, a voltage source with current limit and a pA-meter (like a SMU) to check for pinholes. Moreover, an LCR-meter for the coupling capacitance measurement is necessary and the movement of the probe-tip from pad to pad is done on an automatic probe station.

If a probe needle manipulator can be fixed onto the moving chuck, place the backside sensor on to the chuck and contact the sensor bias rail with the chuck-mounted probe needle. The second probe will go to the AC-contact pads on the strips. It is important that only the AC-testing pads as indicated on the mechanical drawings will be probed.
If there is no place on the chuck for the setting on a probe tip, set the first probe on the "arm" of probe station (ordinary position) and use the "long window" in the passivation on the bias line to contact the sensor bias rail during the strip scan. Then both probes (on the bias line and on the AC-pads) will go from strip to strip synchronically.
The schematic of the measurement is presented in Fig.4. A current limit in the power supply of 50nA should be always applied while charging or discharging the capacitors.

Under computer control, probe all readout strips according to the following instructions.

1. Apply +20V from "bias" voltage source to the sensor backside with the bias rail at ground potential in order to partially deplete the detector.
2. Step to strip N and raise the chuck (contact both probes).
3. Increase the test voltage to +10V, wait 1 second and measure the current to determine the electrical continuity across the oxide. If the current runs into the current limit of 50nA (which defines the existence of a pinhole at low volts) skip step 4 and go to step 5.
4. Increase the test voltage to +80V (with ramp, current limit always applied), wait 1 second and recheck the current.
5. Decrease the test voltage to 0V (with ramp).
6. Wait 1 second and measure C (at 1kHz, with Cs-Rs mode of LCR-meter).
7. Lower the chuck.
8. Repeat the measurement cycle from point 1 above for strip N+1.

Acceptance:
We require <1% (for L0, L1, L2-L5) defective strips. The definition of a defective or bad strip is presented in the appended D0 RunIIb Detector Specification. Defective or bad strips in general have:

- Pinholes – current through the capacitor >10 nA at 80 V and RT
- Short – coupling capacitor >1.2 times the typical value
- Open - coupling capacitor <0.8 times the typical value
- Strip leakage current in excess of 10nA measured at RT and FDV
- Bias resistor or interstrip resistor values out of specs

The first three defects can be detected with the AC-scan. The testing person should try to verify the defect in case of a metal open or metal short, by visual inspection of the bad strip.

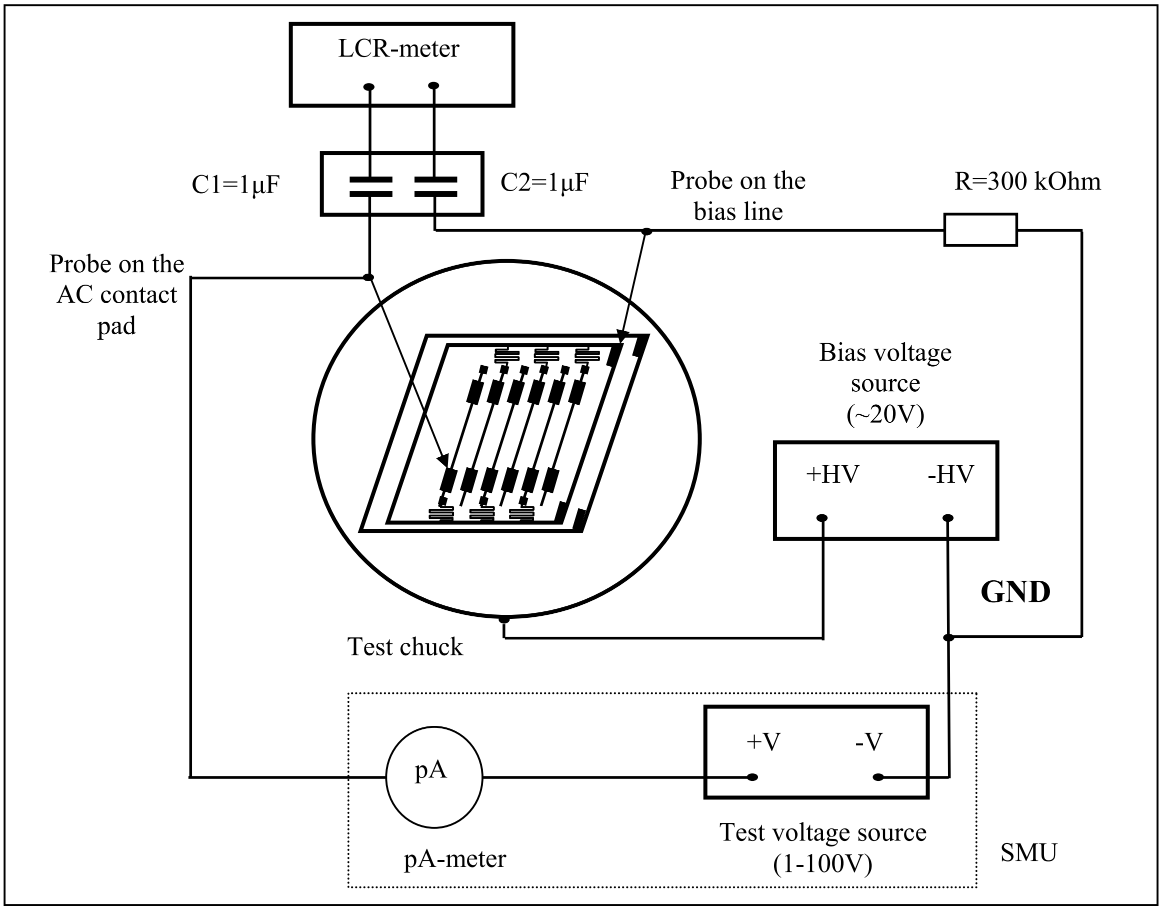

Fig.4: The setup for the full AC strip test (AC-test).

The typical coupling capacitor value as obtained from the AC-scan has to be stored in the database, as well as the bad strip numbers according to the strip numbering convention.

4.3.4. Strip leakage current test (DC-scan)

If the bias current from the I-V test (see 4.2.4) is significantly different from the bias current data according to the manufacturer, or the leakage current stability test (see 4.3.2.) gives bad and unstable results, one should measure every strip leakage current in order to try to find out the source of the big or unstable leakage.

This test requires an automatic probe station with a high moving accuracy and good repeatability, since the DC-pads on the sensor are very small. Moreover, a voltage source, two pA-meters (called "strip" and "bias") and an automatic probe station are necessary. If a probe needle manipulator can be fixed to the moving chuck, place the backside sensor onto the chuck and contact the detector bias rail with the chuck-mounted probe needle. The second probe will be placed on the DC-contact pads of the strips.

