Encapsulation Materials Technology
For SiP in Automotive

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Panasonic Corporation
Electronic Materials Business Division

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Our Business Fields

Electronic Instruments
- Networking equipment
- Smart phone

Devices and Components
- Circuit Boards
- Semiconductors
- Automotive parts and others

Electronic Materials
- Circuit Board Materials
- Semiconductor Encapsulation Materials
- Plastic Molding Compound
- Advanced Films

Raw Materials
- Glass cloth
- Copper foil
- Resin
- Silica

Encapsulation Materials
Advanced Films
Molding Compound
Module Components
Automotive Components

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2. Encapsulation Material Technology for WLP/PLP
3. Technical Concerns for Automotive application and our proposal
1. Encapsulation Material Technology for SiP

2. Encapsulation Material Technology for WLP/PLP

3. Technical Concerns for Automotive application and our proposal
PKG road map

2001 → 2013 → 2018 → 2020 ~

Market Trend
3G → 4G → Pre 5G → 5G

Device Key word
- Small
- Low loss
- Modularization

Device Key word
- Low electric power
- High integration of parts
- Super Small & Thin
- Low loss & high cost performance

Packaging Trend
FC CSP + discrete → Double-sided FC substrate SiP → Embedded SiP → FO-3D SiP

Advanced SiP Coming Soon!

- mm Wave Technology
- 6GHz< Super high frequencies
- Compatible for IoT
SiP Typical Technical Requirement

◆ Warpage control

- Substrate: Thin or Less
- Chip & Parts: many & high integration
- Small warpage in various PKG
  Warpage control Tech.

◆ Low PKG concealment at Narrow gap

- Damage by laser marking
- Narrow gap transparent
- High shading function
- Shallow laser marking

◆ Transmission loss of antenna

- Communication system:
  - High frequency
  - Wide frequency band
- Transmission loss trends to increase
  Low Dk/Df Technology

◆ Various components compatibility

- * Adhesion to EMI shield and stable metal
- * Adhesion to Inductor
- * Protect Saw filter ⇒ Low pressure molding
- * Protect Image sensor ⇒ Low temp. molding
  High reliability performance Technology

◆ Unfilled trouble issue at various place

- * Solder extrusion after reflow
- * Unfilled under parts
- * Unfilled under FC
  High Filling ability Technology
SiP typical failure mode Requirement Technology

◆ Warpage control

Substrate: Thin or Less
Chip & Parts: many & high integration
Small warpage in various PKG

Warpage control Tech.

◆ Transmission loss of antenna

Communication system:
High frequency
Wide frequency band
Transmission loss trends to increase

Low Dk/Df Technology

◆ Various components compatibility

* Adhesion to EMI shield and stable metal

* Adhesion to Inductor

* Protect Saw filter ⇒ Low pressure molding

* Protect Image sensor ⇒ Low temp. molding

High reliability performance Technology

◆ Unfilled trouble issue at various place

* Solder extrusion after reflow
* Unfilled under parts
* Unfilled under FC

20-50um

High Filling ability Technology

◆ Low PKG concealment at Narrow gap

Damage by laser marking
Narrow gap transparent

50-90um

High shading function
Shallow laser marking
## Warpage control solution

<table>
<thead>
<tr>
<th>Generation</th>
<th>Current</th>
<th>Next generation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PKG structure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chip &amp; components volume:</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>EMC volume:</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Heat shrinkage force</strong></td>
<td><strong>Molding area &gt; substrate</strong></td>
<td><strong>Molding area &lt; substrate</strong></td>
</tr>
<tr>
<td><strong>Trend of Warpage Behavior</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>concave</td>
<td>convex</td>
</tr>
<tr>
<td>HT</td>
<td>convex</td>
<td>concave</td>
</tr>
<tr>
<td><strong>EMC property direction</strong></td>
<td>Lower CTE</td>
<td>Higher CTE</td>
</tr>
<tr>
<td></td>
<td>Lower Modulus at HT</td>
<td>Higher Modulus at HT</td>
</tr>
</tbody>
</table>
## Warpage measurement evaluation for Next generation PKG

