IST Ladder Chip and Sensor Assembly And Testing Procedure at Fermilab/UIC

Bert Gonzalez, Tammy Hawke, Zhenyu Ye (yezhenyu@uic.edu)

Version 6, Updated on 1/9/2013

1. Introduction

This document describes the IST ladder assembling and testing procedure for work to be done at Fermilab and UIC. Ben Buck from MIT Bates and/or Gerrit van Nieuwenhuizen from BNL will send the following items to Bert Gonzalez at Fermilab and/or Zhenyu Ye at UIC:

- 18 ladders with flexible hybrids laminated onto carbon-fiber structures;
- 72 fully tested Hamamatsu Silicon sensors;
- 432 fully tested APV readout chips;
- 75 kits of "TRA-DUCT BA2902 kit 2.65 GM BIPAX" (Silver epoxy);
- 1 HUNTSMAN ADHESIVES TDR 1100-11 RO 35LB (TDR 1100);
- 3 Dow Corning Sylgard 186 Silicone Elastomer 0.5kg Kit Translucent.

Bert Gonzalez, Tammy Hawke/Michelle Jonas and Gordon Glllespie/Michael Roman will assemble 18 IST ladders at the Fermilab Silicon Detector facility. Zhenyu Ye, Anatoly Evokimov and Yaping Wang will test all the assembled ladders at UIC. There will be transportations of staves among MIT/BNL/FNAL/UIC. Upon receiving a ladder, it is required to visually check and document any damage that might happen during the transportation to the ladder and its components. It is anticipated that 18 fully assembled and tested IST ladders will be available by February 28, 2013.

2. Assembling and Testing Procedure

Below is a brief description of assembling and testing procedure for one IST ladder:

1. Tammy/Michelle will perform wire bond pull test on the hybrid and record the test results (section 2.1). Hybrids that do not meet the requirement will not be used in the following steps;
2. Bert will glue 36 APV readout chips onto the hybrid (section 2.2);
3. Tammy/Michelle will wire bond the backend readout pads of all the readout chips to the hybrid and do a visual inspection of all the wire bonds (section 2.3);
4. Zhenyu/Anatoly/Yaping will perform an electronic test at UIC (section 2.4);
5. Bert will glue 6 silicon sensors to the hybrid (section 2.5);
6. Tammy/Michelle will wire bond the frontend readout pads of all the readout chips with the silicon sensors and do a visual inspection of all the wire bonds (section 2.6);
7. Zhenyu/Anatoly/Yaping will perform an electronic test at UIC (section 2.7);
8. Bert will encapsulate the wire bonds and do a visual inspection of all the wire bonds (section 2.8);
9. Gordon/Michael will measure the positions of 12 points on each Silicon sensor with respect to the reference and record the results (section 2.9);
10. Zhenyu/Anatoly/Yaping will perform an electronic test at UIC (section 2.10).

2.1 Wire bonding Pull Test for the Hybrid

1. Locate traveler document for entering component information.
2. Weigh the ladder and record the measured weight on the traveler.
3. Inspect the hybrid under a microscope: inspect all areas before putting it on the machine for wire bonding. Look for and note shorts, damage, dirt, and pad quality, anything that could cause problems when bonding.
4. Check temperature and humidity in the room as they play a role in how the wire bonder will perform and what power setting are likely needed for the quality of work.
5. Place module on the machine and apply vacuum to secure bonding fixture.
6. Set the heights of the work surface at the lowest bond point.
7. Program first chip where the bond-off area is (see Fig.1).
8. Reference systems, pad size, pad location, bounty points, wire bond locations
9. Copy the program to all 36 bond-off areas.
10. Set bond parameters:
    a. Set USG powers for 1st and 2nd bond.
    b. Set bond time for 1st and 2nd bond.
    c. Set force for 1st and 2nd bond
    d. Set tail length. For 1st bond
    e. Set loop height
    f. Set bond search.
    g. Set speed in which the wire is bonded.
11. Wire bonds first couple pads check to see if changes need to be made, such as, loop heights, powers. Force, …... etc. then run the program in auto mode.
12. Inspection: after the bonding is completed, remove from the machine and inspect under the microscope.
13. Measure the pull strength of all the 36 wire bonds and record the results.
14. Remove all the wire bonds on the bond-off areas.
15. Weigh the ladder and record the measured weight on the traveler.
16. If any of the pull strength is smaller than 4 gram, hold the hybrid from the production line and inform UIC. Otherwise give the ladder to Bert.

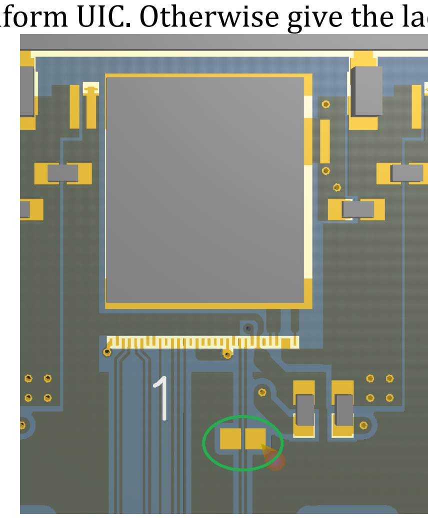


Figure 1 Bond-off area (in circle) for wire-bonding pull test.

