ATLAS ITk Pull tests of wire bonds at IHEP

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On behalf of IHEP/THU ATLAS ITk Group

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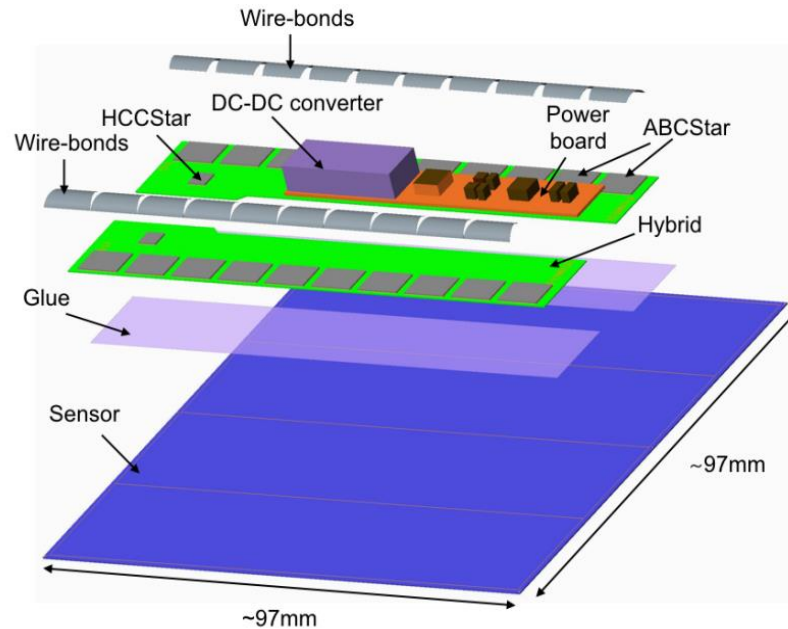
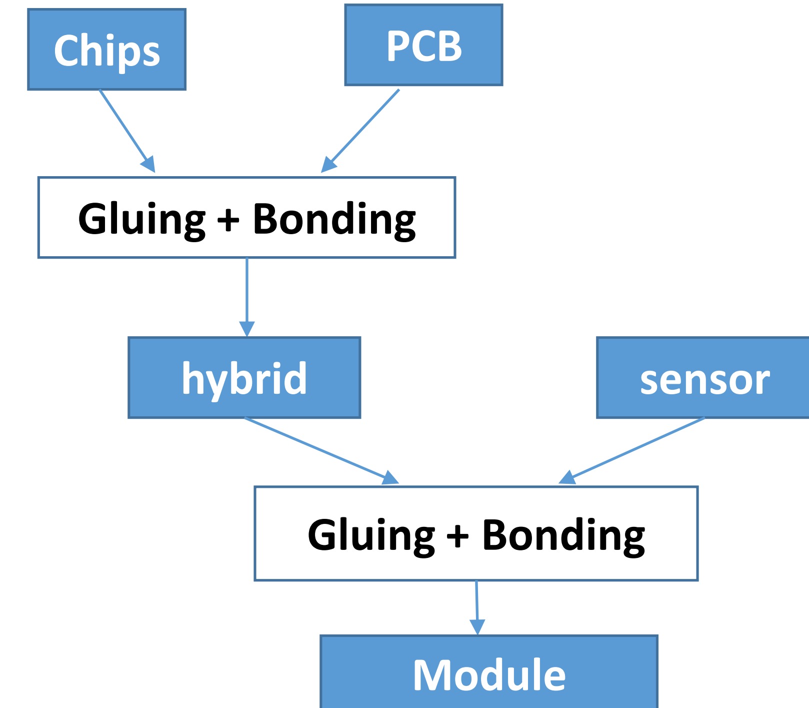
Outline

- Introduction of wire bonding and pull test
- Optimization of Bond machine parameter
- Pull tests on ASICs, Hybrid, Powerboard and Sensor
- Summary