<table>
<thead>
<tr>
<th></th>
<th>Ref.</th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
<th>Run 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexural modulus</td>
<td></td>
<td>High shrink.</td>
<td>Medium Shrink. High Tg</td>
<td>Medium shrink. High Tg</td>
<td>High shrink. &amp; CTE Low modulus</td>
</tr>
<tr>
<td>25°C GPa</td>
<td>13</td>
<td>15.3</td>
<td>15.9</td>
<td>11.6</td>
<td>10.9</td>
</tr>
<tr>
<td>260°C GPa</td>
<td>0.354</td>
<td>0.67</td>
<td>0.74</td>
<td>0.25</td>
<td>0.32</td>
</tr>
<tr>
<td>C.T.E. 1 ppm/C</td>
<td>19</td>
<td>18</td>
<td>22</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>C.T.E. 2 ppm/C</td>
<td>69</td>
<td>55</td>
<td>62</td>
<td>81</td>
<td>79</td>
</tr>
<tr>
<td>Mold Shrinkage PMC</td>
<td>0.52</td>
<td>0.35</td>
<td>0.44</td>
<td>0.68</td>
<td>0.66</td>
</tr>
<tr>
<td>Reduction rate of STRIP Warpage (BA) %</td>
<td>Ref.</td>
<td>-14</td>
<td>-20</td>
<td>-22</td>
<td>-27</td>
</tr>
</tbody>
</table>

### Unit Design
- Mold Edge = 200um
- Mold gap = 100um
- Die thickness: 175um
- Substrate thickness: 110um
- Die volume ratio 57% (per 1 unit)

### STRIP Design
- Concave warpage decreased

### Stripping Warpage
- 27% Reduction
Warpage measurement evaluation for Next generation PKG

- Run 1: UNIT concave warpage decreased
- Run 2: STRIP concave warpage decreased
- Run 3: STRIP concave warpage decreased
- Run 4: Effective for balancing STRIP and UNIT warpage

- Control

- HT Modulus (GPa): 0.2, 0.4, 0.6, 0.8
- CTE 2 (ppm): 40, 48, 56, 64, 72, 80

- Warpage measurement evaluation for Next generation PKG

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Warpage control Technology (1) control of small shrinkage

Purpose: Adjustment of RT warpage, Control of Mold shrinkage (keep Tg, CTE & Modulus)

Target | Prescription | The expected change
---|---|---
Increase of Mold Shrinkage | to use High shrinkage additive (HSA) | • Increase of Mold shrinkage (increase of chemical shrinkage) • Keep Tg Modulus CTE
Decrease of Mold Shrinkage | to use Small Shrinkage Additive (SSA) | • Decrease of Mold shrinkage (decrease of chemical shrinkage) • Keep Tg Modulus CTE

PSA generates a volatile matter, spreads the molecular chain during curing.

NSA restrains the contraction of the molecular chain.

PSA generates a volatile matter, spreads the molecular chain during curing.
Warpage control Technology (1) control of small shrinkage

◆ Property data

<table>
<thead>
<tr>
<th>Shrinkage additive</th>
<th>CTE1 ppm / °C</th>
<th>+1.0 (SSA)</th>
<th>+0.5 (SSA)</th>
<th>Org (Ref)</th>
<th>+0.5 (HSA)</th>
<th>+1.0 (HSA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTE1</td>
<td>8.5</td>
<td>8.5</td>
<td>8.5</td>
<td>8.5</td>
<td>8.5</td>
<td>8.5</td>
</tr>
<tr>
<td>CTE2</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>Tg °C</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Flexural modulus (RT) GPa</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Mold shrinkage %</td>
<td>0.09</td>
<td>0.14</td>
<td>0.19</td>
<td>0.24</td>
<td>0.29</td>
<td></td>
</tr>
</tbody>
</table>

◆ TSM results

We can adjust RT warpage with same warpage behavior.

PKG structure:
PKG size : 15X15  Die size : 12X7
Side by side structure
Mold thickness : 0.23mmt
Die thickness : 0.07mmt
Substrate thickness : 0.09mmt
SiP typical failure mode Requirement Technology

- **Warpage control**
  - Substrate: Thin or Less
  - Chip & Parts: many & high integration
  - Small warpage in various PKG
  - Warpage control Tech.

