

# Agile Manufacturing of Glass Carriers for Fan-Out

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**CONNECT**

# Presentation Outline

- I. Introduction to Corning Precision Glass Solutions**
- II. Carrier requirements for fan-out**
  - Understanding in-process warp
  - Levers to control warp
  - Real-world customer challenges
- III. Introducing Corning Advanced Packaging Carriers**
- IV. Glass Considerations and Corning's Agile Manufacturing Platform**
- V. Concluding Remarks**

Founded:  
**1851**

Headquarters:  
**Corning, New York**

Employees:  
**~ 46,000 worldwide**

2017 Core Sales:  
**\$10.3 billion**

Fortune 500 Ranking (2017):  
**298**

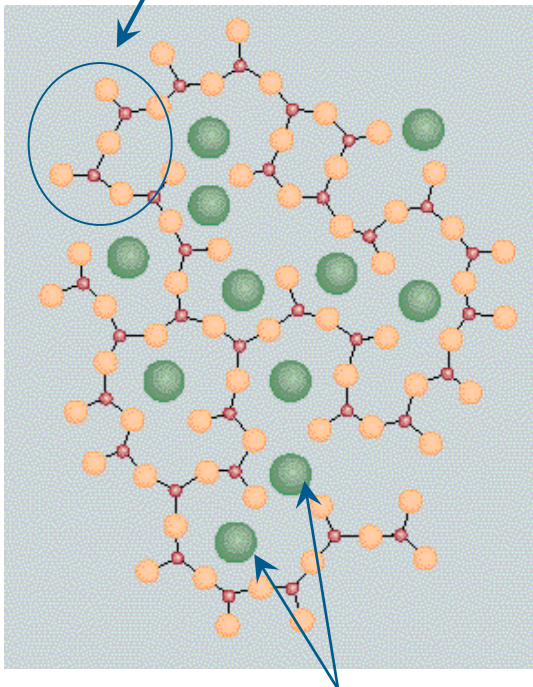
Corning Incorporated is one of the world's leading innovators in materials science. For more than 165 years, Corning has applied its unparalleled expertise in glass science, ceramics, and optical physics to develop products and processes that have transformed industries and enhanced people's lives.

