# Product Training Module for the use of PCM-99 in Automotive Battery Applications

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# Introduction

- Purpose
  - This training module is used to give an introduction to t-Global Technology's range of phase change materials specifically designed for cooling the batteries of electric vehicles
  - Objectives
  - To identify the key properties of the product range
  - To identify the key design criteria for product selection
  - Content
  - Introduction and background to the product range
- Learning time
  - 30 mins

# Introduction

- The electrification of the automobile has begun. The pace was slow and unsure at first, but it is now gaining steam and ready to take off.
- At present, every major auto maker has an electric vehicle (EV) on the market or is in development with plans for release on the docket.
- Concurrently, leaders worldwide are strongly pushing for EV development and increased production to promote a cleaner environment and to reduce oil dependency
- The European Union has established stringent green house emission rules that can only be met with the mass adoption of EV technology in the coming years.
- The United States and China have both recently vowed to be the first country to put one million EVs on the road by the year 2015.

# Introduction

- The catalyst for change among consumers is the skyrocketing gas prices at the pump.
- Hard economic reality has car drivers looking for better fuel efficiency and cheaper alternatives.
- EV producers are making their case stronger through significant engineering advances that have addressed many of the initial shortcomings of early EV technology.
- This includes travel range, cabin heating and cooling, speed and method of recharging, and vehicle cost.
- Most of these performance improvements are tied into the advancements of the EV's key component, the battery.
- Lithium-ion (Li-ion) technology has quickly moved to the forefront and is now becoming the dominant energy source.

# Introduction

- While EV battery construction will vary by manufacturer, they all use the same basic building block - the individual electrochemical cell
- Several cells, each in its own cylindrical or rectangular package are assembled together inside individual carrier modules
- Multiple modules are then connected in series to form a battery pack
- In order for the battery pack to function properly and to operate at optimum available charge at all times, its temperature must be kept uniform and maintained within a specified temperature band
- Batteries are very different from the products traditionally developed by auto manufacturers and suppliers.

# Introduction

- Batteries are very different from the products traditionally developed by auto manufacturers and suppliers. Chemistry, electricity and flow–thermal–structural physics inside batteries operate in a complex interplay that must be strictly controlled within narrow margins to ensure long battery life and low cost. T
- The slightest deviations from these margins can lead to dramatically shortened battery life and to serious safety hazards
- Passive thermal management systems using phase change materials (PCM) can control the temperature differentials and maintain temperature uniformity in Li-ion batteries without the use of active cooling components such as a fan, a blower or a pump found in air/liquid-cooling systems

# Phase Change Materials

- Phase Change Materials (PCMs) are solid materials at room temperature that melt at operating temperatures forming intimate contact on the mating surfaces to produce a low thermal resistance
- Generally, PCM materials are used as a replacement for grease, which can be messy in a production environment and has been shown to exhibit migration, or pump out issues, particularly under conditions where thermal cycling occurs
- Generally the phase change occurs at a temperature of 50 – 70ºC. This is chosen so that the material will flow when the device is initially powered up but will not flow during transportation or storage.
- Typically these materials are composed of a mixture of organic binders, thermally conductive fillers, and an optional substrate such as polyimide or aluminium to give additional functionality and ease of handling

# Phase Change Materials

- In use the PCM material will initially perform like a dry joint. However, as the operating temperature increases the material will flow under the pressure of the clips used to attach the heatsink.
- As the material flows it displaces the interstitial air and this lowers the thermal resistance.
- The next time the device is powered up there will not be this delay in achieving good thermal management as the thermal joint has already been established
- t-Global manufacturers a range of PCM materials which are ideally suited for thermal management in battery systems

# PC-99

- PC-99 is a phase change material which has a thermal conductivity of 1.5 W/m.k
- It is available in thickness of 0.06 and 0.12mm
- The phase change temperature is 51C
- The operating temperature range for this product -30 – 125C
- PC99 is designed to be a low-cost solution to minimize the thermal resistance between power dissipating electronic components and heat sinks.
- This low thermal resistance path maximizes heat sink performance and improves component reliability

# PC-99A

- PC-99A is a non-reinforced high thermal conductivity PCM material
- Thermal conductivity is 2 W/m.k
- Thickness is 0.12mm
- Working temperature is -30 – 125C
- It has a low thermal impedance