- **Low PKG concealment at Narrow gap**
  - Damage by laser marking
  - Narrow gap transparent
  - 50-90um
  - High shading function
  - Shallow laser marking

- **Various components compatibility**
  - Adhesion to EMI shield and stable metal
  - Adhesion to Inductor
  - Protect Saw filter ⇒ Low pressure molding
  - Protect Image sensor ⇒ Low temp. molding

- **Transmission loss of antenna**
  - Communication system:
    - High frequency
    - Wide frequency band
  - Transmission loss trends to increase
  - Low Dk/Df Technology

- **Unfilled trouble issue at various place**
  - Solder extrusion after reflow
  - Unfilled under parts
  - Unfilled under FC
  - 20-50um
  - High filling ability Technology

- **High reliability performance Technology**
### About Df, Dk

- **Df (Dissipation factor)**
  - Energy loss at polarization reversal when AC voltage is applied.

- **Dk (Dielectric constant)**
  - Degree of polarization

#### Transmission loss

\[
\alpha = K \cdot f \cdot \sqrt{Dk \cdot Df}
\]

- \( f \): frequency

In case of high frequency, transmission loss seems to be increased.

For communication with high frequency (high speed), it will be needed to achieve low Dk/Df.

### Low Df, Dk

- **Low Df**
  - Small energy loss at polarization reversal

- **Low Dk**
  - Small amount of polarization

Polarization reversal

- Electrical charge changes by AC (Alternating current)

Polarization of molecule, ionic material

Df also becomes smaller
## Direction and mechanism

<table>
<thead>
<tr>
<th>Direction</th>
<th>Mechanism</th>
<th>Side Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>High filler content</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Df</td>
<td>Dk</td>
</tr>
<tr>
<td>Silica</td>
<td>0.00025 (3GHz)</td>
<td>3.8 (1GHz)</td>
</tr>
<tr>
<td>Resin</td>
<td>0.01-0.03 (1GHz)</td>
<td>3~5 (1GHz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silica has very small Df compared to resin.</td>
</tr>
<tr>
<td>Low Df resin</td>
<td>Rigid structure</td>
<td>amorphous</td>
</tr>
<tr>
<td></td>
<td>Normal cure</td>
<td>molecule movement is limited</td>
</tr>
<tr>
<td>Monomer</td>
<td>Rigid structure (Prevent moving with AC voltage)</td>
<td></td>
</tr>
<tr>
<td>Low Dk resin</td>
<td>Low Dk resin has low Df</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Normal monomer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less polar monomer(raw resin) (small amount reactive group)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additive</td>
<td>Decrease or eliminate additive which has large polar.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
New low Df resin development

**Purpose**: Control of Dk/Df by new resin

<New resin concept>

**New X** + Epoxy

“New X“ is the special structure due to low Df

Curing

New reacted structure for low Df

<table>
<thead>
<tr>
<th>Feature</th>
<th>Unit</th>
<th>Current EMC</th>
<th>New EMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dk (@10GHz) method B</td>
<td>-</td>
<td>3.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Df (@10GHz) method B</td>
<td>-</td>
<td>0.006</td>
<td>0.005</td>
</tr>
<tr>
<td>Dk (@60GHz) method C</td>
<td>-</td>
<td>3.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Df (@60GHz) method C</td>
<td>-</td>
<td>0.004</td>
<td>0.003</td>
</tr>
</tbody>
</table>

*method B : Cavity resonance method  
**method C : Free space method*
SiP typical failure mode Requirement Technology

◆ Warpage control

Substrate: Thin or Less
Chip & Parts: many & high integration
Small warpage in various PKG

Warpage control Tech.

◆ Low PKG concealment at Narrow gap

Damage by laser marking
Narrow gap transparent

High shading function
Shallow laser marking

◆ Transmission loss of antenna

Communication system:
High frequency
Wide frequency band

Transmission loss trends to increase

Low Dk/Df Technology

◆ Unfilled trouble issue at various place

*Solder extrusion after reflow  * Unfilled under parts  * Unfilled under FC

High Filling ability Technology

◆ Various components compatibility

* Adhesion to EMI shield and stable metal
* Adhesion to Inductor
* Protect Saw filter ⇒ Low pressure molding
* Protect Image sensor ⇒ Low temp. molding

High reliability performance Technology
**Filling ability evaluation of EMC with fine cut filler**

**Background:** Mounted components increases, minimum mold gap trend to narrow.

**High integration design SiP**

Mounted components on PKG increase. The distance between the components will be close. The mold gap will be very narrow.

