Can we prepare organic materials for 2.1 D next generation interposers?

Hitachi Chemical Co., Ltd. Tsukuba Research Laboratory
Telecommunication Materials Development Center

Hikari Murai
Hitachi Chemical Co., Ltd.
1. Trends and road map of new generation PKG
2. Required properties of 2.1D interposer
3. Ultra low CTE core laminates
4. Fine pattern formation technology
   4-1 Flat surface and high adhesive primer
   4-2 Nano fractal treatment of copper surface
   4-3 Low loss laminates
5. Conclusion
Trend of Advanced PKG

- Substrate tech.
- Under fill tech.
- FC mounting
  - Coreless PKG
  - Build-up tech.
  - EMC tech.
  - Buffer coating tech.
- Multi chip mounting
  - Solder resist tech.
- High performance mounting

- Die bonding paste tech.
- Die bonding film tech.
- P-BGA
  - Stacked CSP
  - PoP
  - TSV PKG
  - Embedded
  - Chip on chip PKG
  - QFP
  - COF
  - Auto mobile
  - LED
  - RFID
  - Sensor
  - Solar battery
  - Consumer equip.

Photo sensitive film tech.
### PKG Trend & Roadmap of Hitachi Materials

#### Year | 2014 | 15 | 2016 | 17 | 2018
---|---|---|---|---|---
**Technology node**  
PKG height [mm] | 20nm | 0.60 | 16nm | 0.55 | < 10nm | 0.50  
Die size [mm] | 5-15 | 6-15 | 5-15 | 5-15 | 5-15  
Die thickness [μm] | 70 | 60 | 60 | 50 | 50  
Cu pillar Pitch [μm] | 50 | 40 | 40 | 35 | 35  
Work size | Strip size | Transfer | PNL300mm | Compression Granule/sheet | PNL 400mm Comp./Lami. Sheet  
Molding methodology | Tablet/Granule | | Granule/sheet | | Sheet  
Molding material | | | | | Sheet MUF ( Fine pitch)  
#### Materials

- **Core material**  
  - E-705G, 770G 2-5ppm/C  
  - E-770G  
  - New type 0-3ppm/C  

- **Solder resist**  
  - FZ-2700GA  
  - FZ / SR-F  
  - FZ SR-F  

- **Molding material**  
  - MUF CEL-1800HF Series  
  - MUF / EBIS  
  - EBIS New type Photo NCF  
  - Ultra low CTE  
  - High reliabilities productivity  
  - Narrow pitch available  
  - Fine-pitch available

---

© Hitachi Chemical Co., Ltd. 2014. All rights reserved.
# PKG Trend & Roadmap of Hitachi Materials

## FOWLP for Smartphone / Tablet

<table>
<thead>
<tr>
<th>Year</th>
<th>2014</th>
<th>15</th>
<th>2016</th>
<th>17</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology node</strong></td>
<td>20nm</td>
<td>16nm</td>
<td>10nm</td>
<td>&lt; 10nm</td>
<td>&lt; 10nm</td>
</tr>
<tr>
<td><strong>PKG height [mm]</strong></td>
<td>0.45</td>
<td>0.40</td>
<td>0.40</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Die size [mm]</strong></td>
<td>5-10</td>
<td>5-10</td>
<td>5-10</td>
<td>5-10</td>
<td>5-10</td>
</tr>
<tr>
<td><strong>Die thickness [μm]</strong></td>
<td>0.40</td>
<td>0.35</td>
<td>0.40</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Ball Pitch [μm]</strong></td>
<td>0.40</td>
<td>0.40</td>
<td>0.35</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Work size</strong></td>
<td>12inch</td>
<td>12inch</td>
<td>PNL 400mm</td>
<td>PNL600mm</td>
<td>PNL600mm</td>
</tr>
<tr>
<td><strong>Molding methodology</strong></td>
<td>Compression</td>
<td>Compression</td>
<td>Comp./Lami.</td>
<td>Comp./Lami.</td>
<td>Comp./Lami.</td>
</tr>
<tr>
<td><strong>Molding material</strong></td>
<td>Liquid/Granule</td>
<td>Granule/Sheet</td>
<td>Sheet</td>
<td>Sheet</td>
<td>Sheet</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td><strong>RDL (Liquid)</strong></td>
<td><strong>HD-8930</strong></td>
<td><strong>HD-8940</strong></td>
<td><strong>HD-8940</strong></td>
<td><strong>High resolution &amp; reliabilities</strong></td>
</tr>
<tr>
<td></td>
<td><strong>RDL (Film)</strong></td>
<td><strong>DIF</strong></td>
<td><strong>DIF</strong></td>
<td><strong>New type</strong></td>
<td><strong>High reliability</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Temporary bond film</strong></td>
<td><strong>New type</strong></td>
<td><strong>Comp. CEL-1800HF</strong></td>
<td><strong>Comp./Lami. New type</strong></td>
<td><strong>productivity</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Molding material</strong></td>
<td><strong>Comp. EBIS</strong></td>
<td><strong>Comp. EBIS</strong></td>
<td><strong>New type</strong></td>
<td><strong>Narrow pitch available</strong></td>
</tr>
</tbody>
</table>

