High Reliability in Automotive: Materials Challenges
Inventec Performance Chemicals is a company of the Dehon Group

DEHON Group
• HQ in Paris, France
• 100% owned by the Dehon family
• Since 1874
• >500 employees over 15 sister companies in Europe, Asia & America

One of the first high-tech Performance chemicals companies in Europe.

Chemicals for the B2B and commercial automotive market.

Liquified gasses for the refrigeration, air conditioning and heating market.
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About Electronic Business Unit

- **Electronic BU**: Soldering, cleaning & coating for electronics assembly & semiconductor packaging
- **Surfaces Technologies BU**: Cleaning and Surface Treatment products for various markets
- **Fine Chemicals BU**: Specialty chemicals for foam expansion, aerosols and chemical synthesis

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One of the first high-tech Performance chemicals companies in Europe.
Soldering, cleaning & coating materials used in the packaging of semiconductors and in the assembly of electronic devices
Main markets

...with a common need: high RELIABILITY
Main markets

...with a common need: high RELIABILITY
Automotive electronics

Thanks to the power semiconductor and electronics developments, automotive today is

- SAFER than ever before
- Less CO2 emissions than ever before
- SMARTER than ever before
- More ENTERTAINING than ever before
Automotive electronics trends

END CUSTOMER

• CO2 emissions
• Increase Safety
• Networking/ connectivity
• Comfort

• 85% of the innovations done at electrical/ electronic level
Automotive electronics trends

AUTOMOTIVE ELECTRONICS SUPPLIER

- Reduce number of ECUs
  - Increase features

- Miniaturization

- Lighter

- Lead Free

- Thermal performance

- Complex system integration

- Cost

- Reliability > 15 years
Automotive electronics high reliability

**INEMI Automotive PEG: automotive underhood temperatures**

<table>
<thead>
<tr>
<th>Component Location</th>
<th>Operating Temperature (Baseplate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Compartment</td>
<td>-40 °C to 85 °C</td>
</tr>
<tr>
<td>Engine Compartment</td>
<td>-40 °C to 125 °C</td>
</tr>
<tr>
<td>On-Engine and On-Transmission</td>
<td>-40 °C to 140 °C</td>
</tr>
<tr>
<td>Wheel-Mounted Components</td>
<td>-40 °C to 250 °C</td>
</tr>
</tbody>
</table>
Automotive electronics operating conditions

THERMAL

- operating temperature range
- number and range of temperature cycles

MECHANICAL

- vibration load

CLIMATE/ ENVIRONMENT

- humidity and corrosive agents
### Requirements for semiconductors in different markets

<table>
<thead>
<tr>
<th>Market</th>
<th>Consumer</th>
<th>Industrial</th>
<th>Automotive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>0°C to 40°C</td>
<td>-10°C to 70°C</td>
<td>-40°C to 155°C</td>
</tr>
<tr>
<td>Operation time</td>
<td>1 to 3 years</td>
<td>5 to 10 years</td>
<td>Up to 15 years</td>
</tr>
<tr>
<td>Humidity exposure</td>
<td>low</td>
<td>environment</td>
<td>from 0% to 100%</td>
</tr>
<tr>
<td>Tolerated field failure rates</td>
<td>&lt; 10%</td>
<td>&lt; 1%</td>
<td>Zero failure target</td>
</tr>
<tr>
<td>Documentation</td>
<td>none</td>
<td>conditional</td>
<td>True &amp; accurate</td>
</tr>
<tr>
<td>Supply</td>
<td>none</td>
<td>Up to 5 years</td>
<td>Up to 30 years</td>
</tr>
</tbody>
</table>
### Automotive electronics vs aerospace