If there is no place on the chuck for the probe manipulator, set the first probe on the “arm” of probe station (ordinary position) and use the “long window” in the passivation on the bias line to contact the detector bias rail during the strip scan. Then both probes (one on the bias line and the other one on the DC-pads) will move from strip to strip synchronically. The schematic of measurement is presented on Fig.5.
Under computer control, probe all readout strips according to the following instructions.
There will be two slightly different procedures for this test. Which of the two procedures one has to follow, depends on the type of the contact to the bias line.

Procedure A:
In case it is possible to put a probe directly on the chuck to establish a contact to the bias line contact pad (Probe tip for biasing moves with chuck and sensor!!!):

1. Set (with ramp) the bias voltage at 1.1×FDV.
2. Step to strip n and raise the chuck, i.e. contact the pad with the tip.
3. Measure the bias current with the "bias" pA-meter. If the bias current is significantly lower than in the previous step, stop the measurement, turn off the bias voltage, switch on the light in the dark box and check the contact of probe to the bias line.
4. If step 3 was OK, then measure the strip current by "strip" pA-meter.
5. Lower the chuck, i.e. lift the probe tip from the pads.
6. Repeat the measurement cycle from step 1 onward for strip n+1.
7. After the last strip measurement has been performed, decrease the bias voltage source to 0V (no ramp).

Procedure B:
In case the "long window" in the passivation is used to contact the bias line.

1. Step to strip n and raise the chuck, i.e. contact the pads
2. Set (with ramp) the bias voltage at VFD+20V, wait 1 second.
3. Measure the bias current with the "bias" pA-meter. If the bias current is significantly lower than in the previous step, stop the measurement, turn off the bias voltage, switch on the light in the dark box and check the contact of probe to the bias line.
4. If step 3 was OK, then measure the strip current by "strip" pA-meter.
5. Decrease the bias voltage source to 0V (no ramp).
6. Lower the chuck, i.e. lift the probe tip from the pads.
7. Repeat the measurement cycle from point 1 above for strip n+1.

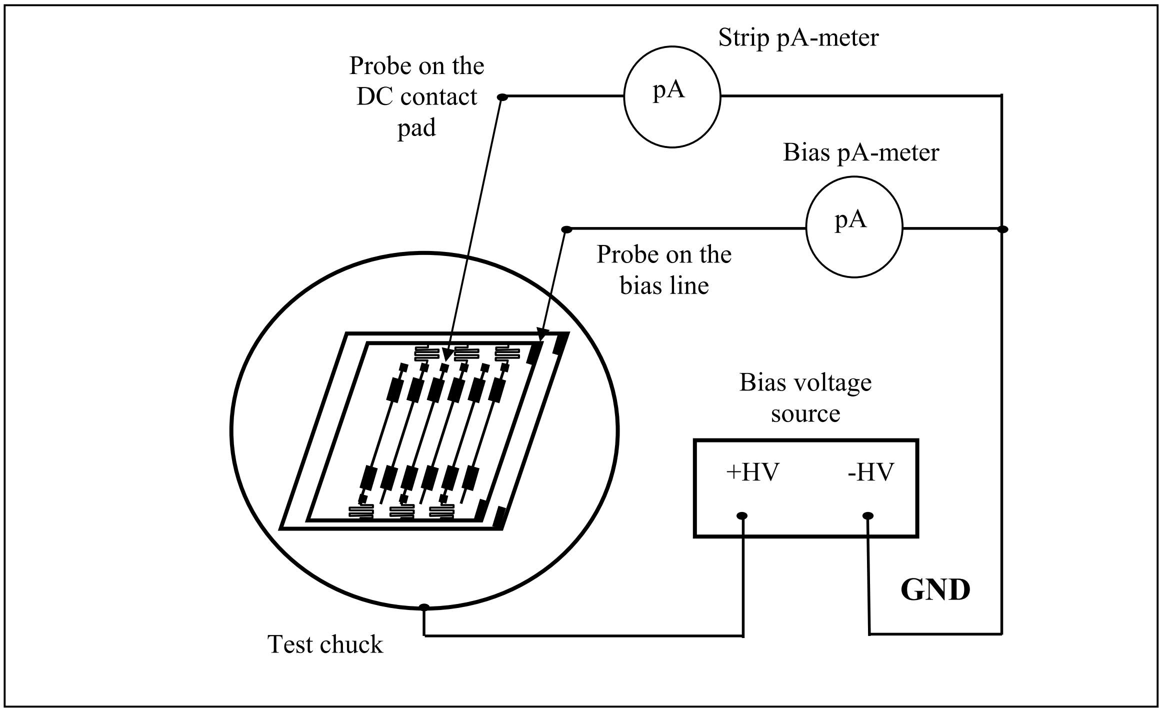

Fig.5: Setup for the full strip test (DC-scan).

Acceptance:
We require <1% (for L0, L1, L2-L5) defective strips. If the strip current exceeds 10nA at FDV and RT, the strip is counted towards the bad or defective strip list. After the DC-scan has been performed, the database should be updated and the bad strip numbers as obtained from the DC-scan should be stored in the database.

4.4. Diagnostic Tests

This subsection lists recommended procedures for a more detailed evaluation of the electrical parameters of the sensors. The tests are either done on single strips of the sensors or on test structures. The diagnostic tests are a set of detailed electrical measurements of complex sensor/wafer properties. The results of the diagnostic tests will give enough information of the overall silicon sensor performance. We recommend that the testing centers perform these tests routinely on a small random subset sample of delivered sensors - approximately 10-15% of the delivered sensors. After each diagnostic test, the I-V measurement on the sensor as listed in Section 4.2.4 should be repeated.

4.4.1 Polysilicon resistance

On the test structure (if available):
This test requires a voltage source and a pA-meter and the appropriate resistor structure on the test structure. Place the piece of wafer with the test structure on the backside on the chuck of a probe station. Contact the two contact pads of the polysilicon resistor piece

on the test-structure and set a testing voltage from -5V to + 5V with 0.1V step and read the current. Calculate a value of the polysilicon resistor from the I-V curve.

On the sensor:

Place the sensor backside on the chuck of a probe station and contact the bias rail, chuck and DC-pad of any strip according to the schematics of Fig.6. Set the testing voltage from +0.1V to + 5V in 0.1V step and read the strip current. Calculate the value of the polysilicon resistor from the I-V curve. Note that you can get a mistakenly low resistance if the strip has extremely high leakage current (>100nA@10V). Measure at least 5 strips on the sensor to get a representative sample.

Acceptance:
The polysilicon resistor values have to be within 0.8±0.2 Mohm.

