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Run2b Sensor Quality Assurance Measurements at the University of New Mexico

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Abstract

The quality assurance measurements performed at the University of New Mexico on the Run2b sensors between September 2002 and January 2003 are presented.

1 Introduction

In Fall 2002 the University of New Mexico group joined the CDF Run2b silicon upgrade project as one of the institutes responsible for the Quality Assurance of the silicon sensor devices. The initial activity revolved around the irradiation of four Run2b detectors, including post irradiation measurements and measurements on non irradiated sensors.
In September 2002 UNM along with UC Davis lead the effort to irradiate four Run2b detectors at the UCD/MNRC reactor facility in Sacramento, California. New Mexico prepared and installed the samples in the reactor facility, where two of the detectors received 0.7×10^{14} cm^{-2} 1 MeV neutron equivalent fluence and the other two received 1.4×10^{14} cm^{-2} 1 MeV neutron equivalent. Some post irradiation measurements of two of the detectors were performed at UNM and the other measurements were performed by our Purdue and Tsukuba colleagues.

Currently we are in the process of performing long-term stability measurements of the coupling capacitors and the device leakage curents.

2 Sensors

In this note we present measurements performed on unirradiated sensors with serial numbers 044 and 045, and on irradiated sensors serial numbers 001 and 002. The irradiated sensors were irradiated to an equivalent fluence of 0.7×10^{14} cm^{-2} 1 MeV neutron and were also characterized at Tsukuba University.

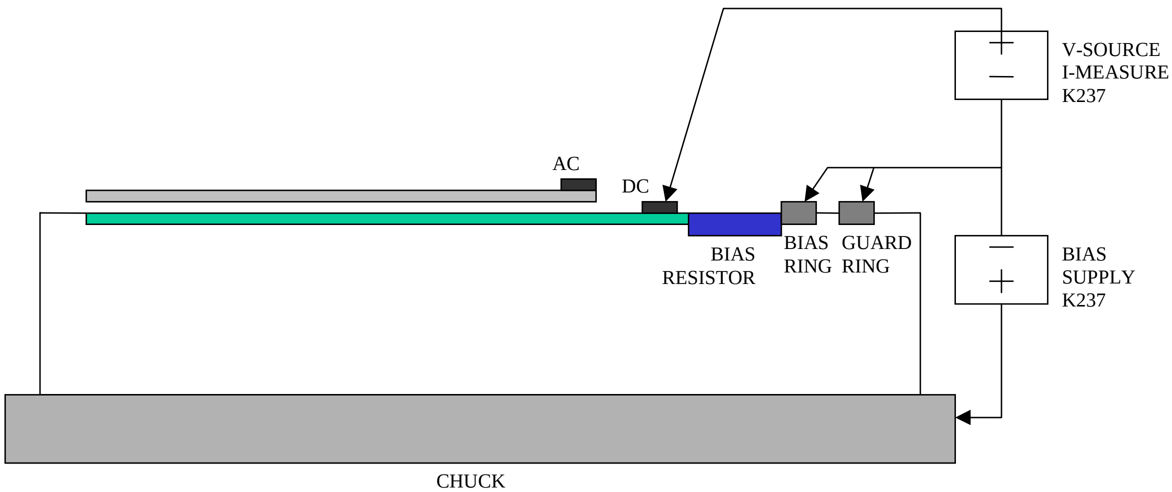

Figure 1: Setup for Measurement of Bias Resistor

3 Measurements

3.1 Bias Resistor

The setup for measuring the Bias Resistor is shown in Figure 1. As in all the measurements, the sensor is placed directly on the chuck which is connected to the positive bias potential and the bias and guard rings are connected to the negative bias side. In this case the sensor is biased to a 500V potential and the output of the source/measure unit is swept from -0.5V to +0.5V. The value of the Bias Resistor is obtained from the slope of the IV curve. Figure 2 shows that on the unirradiated sensor the Bias Resistors are between 1.67 Mohm and 1.72 Mohm and this meets the specified requirement of 1.5 +/- 0.5 Mohm. The results for the irradiated sensors is shown in Figure 3 and Figure 4, and the resulting values are seen to be between 670 Kohm and 790 Kohm. This is much lower than what was measured in the unirradiated case. The difference is attributed to the low -0.05V to +0.05V level of voltage applied across the bias resistor. This level of voltage produces currents on the order of a few nanoamps flowing through the resistor which are difficult to distinguish from the microamps of strip leakage current in the irradiated detector case. To properly measure the bias resistance the voltage across the resistor should be swept at about the -50V to +50V level. Future measurements on production sensors will use this proposed revised protocol. Figure 5 shows the stability of the bias resistance versus level of bias voltage for the irradiated case. The resistance is very constant between 100V and 800V of applied bias.