<table>
<thead>
<tr>
<th>Market</th>
<th>Aerospace</th>
<th>Automotive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>-55°C to 85°C</td>
<td>-40°C to 155°C</td>
</tr>
<tr>
<td>Operation time</td>
<td>24 years</td>
<td>Up to 15 years</td>
</tr>
<tr>
<td>Humidity exposure</td>
<td>from 0% to 100%</td>
<td>from 0% to 100%</td>
</tr>
<tr>
<td>Tolerated field failure rates</td>
<td>Zero failure target</td>
<td>Zero failure target</td>
</tr>
<tr>
<td>Environmental</td>
<td>Less pushed</td>
<td>Pushed</td>
</tr>
<tr>
<td>Cost pressure</td>
<td>High</td>
<td>Very high</td>
</tr>
</tbody>
</table>
Miniaturization in automotive

Heterogeneous Assembly

Image courtesy of Paul Evers, Philips

Graping defect in passive components
## Miniaturization in automotive

<table>
<thead>
<tr>
<th>Feature</th>
<th>Automotive Today</th>
<th>Automotive Tomorrow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature/ Reliability</td>
<td>-40°C to 125°C</td>
<td>-40°C to 150°C</td>
</tr>
<tr>
<td>Line/ space in substrate</td>
<td>125 µm/ 125 µm</td>
<td>50 µm/ 50 µm</td>
</tr>
<tr>
<td>Small components</td>
<td>0402</td>
<td>0201, considering 01005</td>
</tr>
<tr>
<td>Pitch</td>
<td>0.5 mm (BGA, QFP)</td>
<td>0.35 mm</td>
</tr>
<tr>
<td>Flip Chip pitch</td>
<td>320 µm</td>
<td>200 µm</td>
</tr>
<tr>
<td>Solder Printing</td>
<td>Standard printing</td>
<td>Advanced printing / jet printing</td>
</tr>
</tbody>
</table>
Lead Free in automotive

Lead Free materials in electronic devices since many years
But slow entrance in markets linked to « life critical systems »

• Automotive (airbag, braking systems, …)
• Aerospace (air traffic controls, avionics, …)
• Transport (railway, control systems)
• Military & defence (missil launch systems)

But still not in high melting point applications (mass production)

• Die attach in power semiconductors

• High operating temperature assembly
Lead Free in automotive

SAC405/ SAC 305 alloys may be enough for some applications

But not best for underhood electronics, devices close to 200 °C

Image courtesy of Techno Fandom

Image courtesy of Yöle Development
Lead Free in automotive – high temperature

Nano doped lead free alloys/ mixed alloys

Need to improve thermal cycling performance at high temperatures

Silver sintering

Thermal cycling reliability improved
Need to invest in new equipment/ methods
No easy visual inspection
Pressure applied could affect other parts
Price of silver is a disadvantage

Conductive adhesives

Very good process for temperature sensitive components (100 to 150 C)
Less conductive than solder
Price of Ag is a disadvantage
Cleaning in automotive electronics

The amount of contamination trapped under packages may increase and the occurrence of ECM can be expected to rise, unless new effective cleaning methodologies are used.

Cleaning (defluxing) is common in other high reliability applications: hybrid packaging, aerospace, defense, mining…

It is an additional production cost.
Sustainability: the capacity to endure (wikipedia)

Sustainable supply for 30 years in automotive

Surveillance on the chemicals and substances
Heavy copper

Mechanical strength

Higher current carrying capacity in traces and Through-hole vias

Reduce product size

Could increase the RISK for corrosion
Automotive electronics failure sources

**Loss of electrical connections**
(corrosion, breakage, mechanical deformation, component failure…)

**Not intended electrical connections**
(arching, tin whiskers, water from multiple sources, component failure…)

**Electromagnetic Compatibility**

**Software**

Commonly *intermittent* ► **No-fault-found** (NFF) occurrences
Electrochemical migration (ECM)

- Loss of insulation resistance between 2 conductors due to the growth of conductive metal filaments (dendrites)
- Potential to produce leakage currents and shorts
- Reduction of SIR
- Influence of DC voltage bias
- Lead Free alloys trend towards ECM
- Drivers: *temperature, moisture & contaminants*
Conductive Anode Filament (CAF)