2.2 APV Chip Placement

1. Locate traveler document for entering component information.
2. Inspect the fixture/chip alignment bar and use nitrogen to remove dust if necessary.
3. Weigh the ladder and record the measured weight on the traveler.
4. Locate module core into fixture and secure with screws at each end.
5. Place chip alignment bar into place; align notches with the gaps between chip pattern and at edge of gold pattern where front edge chip contacts the G-10 portion of placement bar.
6. Locate readout chip package, identify 36 chips to be placed and placement sequence that is intended, enter 36 chip I.D.s into traveler.
7. Mix a packet of silver epoxy for 4 to 5 minutes and transfer into a 5cc B&D syringe. Replace plunger and attach red tapered tip with .010" inner diameter.
8. Carefully place a drop 1 to 2 mm in diameter at center of chip location on the first 18 chip locations of the module.
9. Locate pen-vac and inspect contact surface is clean.
10. Adhere to the chip placement plan and place 18 chips into position lightly.
11. Use a clean ESD swab and apply a few grams of pressure on the center of each chip in a downward direction.
12. Implement the CMM camera to view the gold micro-bond pads on the hybrid at the back of chip 1 and align the chip back end pad in the x coordinate accordingly centering chip pad to gold pad. Repeat this alignment procedure for the next 17 chips.
13. Repeat steps 6 -11
14. Carefully inspect there is no excess epoxy that squeezed out that can be problematic.
15. Allow curing a few hours before removing from fixture.
16. Weigh the ladder and record the measured weight on the traveler.
17. Give the ladder to Tammy/Michelle.

2.3 APV Chip backend Wire bonding

1. Locate traveler document for entering component information.
2. Inspection under a microscope. Inspect all areas of the module before putting in on the machine for wire bonding. Look for shorts, damage, dirt, and pad quality, anything that could cause problems when bonding. And note it.
3. Weigh the ladder and record the measured weight on the traveler.
4. Check temperature and humidity in the room.
5. Place module on the machine and apply vacuum to secure bonding fixture.

6. Set the heights of the work surface at the lowest bond point.
7. Program first chip and first chip where sensor would be.
8. Reference systems, pad size, pad location, bounty points, wire bond locations.
9. Copy the program to all chips.
10. Bond parameters.
    a. Set USG powers for 1st and 2nd bond.
    b. Set bond time for 1st and 2nd bond.
    c. Set force for 1st and 2nd bond
    d. Set tail length. For 1st bond
    e. Set loop height
    f. Set bond search.
    g. Set speed in which the wire is bonded.
11. Run program. Wire bonds first couple pads check to see if changes need to be made, such as, loop heights, powers. Force, …... etc. then run the program in auto mode. (see wire-bonding diagrams below)
12. Inspection. After the bonding is completed, remove from the machine and inspect under the microscope for any repairs that are needed before sending over to the next procedure.
13. Weigh the ladder and record the measured weight on the traveler.
14. Give the ladder to UIC.