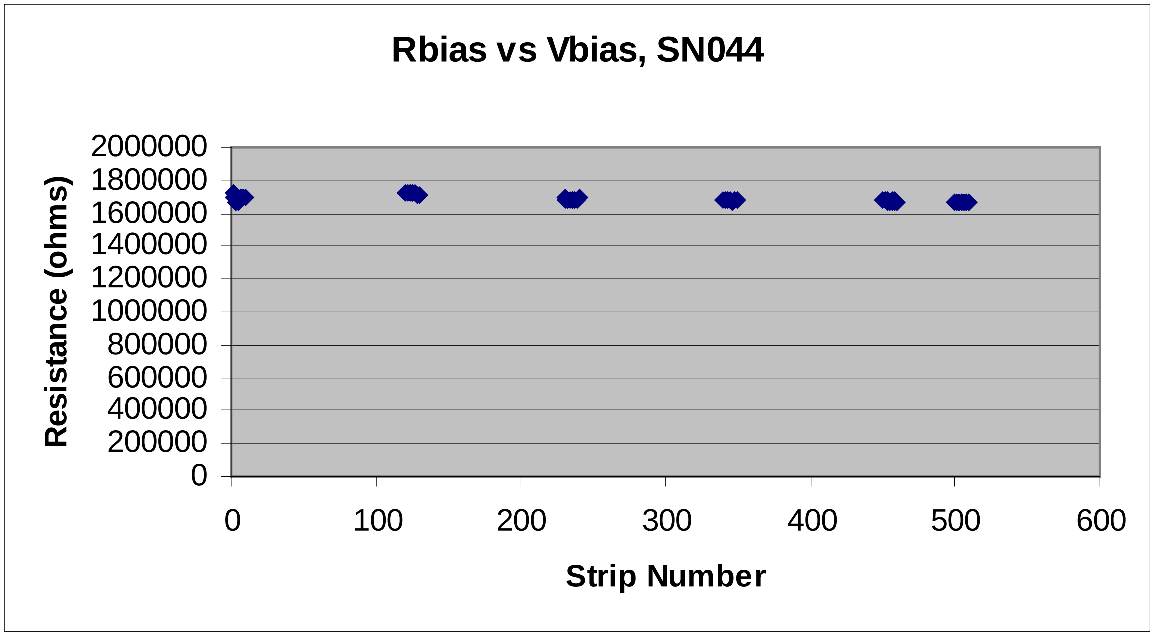

Figure 2: Unirradiated Sensor, SN044 Bias Resistance vs Strip

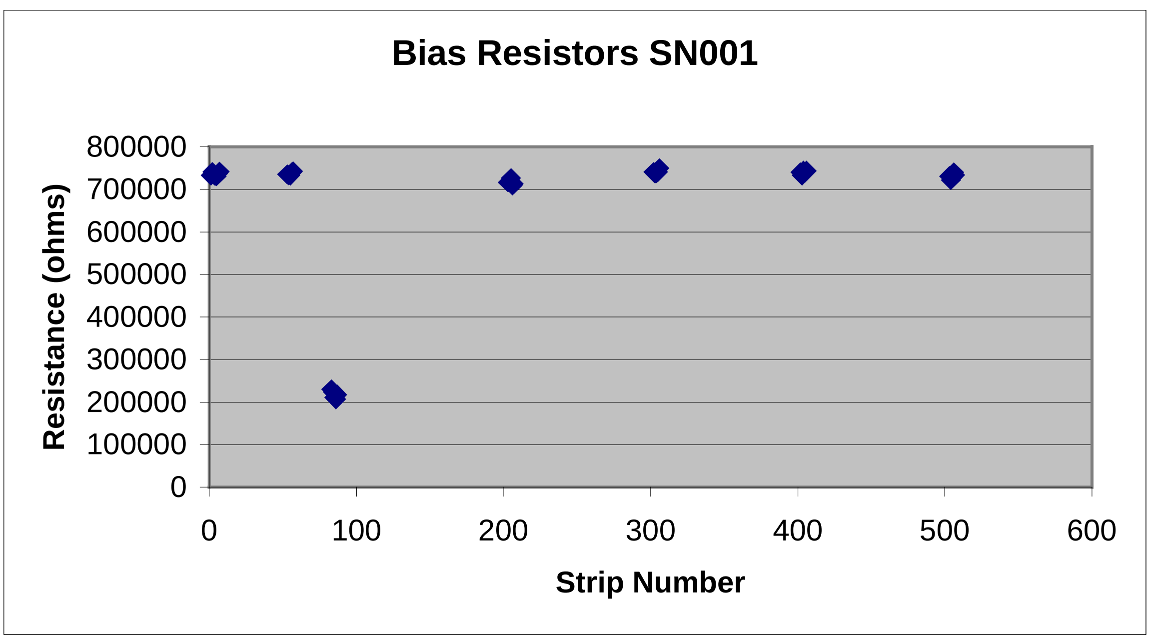

Figure 3: Irradiated Sensor, SN001 Bias Resistance vs Strip

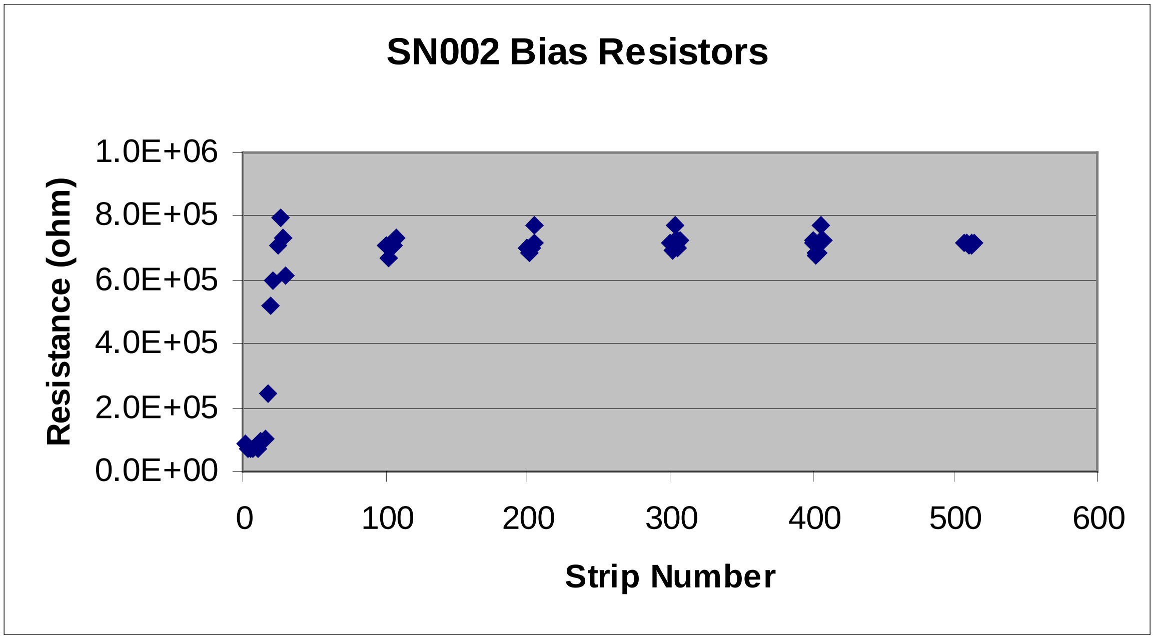

Figure 4: Irradiated Sensor, SN002 Bias Resistance vs Strip

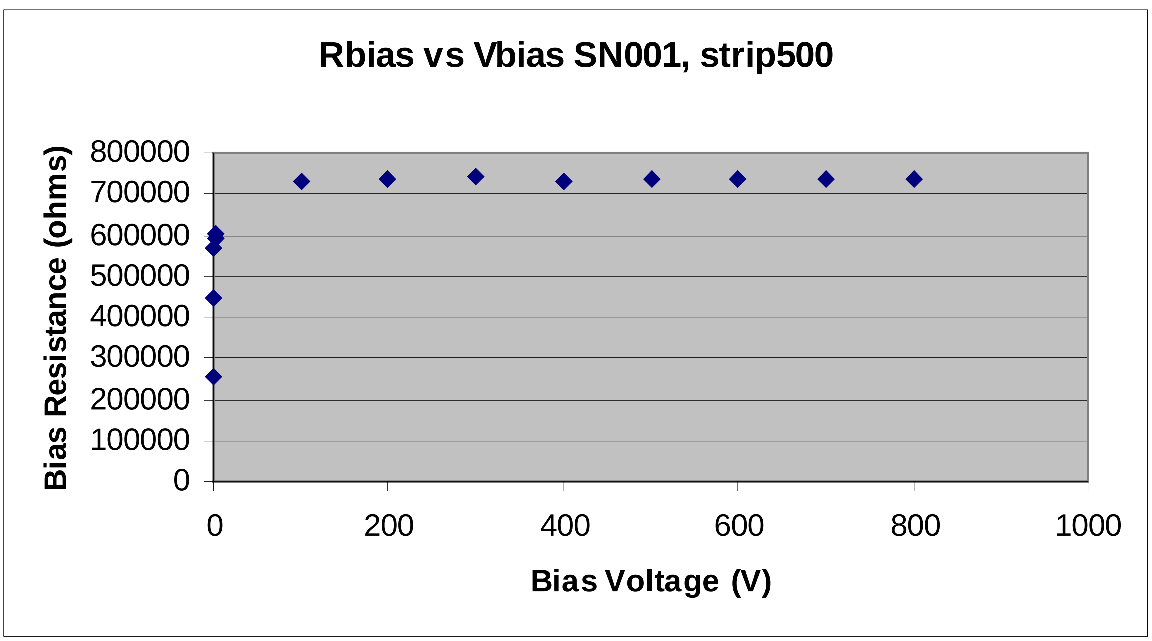

Figure 5: Irradiated Sensor, SN001 Bias Resistance vs Bias Voltage

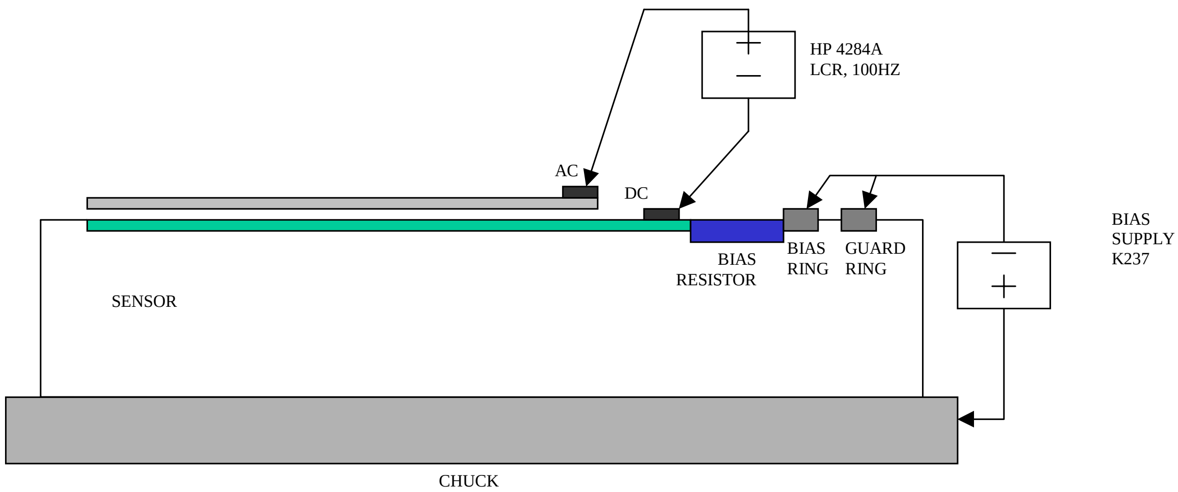

Figure 6: Setup for Measurement of Coupling Capacitor

3.2 Coupling Capacitor

Following extensive study of a variety of test setup options, the final setup configuration for this measurement is as shown in Figure 6. As can be seen in the figure one simply has to connect an LCR meter between the AC and DC pads of the strip. We considered using a setup which included a capacitive isolation network between the measured capacitance and the LCR meter, as this is necessary for some silicon devices. When this isolation network, which is made of some very high valued capacitors, was used in the setup for the Run2b measurement on several occasions a high voltage/current discharge into the sensor occured. The damage is apparent in the plots showing the leakage current per strip and in the photos of Figure 7 and Figure 8. As is apparent in Figure 6, the isolation network is not necessary when measuring the Run2b sensors because the DC pad of the strips is always held at approximately ground potential and there is no danger of damaging the LCR meter with the sensor bias voltage. After removing the isolation network the Coupling Capacitor measurement was safely performed on the unirradiated sensor, Figure 9, and on the two irradiated sensors as seen in Figure 10 and Figure 11. The results for both unirradiated and irradiated sensors show the Coupling Capacitors have a value of around 120pF, which is well within the specification required value of greater than 10pF/cm.