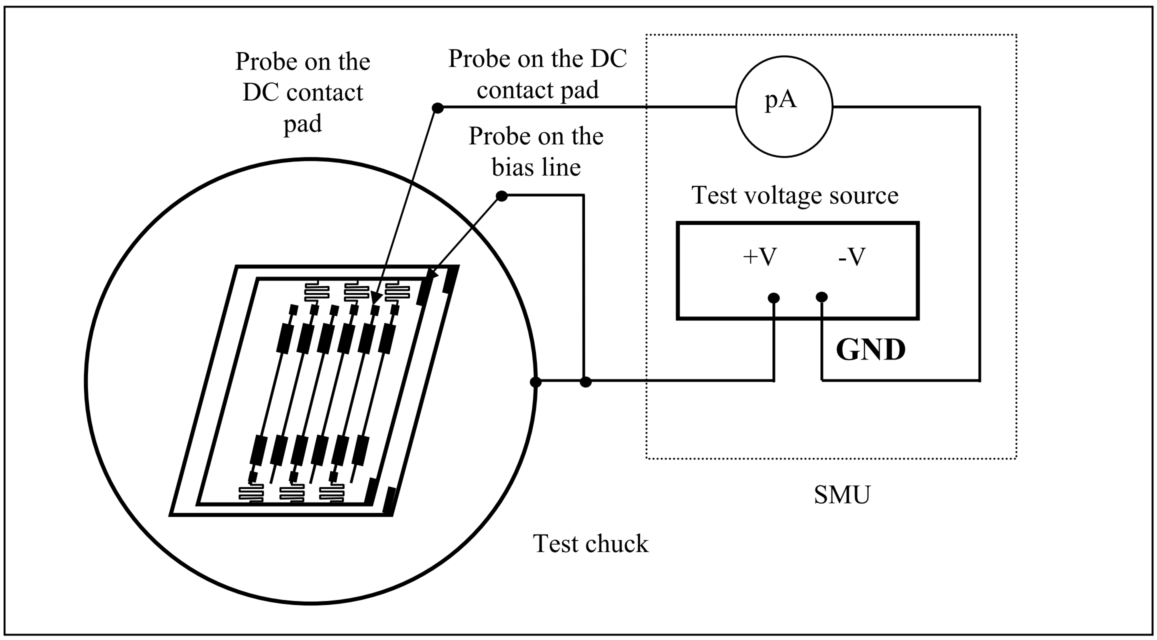

Fig.6: Setup for the polysilicon bias resistor measurements.

4.4.2 Strip and Interstrip Capacitance

This test consists of two measurements with the goal to determine the total strip and interstrip capacitance. The total strip capacitance is the capacitance to ground, which represents the total load capacitance for the preamplifier and hence determines the noise in the front-end. The total strip capacitance consists of the interstrip capacitance, i.e. the contribution from one strip to the neighbor strips and the capacitance of one strip to the backplane. The test requires an LCR-meter with external adapter (Fig.7) and a voltage source, as well as up to four probe manipulators. This measurement has a very important impact on the noise estimations for silicon ladders and we recommend performing this test on at least 20% of the prototype sensor samples for up to 5 strips per sensor.

Procedure:
Place the sensor on the chuck of a probe station, and contact the bias rail by a probe needle. The backside and the bias rail should be connected to the high and grounded-low sides respectively of the voltage source (see schematic Fig.8). Turn on the bias voltage to FDV+20V. Place three coaxial probes on the AC-contact pads according the schematics of Fig.9.a, and measure the capacitance value defined here as C1. Place in addition three coaxial probes on the AC-contact pads according the schematic on Fig.9.b and measure the capacitance value C2. For the capacitance measurements different frequencies should be used. Start the frequency sweep at 1 kHz test frequency and measure up to 1MHz in Cs-Rs mode.
Calculate value of the interstrip capacitance ($C_{intrstr}$) and the value of the strip capacitance to the backside (C_s) in the following way:

$$C_s = C1 - 2\times C2;$$
$$C_{intrstr} = C2.$$

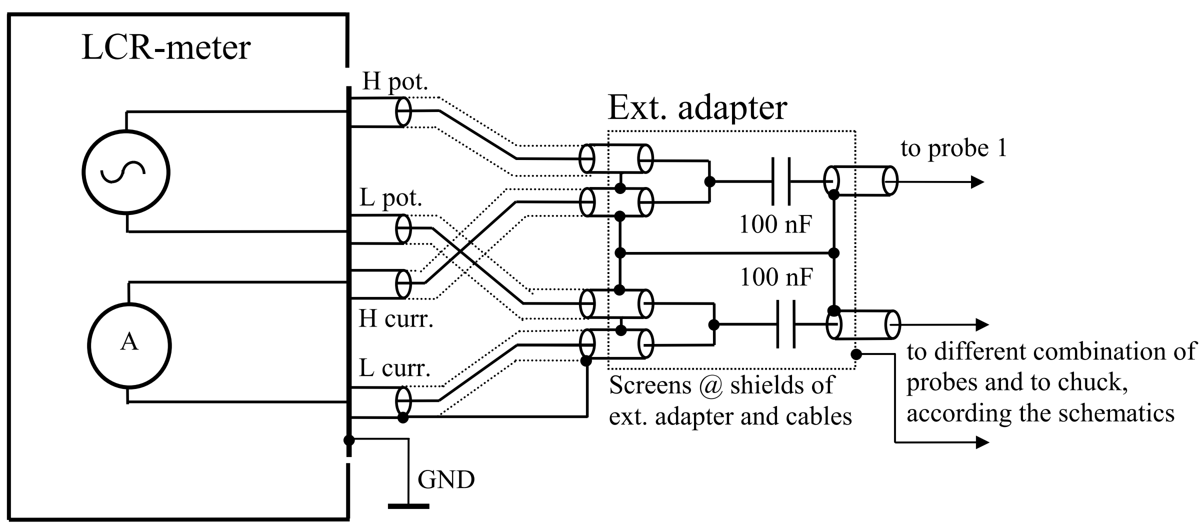

Fig.7: External adapter for the LCR meter for the strip capacitance measurements.