**Keywords**
- Low cost
- High density / fine pitch
- Low warpage & high reliabilities

---

© Hitachi Chemical Co., Ltd. 2014. All rights reserved.
## PKG Trend & Roadmap of Hitachi Materials

### Year 2014 15 2016 17 2018

**2.1 / 2.5 / 3D-PKG**

*for PC / Server*

<table>
<thead>
<tr>
<th>Technology node</th>
<th>2014</th>
<th>2016</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>Die size [mm]</td>
<td>25</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Ball Pitch [μm]</td>
<td>120</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Gap between Die &amp; Sub.</td>
<td>9-14</td>
<td>5-12</td>
<td>5-12</td>
</tr>
<tr>
<td>L/S [μm]</td>
<td>30</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>SR thickness [μm]</td>
<td>18</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>SRO</td>
<td>70</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

### Materials

**RDL (Film)**

- **Buildup, Air foil**
- **NFT**
- **Glass film**
- **UF material**

<table>
<thead>
<tr>
<th>RDL (Film)</th>
<th>DIF</th>
<th>DIF</th>
<th>DIF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildup, Air foil</td>
<td>5/5-3/3μm</td>
<td>2/2μm</td>
<td>1/1μm</td>
</tr>
<tr>
<td>NFT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glass film</td>
<td>100/50μmt</td>
<td>100/50μmt</td>
<td>100/50μmt</td>
</tr>
<tr>
<td>UF material</td>
<td>CUF/NCF</td>
<td>CUF/NCF</td>
<td>Photo NCF</td>
</tr>
</tbody>
</table>

**Keywords**

- High electrical performance
- High density / fine pitch
- Low warpage & high reliabilities

### High density wiring layers

- Extremely low CTE substrate

### Keywords

- High resolution & reliabilities
- Low CTE & Low tan δ (Df)
- High process-ability
- Fine-pitch available
- Low warpage
- Narrow pitch available
Integrated technology for newly PKG

**Needs!**

- Ultra fine line
- Low cost
- High speed • Big volume

Integrated technology

- Adherence
- Insulation
- Photosensitive
- Process
- Evaluation

New process/material Proposal for harmonized field

Low performance

- Ultra Low CTE
- Low ε • Low tanδ
- High thermal conduction
- High adherence
- High modulus
1. Trends and road map of new generation PKG
2. Required properties of 2.1D interposer
3. Ultra low CTE core laminates
4. Fine pattern formation technology
   4-1 Flat surface and high adhesive primer
   4-2 Nano fractal treatment of copper surface
   4-3 Low loss laminates
5. Conclusion
TSV Related Materials

2.5D PKG

- Thermally conductive film; HS series
  - High thermal
  - Good adhesion

- Underfill; CEL-C series
  - Good gap filling

- Low CTE Substrate; MCL / AS series
- High Tg Solder resist; SR/FZ series
  - Low warpage
  - High insulation

- Materials for Fine Patterning
  - Fine patterning

- Dry film resist for Cu pillar
  - High resolution

3D PKG

- Pre-applied under Fill; CEL-C / UF series
  - Good connection
  - Short cure bonding

- EMC; CEL series
- EMC film; EB series
  - Good molding

- CMP; HS series
  - High removal rate
  - Good planarity

- Temporary bonding film; XTM series
  - Easy debonding
  - Heat resistance

- RDL; DIF series
  - High resolution
  - Trench/Photo-via
2.1D-PKG

- High density wiring layers
  - Very fine line formation
  - Good filling property
  - Smaller via diameter
  - Excellent reliability
  - Low Df property
  - Good warpage (with prepreg?)