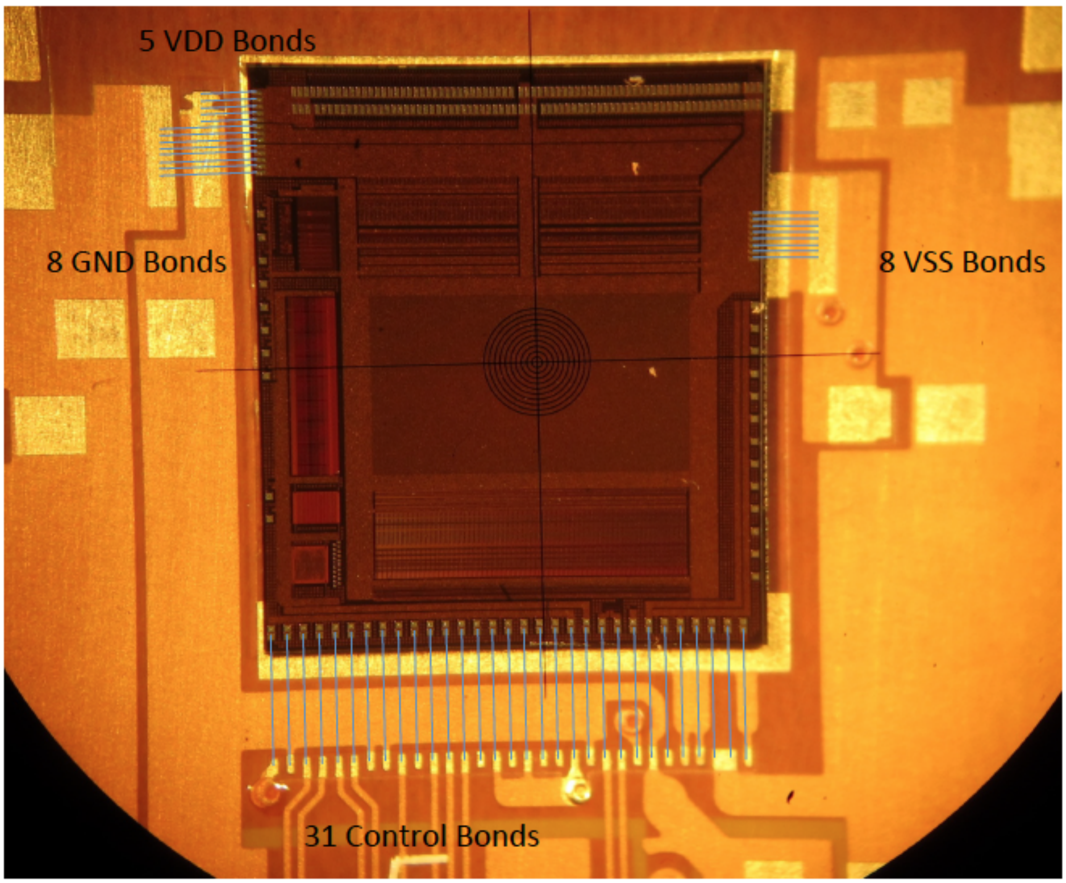


Figure 2 Backend wire-bonding diagram.

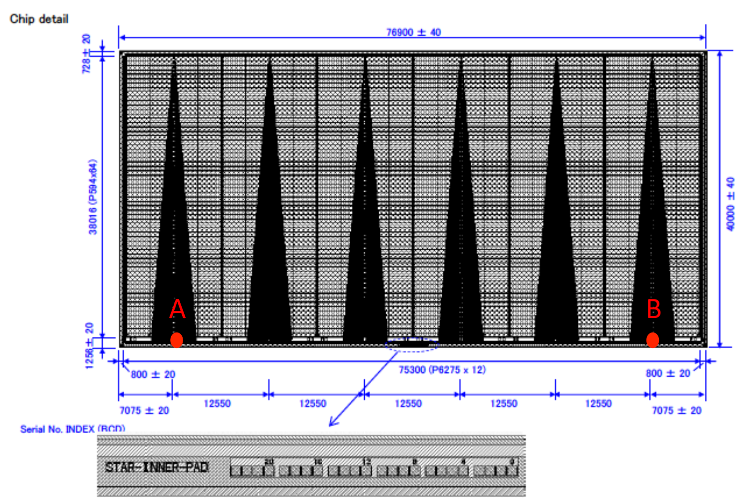
2.4 Electronic Test After Chip Wire bonded

1. Locate traveler document for entering test information.
2. Upload the information of the previous steps into the production database.
3. Visually inspect the stave under the microscope, check especially if there is remaining wire-bonds from pull test, or missing wire-bonds on the chip.
4. Connect the 3 sections (A, B, C) to the readout system, where A goes to ARM0 Port 0, B to ARM0 Port 1, and C to ARM1 Port 0.
5. Record power supply currents after just powering up and when taking data.
6. Take 1000 events at 10-100 Hz with VPSP=43 and VPSP=48, respectively.
7. Run analysis code and record pedestal and noise for each section.
8. Record the number of broken channels.
9. Upload the information of the testing results into the database.
10. If all the 36 chips have proper I2C communication (all the chips have similar pedestal and average noise less than 14 with RMS less than 2, the pedestal change vs VSPS), and there are no more than 50 randomly distributed channels not functioning, we can proceed with the following steps. Otherwise identify the problem, and decide whether to pull the stave off the production line, or repair the stave.
11. Give the stave to Bert at Fermilab.

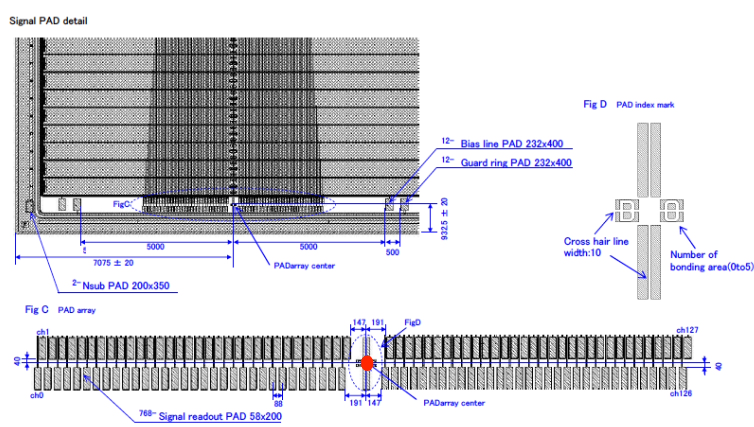
2.5 Silicon Sensor Placement

1. Identify module number to see if it is consistent with the traveler.
2. Weigh the ladder and record the measured weight on the traveler.
3. Locate module into fixture and secure with screws at each end.
4. Inspect sensor contact surface and clean as needed.
5. Mask sensor area with .003” thick ¼ “ wide kapton tape. Pattern requires full length of contact area at 3 points (top, center, bottom and short strips at gaps between sensors). Be extra careful to not touch the micro-bonds on any of the readout chips while locating kapton.
6. Identify the 6 sensors with the same full depletion voltage to be placed. Confirm orientation, position and put into traveler.
7. Mix a batch of Huntsman TDR 1100-11, 10 g resin to 4.2 g of hardener and mix for 5 minutes, transfer into EFD 10cc syringe add piston and cap. Centrifuge for 5 minutes add blue tapered tip and attach to EFD dispensing machine.
8. Set pressure to 30 psi and begin dispensing epoxy in between masked area at the 6 sensor locations. Use a new razor blade and slid over mask area spreading epoxy uniformly. Inspect epoxy film and add epoxy if needed and repeat until a uniform area is evident. Remove all the masking, being extremely carefully to not damage any micro-bonds in the process.