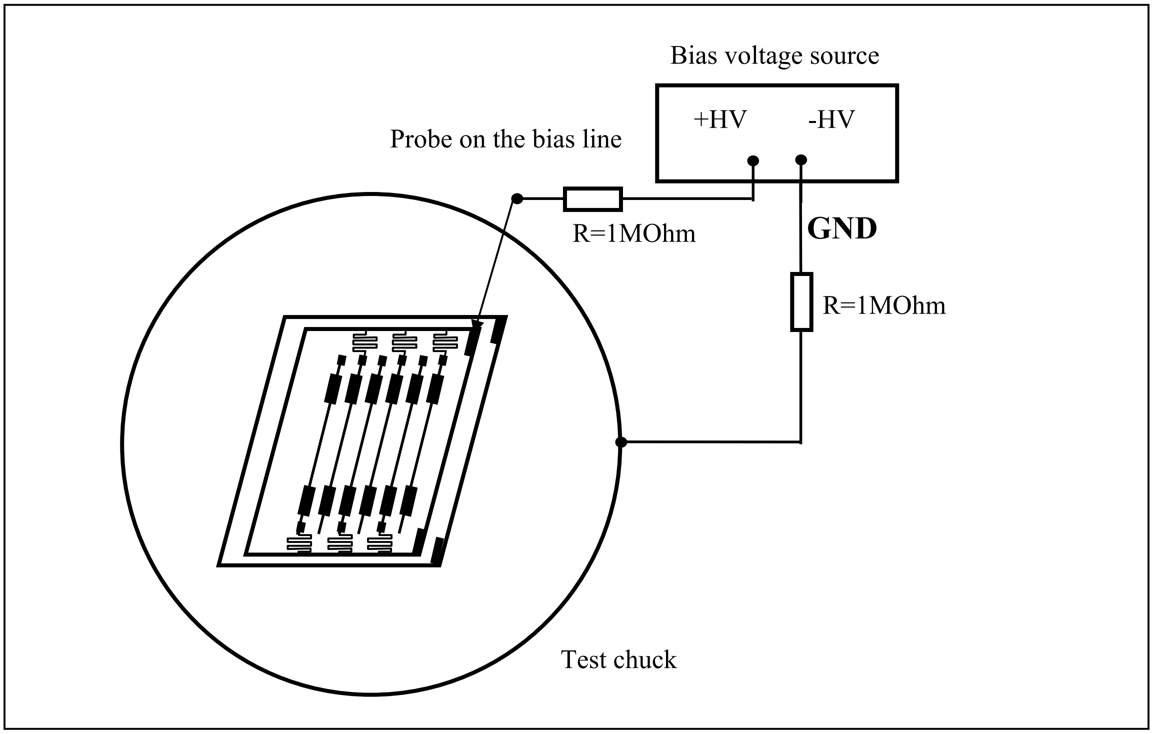

Fig.8: Biasing the detector for the strip capacitance measurement.

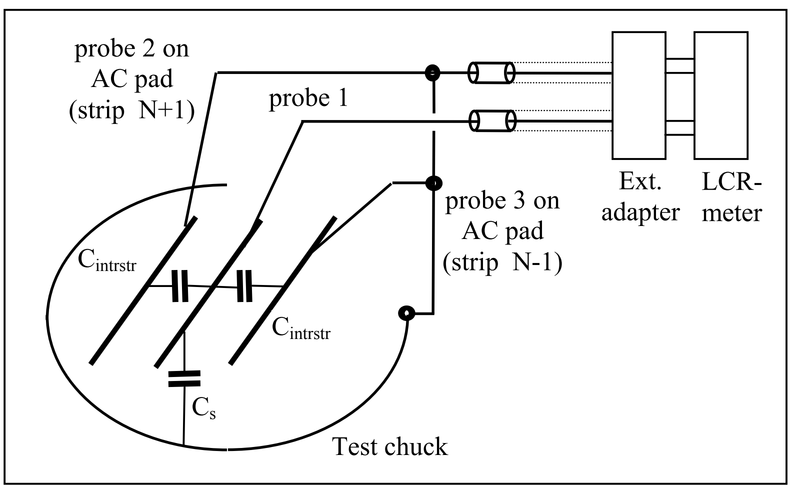

Fig.9.a: Measurement of the strip capacitance C1.

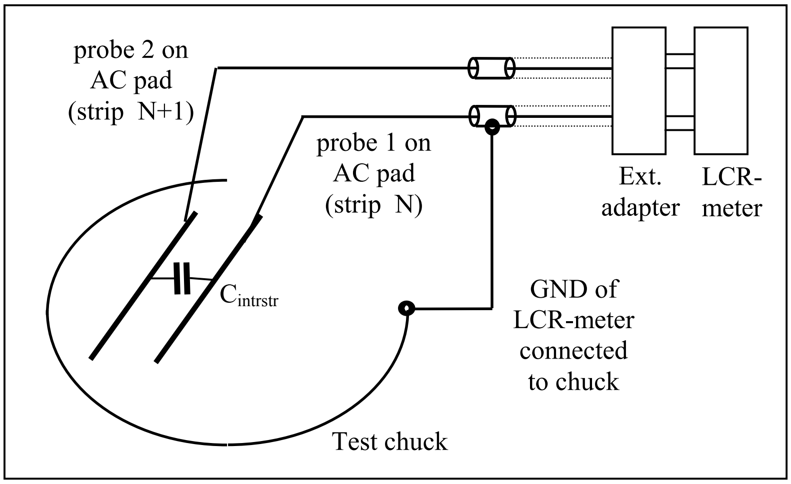

Fig.9.b: Measurement of the strip capacitance C2.

Note, that C_{instr} or C2 as it is measured in figure 9b is defined as the capacitance to only one neighbor. The total interstrip capacitance is twice as much and is specified in the acceptance criteria.

Acceptance:

- The capacitance from the strip to the backside should be less than 0.3 pF/cm at FDV+20V bias, although this is not explicitly stated in the specifications.
- The interstrip capacitance (here: total interstrip capacitance, i.e. to left and right neighbor) has to be less than 1.2 pF/cm at FDV+20V bias, i.e. less than 9.2 pF for L0&L1 and less than 11.8 pF for L2&L5.

4.4.3 Metal series resistance

This test requires a voltage source a pA-meter and a special test structure. Apply a voltage between the two ends of the appropriate metal line test-structure (if available) or to either end of one of the detector metal strips (if no test-structure is available). Set the testing voltage from -0.5V to + 0.5V in 0.1V step and read the current. Calculate the resistance value per 1cm of the metallization from the I-V curve.

Acceptance:
The series resistance should be less than 20 Ohm/cm for L2&L5 and less than 30 Ohm/cm for L0&L1.

4.4.4 Implant sheet resistance ***(on the test structure only)***

This test requires a voltage source and pA-meter and a special test structure. Place the piece of the wafer with the test structure with the backside on the chuck. Apply a voltage between the two ends of the contact pads of the test structure. Set the testing voltage from

–1V to +1V in 0.1V step and read the current. Calculate the resistance value per 1cm of implantation from the I-V curve.