- Extremely low CTE
- Higher Modulus
- High heat resistance
- Lower shrinkage
- Excellent reliability
- Good process ability
- Good reliability

Low Warpage @ reflow/after reflow
Integrated Technology

Ultra fine pitch primer
  • **AirFoil** (flat surface)

High resolution Photosensitive Film
  • **RY/RD series**

L/S=3/3μm Ultra fine line

Thinner seed copper
  • **NFT** (Nano copper treat)

Ultra Low CTE Laminate
  • **E-770G, Mary(next generation)**

© Hitachi Chemical Co., Ltd. 2014. All rights reserved.
1. Trends and road map of new generation PKG
2. Required properties of 2.1D interposer
3. Ultra low CTE core laminates
4. Fine pattern formation technology
   4-1 Flat surface and high adhesive primer
   4-2 Nano fractal treatment of copper surface
   4-3 Low loss laminates
5. Conclusion
Ultra Low CTE Core Materials

|------|-----------|------------|-----------|---------|---------|

- E glass
- S glass
- S HD glass
- Q glass, Organic

CTE: ppm/°C

© Hitachi Chemical Co., Ltd. 2013. All rights reserved.
Molecular design of new resin system

**CTE formula for ultra low CTE material**

*Scharperry formula (Approximate formula of CTE)*

\[
\text{CTE(material)} \approx \frac{a_r E_r V_r + a_g E_g V_g + a_f E_f V_f}{E_r V_r + E_g V_g + E_f V_f}
\]

- \( a_r \Rightarrow 0 \) \quad \text{Low CTE resin}
- \( E_r \Rightarrow 0 \) \quad \text{Low elastic modulus}
- \( V_r \Rightarrow 0 \); \( \text{CTE(material)} \Rightarrow \text{CTE(Glass cloth)} + \text{CTE(Filler)} \)

**Close packing of low CTE filler, Low CTE glass**
The relationship between Resin shrinkage and Warpage (PKG)

Substrate

Die mount

(RT → 260°C → RT)

After mount

Resin shrinkage (%)
0.20 0.25 0.30 0.35 0.40

Warpage (PKG) (mm)
0 20 40 60 80

(3.3) (3.4) (3.5) (3.3)

( ) : CTE (ppm/°C)

Warpage reduced by decreasing of resin shrinkage even in same CTE value.

Warpage reduction

Decreasing of resin shrinkage
3. Molecular design of new resin system

(4) Molecular design of new resin

**Ultra low CTE**
**Low shrinkage**

Hard segment (New rigid matrix)

**Ultra low CTE**
**Low elastic modulus**

Soft segment (New low elastic matrix)
3. Molecular design of new resin system

(5) Close packing of filler

**Conventional**

- Aggregation
- Poor dispersion of filler

**FICS**

- Original coupling agent
- Good dispersion (no aggregation)
- Enabling higher filler content

**Improvement in properties**

- Low CTE

**Deterioration in properties**

- Water absorption
- Heat resistance
- Electrical insulation
- CAF restraining property
3. Core / Prepreg Portfolio

High Density Glass cloth

2116 (100μm standard type)
Fabric count: 59 x 57 /inch

2118 (100μm HD type)
Fabric count: 65 x 62 /inch
## 4. General properties of new ultra low CTE material