9. Locate a packet of silver epoxy and mix for 5 minutes. Transfer into a 5cc B&D syringe and a blue tapered tip. Apply a strip of epoxy along the length of the sensor area at the center, avoiding area at gaps of each sensor.
10. Release sensor alignment bar on fixture at each end for setting Y position (see sensor alignment pictures below). Carefully place one sensor at far left as accurately as possible referencing chip pads and locate weight. Repeat same procedure for the next five sensors.
11. Power on CMM and focus on far left chip pads and align sensor pads to match chip coordinate at 1st and last chip of each sensor. Use an ESD safe swab and adjust the sensor in X-axis until sensor pads align to chip pads. Repeat on the next 5 sensors.
12. Return to far left sensor and double check align has not changed, confirm next 5 sensors.
13. Let cure overnight.
14. Weigh the ladder and record the measured weight on the traveler.
15. Next day remove from fixture and give it to Tammy/Michelle.



A, B: sensor alignment feature



sensor alignment feature

Figure 3 Sensor alignment features for placing the sensors.

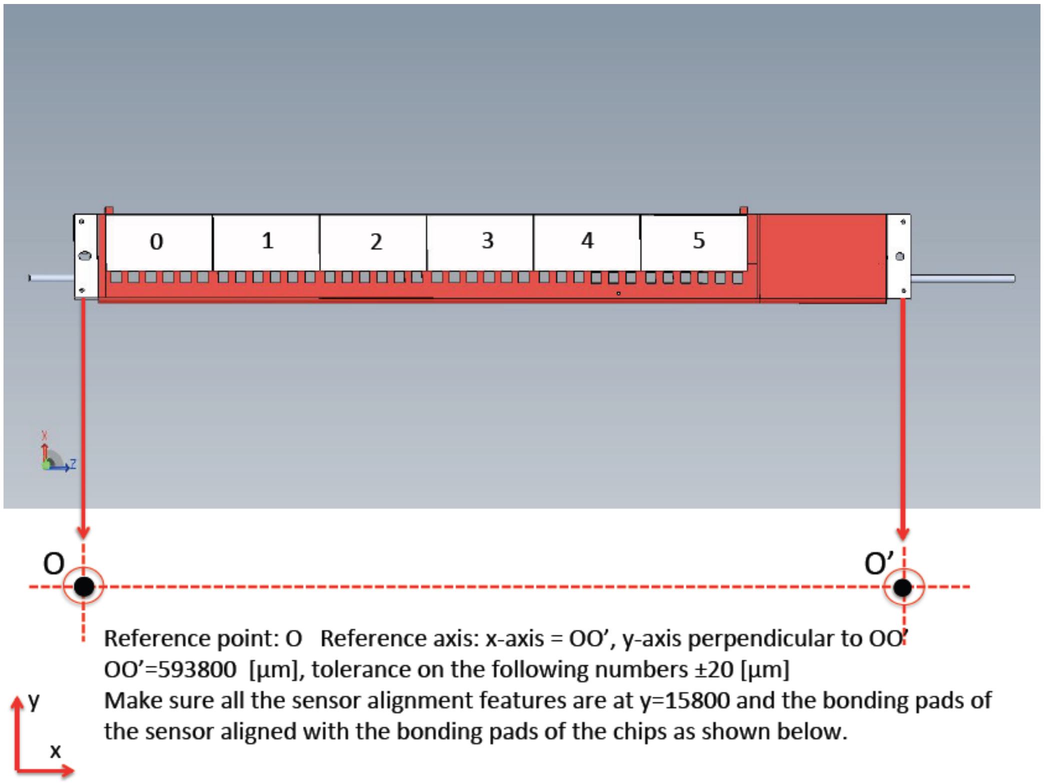


Figure 4 Sensor alignment requirements for placing the sensors.