- Loss of insulation internally to the PCB
- Lead Free materials trend towards CAF
- Drivers: Circuit density, harsh environments, LF laminates
Intermittent Failures in Electronic Assemblies

Connectors
- Corrosion
  - Pitting
  - Plating defects
- Environment
  - Moisture
- Wear out
  - Aging
- Damaged wire
  - Contamination
- Mating surfaces

Electro-chemical migration
- Conductive filament
  - Inner layer adhesion
- Contamination
  - Use conditions
  - Moisture
- Dendrites
  - Use conditions
- Material
  - CTE

Printed Circuit Boards
- Contamination
  - Vibration
  - Convection air flow
  - Abrasion
- Use conditions
  - Pad
  - Temperature
  - Component size

Via cracking
- Thickness
  - Quality
- Via creation method
  - Plating

Warpage
- Copper PCB stiffness
  - Component
  - Pad
  - Temperature

Electrical Interference
- Lay out
- Damaged wire
- Mating surfaces

IC
- Interconnect crosstalk
- Soft error
  - Radiation
- Short/Open Circuits
  - Electro-migration

Defects in via
- Metallization
  - Dielectric breakdown
- Ionic contamination
  - Crack

Pastivation
- Wire bondlift
- Strength
  - Stress

Lead finish
- Delamination
- Intermetallic

Temperature
- Warpage

Component-PCB Interconnects
- Loosened solder
  - Pinlift
  - Black Pad
  - Non-wet

Insufficient solder
- Oversized solder
- Voids/cracks

Manufacturer defects
- Atmospheric contamination
  - Creep corrosion
- Chemistry of Corrosion product

Component
- Creep corrosion
- Atmospheric contamination
- Moisture

CALCE Electronics paper «No-fault-found and intermittent failures in electronic products »
Automotive electronics failures in media

Officials announced a few weeks ago that Toyota Motor Corp. has agreed to pay a $29 million settlement to end lawsuits accusing the Japanese car manufacturer of misleading people by issuing false statements in regards to safety issues related to unintended acceleration.

“We are confident that no problems exist in our electronic throttle systems in our vehicles,” Jim Lentz, the CEO of Toyota Motor Sales U.S.A. Inc., testified in February 2012. He also reported Toyota did not find “any malfunction that caused unintended acceleration.”

However, Toyota documents recently analyzed by Keith Armstrong, Antony Anderson and Brian Kirk of the UK and automotive engineer Neil Hannemann of California reportedly directly contradict Toyota’s assertion that the vehicles have no electronic problems. The documents were translated from Japanese to English by translator Betsy Benjaminson, who also initially discovered the discrepancies in Toyota's claims. The documents were made public Wednesday, March 13.

“Is Toyota Telling the Truth About Sudden Acceleration?”, asks law.com in a breaking article chronicling the alleged cover-up. “The experts don’t believe that [driver error or floor mat slippage] explain the surge in complaints. Instead, they believe precisely what Toyota has for many years steadfastly denied: that the problem is rooted in electronics,” the article says.

According to the article, an undated spreadsheet showed “test results of an engine’s electronic throttle control system, including numerous faults that the document said cause sudden acceleration.”

Other translated documents reportedly illustrate Toyota’s willingness to “define problems as they wish them to be, regardless of the facts.”

“Previously, when I was in charge of Hilux [a Toyota truck model] in the Japan domestic service division, I experienced an engine stall malfunction due to radio wave interference from a nearby U.S. naval base in Yokohama. At that time, I was told that it could absolutely never occur,” one document, an undated email from an unnamed engineer, stated.

However, the article says, despite numerous consumer complaints, incidents and testimonials from engineers, plaintiffs have made slow progress convincing the courts that electronic malfunctions are real because expert findings cannot always be replicated in tests.