3.3 Interstrip Capacitance

Interstrip capacitance was measured using the setup shown in Figure 12 with the LCR meter connected from the measured strip to the two adjacent neighbors. The results for the unirradiated sensor are shown in Figure 13 and for an irradiated detector in Figure 14. In both cases the result is an interstrip capacitance of approximately 5.5 pF consistently across the sensor strips. The specification requirements of less than 1.2 pF/cm are met.

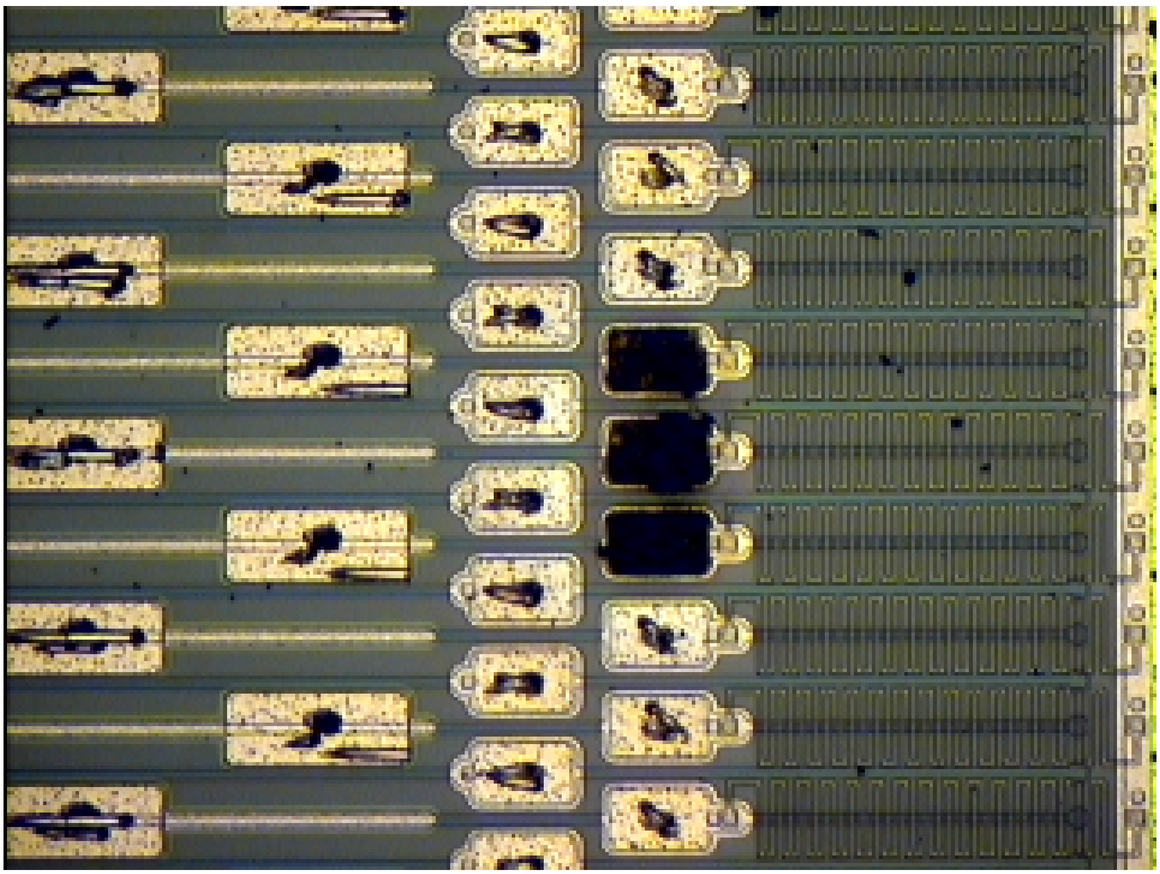

Figure 7: Damage on Irradiated Sensor SN001 due to discharge from bias isolation network

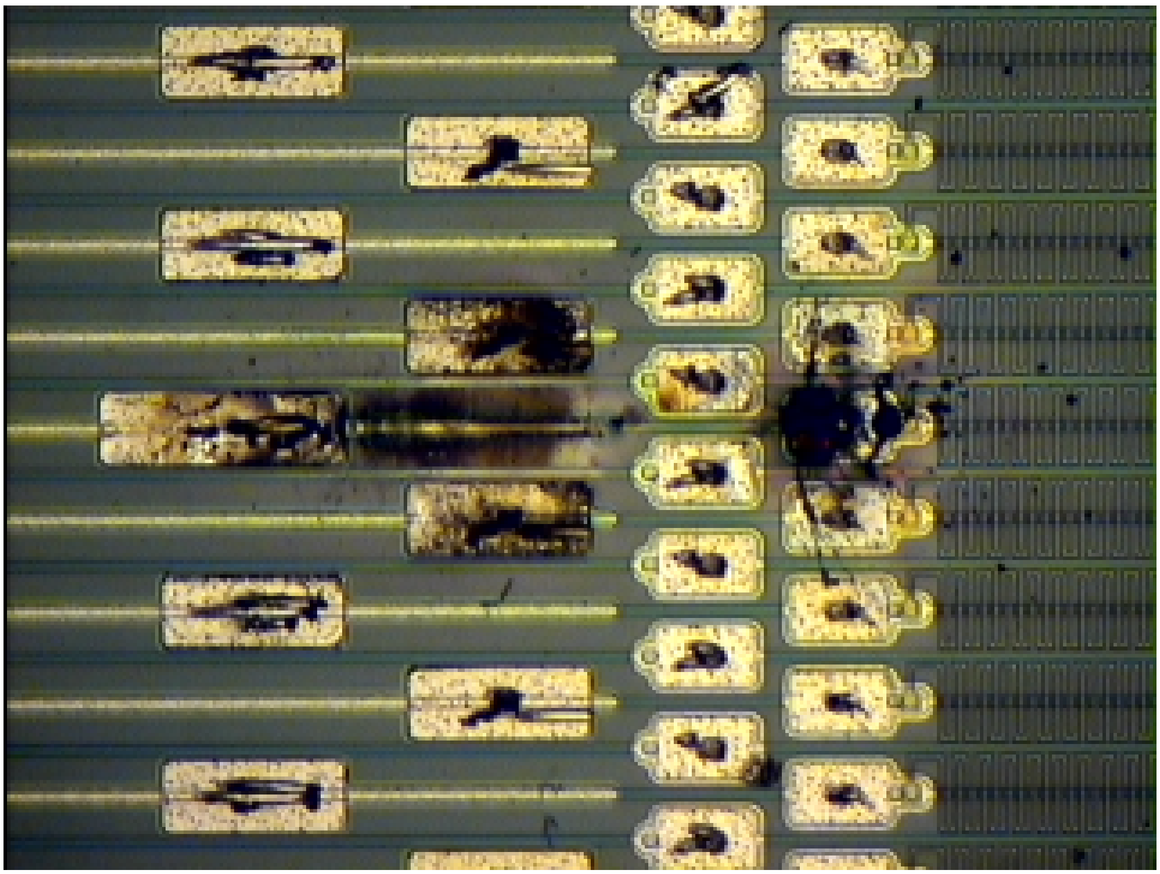

Figure 8: Further damage on Irradiated Sensor SN001 due to discharge from bias isolation network