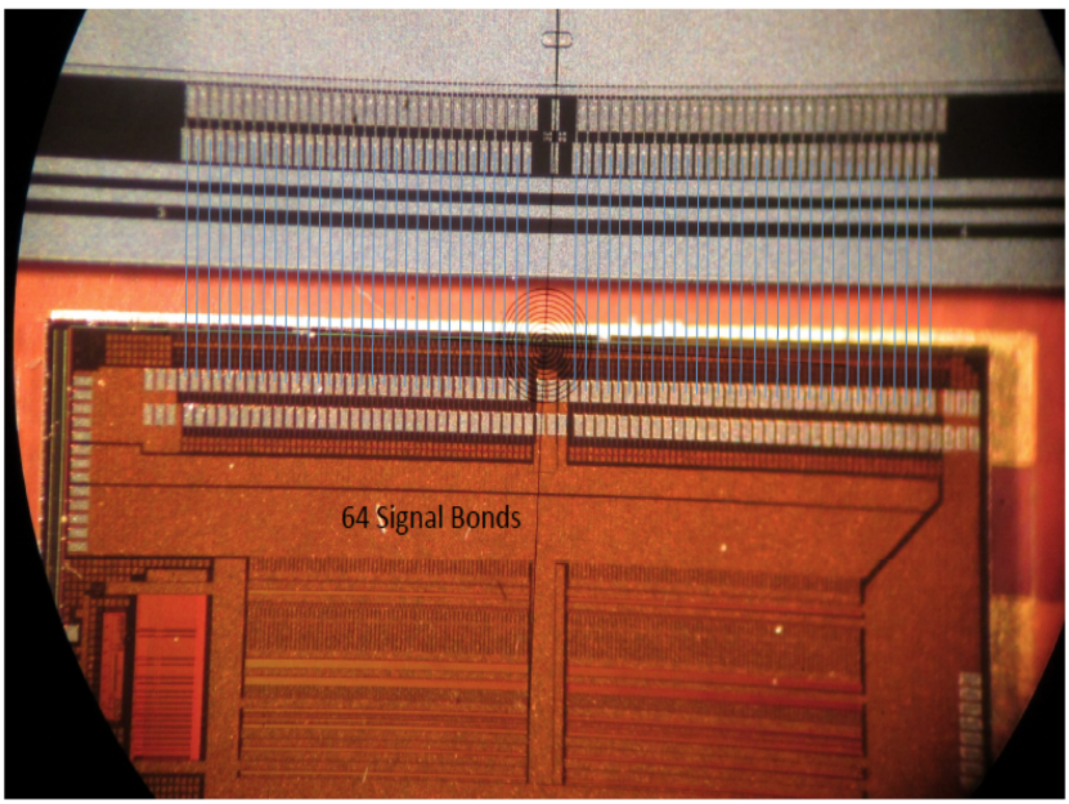


Figure 5 Sensor alignment with respect to APV chips for placing the sensors.

2.6 Wire Bonding After Sensor Placement

1. Locate traveler document for entering component information.
2. Weigh the ladder and record the measured weight on the traveler.
3. Inspection under a microscope. Inspect all areas of the module before putting in on the machine for wire bonding. Look for shorts, damage, dirt, and pad quality, anything that could cause problems when bonding. And note it.
4. Check temperature and humidity in the room.
5. Place module on the machine and apply vacuum to secure bonding fixture.
6. Set the heights of the work surface at the lowest bond point.
7. Program first chip and first chip where sensor would be.
8. Reference systems, pad size, pad location, bounty points, wire bond locations.
9. Copy the program to all chips.
10. Bond parameters.
    a. Set USG powers for 1st and 2nd bond.
    b. Set bond time for 1st and 2nd bond.
    c. Set force for 1st and 2nd bond
    d. Set tail length. For 1st bond
    e. Set loop height
    f. Set bond search.
    g. Set speed in which the wire is bonded.
11. Run program. Wire bonds first couple pads check to see if changes need to be made, such as, loop heights, powers. Force, …... etc. then run the program in auto mode. (See wire-bonding diagrams below).
12. Inspection. After the bonding is completed, remove from the machine and inspect under the microscope for any repairs that are needed before sending over to the next procedure.
13. Weigh the ladder and record the measured weight on the traveler.
14. Give the stave to UIC.

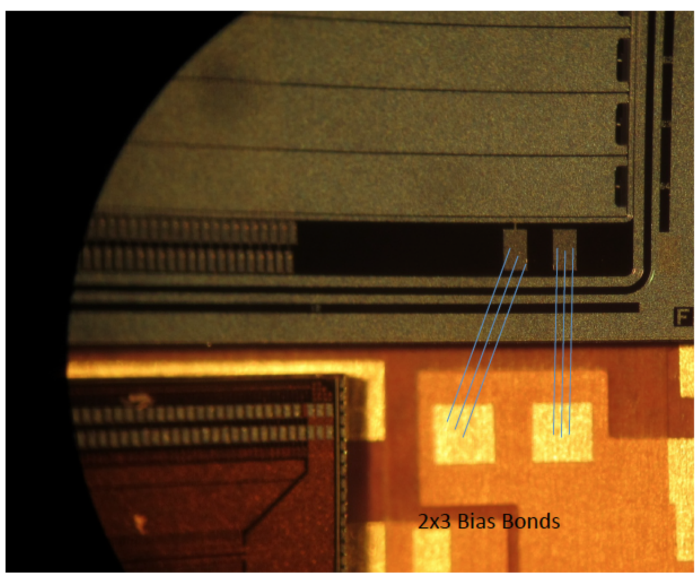


Figure 6 Sensor bias wire-bonding diagram.