Acceptance:
The sheet resistance is not explicitely specified, however we expect values of less than 200 KOhm/cm.

4.4.5 Flat band voltage ***(on the test structure only)***

This test requires an LCR-meter with an internal DC voltage source. Also a MOS test-structure is necessary. Place the piece of wafer with the MOS test structure with the backside on the chuck of the probe station and contact the MOS pad with a probe needle. Connect the MOS metal to the H-output of the LCR-meter and the backside to the L-outputs of the LCR-meter. Measure the capacitance across the MOS as a function of the internal DC bias from -20V to +20V with a step of 1V and delay 1s (before the measurement). Set the following parameters on the LCR-meter:
- test frequency 1kHz;
- mode Cs-Rs;
- AC test voltage value 0.1V.

Acceptance:
There are no defined acceptance criteria. The flat band voltage is used as a monitor of the processing consistency, mainly the $Si\text{-}SiO_2$ interface charge density.

4.4.6. Interstrip Resistance.

This test requires a pA-meter and two voltage sources. Place the detector backside on the chuck of a probe station and contact the bias rail, chuck and DC-pads of strips N and N+1 according the schematics of Fig.10.
Set the bias voltage on the sensor by ramping up to FDV+20V. Then do the following steps:
- set a testing voltage (V_t) from -1V to +1V with 0.1V step and a delay not less then 5s;
- read the strip current (I_{str}).

Calculate a value of interstrip resistor from the I(V) curve:

$$R_{intrstr} = \Delta I_{str}/\Delta V_t.$$

Note that for a non-irradiated sensors the interstrip resistance can be very high with values of about 100 GOhm, so your setup must allow to measure small changes of strip currents (10pA). The delay before the actual strip current measurement must be long enough to stabilize the strip current.

Acceptance:
The interstrip resistance should be higher than 2 GOhm.

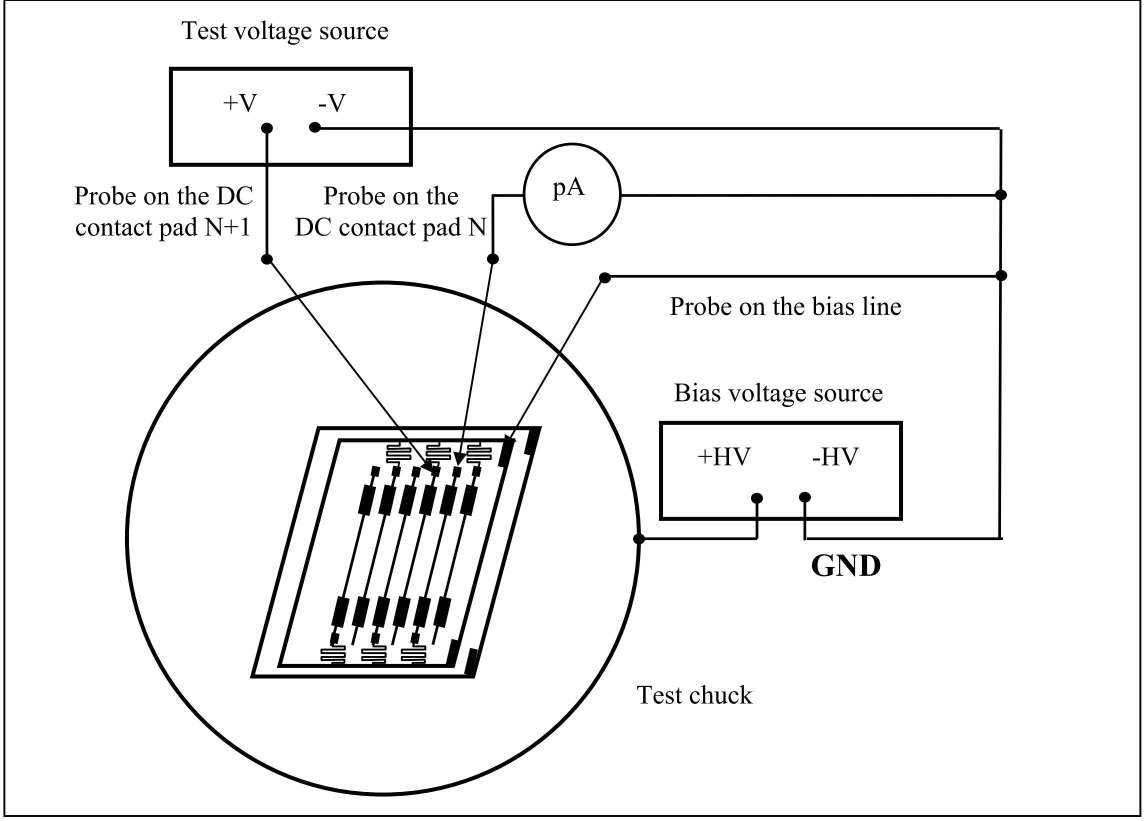

Fig.10: Interstrip resistance measurement.

4.4.7. Coupling Capacitance ***(on the test structure only)***.

4.4.7.1. Coupling capacitor value

The precise measurement of the coupling capacitor is done on a test structure. The measurement requires an LCR-meter and a special test structure, which should have a single AC-coupled strip similar to the ones, which are on the sensors. Place the piece of the wafer with the test structure backside on the chuck of a probe station and contact the AC and DC contact pads of the strip with probe needles to the LCR-meter outputs. Measure the capacitance between the metallization (AC-pads) and implantation (DC-pads) at 1 kHz with CR in Serial.

Acceptance:
The coupling capacitance should be higher than 12 pF/cm.

4.4.7.2. Strip capacitors breakdown voltage

This (destructive) test requires a voltage source/pA-meter (SMU) and the special test structure with a single AC-coupled implantation.
Place the piece of the wafer with the test structure backside on the chuck of a probe station and contact the AC and DC contact pads of the strip with probe needles to the

SMU. Use a serial resistor with 10MOhm value in serial with the input of the SMU pA-meter. Measure the leakage current through the strip capacitor by ramping the testing voltage from 1V to 100V in steps of 5V and with a delay of 1s (at least). The capacitor breakdown is defined at the voltage when the current reaches 100nA.

Acceptance:
The breakdown voltage of the coupling capacitors should exceed 100V.

4.5 Mechanical tests

We recommend that several mechanical measurements on silicon sensors should be performed. The measurements should verify the mechanical specification of wafer thickness, wafer warp and cutting accuracy and should be carried out at the central distribution center at Fermilab mainly on an optical metrology system. A quarter of the delivered sensors per production batch (~25%) are probably sufficient for this QA part. In the prototype phase however, the sensor number should be as high as ~50%.

