Low Loss/Low CTE Semiconductor Carrier Packaging Thin Core Material

Caleb Ancharski
AGC Multi-Material America
Presentation Contents

1. AGC Overview
2. Personal Introduction
3. Material Introduction and Goals
4. Strategy and Approach
5. Desired and Expected Material Properties
6. CTE Study with 5 Stack Microvia Reliability
7. Dk/Df and Resistance to Thermal Aging
8. Resin Flow and Fill
AGC Overview

AGC Group

-Float flat glass
-Figured glass
-Polished wired glass
-Low-E glass
-Decorative glass
-Fabricated glass for architectural use (Heat Insulating/shielding glass, Disaster-resistant/Security glass, Fire-resistant glass, etc.)

Automotive Glass

-Tempered glass
-Laminated glass

Flat Glass

-Display

- LCD glass substrates
- Specialty glass for display applications
- Cover glass for car-mounted displays
- Display related materials
- Glass for solar power system
- Fabricated glass for industrial use

Electronic Materials

- Semiconductor process materials
- Optoelectronics materials
- Lighting glass products
- Laboratory glass, etc.

Display

- Fluor chemicals & specialty chemicals

- Fluorinated resins
- Water and oil repellents
- Gases
- Solvents
- Pharmaceutical and agrochemical intermediates and active ingredients
- Iodine-related products

Chlor-alkali & urethane

- Vinyl chloride
- Vinyl chloride monomer
- Caustic soda
- Urethane

Company name: AGC Inc.
Established: September 8, 1907
Representative director: Yoshinori Hirai
Paid-in capital: ¥90.9 billion*
Consolidated net sales: ¥1,412.3 billion*
Consolidated no. of employees: 55,999*
No. of consolidated subsidiaries: 206 companies
AGC PCB Materials

Nelco
- Joined AGC group on Dec 4th, 2018

Taconic
- Joined AGC group on Jun 11th, 2019

Production
Sales
R&D

FR
CN
SG
KR
JP
AZ
CA
Introduction (Personal)

✓ B.S. – Chemistry, Shippensburg University
  ▪ Graduated 2019

✓ 2+ years at AGC Nelco, now AGC Multi-Material America.

✓ Research Chemist with focus on build-up film materials, technology and their application.
Introduction and Goal of Material

Need low loss, low CTE chip carrier substrate core material suitable for HDI applications that create robust, reliable and efficient boards.
Existing Strategy

Traditional dielectric reinforced prepreg manufacturing techniques that have been in process for years have some drawbacks:

- Very difficult to impregnate fiber glass weave with high filler contents.
- Struggles to control resin contents and thickness.
- Prone to cracking issues in cured laminates; polyimides for example.
Existing Strategy

Raw Materials → Resin Varnish → Raw Fiber Glass → Prepreg → Foil Clad Laminates

Credit: Dineski and Srebenkoska, OTEH 2014
Existing Strategy

- Has potential to impregnate fiber glass weave with high filler content resin.
- Can easily control thickness based on press parameters.

Coat resin varnish directly on release substrate
Existing Strategy

Raw Materials → Resin Varnish → Raw Fiber Glass → Prepreg → Foil Clad Laminates

Coat resin varnish directly on release substrate
Our Strategy

- Incorporate existing AGC-Taconic fastRise™ Build-Up films that have high filler content with fiberglass weave.
  
  A. Laminate Form  
  B. Prepreg Form

- A combination of high heat and/or pressure can force resin into glass bundle fibers creating a coherent and consistent “prepreg-like” material.
## Strategy A- Laminate Form

### High Pressure and Temperature

<table>
<thead>
<tr>
<th>Copper Foil</th>
<th>Resin Build-Up Film</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin Build-Up Film</td>
<td>Raw Fiberglass Weave</td>
</tr>
<tr>
<td>Resin Build-Up Film</td>
<td>Raw Fiberglass Weave</td>
</tr>
<tr>
<td>Resin Build-Up Film</td>
<td>Raw Fiberglass Weave</td>
</tr>
<tr>
<td>Copper Foil</td>
<td>Resin Build-Up Film</td>
</tr>
</tbody>
</table>

Able to be directly used as substrate core.

Can manipulate glass style and finish enough to dial in desired CTE values!
Strategy B – Prepreg Form

High Pressure
↓
Release Liner
Resin Build-Up Film
Raw Fiberglass Weave
Resin Build-Up Film
Release Liner
↑
High Pressure

Thickness can very easily be controlled by amount of BUF pressed on either side of glass weave.