# Introduction to Corning

We understand the Periodic Table of a glass scientist

## THE PERIODIC TABLE

'Backbone' or network formers



1 IA	2 IIA											13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA													
<b>H</b> 1 1.008 Hydrogen													<b>B</b> 5 10.81 Boron	<b>C</b> 6 12.01 Carbon	<b>N</b> 7 14.01 Nitrogen	<b>O</b> 8 16.00 Oxygen	<b>F</b> 9 19.00 Fluorine	<b>Ne</b> 10 20.18 Neon												
<b>Li</b> 3 6.94 Lithium	<b>Be</b> 4 9.01 Beryllium												<b>Al</b> 13 26.98 Aluminum	<b>Si</b> 14 28.09 Silicon	<b>P</b> 15 30.97 Phosphorus	<b>S</b> 16 32.07 Sulfur	<b>Cl</b> 17 35.45 Chlorine	<b>Ar</b> 18 39.95 Argon												
<b>Na</b> 11 22.99 Sodium	<b>Mg</b> 12 24.31 Magnesium												<b>K</b> 19 39.10 Potassium	<b>Ca</b> 20 40.08 Calcium	<b>Sc</b> 21 44.96 Scandium	<b>Ti</b> 22 47.88 Titanium	<b>V</b> 23 50.94 Vanadium	<b>Cr</b> 24 52.00 Chromium	<b>Mn</b> 25 54.94 Manganese	<b>Fe</b> 26 55.85 Iron	<b>Co</b> 27 58.93 Cobalt	<b>Ni</b> 28 58.69 Nickel	<b>Cu</b> 29 63.55 Copper	<b>Zn</b> 30 65.39 Zinc	<b>Ga</b> 31 69.72 Gallium	<b>Ge</b> 32 72.61 Germanium	<b>As</b> 33 74.92 Arsenic	<b>Se</b> 34 78.96 Selenium	<b>Br</b> 35 79.90 Bromine	<b>Kr</b> 36 83.80 Krypton
<b>Rb</b> 37 85.47 Rubidium	<b>Sr</b> 38 87.62 Strontium												<b>Y</b> 39 88.91 Yttrium	<b>Zr</b> 40 91.22 Zirconium	<b>Nb</b> 41 92.91 Niobium	<b>Mo</b> 42 95.94 Molybdenum	<b>Tc</b> 43 (97.9) Technetium	<b>Ru</b> 44 101.07 Ruthenium	<b>Rh</b> 45 102.91 Rhodium	<b>Pd</b> 46 106.42 Palladium	<b>Ag</b> 47 107.87 Silver	<b>Cd</b> 48 112.41 Cadmium	<b>In</b> 49 114.82 Indium	<b>Sn</b> 50 118.71 Tin	<b>Sb</b> 51 121.76 Antimony	<b>Te</b> 52 127.60 Tellurium	<b>I</b> 53 126.90 Iodine	<b>Xe</b> 54 131.29 Xenon		
<b>Cs</b> 55 132.91 Cesium	<b>Ba</b> 56 137.33 Barium												<b>La</b> 57 138.91 Lanthanum	<b>Hf</b> 72 178.49 Hafnium	<b>Ta</b> 73 180.95 Tantalum	<b>W</b> 74 183.85 Tungsten	<b>Re</b> 75 186.21 Rhenium	<b>Os</b> 76 190.2 Osmium	<b>Ir</b> 77 192.22 Iridium	<b>Pt</b> 78 195.08 Platinum	<b>Au</b> 79 196.97 Gold	<b>Hg</b> 80 200.59 Mercury	<b>Tl</b> 81 204.38 Thallium	<b>Pb</b> 82 207.2 Lead	<b>Bi</b> 83 208.98 Bismuth	<b>Po</b> 84 (209) Polonium	<b>At</b> 85 (210) Astatine	<b>Rn</b> 86 (222) Radon		
<b>Fr</b> 87 223.02 Francium	<b>Ra</b> 88 226.03 Radium												<b>Ac</b> 89 227.03 Actinium	<b>Rf</b> 104 (261) Rutherfordium	<b>Ta</b> 105 (262) Tennessine	<b>W</b> 106 (263) Livermorium	<b>Re</b> 107 (262) Bohrium	<b>Os</b> 108 (265) Oganesson	<b>Ir</b> 109 (265) Tennessine	<b>Pt</b> 110 (265) Oganesson	<b>Au</b> 111 (265) Oganesson	<b>Hg</b> 112 (265) Oganesson	<b>Tl</b> 113 (265) Oganesson	<b>Pb</b> 114 (265) Oganesson	<b>Bi</b> 115 (265) Oganesson	<b>Po</b> 116 (265) Oganesson	<b>At</b> 117 (265) Oganesson	<b>Rn</b> 118 (265) Oganesson		
ALKALI METALS	ALKALI EARTH METALS											HALOGENS						NOBLE GASES												

Colorants

Glass formers

Fining agents (get rid of bubbles)

Network modifiers

Network modifiers e.g. sodium or calcium



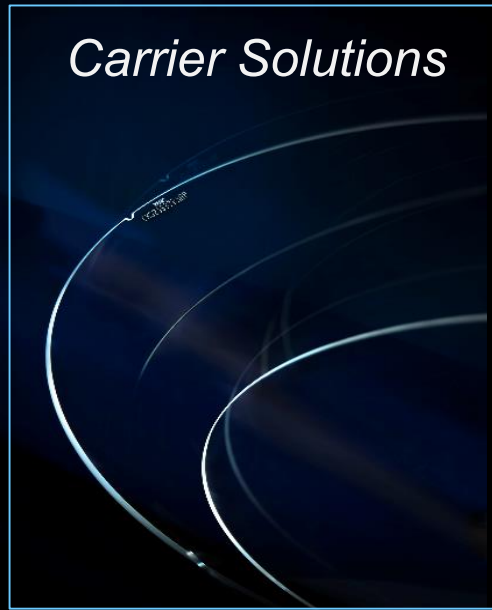
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<b>Ce</b> 58 140.12 Cerium	<b>Pr</b> 59 140.91 Praseodymium	<b>Nd</b> 60 144.24 Neodymium	<b>Pm</b> 61 (145) Promethium	<b>Sm</b> 62 150.36 Samarium	<b>Eu</b> 63 152.97 Europium	<b>Gd</b> 64 157.25 Gadolinium	<b>Tb</b> 65 158.93 Terbium	<b>Dy</b> 66 162.50 Dysprosium	<b>Ho</b> 67 164.93 Holmium	<b>Er</b> 68 167.26 Erbium	<b>Tm</b> 69 168.93 Thulium	<b>Yb</b> 70 173.04 Ytterbium	<b>Lu</b> 71 174.97 Lutetium
<b>Th</b> 90 232.04 Thorium	<b>Pa</b> 91 231.04 Protactinium	<b>U</b> 92 238.03 Uranium	<b>Np</b> 93 237.05 Neptunium	<b>Pu</b> 94 (240) Plutonium	<b>Am</b> 95 243.06 Americium	<b>Cm</b> 96 (247) Curium	<b>Bk</b> 97 (248) Berkelium	<b>Cf</b> 98 (251) Californium	<b>Es</b> 99 252.08 Einsteinium	<b>Fm</b> 100 257.10 Fermium	<b>Md</b> 101 (257) Mendelevium	<b>No</b> 102 259.10 Nobelium	<b>Lr</b> 103 262.11 Lawrencium



Corning Precision Glass Solutions offers industry leading wafer and panel format glass-based solutions.