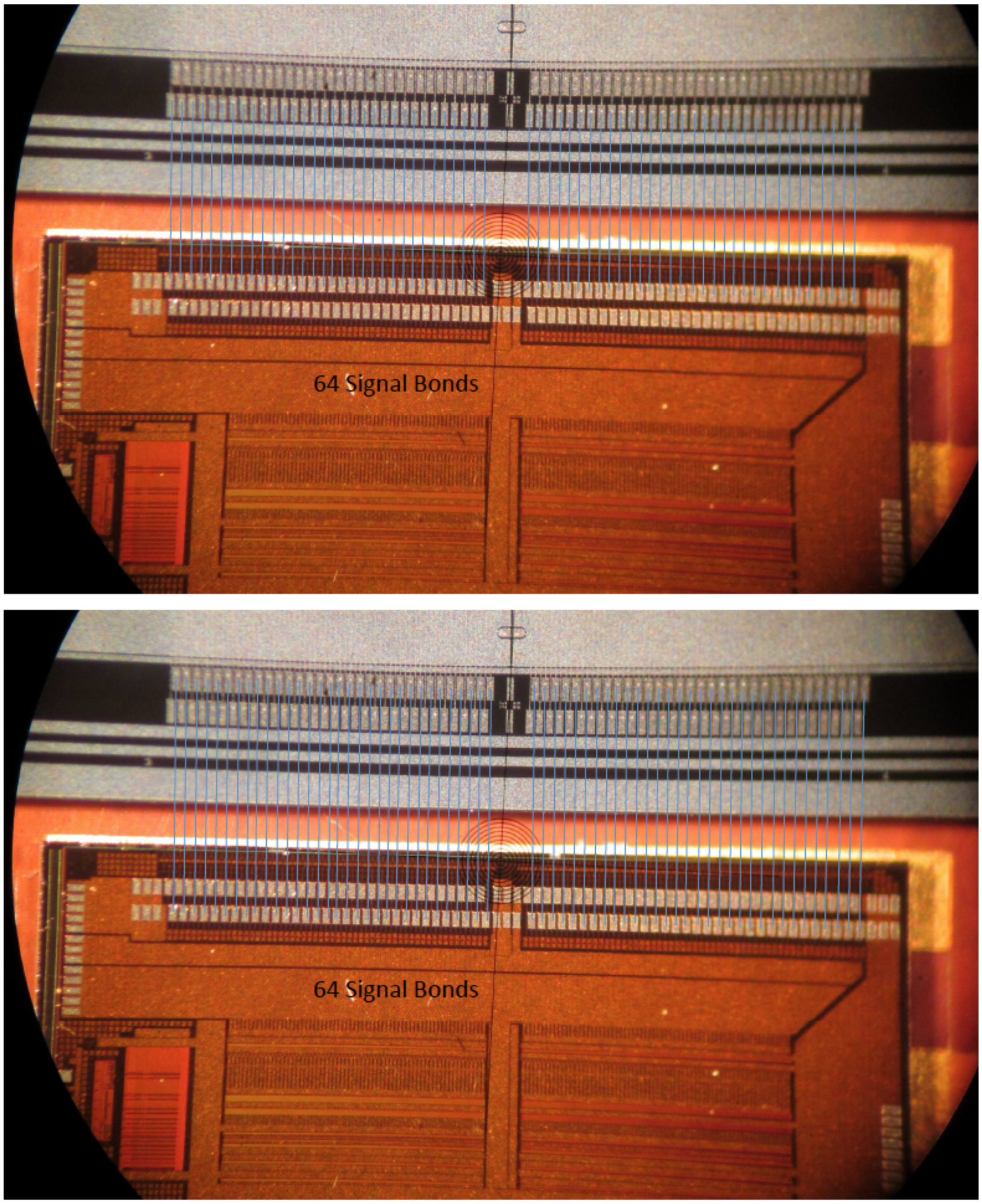


Figure 7 Sensor and APV chip backend wire-bonding diagrams.

2.7 Electronic Test After Sensor Wire bonded

1. Locate traveler document for entering test information.
2. Upload the information of the previous steps into the production database.
3. Visually inspect the stave under the microscope, check and record if there is missing wire-bonds.

4. Connect the 3 sections (A, B, C) to the readout system, where A goes to ARM0 Port 0, B to ARM0 Port 1, and C to ARM1 Port 0.
5. Record power supply currents after just powering up and when taking data.
6. Take 1000 events at 10-100 Hz with VPSP=43.
7. Ramp up the sensor bias voltage to full depletion voltage according to the sensor specification. Check whether the power supply currents change wrt step 5, and record the current draw of the sensor bias supply.
8. Take 1000 events at 10-100 Hz with VPSP=43.
9. Take 1000 events at 10-100 Hz with VPSP=48.
10. Ramp down the sensor bias voltage and power supply voltage.
11. Run analysis code and record pedestal and noise for each section.
12. Record the number of broken channels.
13. Upload the information of the testing results into the database.
14. If all the 36 chips have proper I2C communication (all the chips have similar pedestal and average noise less than 30 with RMS less than 2, the pedestal change vs VSPS), and there are no more than 50 randomly distributed channels not functioning, we can proceed with the following steps. Otherwise identify the problem, and decide whether to pull the stave off the production line, or repair the stave.
15. Give the stave to Bert.