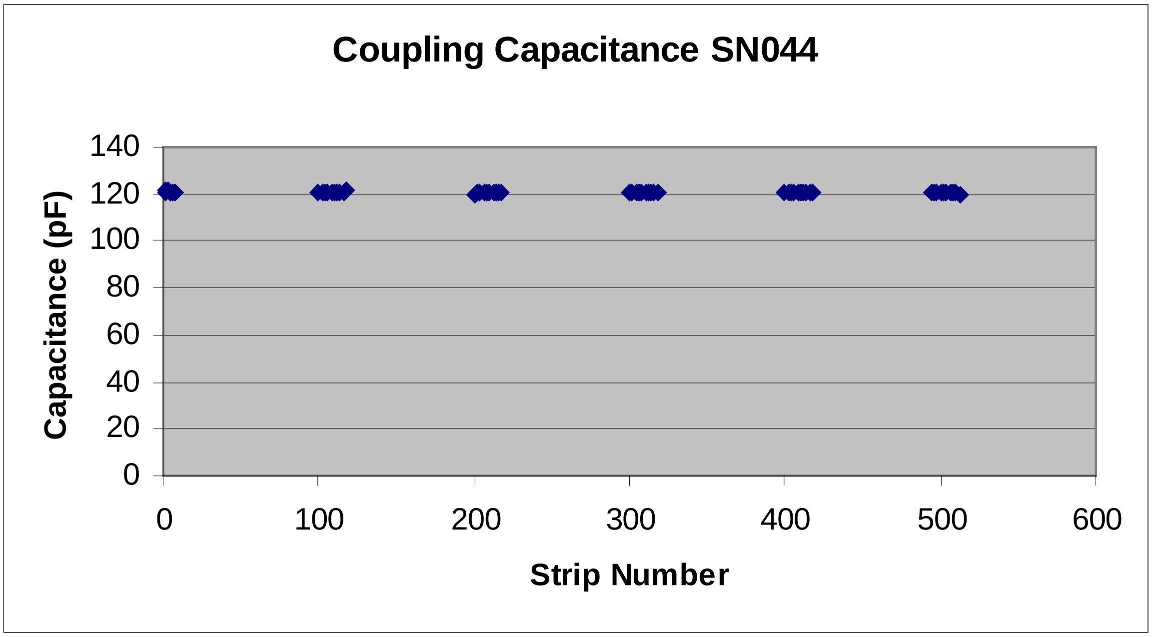

Figure 9: Unirradiated Sensor, SN044 Coupling Capacitance vs Strip

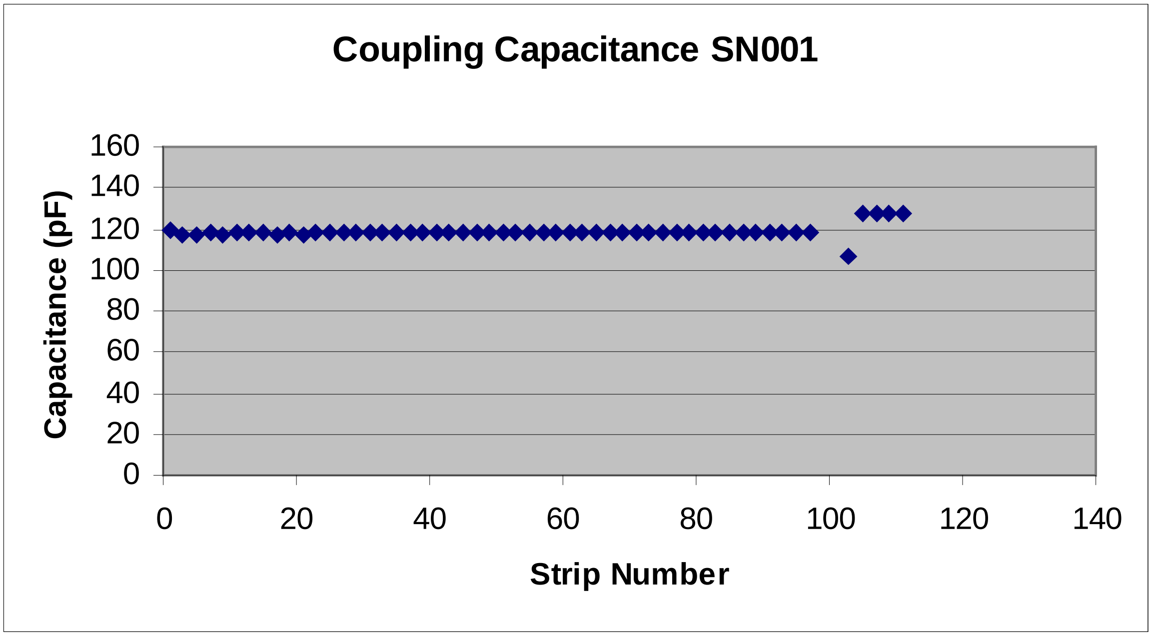

Figure 10: Irradiated Sensor, SN001 Coupling Capacitance vs Strip

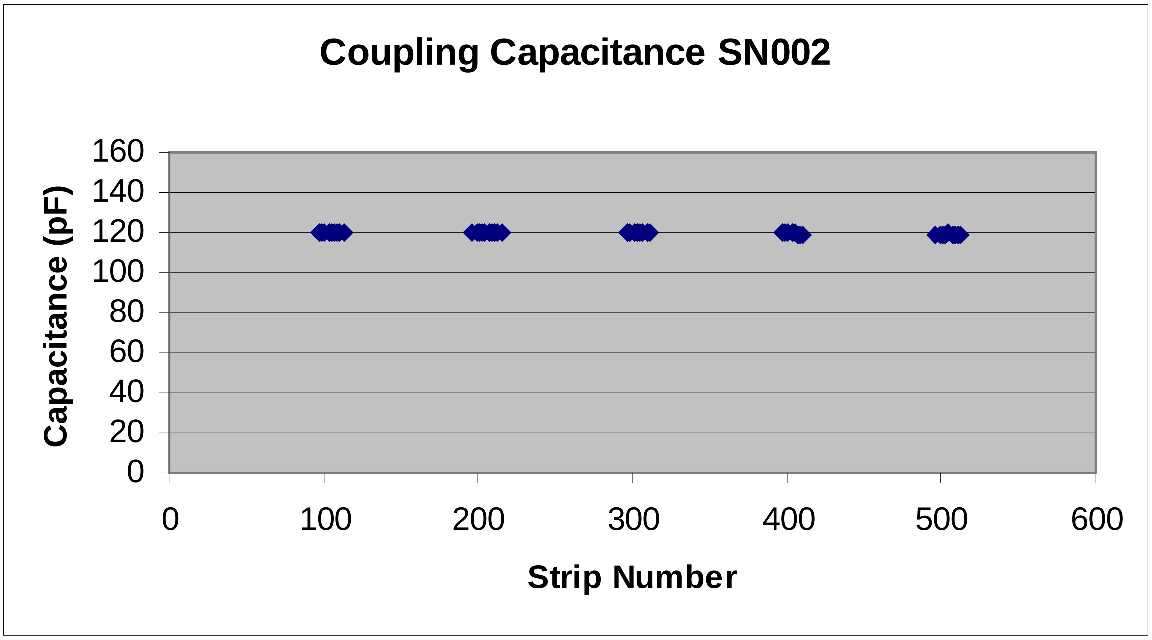

Figure 11: Irradiated Sensor, SN002 Coupling Capacitance vs Strip

To be consistent with the measurement setup used by our colleagues in the future we will only measure the interstrip capacitance from a given strip to one neighbor.

3.4 Strip Leakage Current

The leakage current for each individual strip was measured with the configuration shown in Figure 15. With the bias supply at 500V a picoammeter is connected to the DC pad of the strip. The results for the unirradiated detector, shown in Figure 16 are difficult to interpret. The measurements were performed at two different times and one can see that the leakage is not stable or consistent acrosss the strips measured each time. The first strips measured have approximately twice as much leakage current as the final strips and the level gradually decreases as the measurement progresses across the sensor. This is not normal and could perhaps be due to some chargeup effect. The average value of the unirradiated strip leakage is about 0.06 nA. Figure 17 shows the result for one of the irradiated sensors. One can observe that the strip leakage is uniform except in the area of damage from about strip 98 to strip 125. The leakage values are around 3.2μA per strip. This is approximately 1000 times less than the overall sensor leakage of approximately 3.25 mA. Figure 18 shows the results of the other irradiated sensor. Here again the leakage is uniform, with values around 5μA/strip, except in damaged area around strips 0 to 20.