### (2) General properties

<table>
<thead>
<tr>
<th>Item</th>
<th>Condition</th>
<th>Unit</th>
<th>E-705G</th>
<th>E-770G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass cloth</td>
<td>-</td>
<td>-</td>
<td>E-glass</td>
<td>HD S-glass</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>S-glass</td>
<td>S-glass</td>
</tr>
<tr>
<td>Tg</td>
<td>TMA</td>
<td>°C</td>
<td>260</td>
<td>260</td>
</tr>
<tr>
<td>CTE</td>
<td>a1 (X)</td>
<td>ppm/°C</td>
<td>5.9</td>
<td>3.3</td>
</tr>
<tr>
<td>Flexural modulus</td>
<td>A</td>
<td>GPA</td>
<td>33</td>
<td>36</td>
</tr>
<tr>
<td>Solder heat</td>
<td>288 °C,</td>
<td>s</td>
<td>&gt;300</td>
<td>&gt;300</td>
</tr>
<tr>
<td>resistance</td>
<td>Float</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dk</td>
<td>1 GHz</td>
<td>-</td>
<td>4.3</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>10 GHz</td>
<td>-</td>
<td>4.2</td>
<td>4.0</td>
</tr>
<tr>
<td>Df</td>
<td>1 GHz</td>
<td>-</td>
<td>0.008</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>10 GHz</td>
<td>-</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>Resin shrinkage</td>
<td>TMA</td>
<td>%</td>
<td>0.23</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5. Influence of resin shrinkage

(1) The relationship between the warpage and the shrinkage

**Assembly process**

![Diagram showing heating and cooling processes with temperature changes](image)

- **Heating process**: 30 °C to 260 °C
- **Cooling process**: 260 °C to 30 °C

**TMA measurement of core material**

The Mismatch of CTE between core material and chip in the cooling process.

**Warpage**
5. Influence of resin shrinkage

(2) Measurement result of the shrinkage

The relationship between the shrinkage of resin and core

The decreasing of resin shrinkage effectively lowers the core shrinkage.

The relationship between the CTE in cooling process and core shrinkage

The decreasing of core shrinkage bring the ultra low CTE in the cooling process.
6. Warpage property of thinner PKG substrate

(1) Overview and cross-section of the PKG structure (4-layer)

**Overview**

**Dimensions**
- Package size: 14 x 14 mm
- Chip size: 7.3 x 7.3 mm
- Chip thickness: 150 μm
- Underfill thickness: 60 μm

**Cross section**
- Core thickness: 200 μm
- Prepreg thickness: 40 μm
- Cu thickness: 12 μm (60% island)
- Cu layer: 1-2-1
- Solder resist thickness: 20 μm

© Hitachi Chemical Co., Ltd. 2014. All rights reserved.
6. Warpage property of thinner PKG substrate
(2) Measurement method (Shadow-Moire method)

Overview of Shadow-Moire measurement system

Temperature:
25 °C → 260 °C / 600 s
260 °C → 25 °C / 1800 s
6. Warpage property of thinner PKG substrate

(3) Measurement result of warpage

Measurement result of PKG substrate
(Ball area warpage)
Warpage Evaluation

*Package size : 45x45 mm
*Chip size : 20x20 mm
*Chip thickness : 775 μm
*Underfill thickness : 60 μm

<Sample> Core Thickness 400μm with 12μm copper
MCL-E-770G / MCL-E-705G / MCL-E-700G(R)

As the results of 400μm Core warpage evaluation, E-770G has lower warpage than E-705G in reflow temp.
Contents

1. Trends and road map of new generation PKG
2. Required properties of 2.1D interposer
3. Ultra low CTE core laminates
4. Fine pattern formation technology
   4-1 Flat surface and high adhesive primer
   4-2 Nano fractal treatment of copper surface
   4-3 Low loss laminates
5. Conclusion
Air Foil
Fine line fabrication of glass-cloth prepreg

<table>
<thead>
<tr>
<th>SAP</th>
<th>M-SAP</th>
<th>Subtra.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional film</td>
<td>Conventional LP Cu foil</td>
<td></td>
</tr>
<tr>
<td>PF-EL series (Primer)</td>
<td>PF-EL-3</td>
<td>Conventional LP Cu foil</td>
</tr>
<tr>
<td>PF-EL-3, PF-EL-12</td>
<td>PF-EL-3</td>
<td></td>
</tr>
<tr>
<td>SAPP (Primer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Foil (Primer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5/5 10/10 15/15 20/20 25/25 30/30 35/35 40/40</td>
<td>100µm 100µm 100µm</td>
<td>100µm</td>
</tr>
</tbody>
</table>

PF: Profile-free Cu Foil with resin (Hitachi-chemical)
LP: Low Profile Cu Foil
Advantage of applying glass-cloth prepreg for Build up material.