**Method for good filing ability and side effect of property, defect for SiP**

<table>
<thead>
<tr>
<th>Property direction</th>
<th>Method</th>
<th>Side effect (property, cost)</th>
<th>Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Viscosity</td>
<td>flowability</td>
</tr>
<tr>
<td>Latent Curing</td>
<td>Long GT</td>
<td>-</td>
<td>Increased</td>
</tr>
<tr>
<td></td>
<td>New latent catalyst</td>
<td>Lower</td>
<td>Increased</td>
</tr>
<tr>
<td>Fine filler</td>
<td>≤ 10 um cut</td>
<td>Increased</td>
<td>Decreased</td>
</tr>
</tbody>
</table>

*Latent catalyst and fine filler as solutions to good filling properties.*
**Purpose:** Improve filling performance by latent catalyst (Resin curing reaction control)

**X:** Normal type

- **Onium ion**
- **Counter anion**
- **Melting**
- **Active point**

**Y:** Current Latent type (high crystalline)

- **Highly crystalline catalyst sometimes causes curing troubles by insufficient of melting.**
- **Risk of curing is low**
- **This reaction has risk!!**

**Z:** New Latent type (Low melting point)

- **Controller**
- **Melting**
- **Temperature**
- **Activate**

**Back Ground**
Latent catalysts have been known as good fill ability. But due to the problem of the melting temperature of the current latent catalyst, sometimes cause problem of curing. In order to solve the problem, we are considering improvement of catalyst.

Controlling the activation temperature of catalyst by the chemical structure
### EMC properties with latent catalyst

<table>
<thead>
<tr>
<th></th>
<th>EMC</th>
<th>unit</th>
<th>D1</th>
<th>D2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Catalyst</strong></td>
<td></td>
<td>-</td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>Silica size</td>
<td></td>
<td>max/av.</td>
<td>10 / 3.2</td>
<td>10 / 3.2</td>
</tr>
<tr>
<td><strong>Spiral flow</strong></td>
<td>cm</td>
<td></td>
<td>170</td>
<td>190</td>
</tr>
<tr>
<td>Gelation time</td>
<td>s</td>
<td></td>
<td>60</td>
<td>61</td>
</tr>
<tr>
<td><strong>Tg</strong></td>
<td>C</td>
<td></td>
<td>148</td>
<td>153</td>
</tr>
</tbody>
</table>

### Filling ability (80um pitch bump / 20~25um gap)

<table>
<thead>
<tr>
<th></th>
<th>D1</th>
<th>D2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SAT</strong></td>
<td>Plane polish</td>
<td>SAT</td>
</tr>
<tr>
<td></td>
<td>no unfill</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*New latent catalyst shows good filling ability*
SiP typical failure mode Requirement Technology

- **Warpage control**
  - Substrate: Thin or Less
  - Chip & Parts: many & high integration
  - Small warpage in various PKG
  - *Warpage control Tech.*

- **Transmission loss of antenna**
  - Communication system: High frequency
  - Wide frequency band
  - Transmission loss trends to increase
  - *Low Dk/Df Technology*

- **Unfilled trouble issue at various place**
  - *Solder extrusion after reflow*
  - *Unfilled under parts*
  - *Unfilled under FC*
  - *Solder*
  - 20-50um
  - *High Filling ability Technology*

- **Low PKG concealment at Narrow gap**
  - Damage by laser marking
  - Narrow gap transparent
  - 50-90um
  - *High shading function*
  - *Shallow laser marking*

- **Various components compatibility**
  - *Adhesion to EMI shield and stable metal*
  - *Adhesion to Inductor*
  - *Protect Saw filter ⇒ Low pressure molding*
  - *Protect Image sensor ⇒ Low temp. molding*
  - *High reliability performance Technology*
Low PKG concealment at Narrow gap

**Background:** Mold gap is narrow, chip and parts are easy to be transparent and damaged.

- Damage by laser marking

50-90um

Narrow gap transparent

Method for High concealment ability and Laser making (LM) ability for SiP

<table>
<thead>
<tr>
<th>Property direction</th>
<th>Method</th>
<th>Die mark</th>
<th>Laser marking ability</th>
<th>Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>visibility</td>
<td>Shallow marking</td>
</tr>
<tr>
<td>High concealment</td>
<td>Carbon black quantity up</td>
<td>Improved</td>
<td>No effect</td>
<td>Deterioration</td>
</tr>
<tr>
<td></td>
<td>New colorant</td>
<td>Improved</td>
<td>Improved</td>
<td>Improved</td>
</tr>
<tr>
<td></td>
<td>filler size down</td>
<td>Improved</td>
<td>No effect</td>
<td>No effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nothing</td>
</tr>
</tbody>
</table>

