Table of Contents

Measurement results of the irradiated mini-sensors

This page contains measurement results (IV/CV, etc.) of the mini-sensors that were irradiated at Boston General Hospital. These sensors are going to be used in the upcoming October testbeam.

Sensor descriptions and general information

All of the mini-sensors that were irradiated were supplied by Micron Semicondoctor. The sensor labels correspond to the type of silicon substrate (n or p), which wafer they were cut from, the type of mini-sensor (MS or MBP, explained below), as well as the location of this sensor on the half-moon structure it was cut from. The labels are oragnized as follows,

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<company><substrate ID>-<wafer ID>-<sensor type><sensor location>
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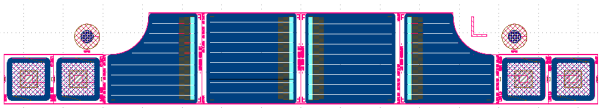
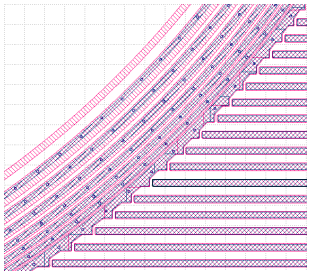
Definitions:

- **MSL**: Micron Semiconductor Limited
- **309x**: 3091 corresponds to n-in-p type while 3092 corresponds to p-in-n type
- **MS**: Mini-sensor, 30 um strip width, 80 um strip pitch, 1.115cm x 1.125cm
- **MBP**: mini-beam pipe sensor, 30 um strip width, 80 um strip pitch. Locations 1 and 2 have different guard ring structures, shown below. The cutout has a radius of about 5mm.

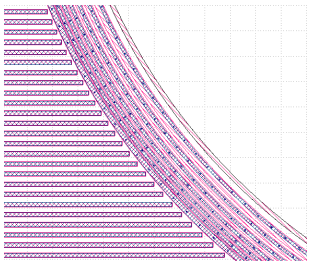
Schematic of the half-moon structure the sensors were cut from. From the left we have MBP1, MS1, MS2 and MBP2. The smaller square structures are diodes.



Zoomed in schematic of the guard ring of the MBP1 sensors:



Zoomed in schematic of the guard ring of the MBP2 sensors:



Irradiation information

Irradiation Group	L1	L2	L3	L4
Radiation dose (Mrad)	1.57	5.77	10.10	23.31
Proton fluence [x10^{14} cm^{-2}]	0.29	1.06	1.86	4.29
Neutron fluence eqv. [x10^{14} cm^{-2}]	0.27	1.00	1.75	4.03

The protons were 226 MeV while the neutron equivalent is given for 1 MeV neutrons.

Sensor Characteristics

Sensor	Depletion Voltage	Doping Concentration (atoms/cm^3)	Resistivity (kOhm-cm)
MSL3092-1-MS2	181.782	5.09723 x 10^{12}	0.875825
MSL3091-7-MBP1	171.113	5.13803 x 10^{12}	2.70315
MSL3091-7-MBP2	172.492	5.12317 x 10^{12}	2.71099
MSL3091-5-MS2	177.448	4.89929 x 10^{12}	2.83488
MSL3092-1-MS1	180.556	5.05295 x 10^{12}	0.883501
MSl3091-8-MS1	176.011	4.97939 x 10^{12}	2.78927
MSL3091-7-MS1	175.804	4.8664 x10^{12}	2.85404
MSL3091-7-MS2	177.903	5.03692 x 10^{12}	2.75742
MSL3091-8-MBP2	178.739	5.16102 x 10^{12}	2.69111
MSL3091-8-MBP1	177.161	4.57063 x10^{12}	3.03873

The depletion voltage is derived from the $\frac{1}{C^2}$ vs. Voltage relationship. The doping concentration and resistivity are calculated using the geometry of the sensor, the primary carrier mobility (holes for n-in-p and electrons for p-in-n), as well as the calculated depletion voltage.

The doping concentration can be derived from the slope of a plot of $\frac{1}{C^2}$ vs. V for $V < V_{dep}$,

$$N = \frac{2}{\epsilon q_e \frac{d}{dV}(\frac{1}{C^2})A^2},$$

where ϵ is the dielectric constant of silicon, 1.034x10^{-14} F/cm^3 and q_e is the charge of the electron, 1.6x10^{-19} C, and A is the area of the silicon.