<table>
<thead>
<tr>
<th>Item</th>
<th>Glass-cloth prepreg</th>
<th>Insulating film</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low CTE</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>Low warpage</td>
<td>good</td>
<td>poor</td>
</tr>
<tr>
<td>High density wiring</td>
<td>difficult</td>
<td>possible</td>
</tr>
<tr>
<td>(by semi-additive process)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Combination of semi-additive process and glass-cloth prepreg is necessary to achieve high density and low warpage.
Airfoil is provided by coating primer resin on carrier film. It can be used for conventional core material and multilayer PWB with prepreg.
Technology concept of Airfoil

Semi-Additive Process

X : functional group of interaction with Cu

Primer
Core
Prepreg

[High adhesive energy material]
(Chemical bonding)

Plated copper
Primer

Higher peel strength on smooth surface

Application: Core, Prepreg, Film
Air Foil is available for various resin system prepregs, maintaining low surface roughness and higher peel strength properties.

Sweller: 80 °C/5 min, Micro-etching: 80 °C/10 min
Desmear system: Atotech,
# Airfoil properties and spec

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Airfoil</th>
<th>PF-EL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primer Thickness</td>
<td>µm</td>
<td>2.5</td>
<td>2 or 3.8</td>
</tr>
<tr>
<td>Carrier</td>
<td>-</td>
<td><img src="image" alt="Organic Film" /></td>
<td><img src="image" alt="LP copper" /></td>
</tr>
<tr>
<td>Surface Formation Method</td>
<td>-</td>
<td><img src="image" alt="Desmearing" /></td>
<td><img src="image" alt="Replica of copper" /></td>
</tr>
<tr>
<td>Ra</td>
<td>µm</td>
<td>0.05-0.08</td>
<td>0.30-0.40</td>
</tr>
<tr>
<td>Peel</td>
<td>kN/m</td>
<td>0.7-0.8</td>
<td>0.7-0.9</td>
</tr>
<tr>
<td>L/S</td>
<td>µm</td>
<td>&lt; 5/5</td>
<td>10/10</td>
</tr>
<tr>
<td>Laser formability</td>
<td>-</td>
<td>excellent</td>
<td>good</td>
</tr>
</tbody>
</table>
Surface flatness of Airfoil

◆Surface roughness of Airfoil on substrate after carrier removal

Equipment: Wyko NT9100

Carrier: Non profile copper foil
Ra = 0.1-0.2 µm

• Waves from copper foil

Carrier: Organic film
Ra = 0.02-0.05 µm

Unevenness of surface increases

Airfoil (film carrier) can reduce uneven of surface
# Surface roughness and plating property

Prepreg: E-700G(R)  
Swelling: 80 ℃ / 5 min, Desmear: 80 ℃ / 15 min

<table>
<thead>
<tr>
<th>Item</th>
<th>Airfoil</th>
<th>PF-EL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ra (µm)</td>
<td>0.09</td>
<td>0.38</td>
</tr>
<tr>
<td>Peel strength (kN/m)</td>
<td>0.76</td>
<td>0.79</td>
</tr>
<tr>
<td>Surface image (After desmear)</td>
<td><img src="image" alt="Surface image" /></td>
<td><img src="image" alt="Surface image" /></td>
</tr>
<tr>
<td>Cross-section image (After plating)</td>
<td><img src="image" alt="Cross-section image" /></td>
<td><img src="image" alt="Cross-section image" /></td>
</tr>
</tbody>
</table>

Surface roughness of the Airfoil after desmear is < 0.1 µm.
Adhesive property of pattern plating copper

Evaluating method

E-700G(R) + Airfoil

Desmear → E'less-plating

Patterning

Seed layer

width: 200 μm

86 mm

Resistance measurement

Resistance of seed layer

Airfoil shows good adhesive property of pattern plating copper
## Electroless copper (seed layer) fixing property