Electric performance is deteriorated.
Purpose: Improve High concealment and Laser marking ability by new color and filler

High concealment mechanism

◆ Current formulation design

- Fused silica is transparent
- EMC Blackness is insufficient

New formulation design direction

- Filler optimization: fine filler has many interface, so visible light can't pass throw

New colorant concept

◆ Current colorant

Carbon black
- high colorant performance
- conductive material
- Good laser mark ability

◆ New colorant

New colorant material
- high colorant performance
- non-conductive material
- Good laser mark-ability

Narrow gap transparent solution
Examination of transparent

◆ Light transmittance
  Test piece thickness: 60um
  Measurement: Spectrophotometer (SHIMADZU MPC-3100)
  Observation wavelength: 560nm-610nm

◆ Die mark transparent
  Test piece data
  Mold thickness: 0.54 mm
  Mold size: 60.0 x 220mm
  Substrate thickness: 0.32mm

Examination of Laser Marking ability

Laser making condition
  Laser type: YAG laser
  Wavelength: 1064 nm, Frequency: 10 Hz
  Laser output: 14A, 800 mm/s
  Image recognition: Luminance mode, Lv.15, (Keyence VHX-6000)

◆ Visibility after laser marking
  Microscope picture (x50)
  Luminance mode (Lv.15)
  fully recognized area: 2.33 mm²

◆ Depth of laser marking
# Development of high concealment EMC

<table>
<thead>
<tr>
<th>EMC</th>
<th>Run 1</th>
<th>Run 2</th>
<th>Run 3</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>Fine cut filler</td>
<td>New color</td>
<td>Carbon black up</td>
<td>-</td>
</tr>
<tr>
<td>Cut point</td>
<td>20</td>
<td>←</td>
<td>←</td>
<td>55</td>
</tr>
<tr>
<td>colorant</td>
<td>Carbon black (%)</td>
<td>x</td>
<td>x</td>
<td>2x</td>
</tr>
<tr>
<td>New Pigment (%)</td>
<td>-</td>
<td>Y</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Die mark transparent**

**Picture**

<table>
<thead>
<tr>
<th>visibility</th>
<th>Luminance</th>
<th>Marking depth (um)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picture</td>
<td>WX</td>
<td>58 %</td>
</tr>
<tr>
<td></td>
<td>WX</td>
<td>71 %</td>
</tr>
<tr>
<td></td>
<td>WX</td>
<td>45 %</td>
</tr>
<tr>
<td></td>
<td>WX</td>
<td>58 %</td>
</tr>
<tr>
<td></td>
<td>17.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>19.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25.8</td>
<td></td>
</tr>
</tbody>
</table>

*New colorant system show high concealment performance*
SiP typical failure mode Requirement Technology

◆Warpage control
Substrate: Thin or Less
Chip & Parts: many & high integration
Small warpage in various PKG
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◆Transmission loss of antenna
Communication system:
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Damage by laser marking
Narrow gap transparent
High shading function
Shallow laser marking

◆Unfilled trouble issue at various place
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* Unfilled under parts
* Unfilled under FC

High Filling ability Technology
Low temperature molding EMC for component protect

**Background:** Various components are mounted, especially Image sensor is weak thermal

**Direction for low mold temp. & Low PMC temp.**
- Use low viscosity with high reactive resin.
- Optimize amount of catalyst

**◆ Property comparison**

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Molding temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>170 °C</td>
</tr>
<tr>
<td>Spiral flow</td>
<td>cm</td>
<td>145</td>
</tr>
<tr>
<td>Gel time</td>
<td>Sec</td>
<td>20</td>
</tr>
<tr>
<td>Viscosity</td>
<td>Pa*s</td>
<td>7.1</td>
</tr>
<tr>
<td>CTE1/2</td>
<td>ppm/°C</td>
<td>13/47</td>
</tr>
<tr>
<td>Tg</td>
<td>°C</td>
<td>150</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>MPa</td>
<td>180</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>GPa</td>
<td>20</td>
</tr>
<tr>
<td>Mold Shrinkage</td>
<td>AM %</td>
<td>0.32</td>
</tr>
<tr>
<td></td>
<td>PMC %</td>
<td>0.35</td>
</tr>
</tbody>
</table>