4.5.1. Sensor thickness
The thickness is measured on the test structure pieces with the help of a micrometer screw. The thickness of the test structure pieces are measured at several positions and averaged. The resulting value and its RMS is stored into the database. The accepted sensor thickness has to be within 320±20 μm.

4.5.2. Sensor warp
The sensor warp is measured in a free state of the sensor on an optical metrology machine (e.g. OGP). The best-fit plane is determined, and the RMS and the maximum deviation are recorded into the database. The acceptance criterion is that the flatness of the sensor has to be within ±25 μm.

4.5.3. Sensor cut dimensions and cutting accuracy
The cutting length and width are determined on an optical metrology machine (e.g. OGP). The accuracy of the cutting line with respect to the nominal cutting line has to be better than ±20μm and its parallelism to the datum line defined by the fiducial targets has to better than ±10μm.

5. A short summary of the QA-program.

This section summarizes the QA-program with the four main parts.

QA-item	QA-subprogram	QA-test performed where	Frequency of QA-test	Manpower
Initial registration	Key test	Central distribution center (CDC)	100%	0.5 FTE
Visual Inspection	Key test	CDC	100%	FTE
C-V	Key test	Testing center (TC)	100%	
I-V	Key test	TC	100%	
I(T)-stability	Subset test	CDC	Sensor subsets (between 10%-100%)	
AC-scan	Subset test	TC	Sensor subsets	
DC-scan	Subset test	TC	Sensor subsets	
Polysilicon resistor	Diagnostic test	TC	10-15% per batch	
Strip Capacictance	Diagnostic test	TC	10-15% per batch	
Metal series Resistance	Diagnostic test	TC	10-15% per batch	
Implant sheet resistance	Diagnostic test	TC	10-15% per batch	
Flat band	Diagnostic test	TC	10-15% per batch	
Interstrip resistance	Diagnostic test	TC	10-15% per batch	
Coupling Capacitor	Diagnostic test	TC	10-15% per batch	
Wafer thickness	Mechanical test	CDC	25% per batch	
Wafer warp	Mechanical test	CDC	25% per batch	
Wafer cut accuracy	Mechanical test	CDC	25% per batch	

5. Requirements for the database.

We suggest splitting the relevant sensor QA-information into several main parts or blocks. The following blocks with typical examples are proposed:

1. vendor block
    - sensor-ID: Long Integer, e.g. 9847463
    - manufacturer: Characters(128), e.g. Hamamatsu
    - sensor type: character(8) e.g. L0 or L1 or L2-L5
    - production type: characters, e.g. prototype or pre-production or production
    - arrival date at central distribution center: date format, e.g. 9/30/02
    - wafer lot/batch information: integer, e.g. 4751
    - wafer thickness in µm: Float, e.g. 320
    - Voltages and leakage current values in µA: 2 floats, i.e. typical measured current values at 10 different bias voltage settings
    - Depletion voltage (V): float, i.e. 147
    - Number of bad channels/strips: integer, i.e. 2
    - Strip numbers and type of defects: integer and characters: e.g. 3 pinhole, 182 metal open. Type of defects are: pinhole, metal open, metal short and leaky strip
    - Polysilicon mean resistor value in Mohm: float, e.g. 1.15
    - Coupling capacitor breakdown value in V: float, e.g. 120
    - Comments for other measurements: characters

2. key test block
    - sensor-ID
    - sensor type
    - initial registration: Boolean, 0=missing information, 1=OK
    - visual inspection: Characters for comments
    - C-V curve: measurement record indicating:
        i. Depletion voltage
        ii. Date and location of measurement
        iii. Temperature and humidity
        iv. comments
    - I-V curve: measurement record indicating:
        i. Leakage current in µA at 100V, 200V, 300V, 400V and 500V for L2-L5 or leakage current at 100V, 250V, 400V, 650V, 800V for L0&L1
        ii. Date and location of measurement
        iii. Temperature and humidity
        iv. Comments
    - Sensor marked for 1=subset tests (1a=I(t), 1b=AC, 1c=DC), 2=diagnostic tests, 3=mechanical tests

3. sensor subset tests (Note that this table is only created if the sensor flag in the previous table key test is set to 1=subset tests)
    - sensor-ID
    - sensor-type
    - leakage current stability: measurement record should contain
        - bias voltage setting
        - min/max current deviation over 24h

    - Date and location of measurement
    - Temperature and humidity range
    - Comments
  - AC-scan: measurement record should contain:
    - Number of bad strips, e.g. 3
    - Bad strip list with fail criteria: e.g. 35 pinhole, 67, 236 metal open
    - Date and location of measurement
    - Temperature and humidity
    - Comments
  - DC-scan: measurement record should contain
    - Number of leaky strips, e.g. 1
    - Bad strip list with fail criteria: e.g. 134, I_strip=20nA
    - Date and location of measurement
    - Temperature and humidity
    - Comments

4. diagnostic tests. (Note that this table is only created if the sensor flag in the previous table key test is set to 2=diagnostic tests)

    - Sensor-ID
    - Sensor type
    - Polysilicon value: measurement record
      - Value in MOhm
      - Date and location of measurement
      - Temperature and humidity
      - Comments
    - Strip and interstrip capacitance: measurement record
      - Value of interstrip capacitance and backplane capacitance in pF/cm at three different frequencies (1kHz, 10kHz and 100kHz)
      - Date and location of measurement
      - Temperature and humidity
      - Comments
    - Metal series resistance: measurement record
      - Value of metal series resistance in Ohm/cm
      - Date and location of measurement
      - Temperature and humidity
      - Comments
    - Implant Sheet resistance: measurement record
      - Value of implant sheet resistance in kOhm/cm
      - Date and location of measurement
      - Temperature and humidity
      - Comments
    - Interstrip resistance: measurement record
      - Value of interstrip resistance in MOhm
      - Date and location of measurement
      - Temperature and humidity

        - Comments
    - Coupling Capacitor breakdown: measurement record
        - Value of coupling capacitor in pF/cm
        - Value of coupling capacitor breakdown in V
        - Date and location of measurement
        - Temperature and humidity
        - Comments
    - Interstrip resistance: measurement record
        - Value of interstrip resistance in MOhm
        - Date and location of measurement
        - Temperature and humidity
        - Comments
    - Flaband voltage: measurement record
        - Value of flatband shift in V
        - Date and location of measurement
        - Temperature and humidity
        - Comments

5. Mechanical tests. (Note that this table is only created if the sensor flag in the previous table key test is set to 3=mechanical tests).