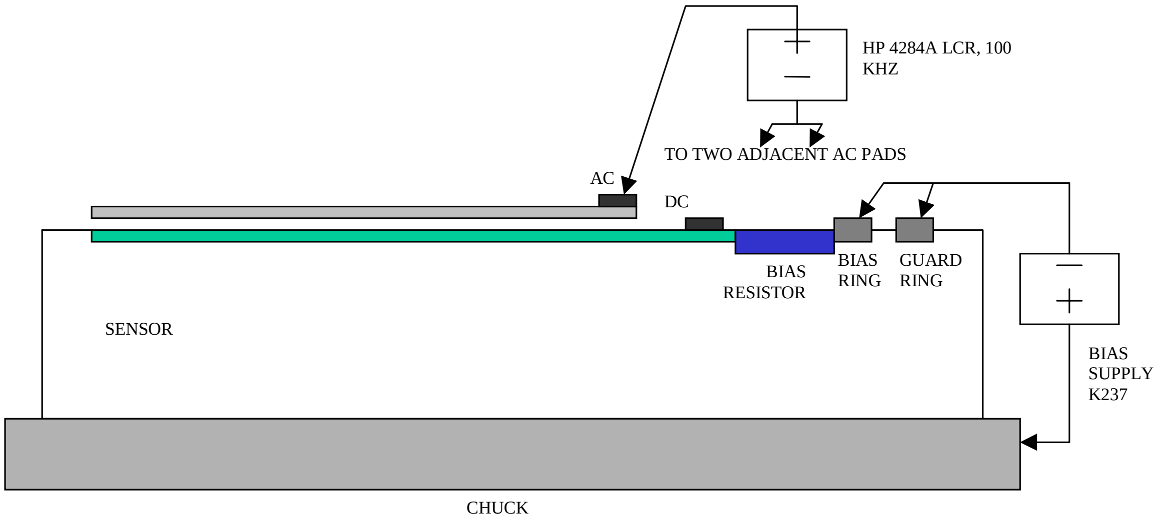

Figure 12: Setup for Measurement of Interstrip Capacitance

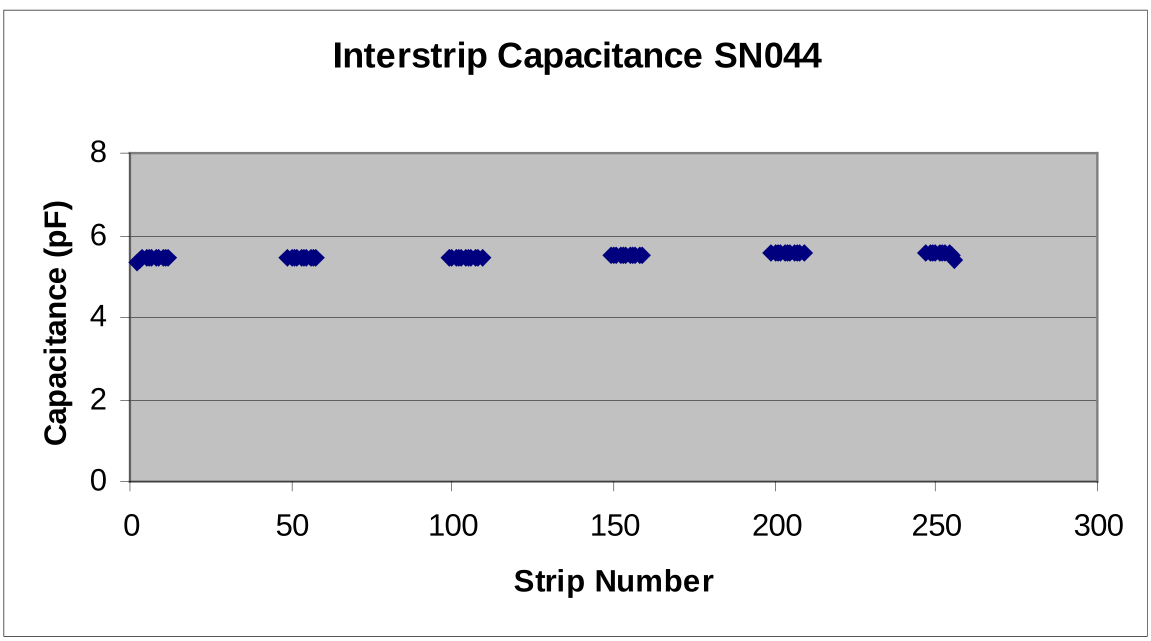

Figure 13: Unirradiated Sensor, SN044 Interstrip Capacitance vs Strip

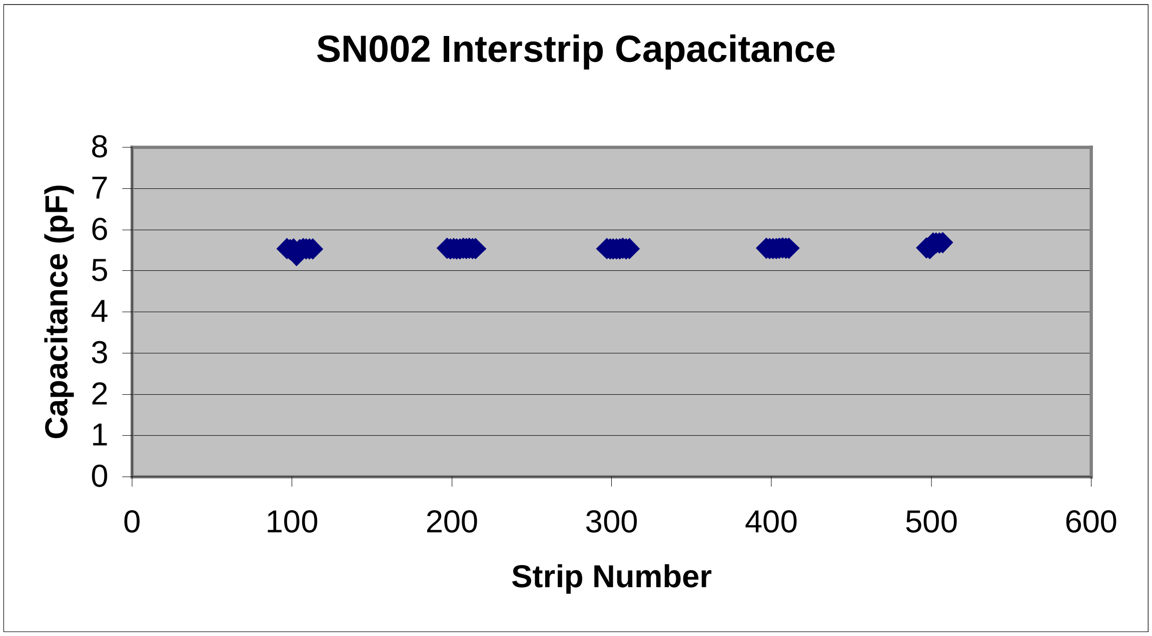

Figure 14: Irradiated Sensor, SN002 Interstrip Capacitance vs Strip

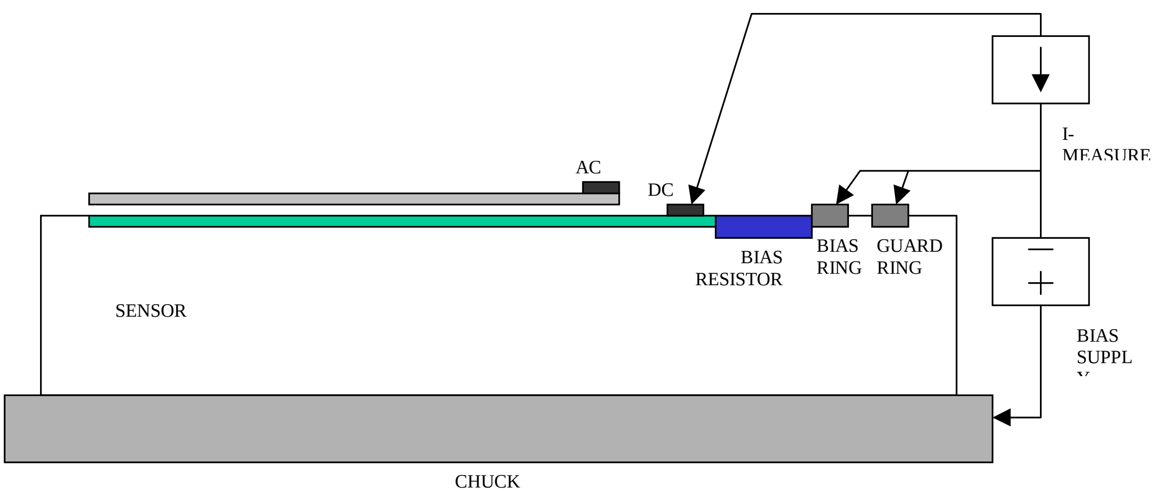

Figure 15: Setup for Measurement of Strip Leakage Current

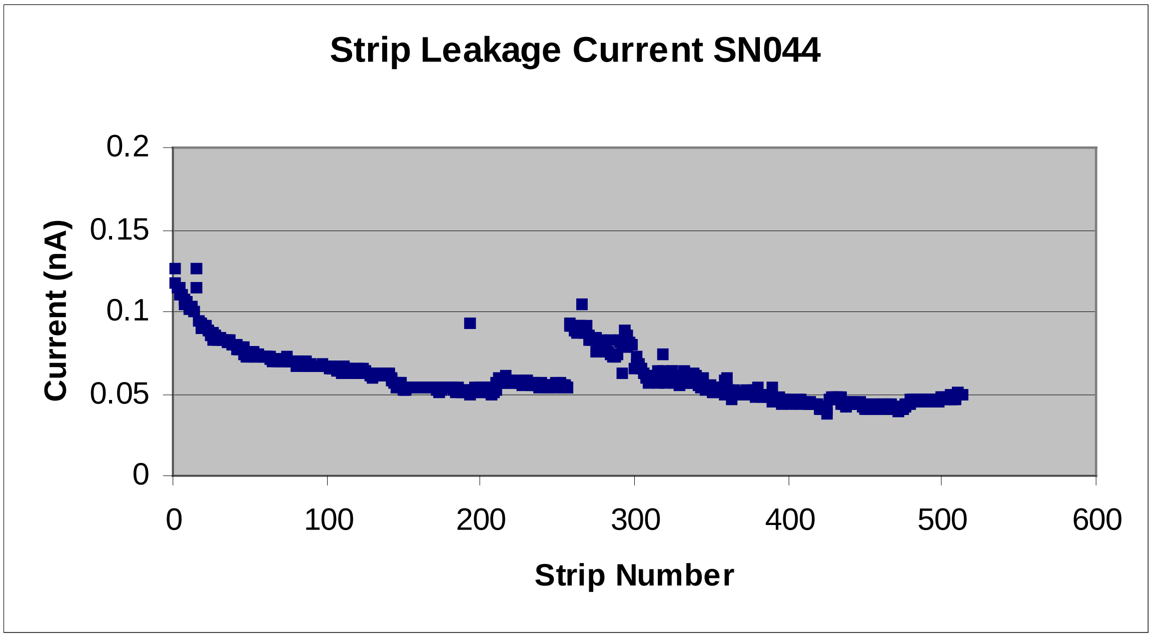

Figure 16: Unirradiated Sensor, SN044 Strip Leakage Current

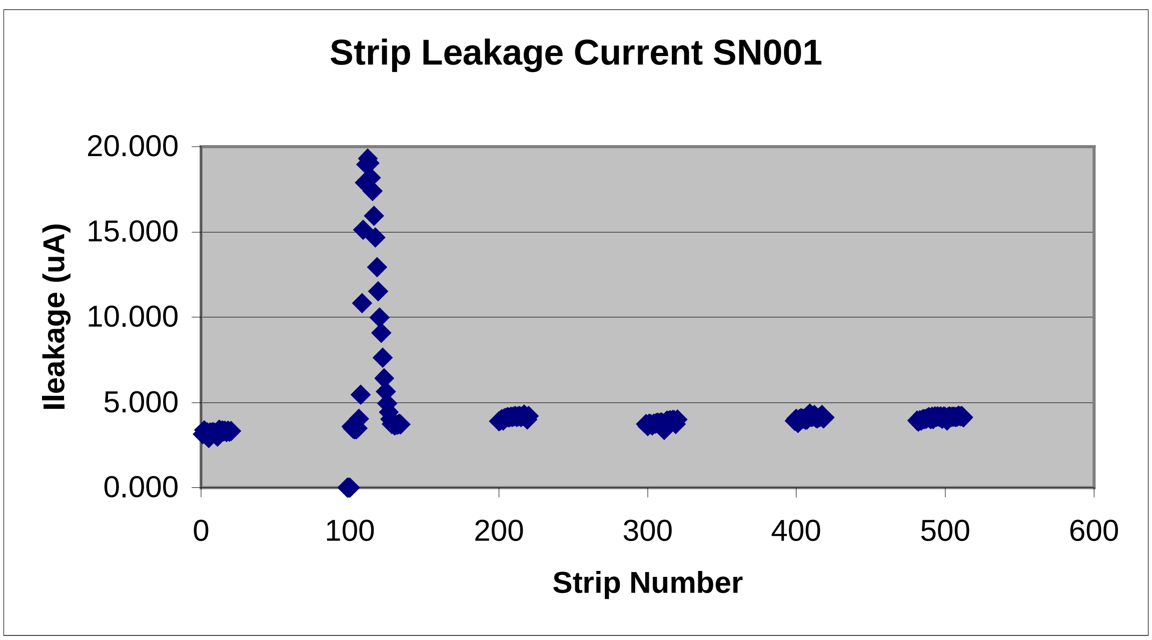

Figure 17: Irradiated Sensor, SN001 Strip Leakage Current

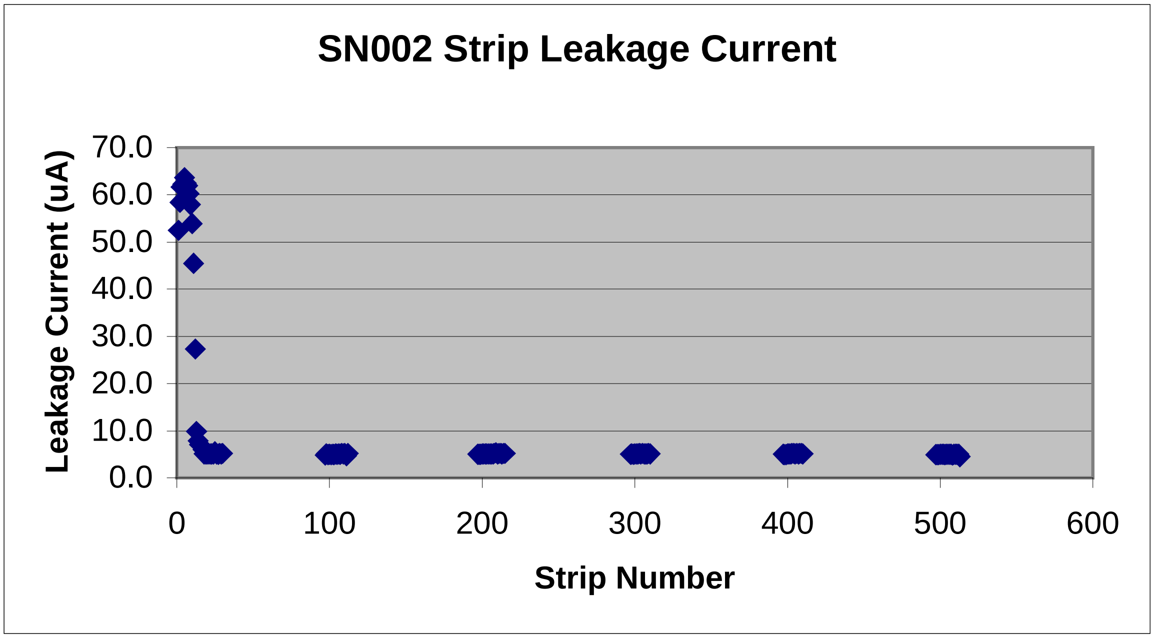

Figure 18: Irradiated Sensor, SN002 Strip Leakage Current

3.5 Coupling Capacitor Stability

The Coupling Capacitor Stability is measured using the configuration shown in Figure 19. The objective of this test is to find out how robust the coupling capacitors are when subjected to worst case conditions. The specification requires the coupling capacitance to breakdown when greater than 100V is applied across it. This test applies a constant 120V between the AC and DC pads of four adjacent strips of an unirradiated sensor. The results are shown in Figure 20, where the leakage current with the applied voltage is seen to be much less than the 1 nA level defined as the breakdown limit in the sensor specifications. As shown in Figure 21, the temperature during the approximate seven day duration of the test varied by only a couple of degrees. Figure 22 plots the values of the four coupling capacitors which had the 120V potential applied to them along with their neighbors on both sides. It is seen that these four coupling capacitors decreased in value by approximately 15 percent.