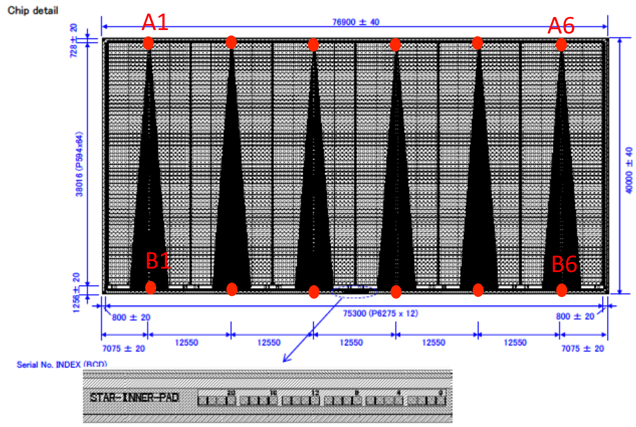
2.8 Encapsulation

1. Identify module number to see if it is consistent with the traveler.
2. Inspect all micro-bonds on chip back end, sides and front to sensor.
3. If there are any missing, (check traveler and identify if intentional) broken or damaged micro-bonds return to micro bonding department for repairs and retesting.
4. Place tested module into fixture with center of sensor #2 at center of vacuum plate as marked on fixture. Turn vacuum on.
5. Turn on encapsulation machine install empty 30 cc (EFD) syringe with purple tip.
6. Enter program #4 (STARA) into pendant.
7. Check start point # 6 fine adjust the start point of program dispense with micrometers on bridge (X, Y and Z). Make adjustment so dispense point aligns at the apex of micro-bond between gold pad and chip at back of chip. Check point #7 is accurate (adjust if necessary).
8. Once alignment appears accurate. Mix a batch of Dow Corning Sylgard 186 encapsulant the mix ratio required is 10 grams encapsulant to 1-gram activator and mix for 5 minutes, transfer to a 30 cc syringe, locate plunger and add cap. Place into centrifuge for ten minutes at 1100 rpm’s.

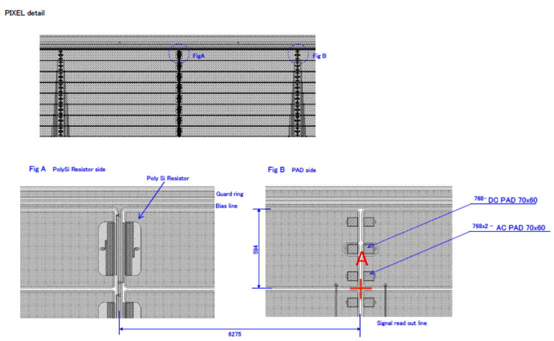
9. Once timer goes off, remove syringe, verify visually all air are out and add purple tip with .020 I.D. tip and remove test syringe and position full syringe into bridge mount and secure thumb screw.
10. Use pendant and select program # 4(STARA). Select menu test run. Except wait stop point if alignment appears accurate and run program. Monitor closely as dispensing and use emergency stop if there are any problems.
11. This program will come to a stop once 1^{st} half of the module has been encapsulated (18 readout chips and 3 sensors front, back and sides.).
12. Now carefully turn off vacuum and slide module backward away from operator to the 2^{nd} position, which requires placement at the middle of the 5^{th} sensor at center of the vacuum fixture.
13. Select program # 5(STARB) and enter test run adjust X, Y and Z if necessary at wait start point then select enter to begin dispensing. Dispense at the apex of the micro-bond between the back of the chip and the gold pad accordingly.
14. If alignment appears acceptable press continue (F3) on pendent and monitor through microscopes during the run. The program will start dispensing encapsulant on the second half of the module which includes chip #19 to chip #36. Monitor closely as dispensing and use emergency stop if there are any problems.
15. Once program is finished turn vacuum off and remove module from fixture and relocate into its storage container box and set on table for curing.
16. Give the stave to Gordon/Mike.

2.9 Survey

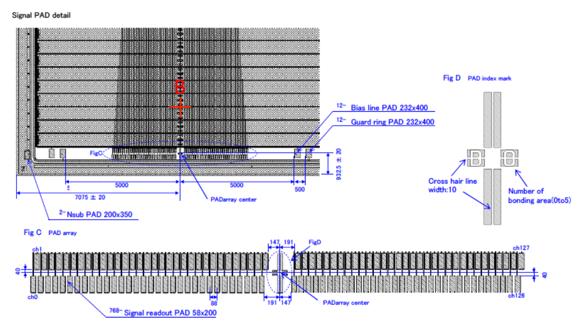
1. Identify module number to see if it is consistent with the traveler.
2. Place the stave onto the optical co-ordinate measuring machine.
3. Locate the reference points and plane (see the requirements below).
4. Run the program to measure the positions of 12 points on each sensor.
5. Repeat step 3 and 4.
6. Fill the survey record into the traveller.
7. Attach a printed copy of survey measurement results to the traveller and send the electronic version of the results to Zhenyu Ye <yezhenyu@uic.edu> and Yaping Wang <wangyap@uic.edu>.
8. Give the stave to Bert who will pass it to UIC.