    - Sensor-ID
    - Sensor-type
    - Average and RMS wafer thickness in µm measurement record:
        i. Average wafer thickness value in µm
        ii. RMS value in µm
        iii. Date and location
        iv. Temperature and humidity
        v. comments
    - Sensor warp measurement record:
        i. RMS in µm
        ii. Maximum deviation in µm
        iii. Date and location
        iv. Temperature and humidity
        v. Comments
    - Sensor cutting accuracy measurement record:
        i. Parallelism in µm
        ii. Cutting accuracy in µm
        iii. Date and location
        iv. Temperature and humidity
        v. Comments

6. Tracking table. This table should be filled automatically, whenever a sensor is checked in/out.
    - Sensor-ID
    - Sensor-type
    - Sensor first arrival at CDC: date

- Sensor shipped to testing center: date
- Sensor arrived at testing center: date
- Sensor shipped to CDC: date
- Sensor shipped back to vendor: date

7. Reject table. This table lists failed sensors
   - Sensor-ID
   - Sensor-type
   - Source of failure: 1=vendor information, 2=key test, 3=subset test, 4=diagnostic test, 5=mechanical test
   - Detailed failure mode comments:
   - Sent back to vendor: date

7. Required and recommended equipment for the testing centers.

A list of required laboratory equipment for the testing centers, which are participating in the D0 RunIIb sensor QA program, is shown below. We give recommendations for the equipment, but alternative equipment is acceptable of course, if the equipment specifications are comparable. The measurement devices and automatic probe stations should be readout by a PC. We recommend using the standard GPIB (IEEE488) bus as an interface between devices and PC, controlled by Labview.

1. Automatic (computer controlled) probe station with at least 5 probes (3 coaxial and 2 ordinary) on a vacuum or magnetic base (preferable).
   Typical models: Wentworth AWP-1050/1080, Summit 10K, Alessi 6100, Rucker & Kolls 680/683, Electroglas 1034A6 etc.
   The chuck has to fit 6’’-wafers.

2. High Magnification Optics with a Video Capture Card or Digital Camera e.g. Leica Microzoom II, up to x500 for the automatic probe station.

3. Additional Stereo-Zoom Microscope with zoom ~50-100.
   Models: Olympus, Nikon, Leica, Microlite, Bausch&Lomb or other types, which provide the necessary magnification for visual inspections.

4. Probe needles with radius ~2μm, ~10μm, ~20μm.
   Type: appropriate for the probe station
   Number: at least 50 for each size.
5. Pico-amperemeter with Voltage source (SMU).
   Models: Keithley 487, Keithley 6517, Keithley 237.
   Number: at least 3.
   The best choice: 2 dev. Keitheley 487/6517 and 1 dev. Keithley 237
6. LCR meter.
   Models: HP4263B, HP4284

7. Temperature Monitor.
   Model: temperature monitor (thermocouple is included) in the SMU
   Keithley 487/6517 is preferable.
   Number: at least 2.
8. Humidity Monitor.
   Model: any digital humidity monitor.
9. Dark box.
   Model: any commercial or "home-made" metal black box large enough to enclose the automatic probe station.

10. Networked PC with GPIB card and appropriate LabView control software.
    .
11. Vacuum pump.
    Model: according to the recommendations of the automatic probe station vendors.

12. Vacuum pincers or vacuum pencils.
    Model: see "Techni-tool" catalog (www.techni-tool.com):
    #784PR444 - "Vampire Vacuum tool" or
    #612PT702 - "Pace Handipic", or
    #847PR902 - "Pen-Vac Deluxe Kit".

13. Conductive rubber.
    Type: 40-10-1010-1221 or 40-20-1010-1273 or 40-10-1010-1285.
    For more details see: http://www.chomerics.com
    Quantity: at least 2 sheets with size 6"×6".

Fig. 12: A typical (here at KSU) probestation setup (w/o enclosure).

April 17, 2002

Silicon sensor specifications for D0 SMTII

○ Project description

For the extended run of the Tevatron collider at Fermilab D0 collaboration is proposing to build a new silicon tracker system – SMTII. It is a six-layer device, located between 1.6 and 16 cm radii. It is expected to become operational in early 2004 and continue to take data until 2007. Reliable operation of silicon sensors in high radiation environment is critical to the experiment's success. Over the operation period inner layers of SMTII will be subject to a fluency of 2×10^{14} 1 MeV equivalent neutrons per cm^2.

Layer 1:

○ Wafers

- 320 ± 20 μm thick, n-type, phosphorus doped, <100> crystal orientation

- wafer warp < ±25 µm (this specification is on a best effort base and negotiable after receiving the first prototypes)
- cutting accuracy ± 20 µm with respect to nominal dicing line
- cutting lines parallel to ± 10 µm with respect to nominal dicing line

○ Detectors (general)

All detectors are p+n, single sided, AC coupled, polybiased silicon microstrip detectors.
L1 sensors need to withstand a dose of 2×10^{14} 1 MeV equivalent neutrons per cm^2. The detector break down voltage must exceed 700V after the irradiation. The exact location of fiducial marks and bond pads as well as the strip numbering definition has to be in accordance to drawing number 3823.210-ME-399436. The sensor has a 20-field scratch pad for a unique identification and for pass/fail marks.

L1 sensor characteristics

- 79.400 mm cutting length,
- 77.360 mm minimum acceptable active length,
- 767 strips,
- 384 readout strips, 383 intermediate strips,
- 29 μm strip pitch,
- 58 μm readout pitch,
- readout strips metallized, intermediate strips have only DC pads
- 24.312 mm cutting width,
- 22.272 mm active width,
- AC and DC bond pads according to drawing,
- every 10^{th} strip numbered as indicated on the drawing,
- fiducial marks and scratchpad according to drawing,
- number of devices – 144+50% spares=216
- tentative schedule - by December 2002

Detector Specifications for L1 type sensors

Depletion voltage	V < 300V
Biasing scheme:	polyresistors on both ends
Poly resistor values:	0.8 ± 0.3 MΩ
Passivation:	SiO_2 > 0.25 μm thick or an equivalent passivation material like polyimide
Unpassivated regions:	Passivation windows around fiducial marks, bias/guard rings etc as specified in drawing
Implant strip width:	7 μm
Metal strips:	Al, C coupled over the p-implant
Al strip width:	2 - 3 μm metal overhang on each side
Al strip thickness:	> 1 μm
Al strip resistance:	< 30 Ω/cm
Coupling capacitance:	> 10 pF/cm
Junction breakdown:	> 700V
Micro-discharge breakdown:	> 700V
Coupling capacitor breakdown:	> 100V
Total detector current:	< 100 nA/cm^2 (at RT, full depletion voltage+10%V)
Total detector current at 700V:	< 4 μA
Interstrip resistance (DC):	> 2GΩ
Total interstrip capacitance:	< 1.2 pF/cm
Not working strips:	< 1%

Definition of not working channels:

- Pinholes – current through capacitor >10 nA at 80 V and RT
- Short – coupling capacitor >1.2 times the typical value
- Open - coupling capacitor <0.8 times the typical value
- Leakage current above 10 nA/strip at FDV and RT (measured by buyer)
- Strips with bias and interstrip resistance values out of the specifications defined above shall be counted towards the not working channel list

Tests performed by supplier.