# PC-99D

- PC-99D is a non-reinforced high thermal conductivity PCM material designed for dispensing
- Thermal conductivity is 2.4 W/m.k
- Working temperature is -30 – 125C
- It has an ultra low thermal impedance

# PC-99AL

- PC-99AL is a PCM material coated onto an aluminum foil to aid rework
- Thermal conductivity is 1.5 W/m.k
- Thickness is 0.1mm
- Working temperature is -30 – 125C
- It is designed for applications were rework may be required

# PC-99P

- PC-99P is a PCM material coated onto an Polyimide film for applications that require a high dielectric breakdown voltage
- Thermal conductivity is 1.3 W/m.k
- Thickness is 0.1mm
- Dielectric breakdown voltage is 6,000 VAC
- Working temperature is -30 – 125C
- It is designed for applications were rework may be required

# Datasheet for PCM Materials

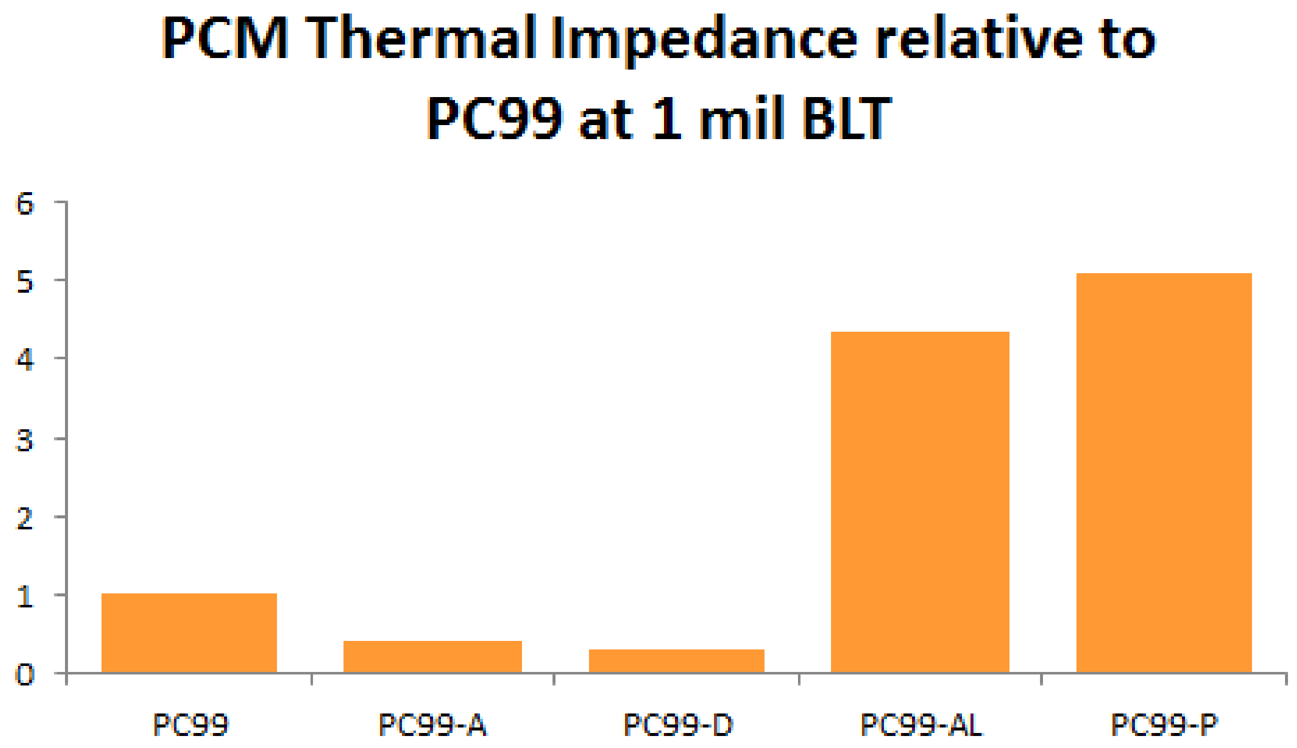
## Phase Change Material (Without reinforced layer)