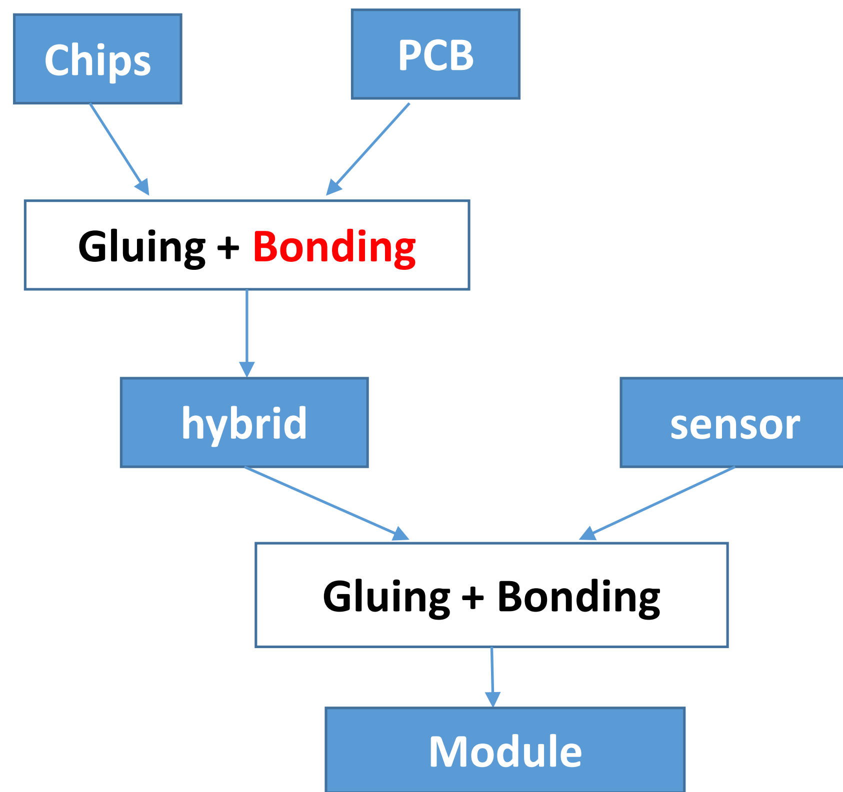
Electrical ATLAS ITk Module

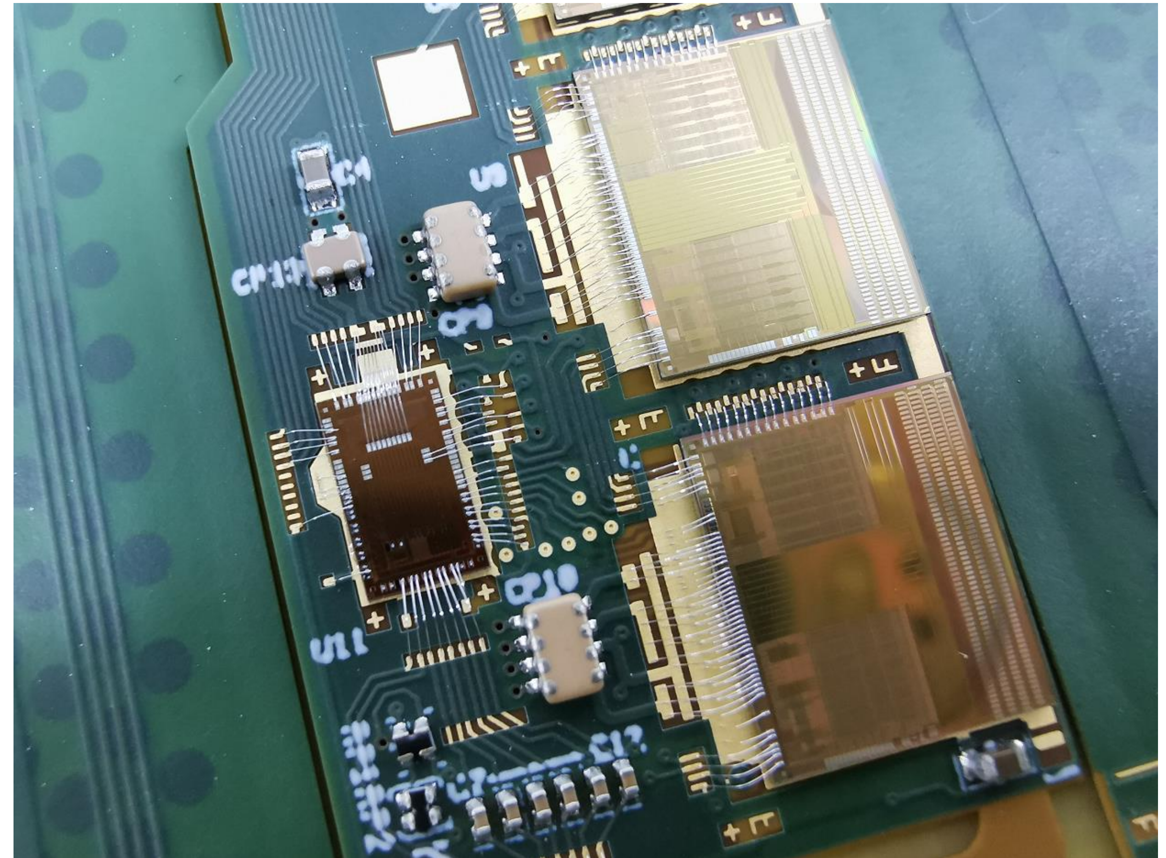
- **Wire bonding is key step of Module assembly**
  - Making the module works electrically
- **Wire bondings:**
  - ABCStar to PCB
  - HCC to PCB
  - Hybrid to PowerBoard
  - ABCStar to Sensor
- **Challenge**
  - Large amount, multilayer wires
    - SS module : > 5,000
    - LS module : > 2,500
  - Withstand ~10 years high luminosity environment



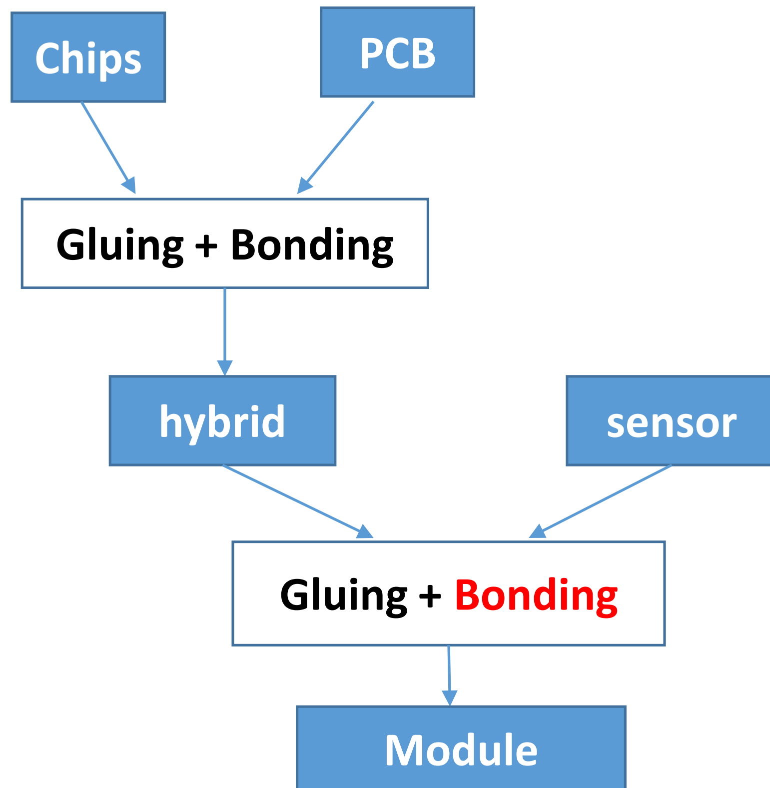


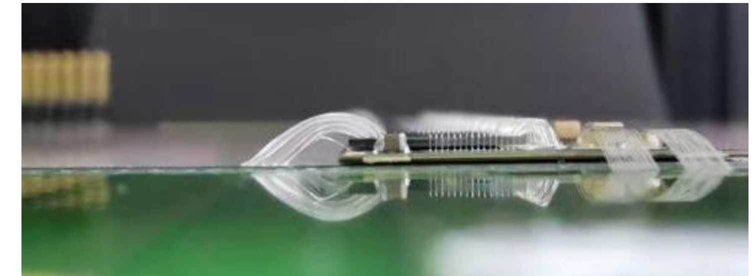
Wire-Bonding： Electrical Hybrid Assembly