The resistivity is given by,

$$\rho = \frac{1}{N q_e \mu},$$

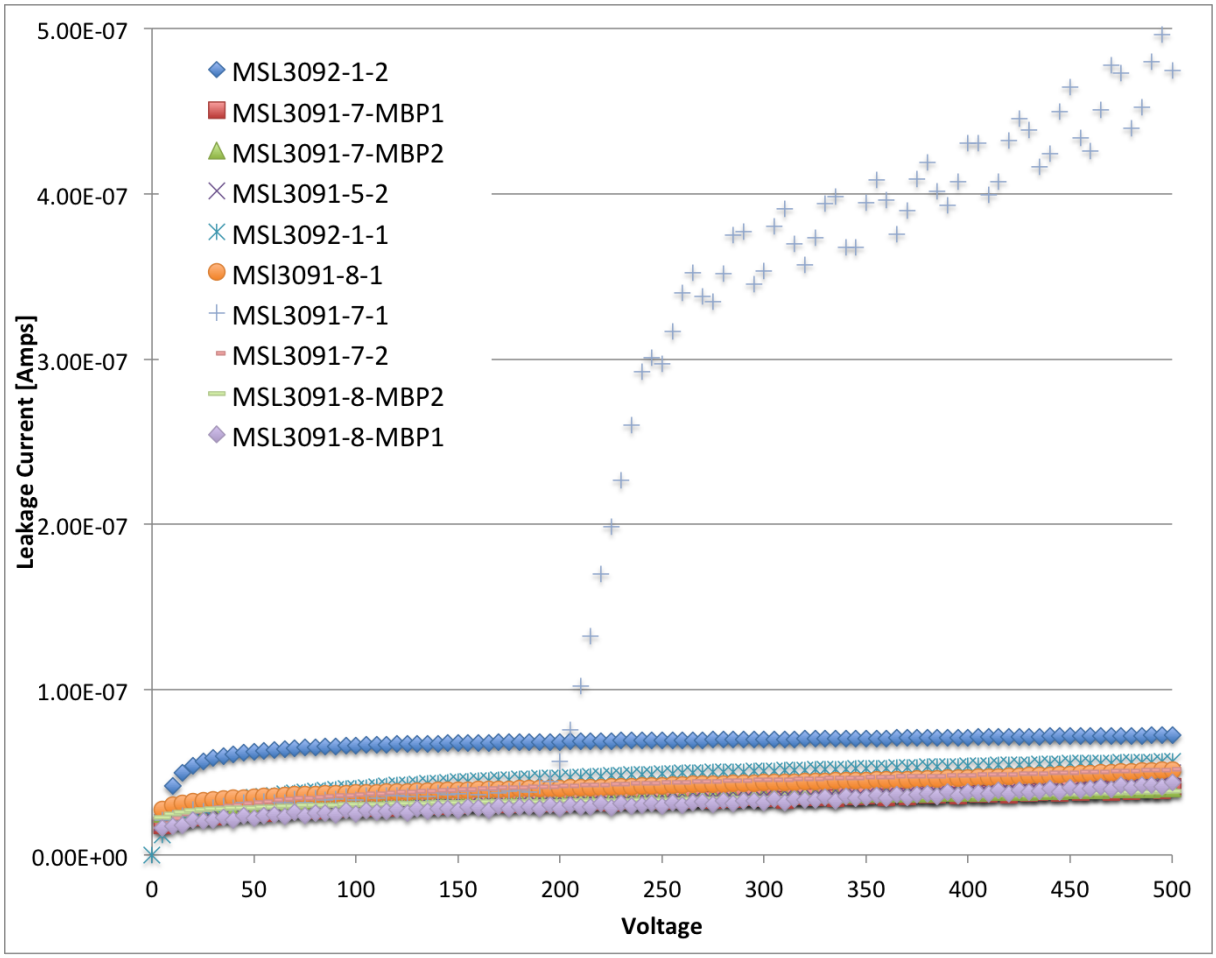
where μ is the carrier mobility of the silicon bulk. For p-type, the main carriers are holes, with a mobility of 450 cm^2/Vs. For n-type, the main carriers are electrons, with a mobility of 1400 cm^2/Vs.