| Property | PC99 | PC99A | PC99D | Test Method | Unit |
|---|---|---|---|---|---|
| Features | Low Cost / Tacky | High K / Tacky | Dispensed | - | - |
| Colour | Yellow | Yellow | Grey | Visual | - |
| Thickness | 0.06/0.12 | 0.12 | - | ASTM D374 | mm |
| Total Mass Loss | $<0.4$ | $<0.4$ | $<0.4$ | ASTM E595 | % |
| Working Temperature | -30 to 125 | -30 to 125 | -30 to 125 | - | °C |
| Operating Temperature | 20 to 60 | 20 to 30 | 20 to 30 | - | °C |
| Phase Change Temperature | 51 | 51 | 51 | - | °C |
| Volume Resistance | $>10^7$ | $>10^7$ | $>10^7$ | ASTM D257 | Ohm-cm |
| Thermal Conductivity | 1.5 | 2.0 | 2.4 | ASTM D5470 | W/mK |
| Thermal Impedance @1mil BLT | 0.053 | 0.022 | 0.017 | ASTM D5470 | °C $in^2$/w |
| Thermal Impedance @2mil BLT | 0.062 | 0.052 | 0.035 | ASTM D5470 | °C $in^2$/w |
| Thermal Impedance @3mil BLT | 0.104 | 0.082 | 0.057 | ASTM D5470 | °C $in^2$/w |
| UL Flammability | V-0 | V-0 | V-0 | UL94 | - |

## Phase Change Material (With reinforced layer)

| Property | PC99AL | PC99P | Test Method | Unit |
|---|---|---|---|---|
| Features | Reusable | Reusable | - | - |
| | Aluminium | Polyimide | - | - |
| Colour | - | - | Visual | - |
| Thickness | 0.10 | 0.10 | ASTM D374 | mm |
| Total Mass Loss | $<0.4$ | $<0.4$ | ASTM E595 | % |
| Working Temperature | -30 to 125 | -30 to 125 | - | °C |
| Operating Temperature | 20 to 60 | 20 to 30 | - | °C |
| Phase Change Temperature | 51 | 51 | - | °C |
| Volume Resistance | $>10^3$ | $>10^{10}$ | ASTM D257 | Ohm-cm |
| Dielectric Strength | No Insulation | 6000 | ASTM D149 | VAC |
| Thermal Conductivity | 1.5 | 1.3 | ASTM D5470 | W/mK |
| Thermal Impedance @1mil BLT | 0.23 | 0.27 | ASTM D5470 | °C $in^2$/w |
| Thermal Impedance @2mil BLT | 0.12 | 0.15 | ASTM D5470 | °C $in^2$/w |
| Thermal Impedance @3mil BLT | 0.10 | 0.12 | ASTM D5470 | °C $in^2$/w |
| UL Flammability | V-0 | V-0 | UL94 | - |

# Octane Chart – thermal impedance



# PCM Overview

- Each of the PCM materials from t-Global has unique benefits and the correct selection can significantly improve the performance of device being cooled
- PC-99 should be used for general purpose applications
- PC-99A is used for more thermally demanding applications due to its higher thermal conductivity
- PC-99D is used where dispensing the PCM would be beneficial for automation purposes
- PC-99AL is used where rework is required as the aluminium backing facilitates this
- PC-99P is used where a high dielectric breakdown voltage is required as the polyimide backing gives exceptionally good performance without adversely affecting the thermal conductivity

# Design Guide Lines for PCM Materials

- These thermal interface materials provide superior long term reliability performance
- For optimum performance, the pads must be exposed to temperatures above 51°C during operation or by a burn-in cycle to achieve lowest thermal impedance and highest thermal performance
- Upon reaching the required burn-in temperature, the pad will fully change phase and attain MBLT (minimum bond-line thickness) and maximum surface wetting

# Summary

- In summary, the emergence of electric vehicles and the technology necessary to power them effectively presents some new and demanding challenges to the automotive industry
- Key to managing these thermal issues are phase change materials
- Phase change materials offer a good combination of performance, ease of use and total cost of ownership which allow the designer to build passive cooling systems that are both effective and reliable
- T-Gbloal produces a range of PCM materials which have been fully optimised for this sector and allow the engineer a greater degree of design freedom than previously obtainable.