3.6 Leakage Current Stability

The stability of the IV measurement on two unirradiated sensors was measured over a five day extended period of time. The measurement configuration was the standard setup for biasing the Run2b sensors and is shown in Figure 23. The results are shown in Figure 24 and are explained by the plot in Figure 25 which shows the monitored temperature of the two sensors during the duration of the test. We observe that the leakage current of both

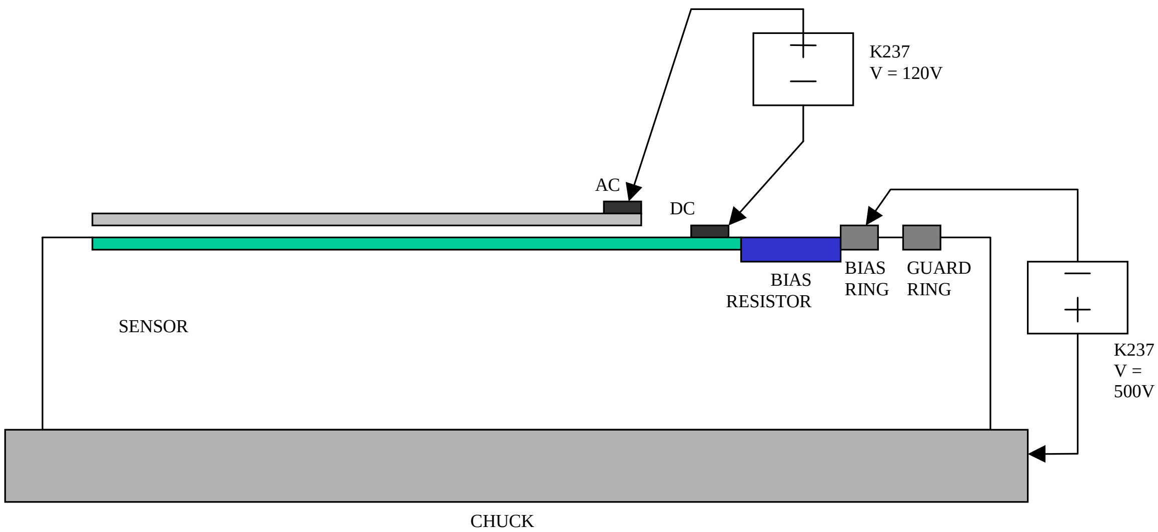

Figure 19: Setup for Measurement of Coupling Capacitor Stability

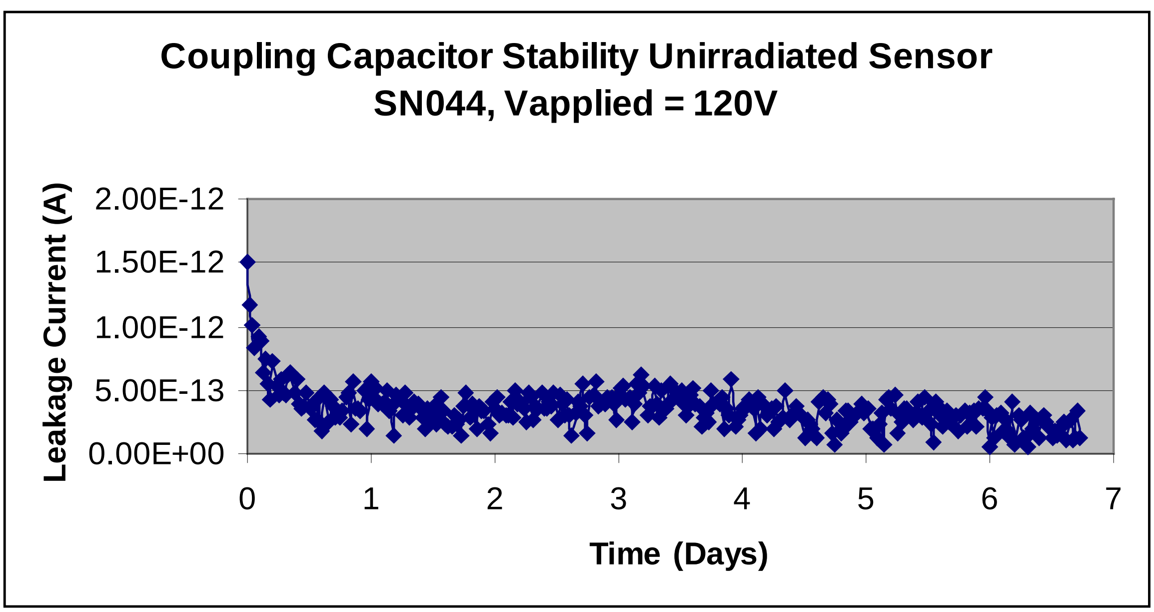

Figure 20: Unirradiated Sensor, SN044 Coupling Capacitor Breakdown vs Time

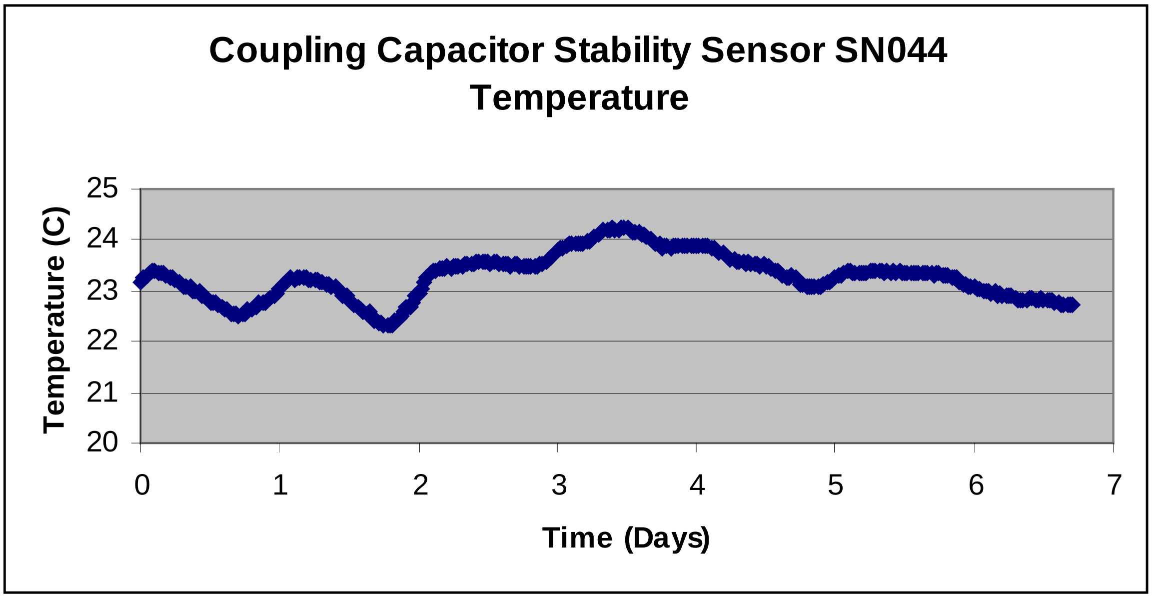

Figure 21: Unirradiated Sensor, SN044 Coupling Capacitor Temperature

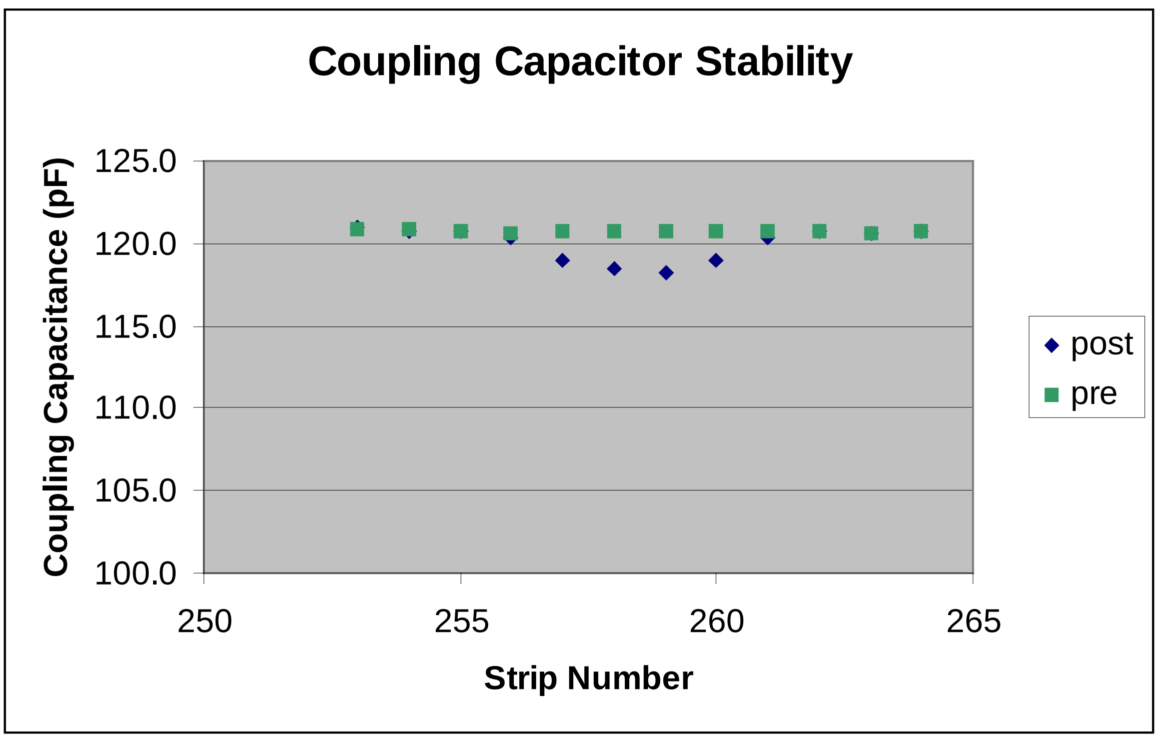

Figure 22: Unirradiated Sensor, SN044 Coupling Capacitance Values

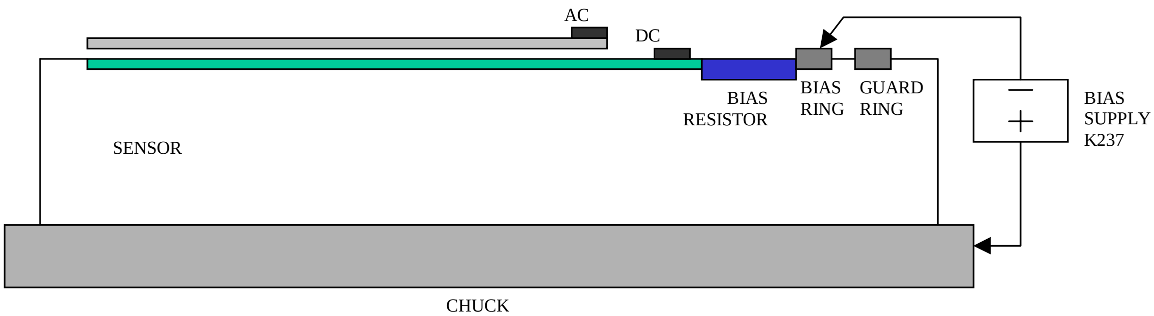

Figure 23: Setup for Measurement of Coupling Capacitor Stability

sensors tracks very closely the variances in temperature, and that when the temperature is fairly stable so is the value of sensor leakage.

4 Summary

- Bias Resistors: Specification met on unirradiated sensor, irradiated measurements require the revised measurement protocol.