Summary of current measurements before irradiation (Amps)

	Voltage (V)								
Sensor	50	100	150	200	250	300	350	400	4
MSL3092-1-MS2	6.263E-08	6.622E-08	6.761E-08	6.852E-08	6.931E-08	6.988E-08	7.048E-08	7.117E-08	7.181
MSL3091-7-MBP1	2.74E-08	2.95E-08	3.02E-08	3.12E-08	3.26E-08	3.41E-08	3.59E-08	3.81E-08	3.98E
MSL3091-7-MBP2	2.99E-08	3.19E-08	3.33E-08	3.42E-08	3.54E-08	3.60E-08	3.68E-08	3.77E-08	3.89E
MSL3091-5-MS2	3.03E-08	3.35E-08	3.44E-08	3.49E-08	3.59E-08	3.83E-08	4.09E-08	4.41E-08	4.46E

MSL3092-1-MS1	3.48E-08	4.04E-08	4.42E-08	4.68E-08	4.90E-08	5.08E-08	5.24E-08	5.38E-08	5.53E
MSl3091-8-MS1	3.48E-08	3.73E-08	3.92E-08	4.04E-08	4.20E-08	4.36E-08	4.51E-08	4.68E-08	4.88E
MSL3091-7-MS1	2.98E-08	3.34E-08	3.70E-08	5.68E-08	2.97E-07	3.53E-07	3.95E-07	4.31E-07	4.65E
MSL3091-7-MS2	3.18E-08	3.65E-08	3.95E-08	4.17E-08	4.37E-08	4.54E-08	4.70E-08	4.83E-08	4.99E
MSL3091-8-MBP2	2.88E-08	3.05E-08	3.18E-08	3.24E-08	3.33E-08	3.43E-08	3.51E-08	3.60E-08	3.71E
MSL3091-8-MBP1	2.24E-08	2.47E-08	2.67E-08	2.81E-08	2.94E-08	3.17E-08	3.49E-08	3.79E-08	4.07E