Goal is to have low degree of “cure” so prepreg is still in state of flow and fill.
## Desired and Expected Properties

<table>
<thead>
<tr>
<th>Properties</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D_f$</td>
<td>N/A</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>$D_k$</td>
<td>N/A</td>
<td>3.0 - 4.0</td>
</tr>
<tr>
<td>$X/Y$-CTE (40-260 °C)</td>
<td>PPM/°C</td>
<td>5 - 10</td>
</tr>
<tr>
<td>TMA Glass Transition (Tg)</td>
<td>°C</td>
<td>&gt;260</td>
</tr>
<tr>
<td>Copper Peel Strength</td>
<td>lb/in</td>
<td>&gt;2.5</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>W/M*K</td>
<td>0.94</td>
</tr>
</tbody>
</table>

### How is ultra reliability achieved?

Matching and consistent CTE values

### Low Loss

Ultra Reliability
X/Y-Axis Coefficient of Thermal Expansion

Substrate Core X/Y-CTE Target = 5-10 PPM/ °C
*Overall 40°C – 260°C

Low CTE: IC Chip < Substrate Core < Solder Connection: Higher CTE
Microvia structure reliability is achieved with a dielectric build-up film that has a closely matched CTE to copper.

Copper = 17 ppm/C  
Build-Up Film ~ 20 ppm/C  
*Overall 40C – 260C
Design, material selection and fabrication quality matter!

- Bad design can shift green to red.
- High quality material can shift red to green.
- Bad fabrication quality can shift green to red.

CTE Study with Stacked Microvias

Study conducted of dielectric build-up material:

A. D-coupon
B. Current Induced Thermal Cycle (CITC)

Both tests reach a solder reflow temperature of 260 °C!

Can be direct attach with no offset or staggered with ~10 mil offset.

Buried Subassembly (55-60 mils)

fastRise™ Build-Up Film
CTE Study with Stacked Microvias (Staggered)

PASSED 24 REFLOWS OF 35 °C – 260 °C.
CTE Study with Stacked Microvias (Direct Attach)

24 reflow cycles, 35 °C – 260 °C

NO MICROVIA FAILURES

5 stack microvia structure successfully survived the following stress cycle:
24x @ 45 to 260C, 100x @ -55 to 155C, 24x @ 45 to 260C
Resin Flow and Fill

Flow needs to be high enough for material to act as a leveling agent to reduce thickness variations in a subassembly.

Advantage of prepreg approach because of flow and fill characteristics.
- Low material viscosity allows highly filled ceramic to penetrate fiber glass weave.

Material with high ceramic needs to completely fill line/space gapping and vias in assembly process.
Dielectric Build-Up has extreme thermal aging resistance to Dielectric Constant.

Aged 45+ days @ 155 °C

<table>
<thead>
<tr>
<th></th>
<th>Dk @ Day 0</th>
<th>Dk @ Day 45+</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUF A</td>
<td>3.32</td>
<td>3.355</td>
<td>0.035</td>
</tr>
<tr>
<td>BUF B</td>
<td>3.245</td>
<td>3.285</td>
<td>0.04</td>
</tr>
<tr>
<td>Hydrocarbon Based Resin</td>
<td>3.37</td>
<td>3.29</td>
<td>-0.08</td>
</tr>
</tbody>
</table>
Dielectric Build-Up has extreme thermal aging resistance to Dissipation Factor.

Low Df over time means transmission can remain low over time with aging!
Summary

- Successfully provide a solution for a low loss, low CTE ultra reliable IC package substrate core material.
  - X/Y-CTE = 5-10 ppm/C and Df < 0.002 with heat resistant properties

- Two approaches include a prepreg and laminate for fabrication.

- Dielectric build-up film material was proven to survive multiple reflow simulations with staggered or stacked vias, directly attached to a subassembly with no offset.
This method is not only suitable for high-volume manufacturing, but for high-mix, low-volume manufacturing for the US advanced chip packaging supply chain.

AGC-Multi Material America is developing and manufacturing here in the “Silicon Desert” of Greater Phoenix, Arizona!
References

Acknowledgment

Special thank you to Thomas McCarthy, Preeya Kuray, Yoji Nakajima and Mark Derwin.

Additional thank you for support from the AGC MMA PD Team in Tempe and the AGC Yokohama Technical Center in Japan.

Thank you to iMAPS for allowing this presentation to take place!

AGC Multi Materials America
Thank you

Caleb Ancharski
caleb.ancharski@agc.com

AGC Multi Materials America