- Coupling Capacitors: Measurements are consistent between the irradiated and the unirradiated sensors, specification requirements are met.
- Interstrip Capacitance: Measurements are consistent between the irradiated and the unirradiated sensors, specification requirements are met, future measurements should be made from strip to only one neighbor.
- Strip Leakage Current: Specification met on unirradiated sensor, irradiated measurements are consistent with the requirements.
- Coupling Capacitor Stability: Specification met on unirradiated sensor, the value of the capacitances decresed by about 15 percent but no breakdown occured.
- Leakage Current Stability: Unirradiated sensors measured at room temperature have very stable leakage current which closely tracks the variations in temperature.

References

[1] Hara K., CDF Sensors Specifications for Run2b

[2] Bacchetta N., et al, Silicon Sensor Quality Assurance for the CDF Run2b Silicon Detector

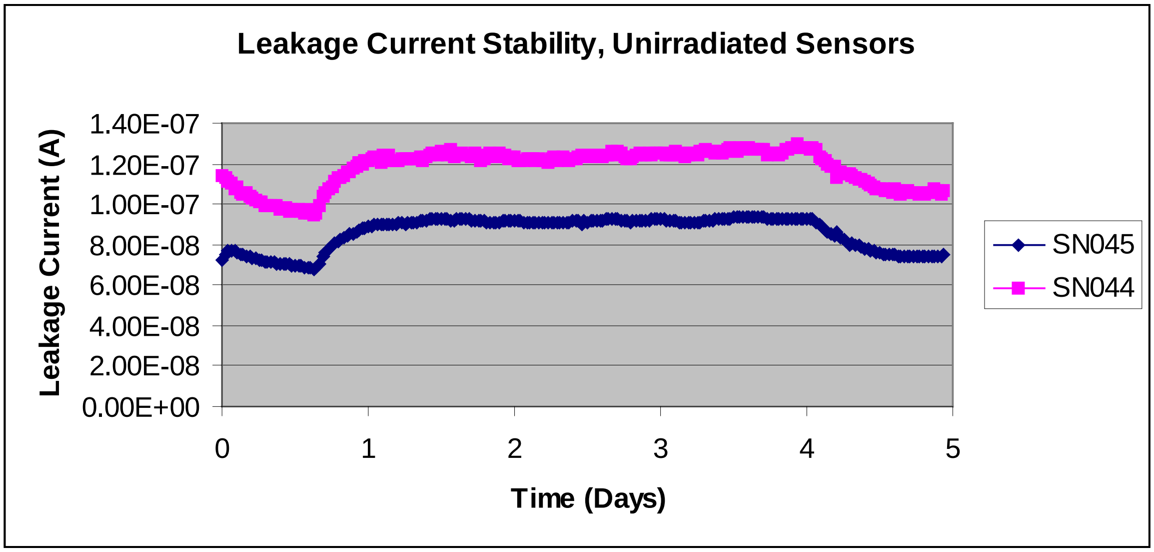

Figure 24: Unirradiated Sensor, SN044 Coupling Capacitor Breakdown vs Time

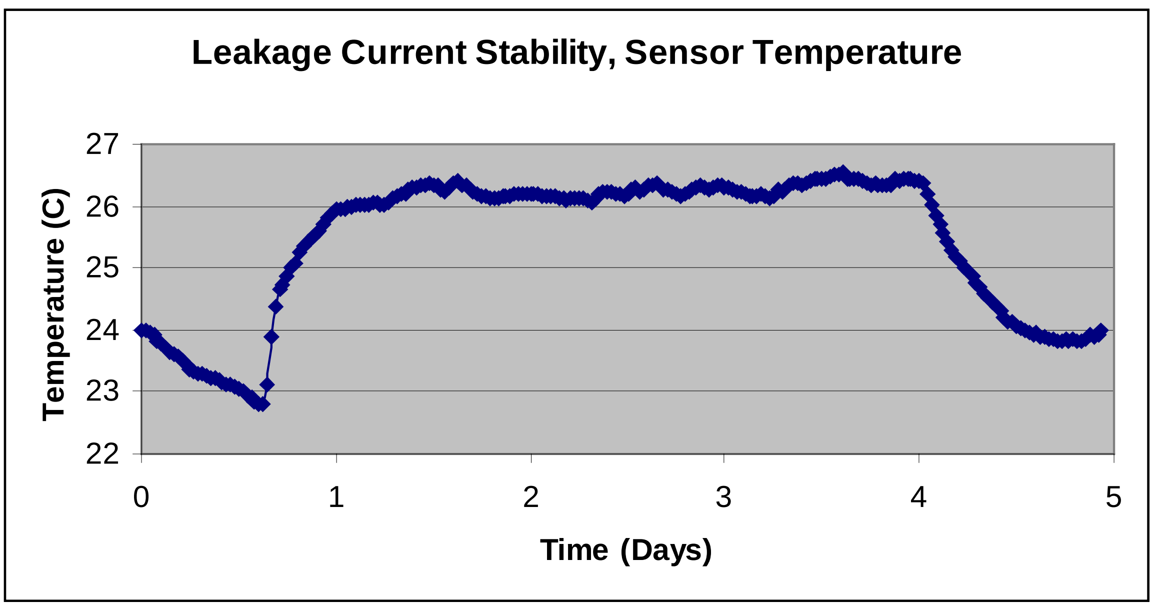

Figure 25: Unirradiated Sensor, SN044 Coupling Capacitor Temperature