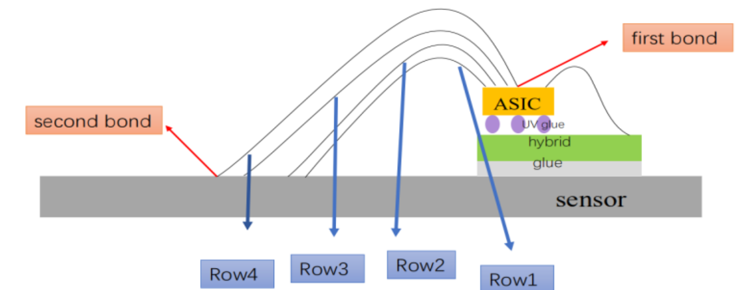




Wire-Bonding: Electrical Module Assembly

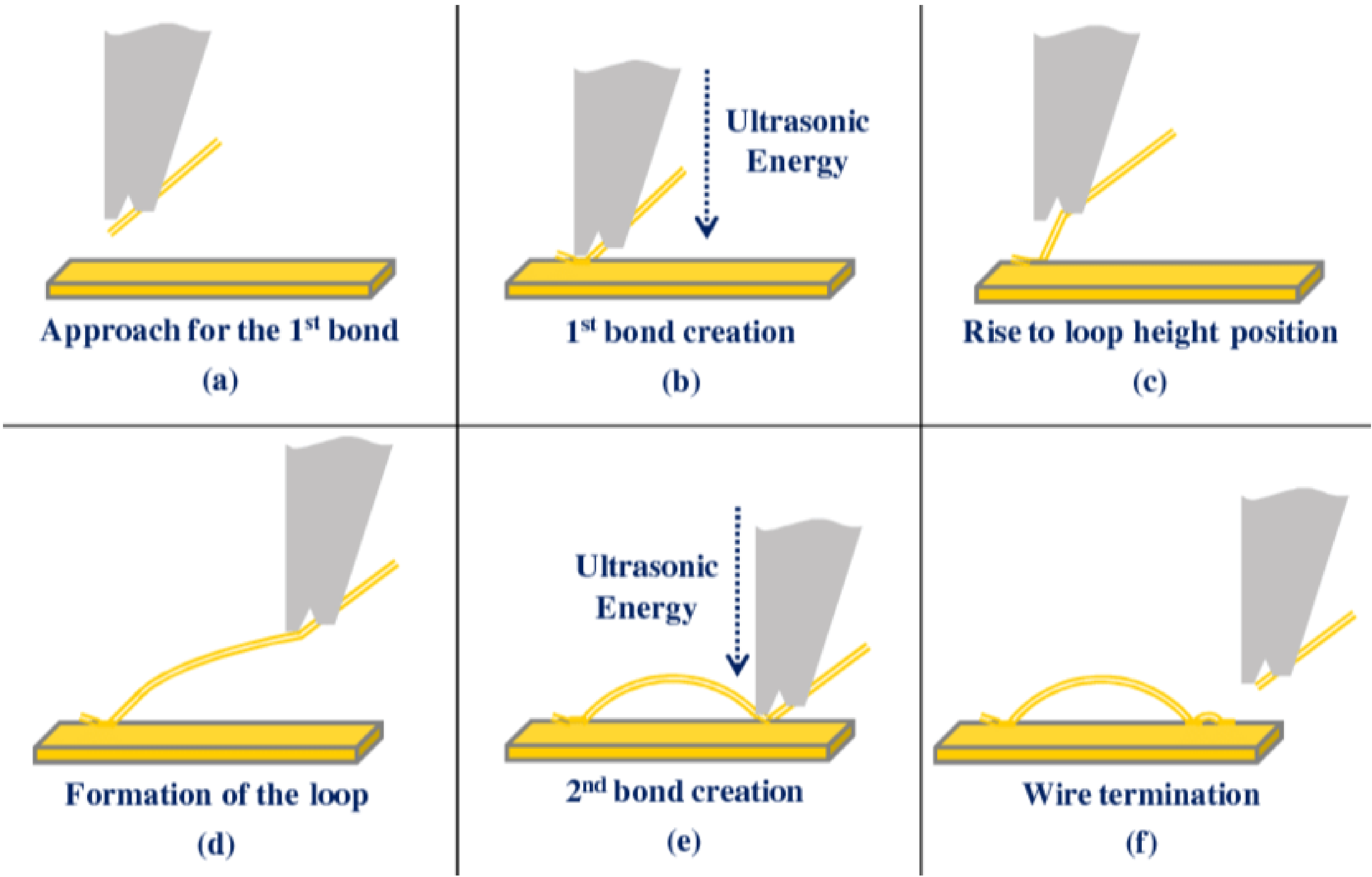






- Large amount and multilayer wires
  - SS module : > 5,000
  - LS module : > 2,500

Steps for Wedge bonding

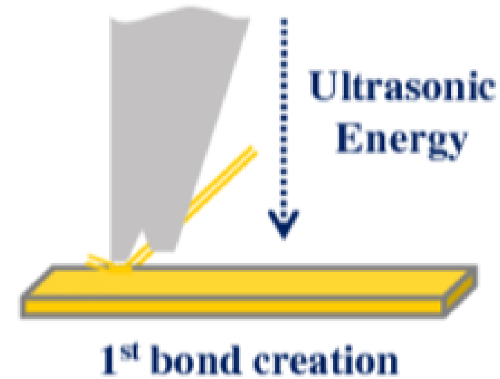


BondJet820

Key Welding Parameters

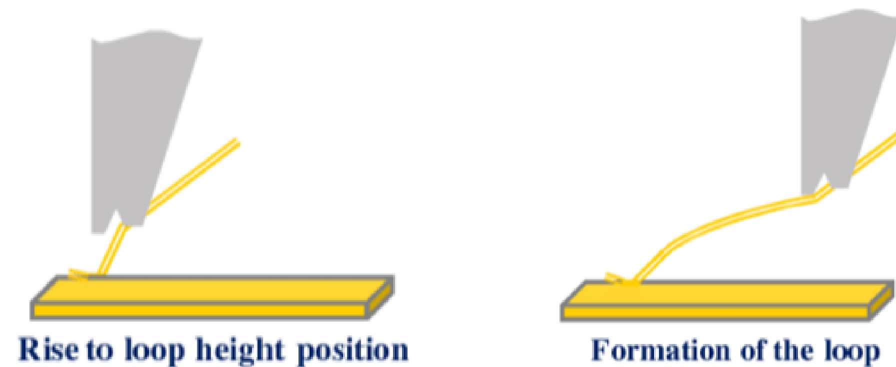
Primary welding parameters:

- Bond force
- Ultrasonic
- Deformation



Secondary parameters:

- Contact velocity
- Contact force
- Loop shaping movements



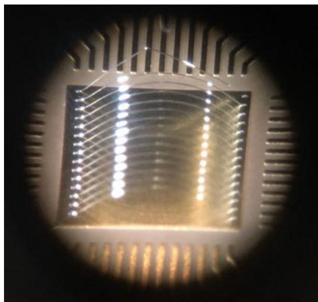
Effects of the secondary parameters negligible

Quality Control/Assurance of wire-bonding

- Directly related to final electrical grading of the module
- Consistency between different groups
  - Project of large scale including many wire-bonding machines in different groups,
  - **Machine**: Although similar bond-Jeter models, there still will be slight variations exist in the parameters
  - **People**: There will also be variations in the experience and knowledge of the personnel operating these wire bonding machines
  - **Components**: E.g., pads whether clean after shipment
- Mainly focusing on welding quality control: performed by **pull testing**

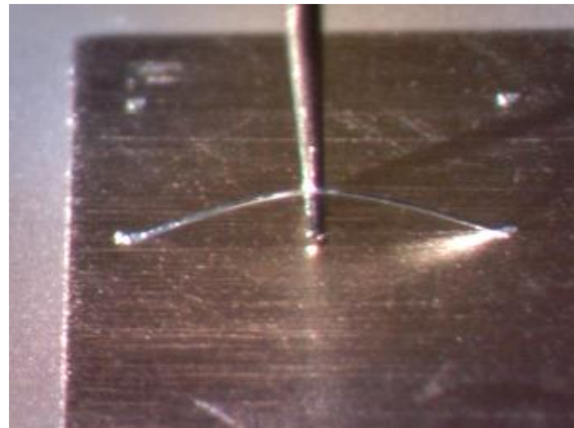
Physics Picture of Pull Test

- Destructive test
- To test the strength of the wire-bonds
- To explore the best machine parameter range by parameter space scan