“We have the burden of proof, and we should,” Molly O’Neill said. O’Neill works with the dean of sudden unintended acceleration (SUA) trial lawyers, Thomas Murray of Sandusky, Ohio. “But you cannot open up the car and show what went wrong. That’s the nature of electronics.”
Chrysler's recalling; PCB's to blame

Chrysler Group is recalling almost half a million SUVs worldwide – as the vehicles’ circuit boards were found to be transmitting signal which trigger unintended gearshifts to neutral.

Chrysler Group LLC will recall approximately 469,000 older-model SUVs worldwide to perform a software update.

Chrysler Group discovered that some circuit boards may transmit compromised signals that enable inadvertent gearshifts to neutral during the start sequence. The software update will prevent such occurrences, the company writes in a statement.

Affected are 469,072 Jeep Commanders and Grand Cherokees, model years 2006-2010 and 2005-2010, respectively. Approximately 295,000 vehicles are in the U.S., 28,500 are in Canada, 4,200 are in Mexico and 141,000 are outside the NAFTA region.

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Automotive electronics failures in media

Tin whiskers may have caused Toyota recalls

An expert on electromagnetic interference has been approached by the US government to give an independent assessment of the problems that have been the cause of a massive recall of Toyota cars.

TechEye claims that they have seen a document written by EMI (electromagnetic interference) expert Keith Armstrong, saying that the Toyota recall due to sticking pedals is only a smokescreen. In the document, Armstrong said he was contacted by the US government’s National Highway Traffic Safety agency to discuss the EMI implications that could have caused unintended acceleration.

Armstrong said that tests performed by the motor industry, by the US government and the Japanese government show it’s almost impossible to stop a runaway vehicle with the brakes. If EMI is involved in an incident, it will not leave any traces. He said that if electronic circuits, software or firmware in cars go full throttle or is exposed to another error, there could not be more stress seen than if it was behaving normally. The cause of the fault is then undetectable afterwards.

Armstrong said that manufacturers are denying that EMI could have caused the sudden acceleration, but that view is logically unsound. He said that this is a “bankrupt argument” and that any competent design engineer knows this. Complex electronic systems are hard to make reliable enough for safety. He also claimed that electronics systems in automobiles do not use the same safety principles that are common in other industries. The standard for functional safety is IEC 61508[2], but the auto industry is lagging behind and has only just produced the first draft of its own version of the standard.

Armstrong said that lead free soldering also can be a problem and can cause tin whiskers to grow, which can cause short circuits. This problem has earlier caused serious problems in the computer industry. He concludes that software also can be affected by EMI and can cause instability to electronic circuits, according to Techeye.

Chrysler Group LLC will recall software update.

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Automotive electronics failures in media

**NEWS**

*Newly Released Toyota Documents Show EMI in Electronic Acceleration Problem*

03/13/2009

Officials have released documents that shed light on the issue of electronic acceleration problems in Toyota vehicles. The documents, obtained through the Freedom of Information Act, reveal that the company has been aware of the problem for several years. The documents also show that Toyota engineers have been discussing the possible causes of the electronic problems for some time.

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*CTS not a supplier of pedals for Prius or Lexus*

**CTS wishes to clarify that it does not, and never has, produced pedals for Prius vehicles.**

CTS also clarified that it never made pedals for Lexus vehicles or for any Toyota vehicles prior to model year 2005. Both Lexus and Prius vehicles have been identified in the media as having allegedly been involved in accidents and injuries from sudden unintended acceleration issues. CTS and Toyota continue to maintain that both companies are unaware of any accidents or injuries due to gas pedal problems associated with Toyota’s recall of 2.3 million vehicles.

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Future automotive electronics

A computer with wheels?

Toyota MeWe concept car
Challenges for a materials supplier

Materials innovations…with proved reliability!

Standards plus test methods and tools to be implemented

Understand the interactions between failure modes and drivers

Compatibility between materials

Sustainable solutions
THANK YOU

raguilar@inventec.dehon.com
www.inventec.dehon.com