Ultra High Temperature Probe Card Solution for Automotive IC Testing

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Alan Liao

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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
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**

<table>
<thead>
<tr>
<th>Touchdown per Wafers</th>
<th>Normalized Cost of Test per Die</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH100 on small Tester</td>
<td>30</td>
</tr>
<tr>
<td>PH100 NG Tester</td>
<td>9</td>
</tr>
<tr>
<td>TSM NG Tester</td>
<td>6</td>
</tr>
</tbody>
</table>

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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 Mechanical Coupling Link 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

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# DragonBlade T11.4 Ultra High Temperature Probe

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

175C Spring Creep Testing

+150C Beam Droop Data
- Non-Repair Pin

- Repaired Pin

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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 11\textsuperscript{th} TD and 200 times TD test

<table>
<thead>
<tr>
<th></th>
<th>-40°C</th>
<th>R.T.</th>
<th>150°C</th>
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<td><strong>OD80um</strong></td>
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<td><img src="image3" alt="Graph" /></td>
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<tr>
<td><strong>OD100um</strong></td>
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<td><img src="image5" alt="Graph" /></td>
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<tr>
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<td><img src="image8" alt="Graph" /></td>
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T11.4 UHT Probe Mark Size Analysis
Probe Mark Size Past Extreme Temperature Test

Prober Chuck Temperature: -40°C

Prober Chuck Temperature: 160°C

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# T11.4 UHT Probe Mark and Pad Reliability Analysis

## No Under Pad Damage at 20TD

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<td><img src="image1.png" alt="Image" /></td>
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**Cold**

Temperature: -40°C

**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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