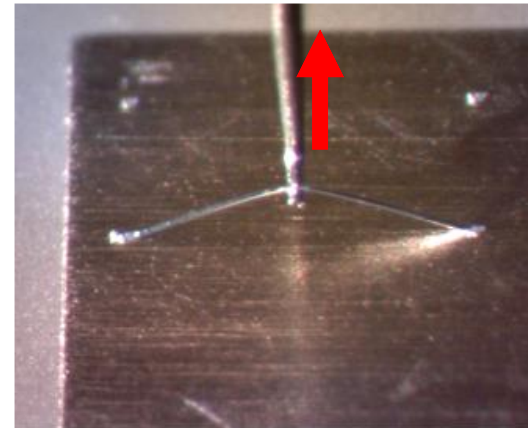


Samples to be tested

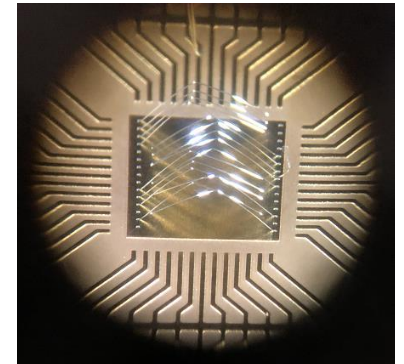
Step-1



Step-2



Step-3



Different types of breaks

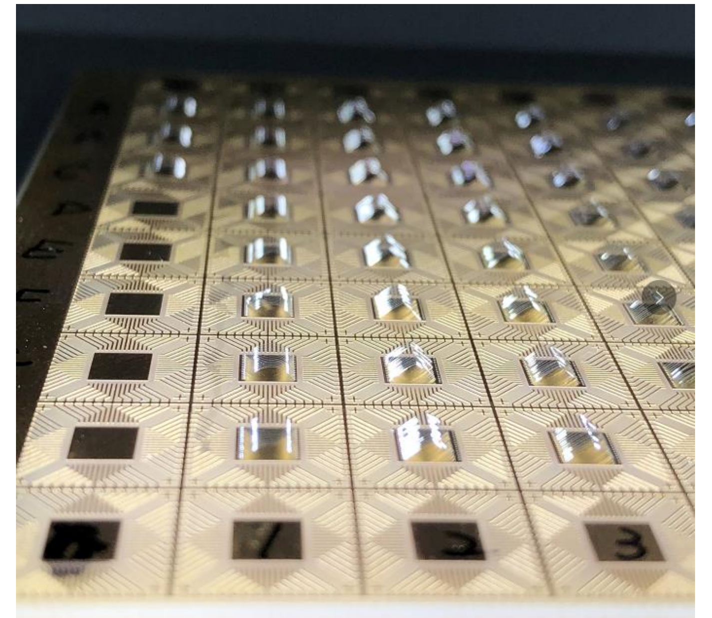
Step-4

Pull Test Requirements

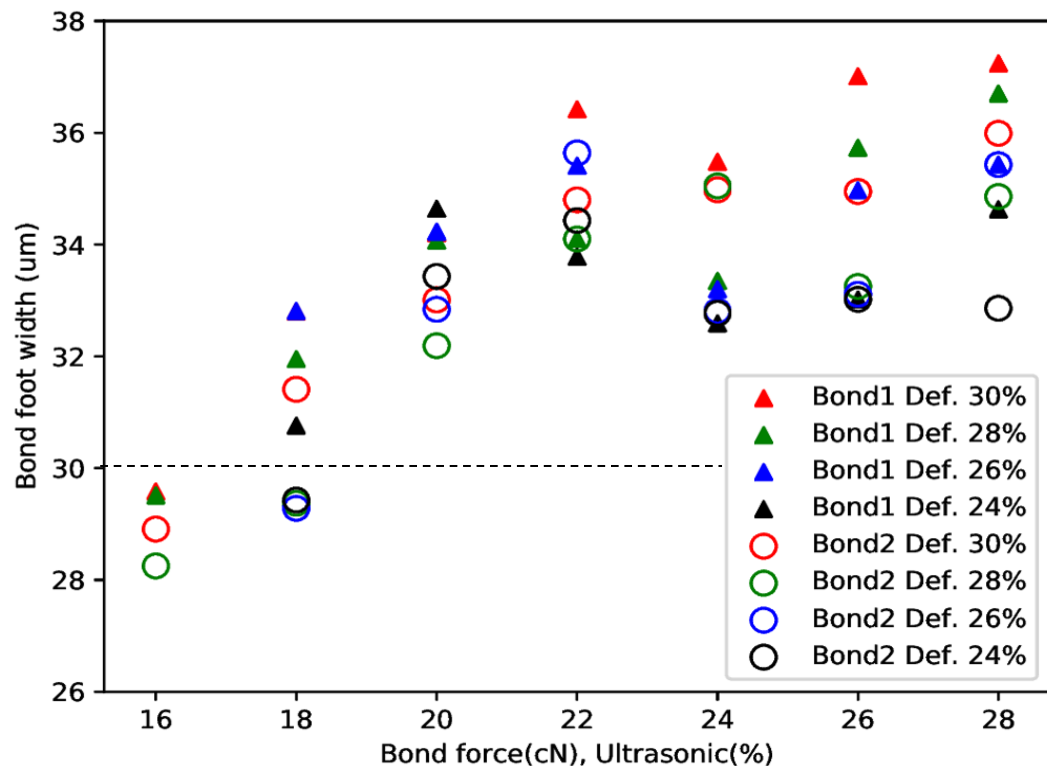
- Sample size > 100 bonds
- Bond Foot width (1.2 ~ 1.8) * wire diameter
- > 90% heel breaks
- mean pull strength > 8g
- Standard deviation < 1.5g
- Single wire pull strength > 5g

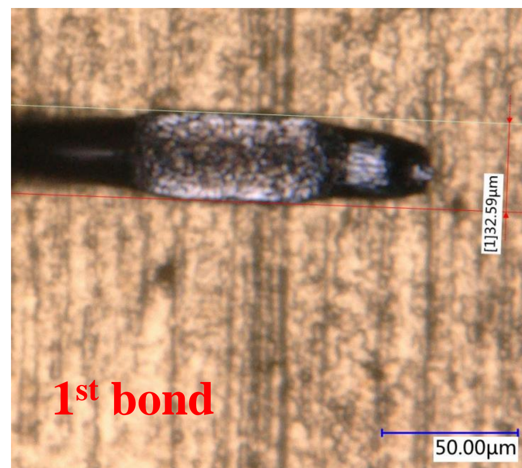
Machine Optimization: pull test sample

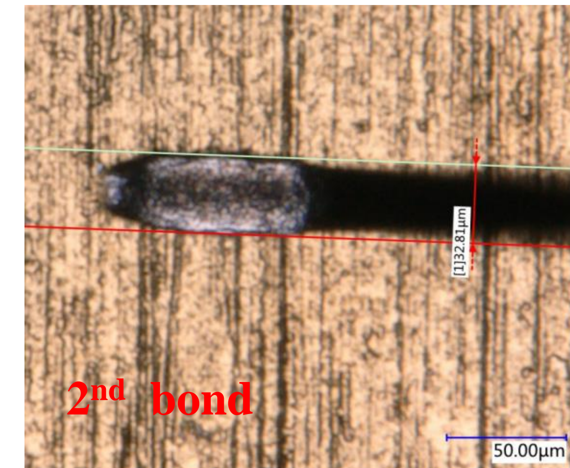
- To make Wire-bonding machines in the optimal parameter range
- Cicorel wire bonding test card.
  - **Deformation**(24%, 26%, 28%, 30%) × **Bond-Force**, **Ultrasonic**(18, 20, 22, 24, 26, 28)
  - 30 wires for each parameter combination
  - For Bond-Force, Ultrasonic = 16, only prepared:
    - 30 wires for Deformation 30%,
    - 15 wires for Deformation 28%



Machine Optimization: Bond foot width



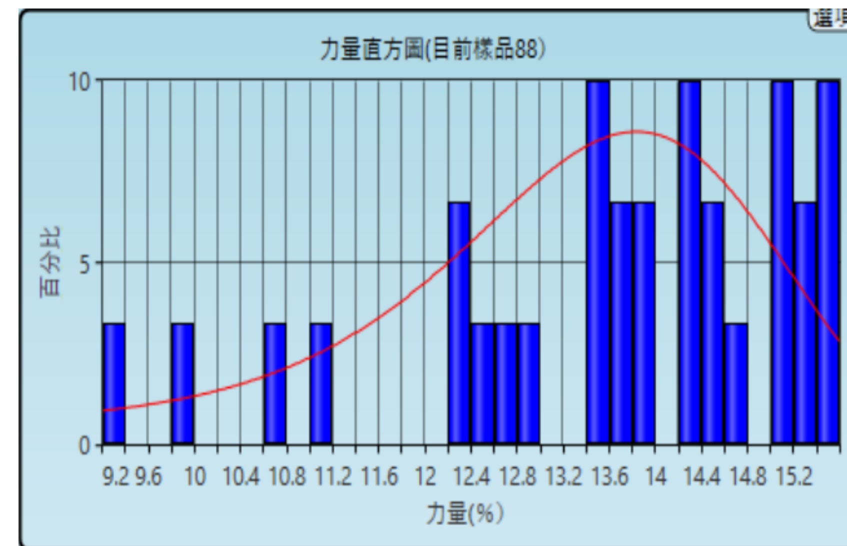




- ✓ Bond Foot width (1.2 ~ 1.8) * wire diameter
- ☐ > 90% heel breaks
- ☐ mean pull strength > 8g
- ☐ Standard deviation < 1.5g
- ☐ Single wire pull strength > 5g