PMC condition is 170°C, 6h or 130 °C, 12h

**Cure curve at 130 °C**

**◆ Molding test**

- Test piece data
  - Mold thickness: 0.55 mm
  - Mold size: 40.0 x 54.5 mm
  - Substrate thickness: 0.25 mm

- Molding condition
  - In mold cure condition: 130 °C, 400 s cure
  - Transfer pressure: 9 MPa
  - Transfer time (setting): 32 s

**Surface appearance good**

Low temp molding should be good for warpage reduction. To maintain good filling ability is big challenge
2. Encapsulation Material Technology for WLP/PLP
Image of size applicable range depending on material form

- **Mold Thickness**
  - 1000um
  - 500um
  - 300um
  - 150um

- **Mold Area**
  - 8inch WLP
  - 12inch WLP
  - 18inch WLP
  - >600mm

- **Process**
  - Tablet: Process : Transfer
  - Granule: Process : Compression
  - Liquid: Process : Compression
  - Sheet: Process : Compression Laminate

- **Panel Sizes**
  - 300mm
  - 450mm
  - >600mm
## Material Form and process, target PKG

<table>
<thead>
<tr>
<th>Material form</th>
<th>Tablet</th>
<th>Liquid</th>
<th>Granule</th>
<th>Sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>Transfer molding</td>
<td>Compression molding (Face up/down)</td>
<td>Vacuum lamination</td>
<td></td>
</tr>
</tbody>
</table>
| Features      | • Grind less (free)  
• Low material cost | • MP experience  
• Excellent flow-ability  
• Low mold shrinkage | • Good process ability (High Tg, Chem. resistance) | • Short dispense time  
• Thinness  
• Low process cost (lamination) |
| Target PKG form | • Low density WLP  
• High density WLP (2.5D, 3D...)  
• WLP with under fill | • Middle density WLP  
• Large size PLP | • Larger size PLP  
• Thin PLP |
# Typical process of FOWLP/PLP

## Die-first
1. Tape lamination on carrier
2. Die mount
3. Molding
4. De-bonding
5. RDL

- **Low warpage**
- **Releasability**
- **Chemical resistance**
- **Coatability**

## Die-last
1. Tape lamination on carrier
2. RDL
3. Die mount (FC bonding)
4. Molding
5. De-bonding

- **Filling ability to narrow gap**
- **Low warpage**

## Two-side RDL
1. 1st RDL
2. Die-mount
3. Molding
4. Grinding
5. 2nd RDL~De-bonding

- **Low warpage**
- **Filling ability to narrow gap**
- **Flowability curability**
- **Coatability**

### Characteristics
- **Low warpage**
- **Filling ability**
- **Flowability curability**
- **Coatability**
- **Releasability**
- **Chemical resistance**
Warpage control Technology

Purpose: Reducing stress index for Warpage control with Low CTE substrate

Relationship between each parameter and warpage

- Test condition
  - 12" Dummy wafer: 775um
  - Mold thickness: 500um
  - Mold Machine: CPM-1080 (TOWA)

The low stress material tends to have good warpage
Reducing stress index

Low modulus additive

Sea-island structure

Decrease Modulus

Low CTE additive

Restrain molecular chain expansion

Decrease CTE

Low stress additive

Relaxing intermolecular stress

Decrease CTE & Modulus

These types of additive improve parameters related with stress index (CTE / modulus), and reduce warpage after molded.
3. Technical Concerns for Automotive application and our proposal
Reliability concerns about Automotive requirement

- **EMC**
  - Good warpage stability at High temp.
  - Higher Tg with low modulus for BLR

- **Board level reliability after TCT**
  - TCT condition for BLR
    - -40/85°C 3000cyc → -40 / 125°C 3000cyc
  - *Solder crack risk

- **Heat resistance & Board level reliability**
  - PKG HTSL condition: 150°C 1000hr → 175°C 1000hr
  - TCT condition for BLR: -40/85°C 3000cyc → -40/125°C 3000cyc
  - *Warpage fluctuation *BLR concern

