Ultra High Temperature Probe Card Solution for Automotive IC Testing

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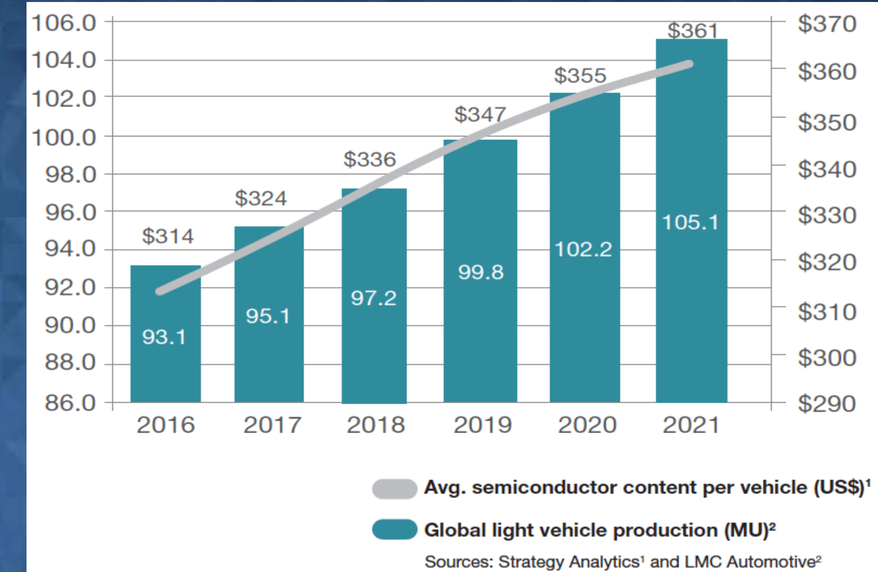
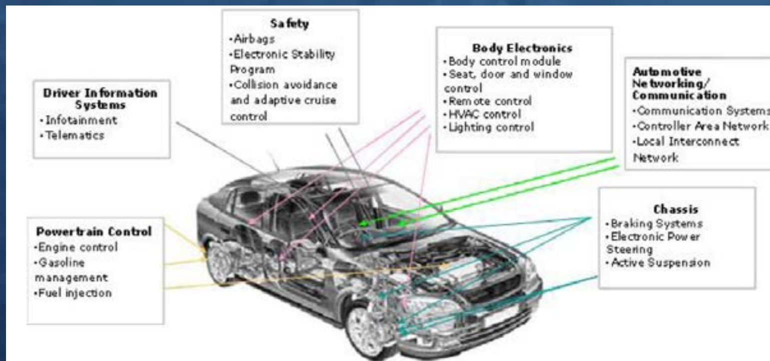
Agenda

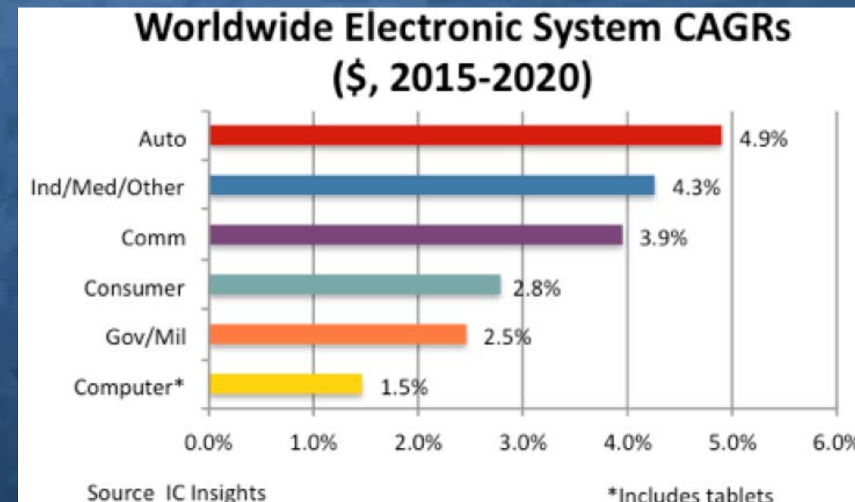
- Automotive IC Market Overview
- Automotive IC Test Requirements and Probe Card Challenges
- FormFactor Ultra High Temperature Probe Card Solution
- Probe Characterization Result Under Ultra High Temperature Testing Environment
- Actual Probe Card Performance Result by Leading Automotive IC Customer
- Summary and Acknowledgement

Automotive Semiconductor Market Overview
Drive Demand of New Testing Solution

- **Automotive electronics is a fast-growing market**
  - Predictions are between 3%~12% CAGR over next 5 years
  - Average number of semiconductors in a car increases significantly in modern cars
  - Key drivers for automotive IC growth
    - Critical safety system
    - Increased fuel efficiency
    - Navigation and communication
    - Comfort & entertainment features





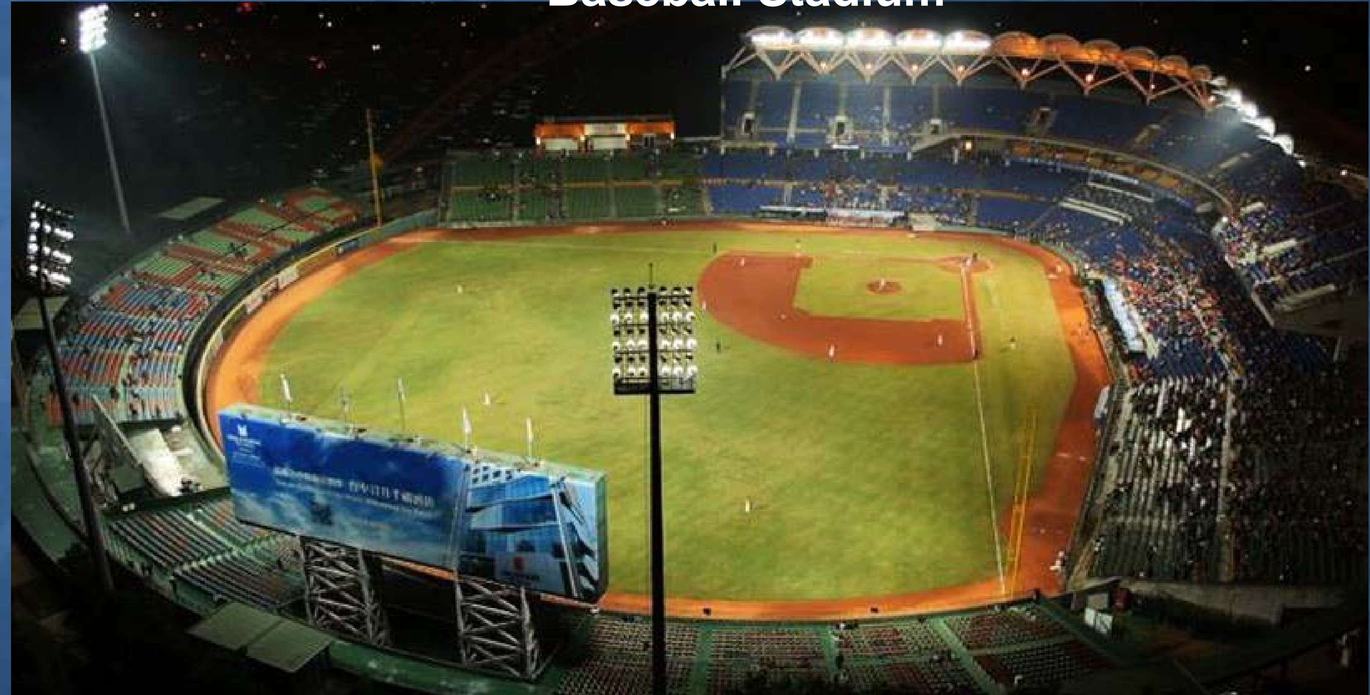


Automotive Safety Consideration: Zero Defect Expectation

- **IC manufacturers adopt Zero Defects Parts per Million (DPPM) design methodology and test to this standard**
  - Finding a golf ball in baseball field
- **Reasons:**
  - Failure rate at the automotive level is higher
  - massive recall and serious economic distress
- **Probing Requirement:**
  - No Dielectric punch-through

ZERO DEFECTS

Taichung Intercontinental Baseball Stadium



Automotive IC Wafer Sort Test Challenges

- **Harsh outdoor environment**
- **Testing at full thermal range**
- **Minimize bond pad reliability impact**
- **Support large volume demand**
- **Lower test cost**

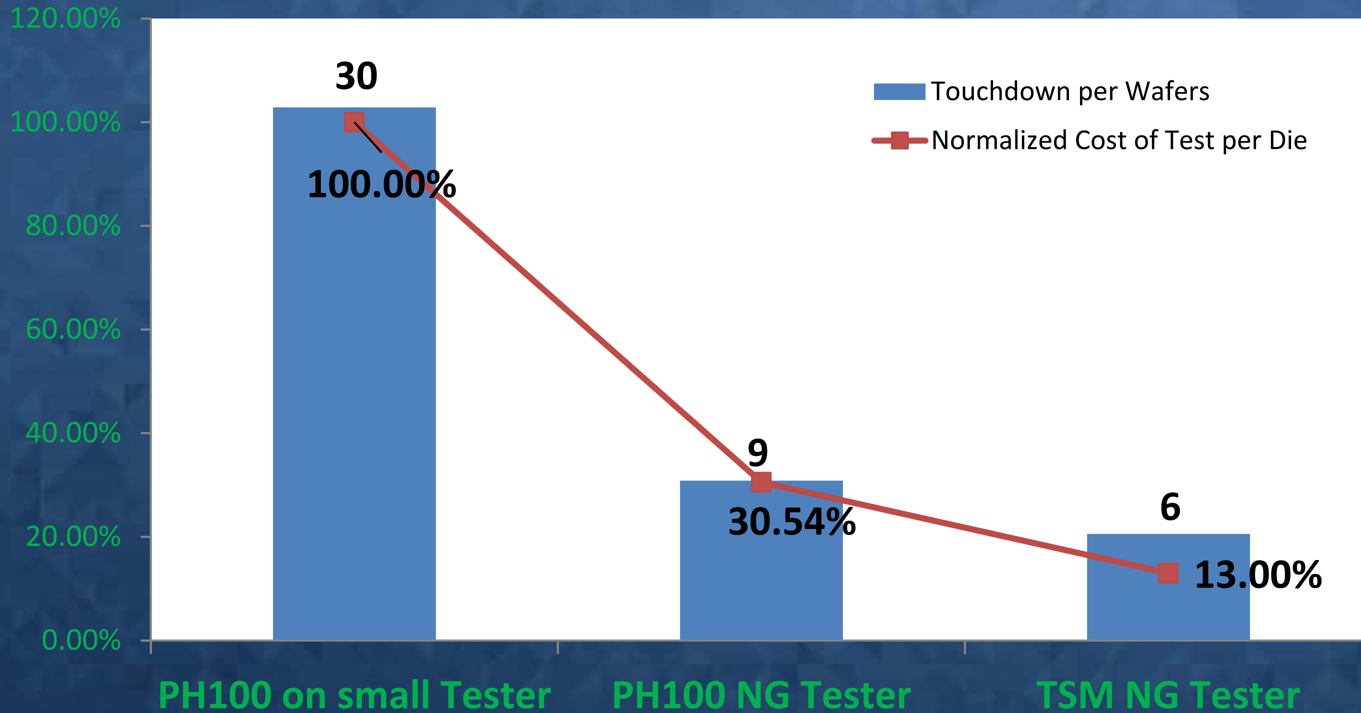
Probe card requirements:

- Wafer sort test with multiple insertion: cold, room, hot temp
- High temp test required 125°C → 150°C → 175°C
- Multiple TD at same bond pad
- Large active area + high parallelism for SoCs

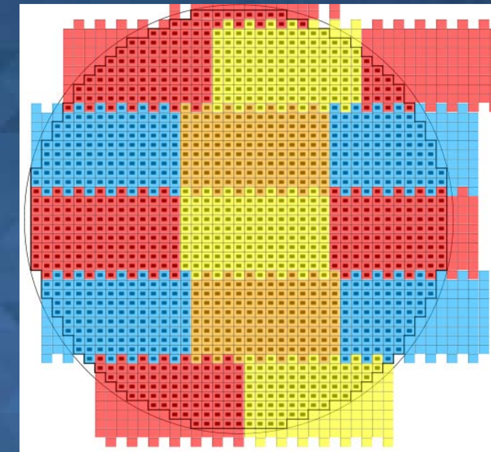
Increase Test Efficiency = Reduce Cost of Test

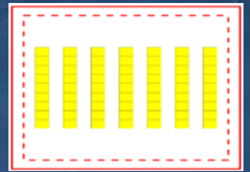
Maximize Number of DUTs to Reduce Number of TDs

- **Require Full Wafer Touch Down Maximize Touch Down Efficiency**
- **Increase Touch Down Efficiency to Reduce Cost of Test**

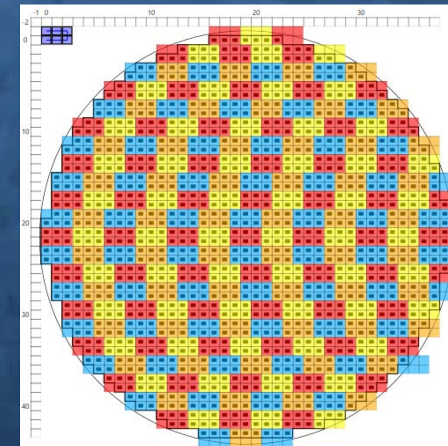


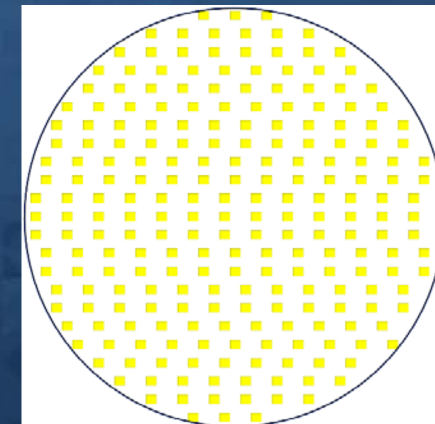
30 TD 63 DUT PH100 Touch Down Pattern





6 TD 234 DUT Full Wafer Contact TD Pattern



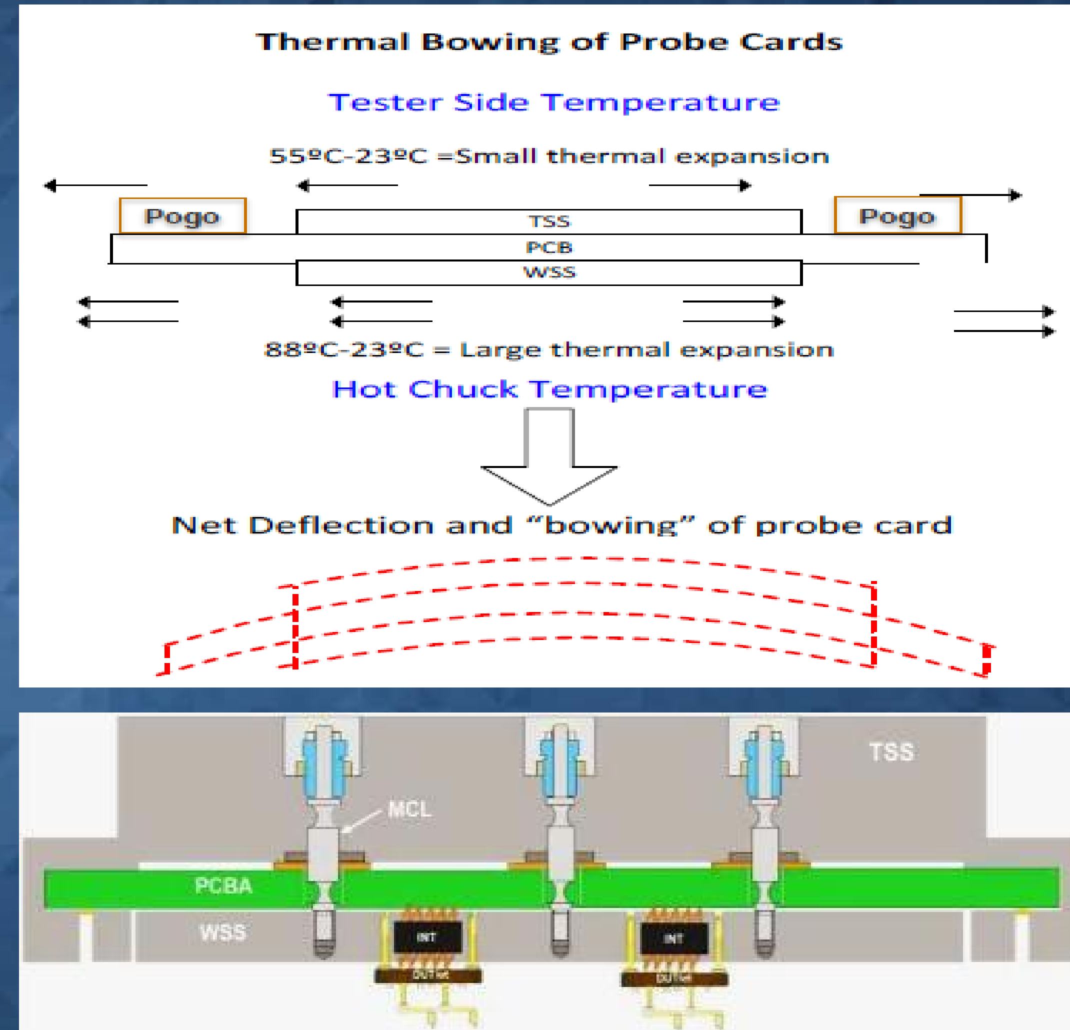


TrueScale Matrix Probe Card

Thermal Planarity Control

- **Thermal gradients in probe card produce differential expansion across probe card components and can produce probe card bow**

- **Design and build the probe card for better thermal planarity control**
  - Mechanical simulation to understand thermal behavior
  - Design automation (real-time probe card deformation simulation) to optimize **M**echanical **C**oupling **L**ink location for planarity control
  - Added flexible shim kit design on inner tester side stiffener
  - Bridge beam hardware add to PC outgoing PXI metrology tool to simulate test head docking condition for planarity adjustment
  - AOT/POT analysis on field to further understand deflection force

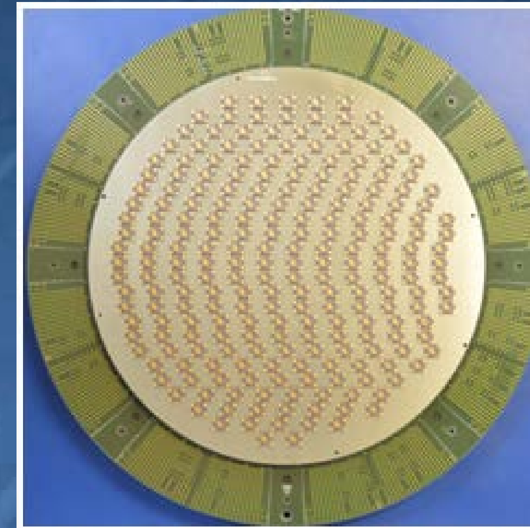


TrueScale Matrix Probe Card Architecture

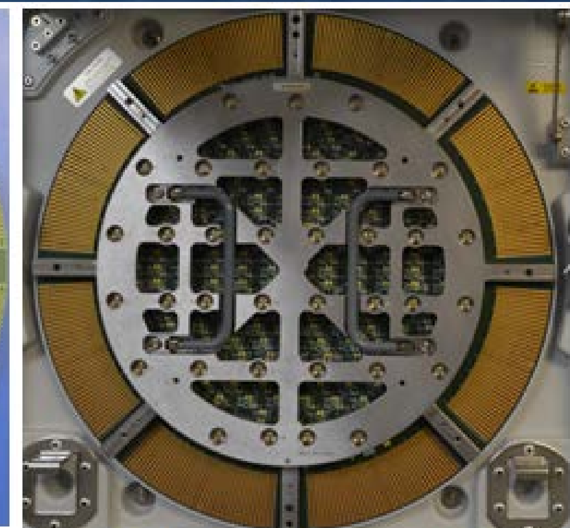
Optimize for High Parallelism and Ultra High Temperature

- **Probe Card Design Requirements**
  - 300mm probing active area
  - Support >256 DUTs, >35000 Probe Count
  - Smallest Pad Size and Pitch: ~55um/65um
  - Temperature Range: -40 to +165°C

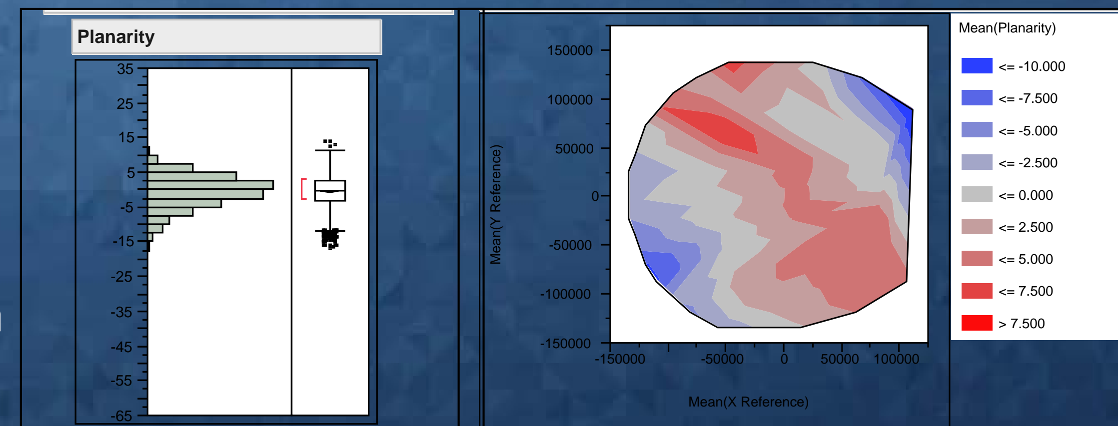
- **TSM PC Achieved Large Active Area with Highest Parallelism**
  - Full 300mm active area probing to improve touchdown efficiency
  - FFI proprietary touchdown efficiency analysis software and service
  - T11 UHT Probe Rated -40 to +175°C
  - Modified TSS and Matrix architecture achieved 30um planarity



Custom Wafer Side Stiffener for wide temp range operation



Modified Tester Side Stiffener



DragonBlade T11.4 Ultra High Temperature Probe

Metric	T11	T11.4 UHT
Max Temperature (°C) / AOT (um)	<=130°C/75um <=160°C/65um	**175°C/100um**
Min pad Pitch (um)	50um	60um
Scrub Ratio	~10%	
Current Carrier Capacity (ISMI)	1.2A	>1A
Typical spring constant (gram-force / mil)	0.8 g/mil	
Tip sizes at beginning of life (um)	6um, 8.5um, or 14um ±3um	
Tip sizes at end of life (um)	20um	

Final Result in Production Test Environment

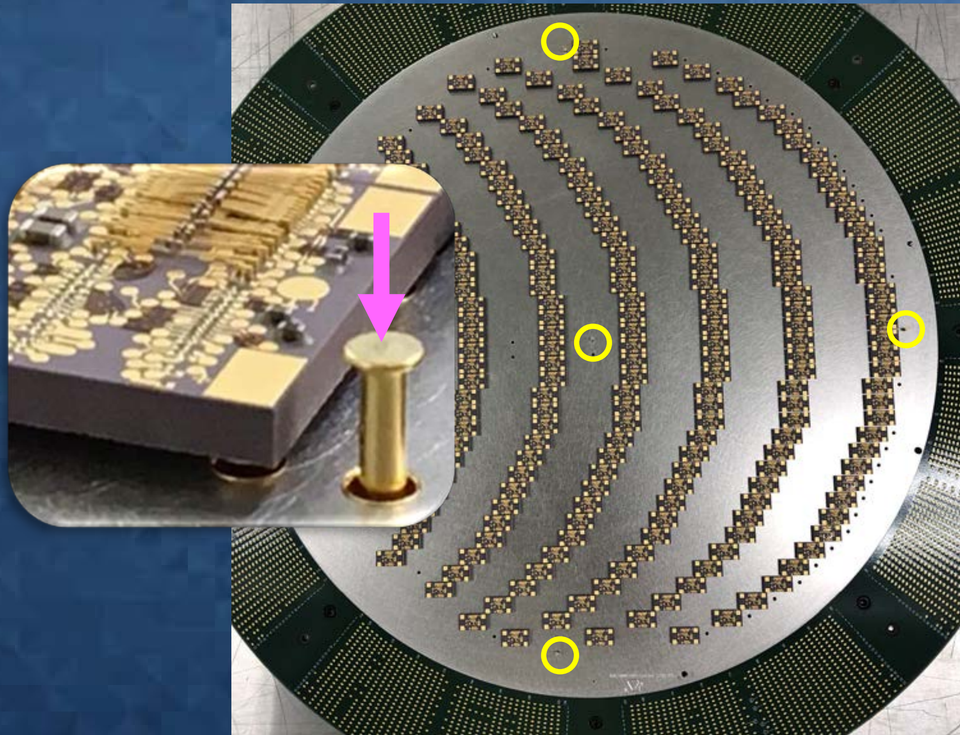
- **Renesas agreed to share their collecting data.**
  - Beam creep data
  - Contact Resistance
  - Probe Mark Characterization Data
  - Probe Mark Photos

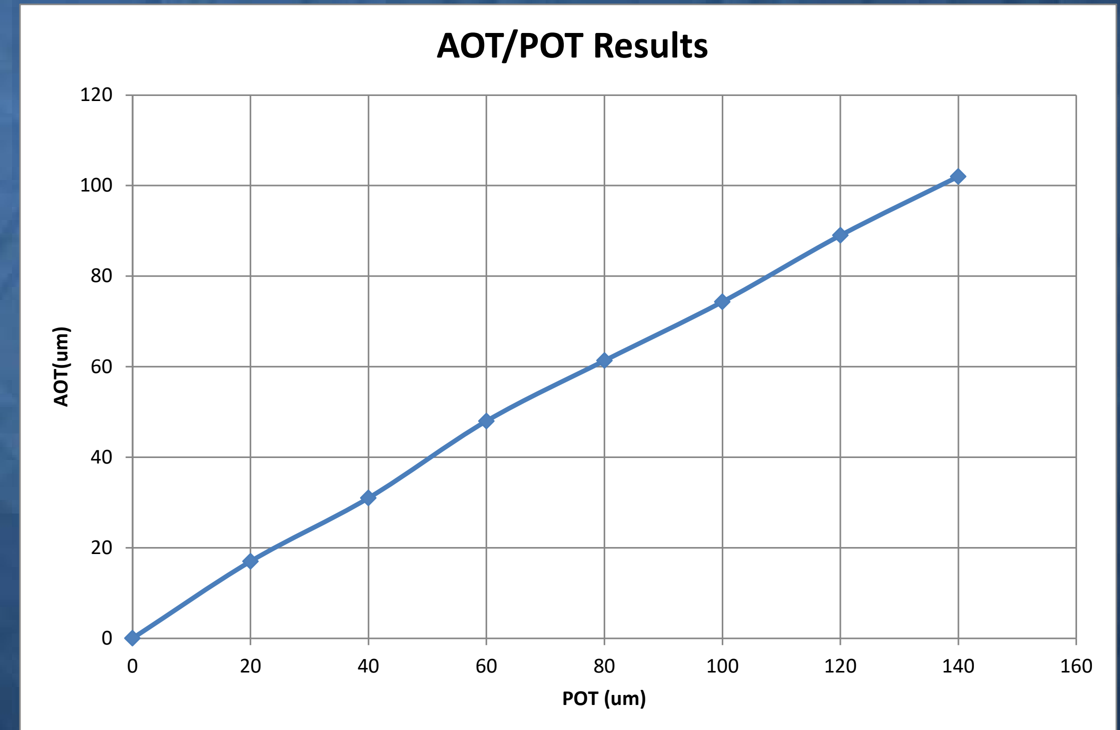
Actual Over-Travel vs. Program Over-Travel Analysis

- **Using Pin and Sleeve to analyze probe actual over-travel**

  Install Pin & Sleeve at 5 locations on the PH.
  Check that the pins have shifted upwards due to the chuck loading

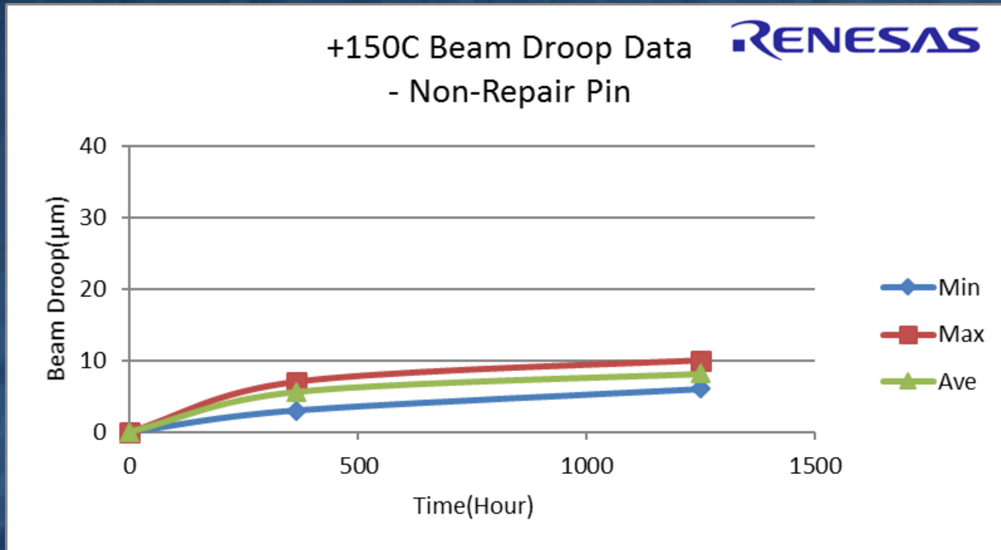
AOT/POT Results ≈ 75%

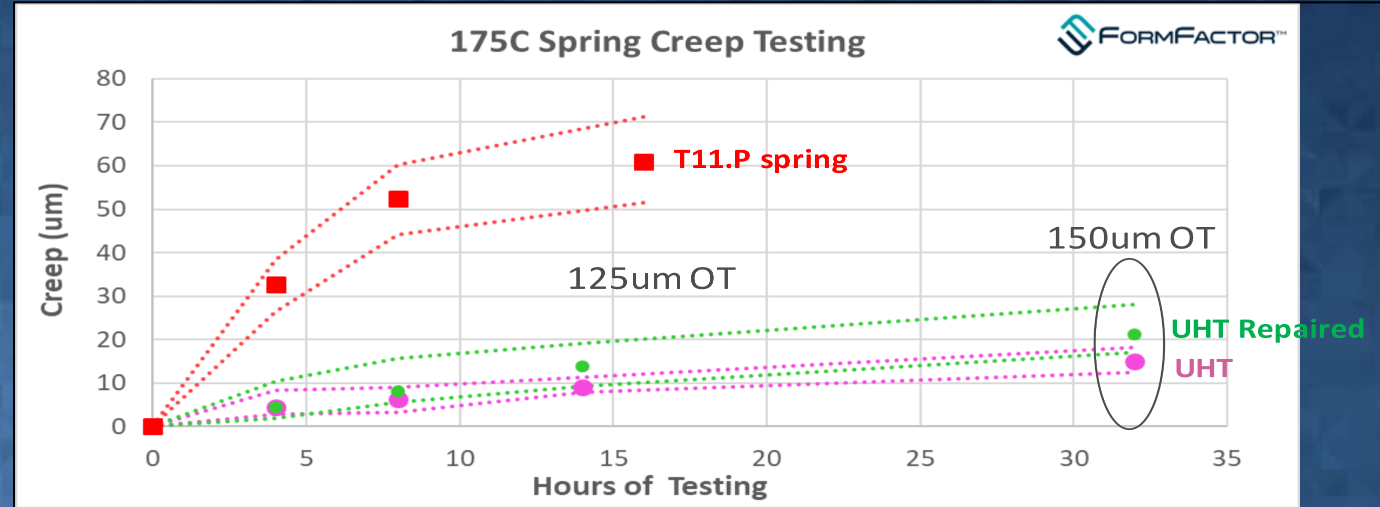


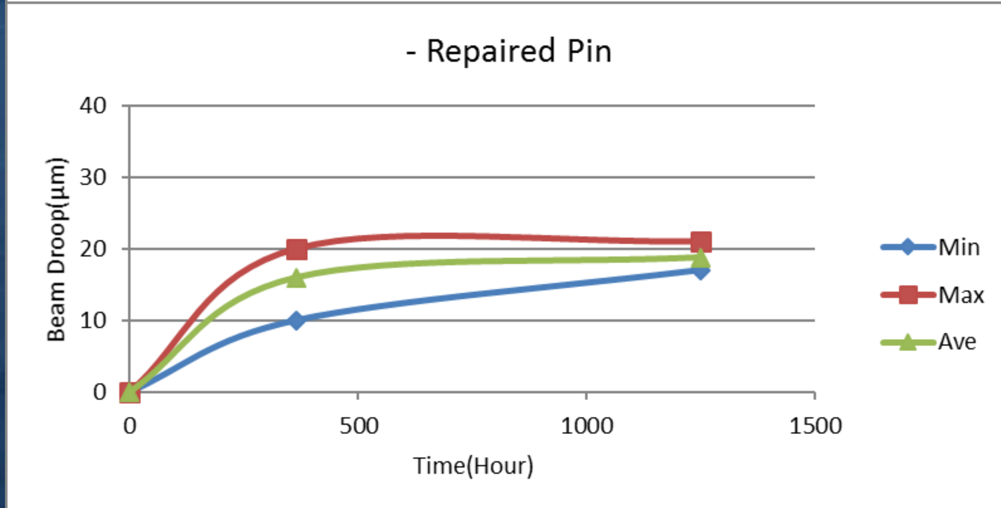


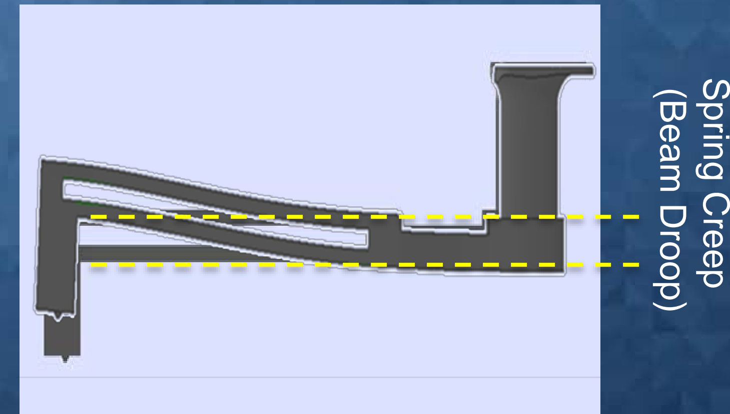
DragonBlade T11.4 UHT Performance

Same capability as T11 with 2x hot temp performance





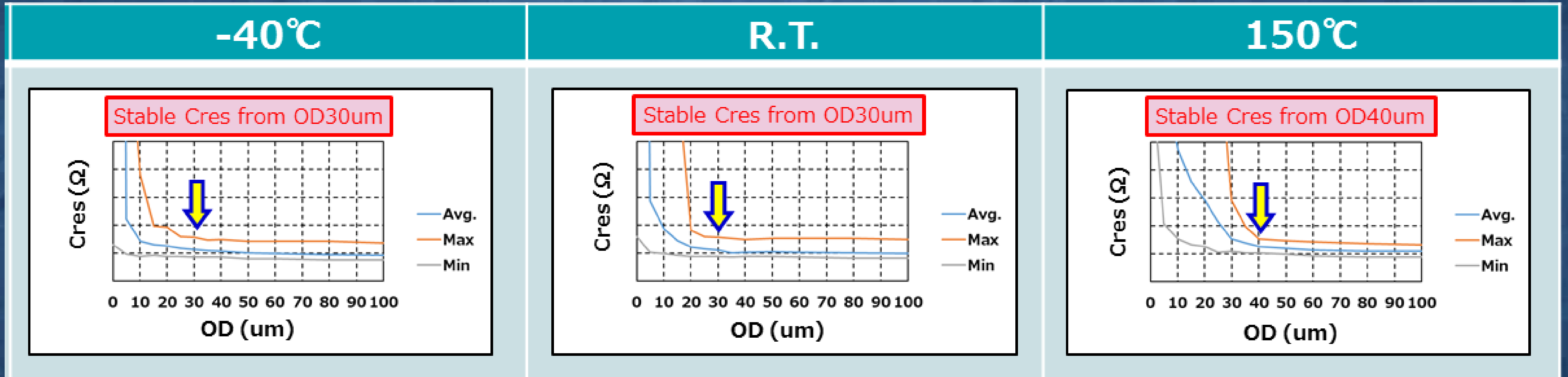




Spring Creep
(Beam Droop)

Contact Resistance vs. OverDrive

- **T11.4 UHT archived stable Cres from 30-40µm OD.**



Multi-Contact Performance

- **T11.4 UHT archived stable Cres for all cases.**
  - 10 times TD and move to new surface at 11th TD and 200 times TD test

	-40℃	R.T.	150℃
OD80um	Cres (Ω) / TD count (0–12)	Cres (Ω) / TD count (0–12)	Cres (Ω) / TD count (0–12)
OD100um	Cres (Ω) / TD count (0–12)	Cres (Ω) / TD count (0–12)	Cres (Ω) / TD count (0–12)
OD100um	Cres (Ω) / TD count (0–200)	Cres (Ω) / TD count (0–200)	Cres (Ω) / TD count (0–200)

T11.4 UHT Probe Mark Size Analysis

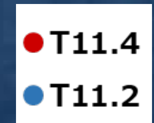
Probe Mark Size Past Extreme Temperature Test

	X-dim	Y-dim	Scrub depth	Prow height	Probe Mark area
OD80um	X (um) / TD count (0, 5, 10, 15, 20)	Y (um) / TD count (0, 5, 10, 15, 20)	Depth (um) / TD count (0, 5, 10, 15, 20)	Height (um) / TD count (0, 5, 10, 15, 20)	Area (um²) / TD count (0, 5, 10, 15, 20)
OD100um	X (um) / TD count (0, 5, 10, 15, 20)	Y (um) / TD count (0, 5, 10, 15, 20)	Depth (um) / TD count (0, 5, 10, 15, 20)	Height (um) / TD count (0, 5, 10, 15, 20)	Area (um²) / TD count (0, 5, 10, 15, 20)

Prober Chuck Temperature: -40°C

	X-dim	Y-dim	Scrub depth	Prow height	Probe Mark area
OD80um	X (um) / TD count (0, 5, 10, 15, 20)	Y (um) / TD count (0, 5, 10, 15, 20)	Depth (um) / TD count (0, 5, 10, 15, 20)	Height (um) / TD count (0, 5, 10, 15, 20)	Area (um²) / TD count (0, 5, 10, 15, 20)
OD100um	X (um) / TD count (0, 5, 10, 15, 20)	Y (um) / TD count (0, 5, 10, 15, 20)	Depth (um) / TD count (0, 5, 10, 15, 20)	Height (um) / TD count (0, 5, 10, 15, 20)	Area (um²) / TD count (0, 5, 10, 15, 20)

Prober Chuck Temperature: 160°C



T11.4 UHT Probe Mark and Pad Reliability Analysis

No Under Pad Damage at 20TD

	Single TD	Multi-TD : 5 times	Multi-TD : 20 times
OD80um			
OD100um			

Cold Temperature: -40°C

	Single TD	Multi-TD : 5 times	Multi-TD : 20 times
OD80um			
OD100um			

Hot Temperature: 160°C

Summary

- **Automotive IC market continues growing with large demand and zero defects parts**

- **FormFactor Matrix platform with T11 Ultra High Temp probe provides capability of meeting zero defect testing requirement and the highest testing efficiency for automotive IC wafer sort test**

- **TrueScale Matrix with T11 UHT probe solution has been validated by key automotive customer and deployed to various tester platforms including T2000, V93K DD, J750**

Acknowledgement

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