Pull Tester

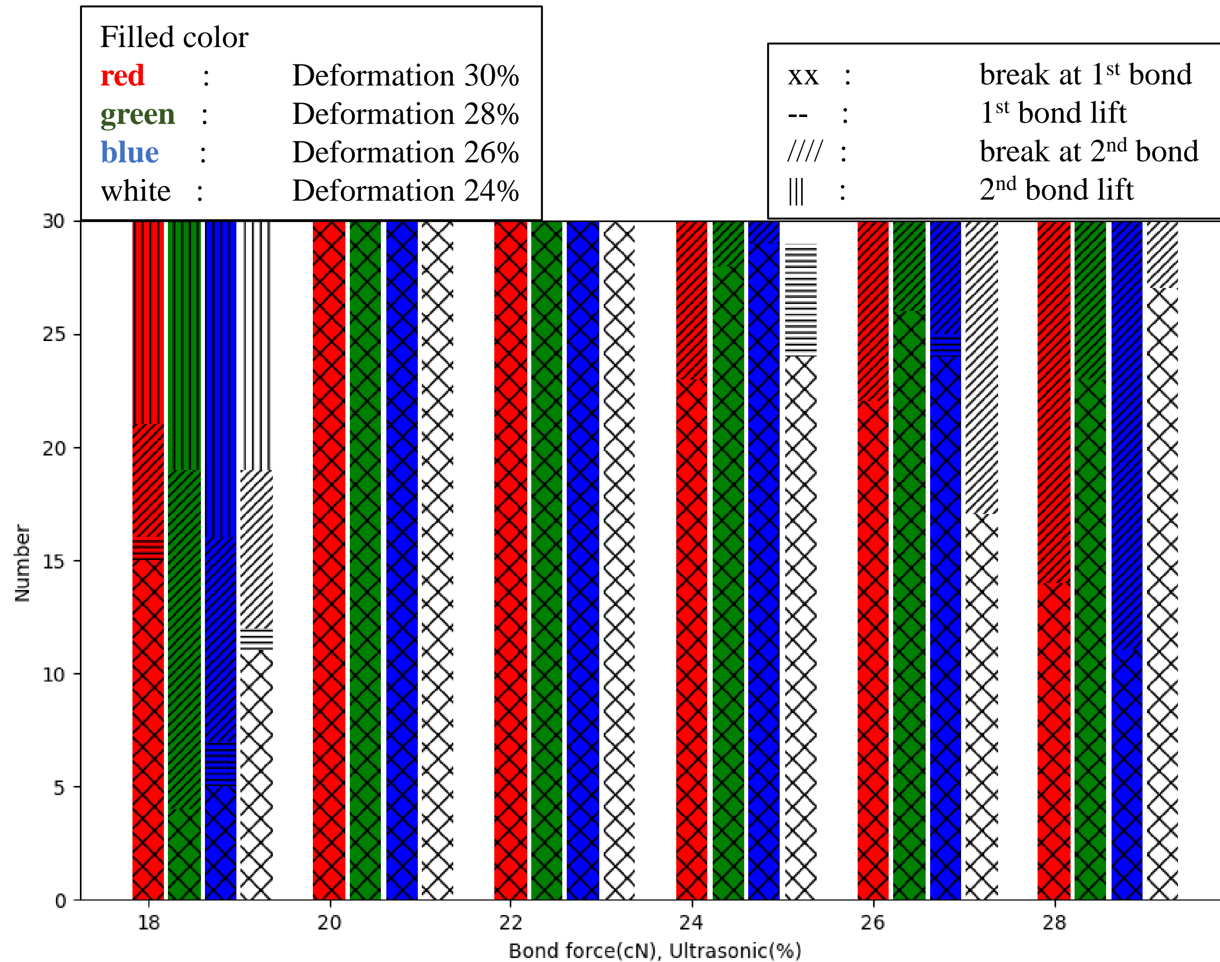
DAGE 4000plus



力量統計圖(目前樣品%)　選項

Mean (force)	13.600 g	Standard Deviation (force)	1.6761 g
Minimum (force)	9.2052 g	Maximum (force)	15.501 g
Range (force)	6.2963 g		
失敗	2		
Cp製程能力	沒有規格限制	Cpk	沒有規格限制
自信上限	沒有規格限制	信心下限	沒有規格限制
操作員	DB	機台	20099919
結果	30	儲存完成	04/06/2020 11:24
batch	1GH		

Machine Optimization: Break type



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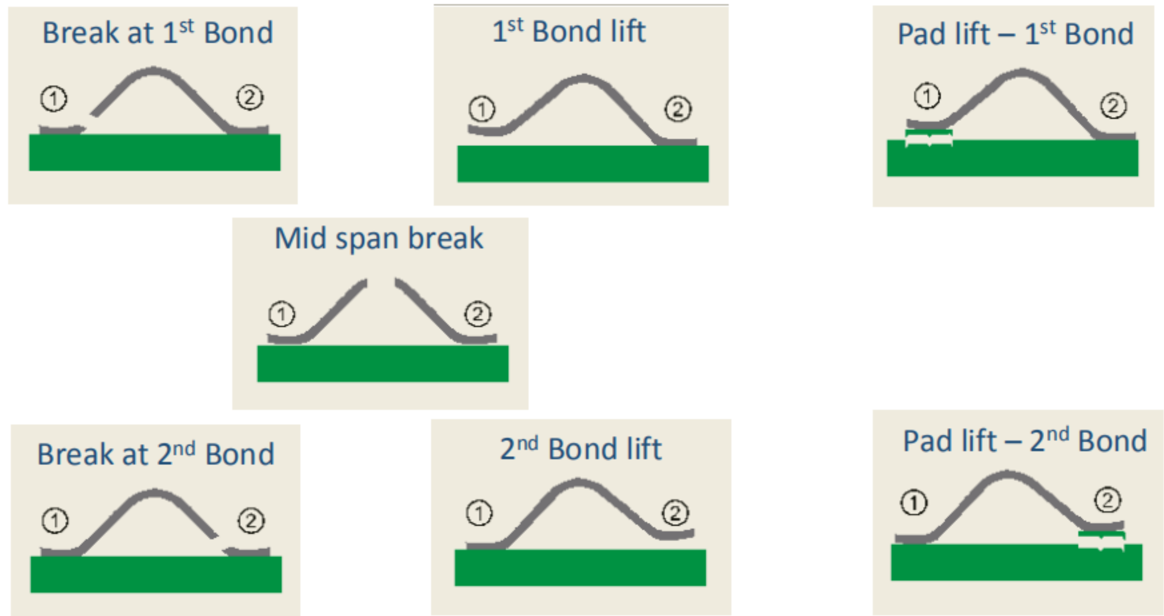
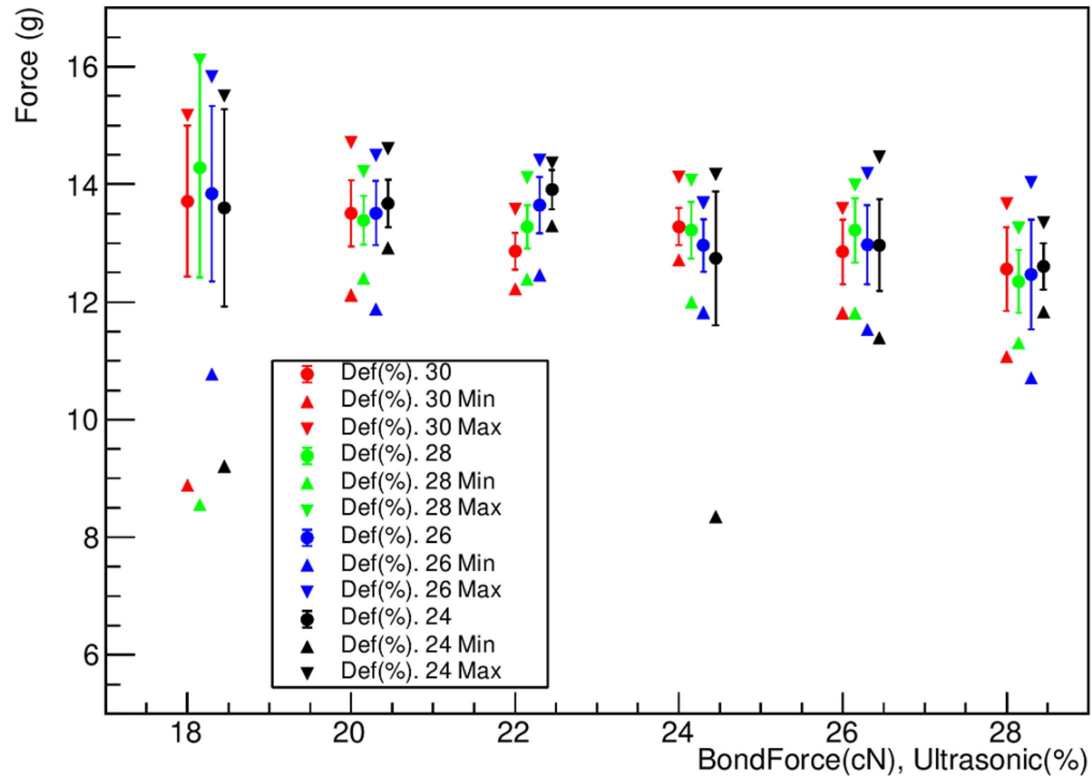