- **Reinforcement material**
  - 2nd Underfill (UF)
  - Corner glue (Sidefill = SF)

*Note: BLR=Board Level Reliability, TCT=Temperature Cycling Test HTSL= High Temperature Storage Life
Reliability concerns about Automotive requirement

**EMC**

- Good warpage stability at High temp.
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HTSL=High Temperature Storage Life

**Heat resistance & Board level reliability**

PKG HTSL condition: 150°C 1000hr → 175°C 1000hr
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* Warpage fluctuation
* BLR concern

**Board level reliability after TCT**

TCT condition on BLR
-40/85°C 3000cyc → -40/125°C 3000cyc

* Solder crack risk

**Reinforcement material**

- 2nd Underfill (UF)
- Corner glue (Sidefill = SF)
Warpage stability after HTS

Internal Study - Mold shrinkage trend after HTS -

<table>
<thead>
<tr>
<th>EMC</th>
<th>unit</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTE1/2</td>
<td>s</td>
<td>11/40</td>
<td>15/41</td>
<td>9/36</td>
</tr>
<tr>
<td>Tg</td>
<td>‘C</td>
<td>137</td>
<td>161</td>
<td>145</td>
</tr>
<tr>
<td>Mold shrinkage</td>
<td>%</td>
<td>0.24</td>
<td>0.24</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Unit warpage might be changed on severe HTS condition.
→ Optimized EMC will be required.
**Required EMC property for BLR**

**TCT condition for BLR : -40/85°C 3000cyc → -40/125°C 3000cyc**

*CTE mismatch make BLR concerns*

*Higher CTE with good warpage performance\* Reduce stress at TCT.*

**High Tg and Low modulus\* Show good reliability !**

<table>
<thead>
<tr>
<th><strong>Tg (°C)</strong></th>
<th><strong>140</strong></th>
<th><strong>170</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RT modulus</strong></td>
<td><strong>200</strong></td>
<td><strong>10 20 25 30</strong></td>
</tr>
</tbody>
</table>

- **Next generation SiP EMC target**
- **Conventional SiP grade**

+ matching CTE with PCB
Reliability concerns about Automotive requirement

- **EMC**
  - Good warpage stability at High temp.
  - Higher Tg with low modulus for BLR

*Note: BLR=Board Level Reliability, TCT=Temperature Cycling Test
HTSL= High Temperature Storage Life

- **Board level reliability after TCT**

  TCT condition on BLR
  -40/85°C 3000cyc → -40 / 125°C 3000cyc

  * Solder crack risk

- **Heat resistance & Board level reliability**

  PKG HTSL condition: 150°C 1000hr → 175°C 1000hr
  TCT condition for BLR: -40/85°C 3000cyc → -40/125°C 3000cyc

  * Warpage fluctuation * BLR concern

**Reinforcement material**

- 2nd Underfill (UF)
- Corner glue (Sidefill = SF)
Panasonic reinforcement proposals

• CSP/BGA package are increasing.
• Chip size is getting larger. >10mm
• Smaller ball size <0.4mm, finer ball pitch <0.5mm
• Severer requirement for BLR TCT*. ⇒ -40~125℃ x >3,000cyc

*Note: BLR=Board Level Reliability, TCT=Temperature Cycling Test

Solder crack risk against temperature change stress, due to large CTE differences between PCB and PKG.

No Reinforcement

With 2nd Underfill

Stress reduction!
Stress Simulation

Under fill/Side fill can obtain 20〜60% down about internal stress of solder by simulation!!

■ 5㎜□BGA(0.4mm pitch)

<table>
<thead>
<tr>
<th></th>
<th>No reinforcement</th>
<th>Under fill</th>
<th>Side fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress value (MPa)</td>
<td>190</td>
<td>92 (▲52%)</td>
<td>140 (▲26%)</td>
</tr>
</tbody>
</table>

CV5794

CV5788

■ 10㎜□BGA(0.8mm pitch)

<table>
<thead>
<tr>
<th></th>
<th>No reinforcement</th>
<th>Under fill</th>
<th>Side fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress value (MPa)</td>
<td>154</td>
<td>87 (▲44%)</td>
<td>121 (▲21%)</td>
</tr>
</tbody>
</table>

CV5794

CV5788

Simulation condition

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature condition</td>
<td>-40 C〜125 C</td>
</tr>
<tr>
<td>Stress free temperature</td>
<td>25 C</td>
</tr>
</tbody>
</table>

※Stress value = Stress applied to outside of solder
Stress simulation data and device TCT result were correlated.