<table>
<thead>
<tr>
<th>Material</th>
<th>Seed layer: 0.07 μm</th>
<th>Seed layer: 0.14 μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Film material</td>
<td><img src="image1.png" alt="Image" /> 20 μm</td>
<td><img src="image2.png" alt="Image" /> 20 μm</td>
</tr>
<tr>
<td>Air Foil</td>
<td><img src="image3.png" alt="Image" /> 20 μm</td>
<td><img src="image4.png" alt="Image" /> 20 μm</td>
</tr>
</tbody>
</table>

AirFoil is available for thin seed layer less than 0.2um
Resist formability of Airfoil with E-700G(R)

<table>
<thead>
<tr>
<th>Design</th>
<th>Surface photograph</th>
<th>Cross section</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/3 μm</td>
<td><img src="image1" alt="Surface photograph" /></td>
<td><img src="image2" alt="Cross section" /></td>
</tr>
</tbody>
</table>

DFR: RY-5319 (Thickness 19 μm, Hitachi Chemical Co., Ltd.)
DFR pre-treatment: NFT (Hitachi Chemical Co., Ltd)
Exposure: EXM-1201 (ORC Manufacturing Co., Ltd.) with 405 nm sharpcut filter, 100 mJ/cm²
Development: 1 % Na₂CO₃, 30 ºC, 18 s,

3 μm width of DFR line on the E-less copper is successfully fabricated.
Fine line formability of Airfoil with E-700G(R) (L/S=5 µm/5 µm)

Desmear system: Atotech
Desmear condition:
  Swelling: 80 °C/10 min, Micro-etching: 80 °C/15 min
  Neutralizing: 40 °C/5 min
DFR : RY 5319

Electro-less plating system: Atotech
Electro-less plating condition
  Electro-less plating: 0.3 µm
  Electro plating: 8 µm

Grass-cloth prepreg with Airfoil can be applicable to the wiring of 10 µm.
HAST results with SR (FZ-2700GA)

**Structure**

- **FZ-2700GA** (thickness: 20 μm, Hitachi Chemical Co., Ltd)
- Line/space = 5/5 μm, Line thickness: 5 μm
- Airfoil
- Core: MCL-E-700G(R)

Condition 130 °C/ 85 %RH/ 5V

*evaluation still ongoing up to 300hr

Hast test with SR (FZ-2700GA) shows good results.
Transmission loss in micro strip-line structure with fine patterning material

**Measurement Conditions**
- Transmission structure: Micro strip-line
- Temperature & Humidity: 25 ℃/40 %RH
- Characteristic impedance: 50 Ω
- Proofreading method: TRL
- Dimension parameters
  - Trace width: 0.068 ~ 0.082 mm
  - Trace thickness: 20 μm
  - Dielectric thickness: 40 μm

![Diagram of micro strip-line structure](image)

Fine pattern formation materials are effective in reducing the transmission loss (conductor loss)
New copper surface treatment technology
For next generation package substrates

**NFT:** Nano Fractal Treatment
Application of NFT

NFT has the high-resolution of the DFR and high adhesion of the wiring.

- Core
- Package substrate
- Build-up material
- Solder resist (SR)
- Inner layer / Resin
  - Inner layer treatments
    - Chemical treatment (Etching)
    - Black-oxide treatment

- Cu layer (DFR / Seed-layer)

- NFT

Multilayer board
Features & Process flow of NFT

1. Very flat-surface copper
2. Adhesion for DFR is excellent
3. The precision of the fine pattern is good
4. Adhesion between build-up material and solder resist is good

- **Activation**
- **Precious metal**
- **Oxidation**
- **CuO**
- **Dissolution of CuO (acid treatment)**
- This step, microscopic indentation is formed
- **Dry treatment**
- This step, thin CuO film is formed
**Characteristic of NFT**

1) **Surface shape of copper**

SEM image (×5K, ×100K)

<table>
<thead>
<tr>
<th>Conventional treatment</th>
<th>New treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etching</td>
<td>Oxi-Red</td>
</tr>
</tbody>
</table>

The surface of NFT is very flat shape
### Characteristic of NFT

#### 2) Cross-section of copper

SIM image used with FIB (45°)

<table>
<thead>
<tr>
<th>Conventional treatment</th>
<th>New treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etching (2.0 - 3.0 μm)</td>
<td>Oxi-Red (0.5 - 0.7 μm)</td>
</tr>
</tbody>
</table>

![SIM images](image)