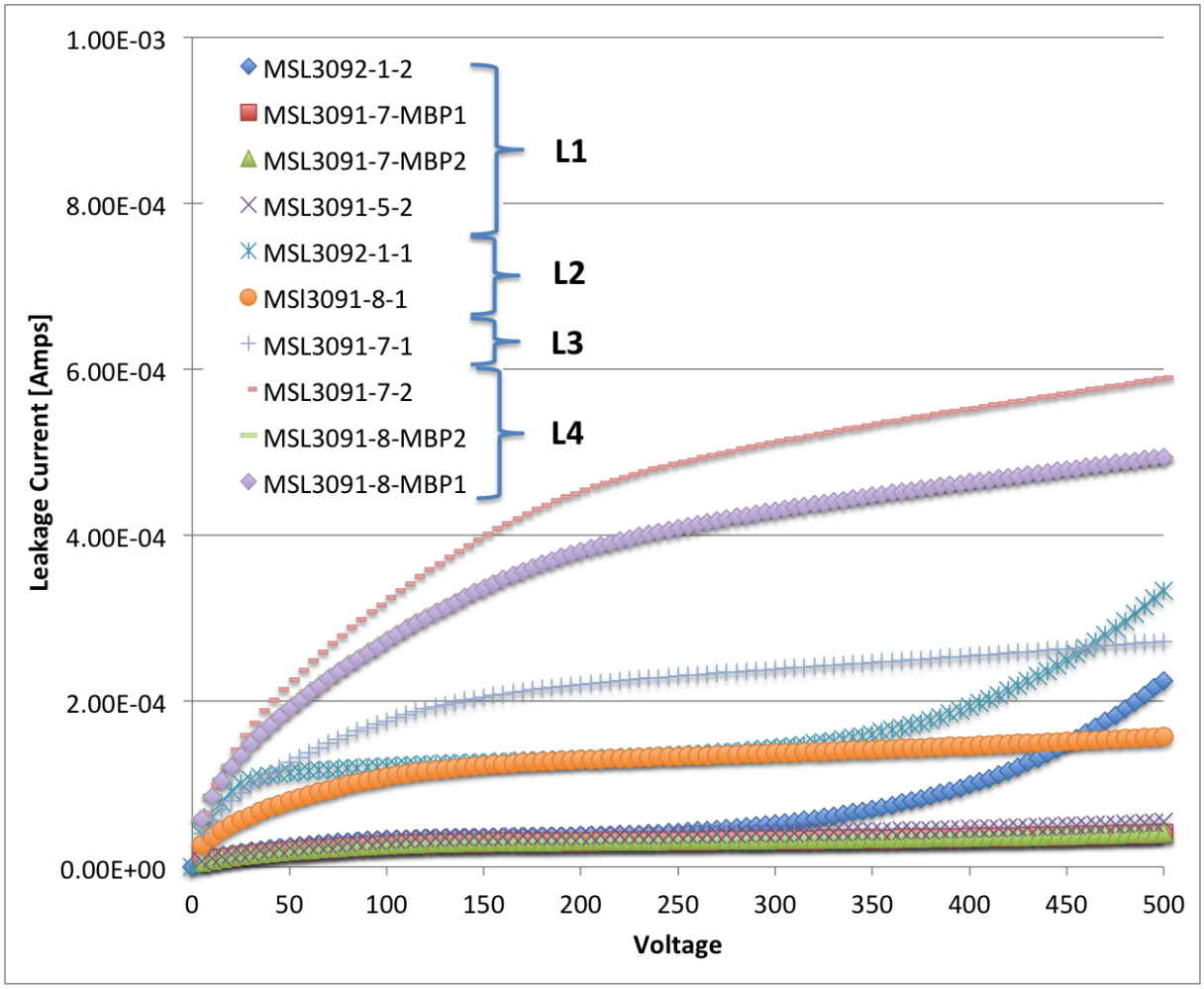
Show IV Curve Hide



Summary of current measurements after irradiation (Amps)

		Voltage (V)							
	Sensor	50	100	150	200	250	300	350	400
L1	MSL3092-1-2	2.428E-05	3.284E-05	3.512E-05	3.746E-05	4.187E-05	5.184E-05	6.955E-05	9.893E-05
	MSL3091-7-MBP1	1.897E-05	2.643E-05	2.927E-05	3.033E-05	3.129E-05	3.232E-05	3.360E-05	3.528E-05
	MSL3091-7-MBP2	1.918E-05	2.673E-05	2.967E-05	3.079E-05	3.179E-05	3.288E-05	3.422E-05	3.595E-05
	MSL3091-5-MS2	2.286E-05	3.203E-05	3.591E-05	3.725E-05	3.868E-05	4.047E-05	4.271E-05	4.556E-05
L2	MSL3092-1-MS1	1.131E-04	1.211E-04	1.260E-04	1.302E-04	1.349E-04	1.431E-04	1.600E-04	1.928E-04
	MSl3091-8-MS1	7.915E-05	1.083E-04	1.225E-04	1.289E-04	1.332E-04	1.372E-04	1.414E-04	1.460E-04
L3	MSL3091-7-MS1	1.259E-04	1.762E-04	2.047E-04	2.200E-04	2.300E-04	2.382E-04	2.461E-04	2.543E-04
L4	MSL3091-7-MS2	2.258E-04	3.245E-04	4.011E-04	4.545E-04	4.879E-04	5.128E-04	5.339E-04	5.530E-04
	MSL3091-8-MBP2	1.927E-04	2.752E-04	3.388E-04	3.823E-04	4.095E-04	4.299E-04	4.472E-04	4.629E-04
	MSL3091-8-MBP1	1.905E-04	2.723E-04	3.357E-04	3.803E-04	4.084E-04	4.293E-04	4.470E-04	4.631E-04

Show IV Curve Hide



Summary of capacitance measurements before irradiation (pF)

	Voltage (V)											
Sensor	30	50	70	90	110	130	150	170	190	210	230	250
MSL3092-1-MS2	119.99	91.97	77.39	68.16	61.66	56.81	52.98	49.90	48.15	47.87	47.76	47.70
MSL3091-7-MBP1	98.65	75.13	63.07	55.47	50.10	46.14	42.97	40.65	40.05	39.90	39.80	39.74
MSL3091-7-MBP2	99.25	75.47	63.30	55.60	50.20	46.19	43.00	40.60	39.92	39.77	39.66	39.60
MSL3091-5-MS2	126.01	94.57	78.62	68.68	61.86	56.75	52.74	49.56	48.36	48.14	48.02	47.91
MSL3092-1-MS1	119.38	91.59	77.03	67.81	61.35	56.53	52.75	49.69	48.09	47.82	47.73	47.67
MSl3091-8-MS1	122.07	92.94	77.78	68.27	61.66	56.66	52.74	49.62	48.59	48.39	48.26	48.19
MSL3091-7-MS1	126.20	94.71	78.58	68.65	61.79	56.64	52.62	49.49	48.46	48.27	48.14	48.08
MSL3091-7-MS2	130.60	96.24	79.83	69.63	62.63	57.40	53.34	50.13	48.91	48.69	48.56	48.50
MSL3091-8-MBP2	101.47	80.11	65.98	57.41	51.57	47.23	43.88	41.19	40.02	39.81	39.71	39.62
MSL3091-8-MBP1	82.80	67.30	58.70	51.50	46.40	43.10	40.00	37.50	36.70	36.70	36.70	36.90