On each sensor

- IV to 800 V (RT = 25 ± 3°C, RH < 50%)
- Optical inspection for defects, opens, shorts and defects, mask alignment (better than 2.5 µm)
- Depletion voltage measurement (C-V method)

On each strip

- AC Capacitance value measurement and Pinhole determination
  - Use the smaller AC pads near the sensor edge for probing. They are labeled as AC test pads in the corresponding drawing.

On test structure

- Poly resistor value
- Sheet and implant R
- Coupling capacitor breakdown voltage

The corresponding quality control data of the applied tests from the supplier shall be provided together with each sensor on paper and in a computer readable format that is agreed upon by both parties. Furthermore we request that the test structure measurement and the test structures on the wafer have to be supplied. We expect the supplier to define in the bid response what exact kind of testing structures on the wafer they will incorporate.

The sensor contains a scratch pad field containing 5x4=20 pads as specified in drawing number 3823.210-ME-399381. The vendor is expected to provide a unique serial numbering for each sensor. We would suggest to the vendor that the leading 1x4 pads should be used for vendor identification and the neighboring 3x4=12 pads should be used for an unique serial number coding of the sensor. The remaining 1x4=4 pads are reserved by the buyer for QC pass/fail marks.

Layer 2-5:

Wafers

- 320 ± 20 µm thick, n-type, phosphorus doped, <100> crystal orientation
- wafer warp < ±25 µm (this specification is on a best effort base and negotiable after receiving the first prototypes)
- cutting accuracy ± 20 µm with respect to nominal dicing line
- cutting lines parallel to ± 10 µm with respect to nominal dicing line

Detectors (general)

All detectors are p+n, single sided, AC coupled, polybiased silicon microstrip detectors. The sensors need to withstand a dose of 2 x 10^{13} 1 MeV equivalent neutrons per cm^2. The detector break down voltage must exceed 350V after the irradiation. The exact location of fiducial marks and bond pads as well as strip numbering definition has to be in accordance to drawing number 3823.210-ME-399382. The sensor has a 24-field scratch pad for a unique identification.

- **L2-L5 sensor characteristics**

  - 10.0 cm cut length,
  - 9.833 cm minimal acceptable active length,
  - 1277 strips,
  - 639 readout strips,
  - 30 µm strip pitch,
  - 60 µm readout pitch,
  - readout strips metallized, intermediate strips have only DC pads
  - 4.034 cm cutting width,
  - 3.834 cm active width,
  - AC and DC bond pads according to drawing,
  - every 10^{th} strip numbered as indicated on drawing,
  - fiducial marks and scratchpad according to drawings,

  - number of preproduction devices – 100+50=150, the 50 devices can be of substandard quality
  - number of production devices - 1900 + 20% spares = 2280,
  - tentative schedule – all sensors delivered by June 2003

Detector Specifications for L2-L5 sensors

- Depletion voltage: V < 300V
- Biasing scheme : polyresistors on both ends
- Poly resistor values: 0.8 ± 0.3 MΩ
- Passivation: SiO_2 > 0.25 µm thick or an equivalent passivation material like polyimide

- Unpassivated regions: Passivation windows around fiducial marks, Bias/guard rings etc as specified in drawing
- Implant strip width: 8 µm
- Metal strips: Al, AC-coupled over the p-implant
- Al strip width: 2 - 3 µm metal overhang on each side
- Al strip thickness: > 1 µm
- Al strip resistivity: < 20 Ω/cm
- Coupling capacitance: > 12 pF/cm
- Junction breakdown: > 350 V
- Micro-discharge breakdown: > 350 V
- Coupling capacitor breakdown: > 100 V
- Total detector current: < 100 nA/cm^2 (at RT, full depletion voltage+10%V)
- Total detector current at 350V: < 16 µA
- Interstrip resistance (DC): > 2 GΩ
- Total interstrip capacitance: < 1.2 pF/cm
- Not working channels: <1%

Definition of not working channels:

- Pinholes – current through capacitor >10 nA at 80 V and RT
- Short – coupling capacitor >1.2 times the typical value
- Open - coupling capacitor <0.8 times the typical value
- Leakage current above 10 nA/strip at FDV and RT (measured by buyer)
- Strips with bias and interstrip resistance values out of the specifications defined above shall be counted towards the not working channel list

Tests performed by supplier.

On each sensor

- IV to 500 V (T = 25 ± 3°C, RH < 50%)
- Optical inspection for defects, opens, shorts and defects, mask alignment (better than 2.5 μm)
- Depletion voltage measurement (C-V method)

On each strip

- AC capacitance value measurement and pinhole determination
- Use the smaller AC pads near the sensor edge for probing. They are labeled as AC test pads in the corresponding drawing.

On test structure

- Poly resistor value
- Sheet and implant R
- Coupling capacitor breakdown voltage

The corresponding quality control data of the applied tests from the supplier shall be provided together with each sensor on paper and in a computer readable format that is agreed upon by both parties. Furthermore we request that the test structure measurement and the test structures on the wafer have to be supplied. We expect the supplier to define in the bid response what exact kind of testing structures on the wafer they will incorporate.

The sensor contains a scratch pad field containing 6x4=24 pads as specified in drawing number 3823.210-ME-399382. The vendor is expected to provide a unique serial numbering for each sensor. We would suggest to the vendor that the leading 1x4 pads should be used for vendor identification and the neighboring 3x4=12 pads should be used for an unique serial number coding of the sensor. The remaining 2x4 pads are reserved by the buyer for QC pass/fail marks.

Terms of agreements

The initial acceptance of the sensors will be based upon the results of the measurements performed by the supplier, according to the criteria described above. For a sub sample of the delivered sensors, these measurements will be confirmed by independent measurements at Fermi National Accelerator Laboratory or at universities. Based upon the results of these measurements, we reserve the right to reject a sensor within 6 months after delivery. The manufacturer will be notified and upon request the sensors will be returned for remeasurements. Both parties can agree upon the acceptance of individual sensors if specifications are missed only marginally.

Disclaimer

We invite the companies bidding on the sensors to take specific exceptions to specifications, which they feel are not appropriate to their process as long as the performance of the detector is not compromised. These exceptions should be considered in the bidding process.