(Surface roughness, Rz)

**NFT of surface roughness (Rz) is less than 0.1 um**

© Hitachi Chemical Co., Ltd. 2014. All rights reserved. 46
**Formation of seed layer**

Thickness of seed layer is 0.5 μm

**AS-Z3, Air Foil**

**Formation of seed layer**

DFR: RY5319

**Pattern formation of DFR**

**Pattern plating**

**Etching of seed layer**

---

**Wiring formation example of 5/5um**

<table>
<thead>
<tr>
<th>Item</th>
<th>AS-Z3</th>
<th>Airfoil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ra (μm)</td>
<td>0.15</td>
<td>0.08</td>
</tr>
<tr>
<td>Surface</td>
<td>![Surface Image] 50 μm</td>
<td>![Surface Image] 50 μm</td>
</tr>
<tr>
<td>Cross-section (FIB)</td>
<td>![Cross-section Image] 5 μm</td>
<td>![Cross-section Image] 5 μm</td>
</tr>
<tr>
<td>Width / height(μm)</td>
<td>4.7/8.5</td>
<td>5.7/9.7</td>
</tr>
</tbody>
</table>

The precision of the fine pattern is good
Ultra Fine Line formation

1) L : 3 μm , S : 3 μm , H : 4 μm

L : 2.9 μm

H : 4.5 μm

50 μm

10 μm
Ultra Fine Line formation

1) \( L : 3 \mu m \), \( S : 3 \mu m \), \( H : 4 \mu m \)

- \( L : 2.9 \mu m \)
- \( H : 4.5 \mu m \)
Ultra Low Loss (Df) material
- MCL-LW-900G -
## Hitachi Low Dk, Df Prepreg

PPG thickness: 50μm

<table>
<thead>
<tr>
<th>Item</th>
<th>Conditions</th>
<th>E-705G</th>
<th>E-770G</th>
<th>LW-900G</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>705G</td>
<td>705G(LH)</td>
<td>770G</td>
</tr>
<tr>
<td>Prepreg</td>
<td>Glass Style</td>
<td>1037</td>
<td>1030</td>
<td>1037</td>
</tr>
<tr>
<td></td>
<td>Resin Content(%)</td>
<td>73</td>
<td>69</td>
<td>72</td>
</tr>
<tr>
<td>Glass type</td>
<td>Glass type</td>
<td>E-glass</td>
<td>S-glass</td>
<td>E-glass</td>
</tr>
<tr>
<td></td>
<td>Weave density</td>
<td>Std</td>
<td>HD</td>
<td>Std</td>
</tr>
<tr>
<td>Dk (SPDR)</td>
<td>1GHz</td>
<td>3.9</td>
<td>4.1</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>10GHz</td>
<td>3.8</td>
<td>4.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Df (SPDR)</td>
<td>1GHz</td>
<td>0.008</td>
<td>0.008</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>10GHz</td>
<td>0.012</td>
<td>0.012</td>
<td>0.009</td>
</tr>
<tr>
<td>Tg DMA °C</td>
<td></td>
<td>300</td>
<td>300</td>
<td>310</td>
</tr>
<tr>
<td>CTE (pull)</td>
<td>a1 (X,Y)</td>
<td>11.0</td>
<td>5.8</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>a2 (X,Y)</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Young Modulus</td>
<td>A GPa</td>
<td>22.0</td>
<td>24.1</td>
<td>21.9</td>
</tr>
</tbody>
</table>
LW-900G(LH) Prepreg (1030N65/S-Glass)
5. Conclusion

1. According with demands of big data and high speed communication, there become high I/O numbers in one chip regarding higher accumulated PKG. 2.1D interposer is paid attention to cheaper general PKG.

2. We have developed E-770G laminate material which has low CTE property (1.8ppm/degC @TMA) and lower shrinkage property, actually our assembly test indicated lower warpage compared with current low CTE material.

3. We tried to make fine line on organic material, after that we success to make L/S=5/5um to use primer technology (Air Foil) with new copper surface treatment (NFT).
The entry contents of these data based on the results of our experiment done until Jan. 2014 do not guarantee their characteristic values. The contents may be revised according to new findings if necessary. Please examine the process and the condition carefully and confirm before mass production.