Machine Optimization: Pull Force



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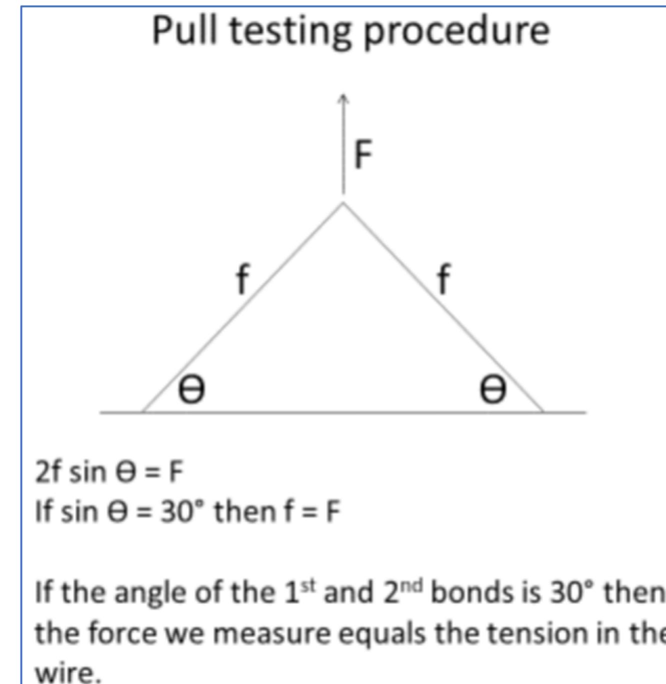
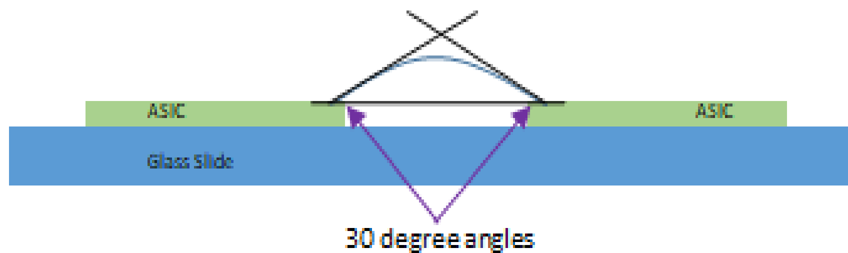
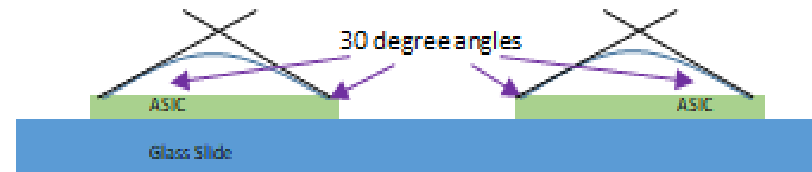


Pull tests for (pre-)production: ASICs

- ASIC to ASIC bonding
- Shall be checked:
  - Pull strength: Max., Min., Mean, Standard deviation
  - Percentage of heel breaks versus bond foot peels
- Each dicing batch of ASICs should receive a pull test to verify that the bond pad surface quality is suitable for production assembly.
- Should be done before ASICs are used in production.