Summary of capacitance measurements after irradiation (pF)

		Voltage (V)											
	Sensor	30	50	70	90	110	130	150	170	190	210	230	250
L1	MSL3092-1-MS2	326.66	224.23	174.61	143.43	121.28	102.68	88.73	84.35	81.82	79.61	77.60	75.70

	MSL3091-7-MBP1	116.53	86.16	71.22	61.83	54.52	47.30	43.30	43.37	43.36	43.30	43.28	43.22
	MSL3091-7-MBP2	117.10	86.55	71.56	62.07	54.79	47.58	43.24	43.22	43.24	43.20	43.13	43.06
	MSL3091-5-MS2	159.39	114.99	93.90	81.13	72.16	64.74	56.82	51.30	51.34	51.53	51.49	51.44
L2	MSL3092-1-MS1	989.05	765.80	551.57	441.32	356.10	215.53	151.64	136.16	127.65	121.02	147.49	42.19
	MSl3091-8-MS1	569.30	366.44	283.79	236.22	204.95	182.37	164.36	148.98	134.54	114.02	21.48	4.87
L3	MSL3091-7-MS1	812.57	612.50	473.80	394.04	341.76	304.71	276.33	31.64	5.78	2.78	1.70	1.15
L4	MSL3091-7-MS2	527.53	839.06	891.14	804.06	714.95	639.75	578.46	529.78	490.72	457.77	430.09	406.0
	MSL3091-8-MBP2	550.59	785.35	739.47	643.88	561.46	497.34	448.02	409.40	378.23	352.13	329.72	310.5
	MSL3091-8-MBP1	435.53	653.87	597.91	533.97	474.03	423.99	41.86	7.43	3.50	2.13	1.45	1.05

Total time spent above freezing after irradiation

This is the total amount of time the sensors have been above freezing after we placed them in our freezer here at Syracuse. This does not take into account the shipping time between Boston General and Syracuse. I still need to find this information.

Sensor	Time
MSL3092-1-MS2	92.75 hours
MSL3091-7-MBP1	0
MSL3091-7-MBP2	0
MSL3091-5-MS2	0
MSL3092-1-MS1	92.75 hours
MSl3091-8-MS1	89 hours
MSL3091-7-MS1	89.75 hours
MSL3091-7-MS2	89.75 hours
MSL3091-8-MBP2	82 hours
MSL3091-8-MBP1	82 hours

Detector board information

Each detector board contains two mini sensors. When referring to sensor 1 and sensor 2, if you are looking from the daughter board to the detector board, the left most is sensor 1 and the right most is sensor 2. (This is the labeling on the daughterboard, but does not match the readout scheme of the Beetle chip using the Aliabava system. So, these have been swapped in the list below)

Cartoons with definitions of Beetle Chip Num, Channel Num, Stage Motion direction for Board 1, Board 2,Board 3,Board 4

Board Number

1. Milano daughter board
   - Sensor 0: 3092-1-MS2 p-in-n. Apply positive HV to the backplane. Irradiation level 1.
   - Sensor 1: 3092-1-MS1 p-in-n. Apply positive HV to the backplane. Irradiation level 2.
2. Syracuse daughter board
   - Sensor 0: 3091-8-MS1 n-in-p. Apply negative HV to the backplane. Irradiation level 2.
   - Sensor 1: 3091-10-MBP2 n-in-p. Apply negative HV to the backplane. Un-irradiated.
3. Zurich daughter board
   - Sensor 0: 3091-7-MS2. n-in-p. Apply negative HV to the backplane. Irradiation level 4.
   - Sensor 1: 3091-7-MS1. n-in-p. Apply negative HV to the backplane. Irradiation level 3.
4. Syracuse daughter board
   - Sensor 0: 3091-8-MBP2. n-in-p. Apply negative HV to the backplane. Irradiation level 4.
   - Sensor 1: 3091-8-MBP1. n-in-p. Apply negative HV to the backplane. Irradiation level 4.

-- PeterManning - 29 Sep 2014

This topic: LHCb > IrradiatedSensorResults
Topic revision: r20 - 2015-06-26 - StevenBlusk