- **5mm □ BGA (0.4mm pitch)**
  - No reinforcement: 2800 Cycle, Under fill: 5000< Cycle, Side fill: 3800 Cycle
  - CV5794

- **10mm □ BGA (0.4mm pitch)**
  - No reinforcement: 1000 Cycle, Under fill: 5000< Cycle, Side fill: 2800 Cycle

- **10mm □ BGA (0.8mm pitch)**
  - No reinforcement: 3600 Cycle, Under fill: 5000< Cycle, Side fill: 5000<
  - CV5794

**Test Condition**
- -40℃ ⇔ 125℃ (30min)

**Test Vehicle**

<table>
<thead>
<tr>
<th>PKG size</th>
<th>5mm□</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin number</td>
<td>97 pin</td>
</tr>
<tr>
<td>Ball pitch</td>
<td>400um</td>
</tr>
<tr>
<td>Ball height (Gap)</td>
<td>220um</td>
</tr>
<tr>
<td>Ball composition</td>
<td>SnAgCu (SAC)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PKG size</th>
<th>10mm□</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pin number</td>
<td>100 pin</td>
</tr>
<tr>
<td>Ball pitch</td>
<td>800um</td>
</tr>
<tr>
<td>Ball height (Gap)</td>
<td>300um</td>
</tr>
<tr>
<td>Ball composition</td>
<td>SnAgCu (SAC)</td>
</tr>
</tbody>
</table>
Stress simulation with 25mmBGA

Under fill/Side fill can obtain 20~60% down about internal stress of solder by simulation!!

■ Stress simulation data
※Outside( ■ )

<table>
<thead>
<tr>
<th>Stress value (MPa)</th>
<th>No reinforcement</th>
<th>Under fill</th>
<th>Side fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>243</td>
<td>91 (▲63%)</td>
<td>161 (▲34%)</td>
</tr>
</tbody>
</table>

PKG information

- PKG size: 25mm
- Pin number: 2025 pin
- Ball pitch: 500μm
- Ball height (Gap): 300μm
- Ball composition: SnAgCu (SAC)

※Inside( ■ )

<table>
<thead>
<tr>
<th>Stress value (MPa)</th>
<th>No reinforcement</th>
<th>Under fill</th>
<th>Side fill</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>250</td>
<td>103 (▲59%)</td>
<td>198 (▲21%)</td>
</tr>
</tbody>
</table>

Simulation condition

- Temperature condition: -40 C~125 C
- Stress free temperature: 25 C
## Panasonic Reinforcement Line up

<table>
<thead>
<tr>
<th>Model</th>
<th>CV5350 series</th>
<th>CV5794 series</th>
<th>CV5788 series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Under fill</td>
<td>Under fill</td>
<td>Side fill</td>
</tr>
<tr>
<td>Application</td>
<td>Camera for Auto Mill wave Radar Engine ECE Antenna PKG for 5G</td>
<td>Engine ECU</td>
<td>Car Navigation System</td>
</tr>
<tr>
<td>Feature</td>
<td>High Tg Good Filling Fast Cure ability Low temp cure</td>
<td>High Tg Low CTE Good Adhesion Refrigerated Storage</td>
<td>High Tg Low CTE Shape Retention Fast cure ability</td>
</tr>
<tr>
<td>Viscosity</td>
<td>4Pa·s</td>
<td>45Pa·s</td>
<td>300Pa·s</td>
</tr>
<tr>
<td>Storage condition</td>
<td>-20℃/4 months</td>
<td>5℃/6 months</td>
<td>-20℃/6months</td>
</tr>
<tr>
<td>Cure condition</td>
<td>80℃/3h 150℃/10分</td>
<td>150℃/10min</td>
<td>150℃/15min</td>
</tr>
<tr>
<td>30℃70%192h 260℃ Reflow x3 times</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
</tr>
<tr>
<td>-50～125℃ x3000cyc</td>
<td>PASS</td>
<td>PASS</td>
<td>PASS</td>
</tr>
</tbody>
</table>

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Partnering to go beyond.

Electronic Materials
Panasonic Corporation