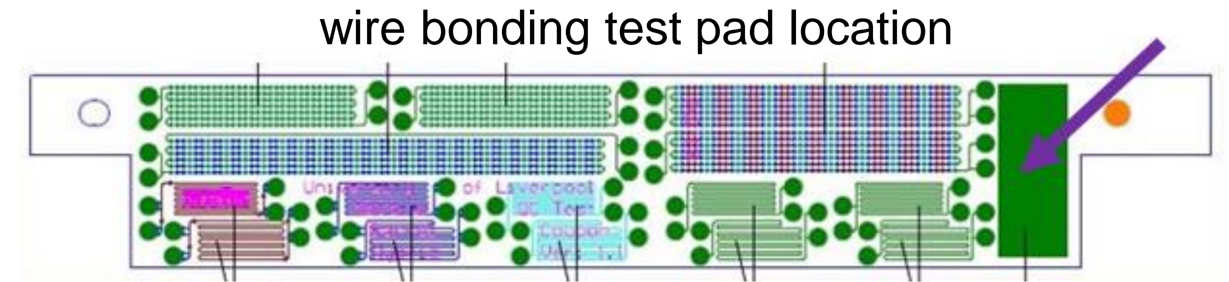


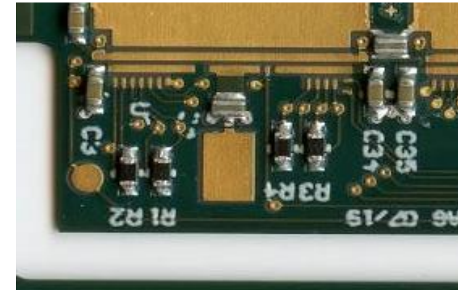


Pull tests for (pre-)production: Hybrids

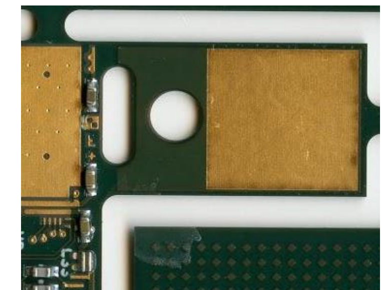
- Tested for cleanliness of the gold pads
- After shipping, reception handling, and certain assembly stages.
- Shall be done before ASIC placement

wire bonding test pad location



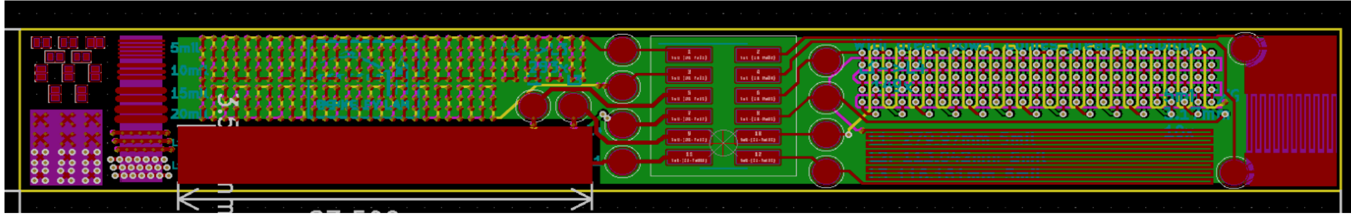


Barrel hybrid wire bond test pad



Barrel hybrid wire bond test Tab

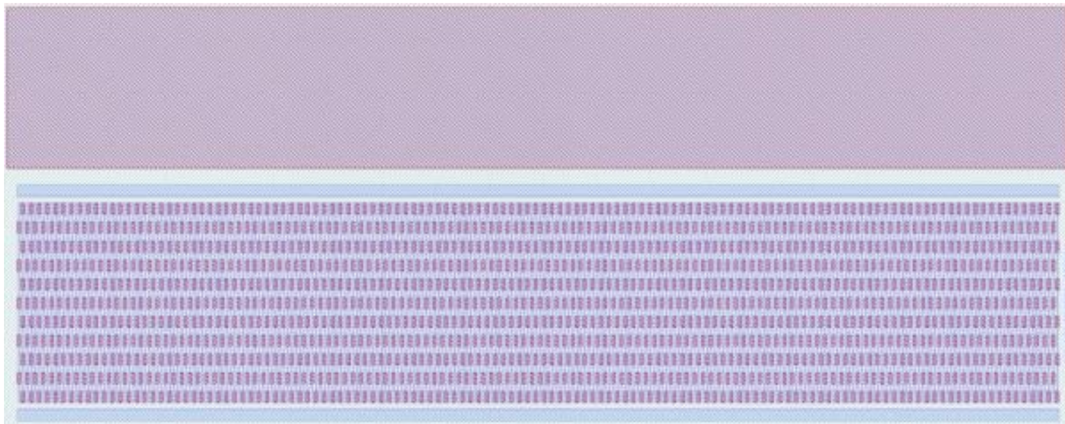
Pull tests for (pre-)production: Powerboard



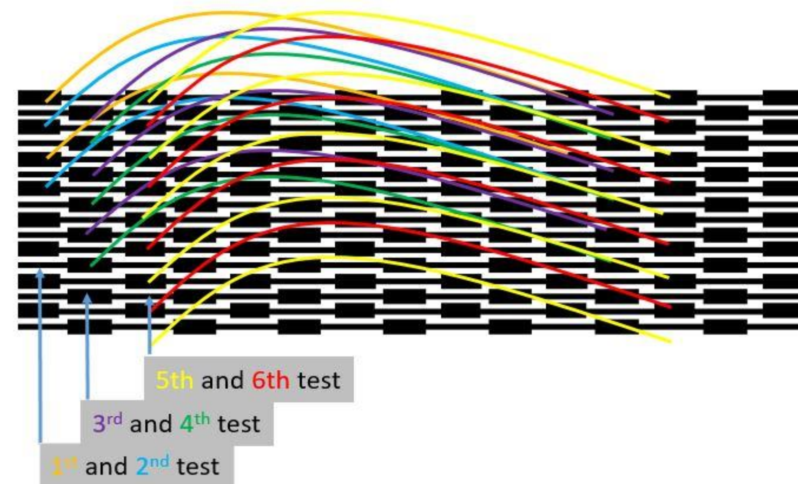
- The pull testing locations are tested for cleanliness of the gold pads
- After shipping, reception handling, and certain assembly stages.
- The results of the pull test should be compared to previous pulls tests on the same substrate types : surface quality remains constant.

Pull tests for (pre-)production: Sensor

- Sensor half moon bonding samples for each wafer lot
- Try to catch possible contamination on the aluminum pads in the test
- Optimized parameters will be used on sensors during assembly bonding
- This test should be done before any sensors are used in production



Sensor wire bond testing sample (Half moon sensor sample)



Wire bonding test bond positions

Summary

- In the prototype stage of STAR module, pull tests performed to optimize welding parameters.
- For the upcoming (pre-)production stage, pull tests in each assembly stage for different components has been designed.