A1-A6, B1-B6: sensor alignment feature

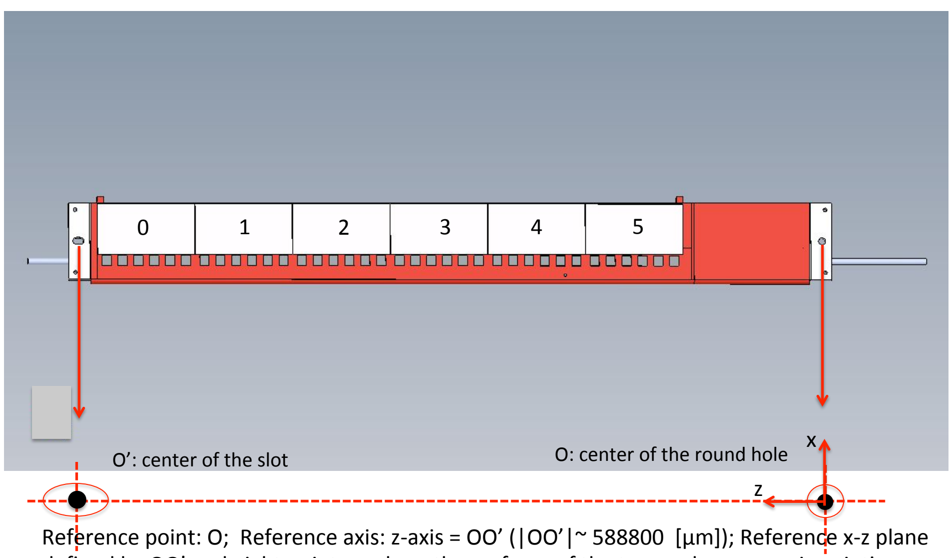


A1-A6: sensor alignment feature



B1-B6: sensor alignment feature

Figure 8 Sensor alignment features for survey measurement.



Reference point: O; Reference axis: z-axis = OO' (|OO'|~ 588800 [μm]); Reference x-z plane defined by OO' and eight points each on the surfaces of the two end-caps; y-axis pointing from the sensor side to the other side of the stave and perpendicular to the x-z plane. Measure the x, y and z positions of A1-A6 and B1-B6 on sensor 0-5 (72 points on a stave) and calculate the flatness and straightness of each sensor and the entire stave using these measurements. Attach a hard copy of the measurement and calculation results to the traveller and send an electronic copy to yezhenyu@uic.edu and wangyap@uic.edu

Figure 9 Survey requirements.

2.10 Final Electronic Test

1. Locate traveler document for entering test information.
2. Upload the information of the previous steps into the production database.
3. Visually inspect the stave under the microscope, check and record if there is missing wire-bonds.
4. Connect the 3 sections (A, B, C) to the readout system, where A goes to ARM0 Port 0, B to ARM0 Port 1, and C to ARM1 Port 0.
5. Record power supply currents after just powering up and when taking data.
6. Take 1000 events at 10-100 Hz with VPSP=43.
7. Ramp up the sensor bias voltage to full depletion voltage according to the sensor specification. Check whether the power supply currents change wrt step 5, and record the current draw of the sensor bias supply.
8. Take 1000 events at 10-100 Hz with VPSP=43.
9. Take 1000 events at 10-100 Hz with VPSP=48.
10. Ramp down the sensor bias voltage and power supply voltage.
11. Run analysis code and record pedestal and noise for each section.
12. Record the number of broken channels.
13. Upload the information of the testing results into the database.

Traveler for STAR IST Ladder Assembly at Fermilab/UIC

Version 2013.1.9

Ladder ID # ____.

HDI ID # ____.

Chip 1-36 ID # ____.

____.

Sensor 1-6 ID # ____.

____.

Ladder Rating ____.

Hybrid Wire-Bonding Test Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Temperature:

Humidity:

Visual Inspection:

Ladder Weight Before Bonding Test:

Ladder Weight After Bonding Test:

Wire-bond Pull Test Results:

# 0	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8
# 9	# 10	# 11	# 12	# 13	# 14	#15	# 16	# 17
# 18	# 19	# 20	# 21	# 22	# 23	# 24	# 25	# 26
# 27	# 28	# 29	# 30	# 31	# 32	# 33	# 34	# 35

Comment:

APV Chip Placement Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Visual Inspection:

Ladder Weight Before Chip Placement:

Ladder Weight After Chip Placement:

APV Chip ID #:
Wafer:

# 0	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8
# 9	# 10	# 11	# 12	# 13	# 14	#15	# 16	# 17
# 18	# 19	# 20	# 21	# 22	# 23	# 24	# 25	# 26
# 27	# 28	# 29	# 30	# 31	# 32	# 33	# 34	# 35

Comment:

APV Back-End Wire-Bonding Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Temperature:

Humidity:

Visual Inspection:

Ladder Weight Before Bonding:

Ladder Weight After Bonding:

Comment:

Stave Electrical Test after Chip Back-end Bonding Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Visual Inspection:

Test Results:

Comment:

Sensor Placement Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Visual Inspection:

Ladder Weight Before Sensor Placement:

Ladder Weight After Sensor Placement:

Sensor ID #:

Wafer:

# 0	# 1	# 2	# 3	# 4	# 5

Comment:

APV Front-End Wire-Bonding Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Temperature:

Humidity:

Visual Inspection:

Ladder Weight Before Bonding:

Ladder Weight After Bonding:

Comment:

Stave Electrical Test after Chip Front-end Bonding Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Visual Inspection:

Test Results:

Comment:

Stave Wire-bond Encapsulation Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Visual Inspection:

Ladder Weight Before Bonding:

Ladder Weight After Bonding:

Comment:

Stave Survey Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Survey Result (See Attachment):

Comment:

Stave Electrical Test after Survey Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Visual Inspection:

Test Results:

Comment:

Stave Repair Record

Operator Name:

Operation Start Date and Time:

Operation End Date and Time:

Visual Inspection:

Ladder Weight Before Operation:

Ladder Weight After Operation:

Repairs done:

Replaced Chip/Sensor ID:

Wire-bonding:

Comment: