Advanced Package Technology for Automotive
(In a Zero Defect World)

Mike Zylinski
Dick McCann

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ADI enables Automotive Innovations

Combining MEMs Structures and Signal Processing

Small High Integrated Safety Solutions


Extract Very Small Signals Out of Noisy Environment

More Efficient Cars

First precision 16-Bit Converter under the Hood (2006) Benchmark for Intelligent Battery Sensing (2013)

Measure and Process High Dynamic Signals

Comfortable and Fun to Drive


Safer

Greener

Smarter
Why Invest in Automotive?

- Accelerating vehicle unit growth
- Technology seen as a differentiator in premium OEM brands
- Proliferation in mass market cars to meet government initiatives
Industry Snapshot

Aging Populations  |  Inexperienced Drivers  |  Increasing Congestion

Fuel Efficiency  |  Autonomous Braking  |  Numerous Distractions
## On the Automotive Horizon

### Evolutionary

- Higher accuracy inertial sensors

### Momentum Building

- Automatic emergency braking

### Game Changing

- (semi) Autonomous driving

### SAFETY SYSTEMS

- Higher accuracy inertial sensors
- Automatic emergency braking
- (semi) Autonomous driving

### POWERTRAIN

- World-wide deployment of Start-stop systems
- Higher-accuracy sensors
- Alternative powertrains

### INFOTAINMENT

- Active Noise Cancellation
- Social Media integration
- Car2Car and Car2infrastructure communication
## Proliferation of technology to meet Government Initiatives

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<tr>
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<th>Safer</th>
<th>Greener</th>
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<tr>
<td><strong>2014</strong> Rearview cameras</td>
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<td><strong>2016</strong> 35.5 mpg</td>
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<td><strong>2017</strong> Rollover prevention</td>
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<td><strong>2025</strong> 54.5 mpg</td>
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<td><strong>2014</strong> Autonomous braking</td>
<td><strong>2014</strong> Euro 6 emissions</td>
<td><strong>2030-2050</strong> Phased reduction of internal combustion engines</td>
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<td><strong>2016</strong> Pedestrian safety systems</td>
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<td><strong>2014</strong> ESC mandate</td>
<td><strong>Aggressive emissions targets similar to EU</strong></td>
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<td><strong>2014</strong> Truck pre-crash safety system mandate</td>
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<td><strong>New safety requirements for drivers and vehicles</strong></td>
<td><strong>Clean air regulations</strong></td>
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<td><strong>Greater use of electric vehicles</strong></td>
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<td><strong>Numerous cities offering clean vehicle incentives</strong></td>
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Fanout WLCSP Package for RF

- Slow adoption of WLCSP in Automotive
- Infotainment has penetration
- Leaded packages still preferred, to the point where many products offer QFP and smaller BGAs for different customers
- Next Generation ADAS Radar Devices may require WLP for performance
Inertial Sensor Packaging
Used for ESC and Airbag Deployment

Single, Dual and Tri Axis
Low and High G Accelerometers

Angular Rate Gyroscopes

Acceleration and Velocity
Position and Tilt
Shock and Vibration

Angular Rate of
Rotation and Position
Packaging Is A Vital Element of Isolation
High Volume Automotive Products

Package Materials and Dimensions Help Define Isolation Capability

Split Paddle Separates Ground References

Distance Between Paddles Limits Breakdown Voltages
Package Cross Section
Supplier’s Suppliers Need Careful Control

Gross delamination observed after Solder Heat Resistance

Failure was not classic mold to leadframe delamination, but rather Cu plating peeling off leadframe
Package Cross Section
Supplier’s Suppliers Need Careful Control

- Carbon Black used for mold compound coloring
- Resistivity of $10^0$ to $10^{-1}$ ohm-cm
- Can cause electrical leakage in sensitive devices (nA-pA range)

- Carbon is interspersed in compound, but cohesion occurs
- Is minimum size above min wire spacing?

References
-Breakthroughs in the Analysis of Leakage Failures in PBGA Packages
Proceedings of 13th IPFA 2006, Singapore
-http://www.kgk-rubberpoint.de/ai/resources/77c7e854450.pdf
Trends Impacting Automotive Quality

- Integration within the package continues
- Mission profiles getting more extreme
- Understanding cost reductions’ impact on performance and quality
- Supplier relationships more important than ever
- Customers are driving toward fewer suppliers with deeper engagements

- “Zero Defects” remains mandatory
ADI – Automotive

1. Automotive Strategy and Business Model
2. Advanced Product Quality Planning (APQP)
3. Abnormality Control - Quality
4. Issue Resolution - Responsiveness
Strategy to Achieve Vision for Zero Defects

Facilitate Quality Mindset and Behavior within Company

- **Focus on Defects**
  - Prevent Defects
  - Detect Defects
  - Respond to Defects

- **Create Cost of Quality Awareness**
  - Zero Defects = Lowest Total Cost
    - Cost of Failure (automotive) can have large tangible & intangible consequences.
    - Investment in prevention always justified (long term perspective).

- **Drive quality throughout supply chain (incl. supplier’s suppliers)**
  - Continuous improvement
Automotive Grade
Enhancements Compared to Industrial Grade Products

- AEC-Q100 Qualification
- Operation up to 125°C (and increasing!)
- Automotive Production Flow
- Extended Test Coverage
- High-Temperature Testing
- Wafer-Level Probe
- Part Average Test/Probe
- Safe Launch
Automotive Requirements - Drivers for Packaging Improvements

- Halogen Free
- Pb Free
  - Plating
  - Die Attach
- Reduced or “Zero Delamination”
- High Temperature
  - Automotive 180’C++
- Inspectable Solder Joints

- Drives material, process and design improvements
Automotive Requirements for Increased Operating Temperatures

- Impacts wirebond integrity
- Several options
  - Overpad metallization
  - Cu wirebonding
- Impacts mold compound
Over Pad Metallisation for High Temp

OPM – NiPdAu plated layers on Al Pad prevent AuAl IMC growth.

Nickel Palladium Gold (NiPdAu)

![Diagram showing NiPdAu layers on Al Pad](image)

Au/Al Bond post 500hrs at 195°C

Au/OPM Bond post 6000hrs at 195°C
Cu Wire

- Improved performance at lower cost

- Advantages over Au wire:
  - Lower Assembly Cost
  - Higher Fusing Current
  - Better high temp performance due to stable intermetallics = less change in resistivity
  - Improved Electrical Conductivity
  - Improved Thermal Conductivity
  - Improved Wire Sweep Performance
  - Better Extended Reliability Performance
Intermetallic Thickness Growth Comparison: Au vs Cu wire

High Temperature Storage (@150 °C)
Mold Compound Improvements

- High temperature mold compounds to 180°C++
  - Requires compound manufacturers to develop new materials
  - Detailed characterization and qualification required

- Need stable compound properties at elevated temperatures
  - High Tg to avoid thermo-mechanical shifts
  - Understanding of delamination performance
  - Stability of material over temperature
Summary

- Rapidly increasing content of electronics in automobiles
  - Package Technology enabling many of these advancements

- Zero defect mindset needs to be pervasive throughout supply chain
  - Suppliers to fan out to their supply base

- ADI is committed to being the Best Automotive Supplier in Class.
  - Quality focus/strategy is closely coupled with Automotive business success

- Material suppliers and OSATs need to meet challenge of increasing Automotive Mission Profile

- Collaboration with Automotive customers/OEMs is essential to effectively meeting the increasing challenge of the automotive market place.