Our products help customers deliver increasingly demanding functionality and form factor requirements in consumer devices and Internet of Things applications.



*\*Development program*

# Presentation Outline

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- II. Carrier requirements for fan-out**
  - Understanding in-process warp
  - Levers to control warp
  - Real-world customer challenges
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## Understanding in-process warp

# CTE mismatch in carrier applications induces in-process warp

Assuming bi-axial bending, the bending curvature due to CTE mismatch and high process temperature is:

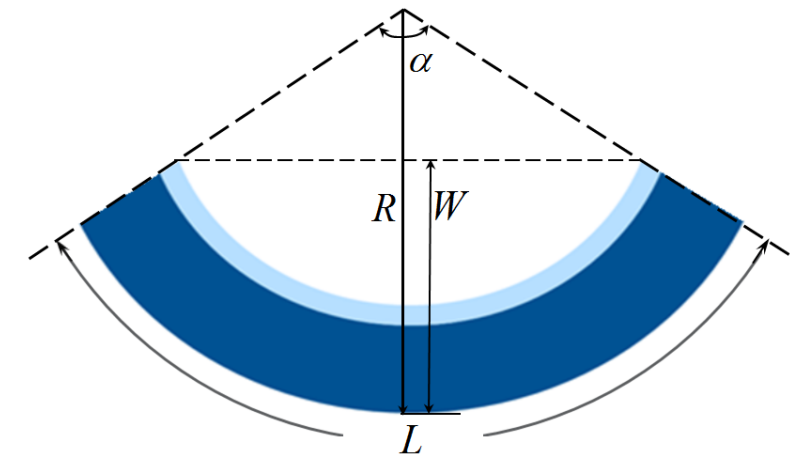
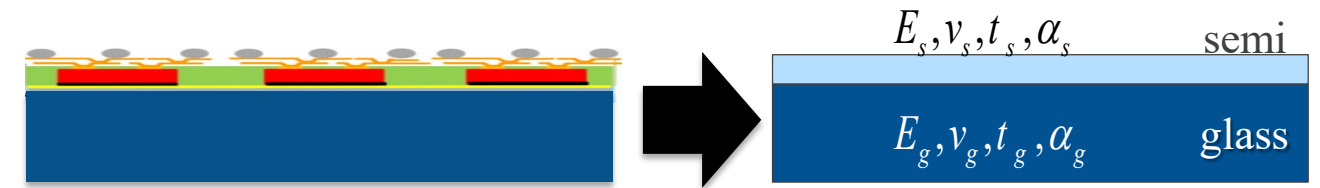
$$\kappa = \frac{6(\alpha_s - \alpha_g)(T_{\text{process}} - T_{\text{room}})(t_g + t_s)t_g t_s}{\left[ \frac{E_g(1-\nu_s)}{E_s(1-\nu_g)} t_g^4 + \frac{E_s(1-\nu_g)}{E_g(1-\nu_s)} t_s^4 + 2t_g t_s (2t_g^2 + 3t_g t_s + 2t_s^2) \right]}$$

and the warp is:

$$W = R \left( 1 - \cos\left(\frac{\alpha}{2}\right) \right) = \frac{1}{\kappa} \left( 1 - \cos\left(\frac{\kappa L}{2}\right) \right)$$

$$\approx \frac{3L^2 (\alpha_s - \alpha_g)(T_{\text{process}} - T_{\text{room}})(t_g + t_s)t_g t_s}{4 \left[ \frac{E_g(1-\nu_s)}{E_s(1-\nu_g)} t_g^4 + \frac{E_s(1-\nu_g)}{E_g(1-\nu_s)} t_s^4 + 2t_g t_s (2t_g^2 + 3t_g t_s + 2t_s^2) \right]}$$

$$\approx 0.75L^2 \Delta\alpha \Delta T \frac{E_s(1-\nu_g)t_s}{E_g(1-\nu_s)t_g^2}$$

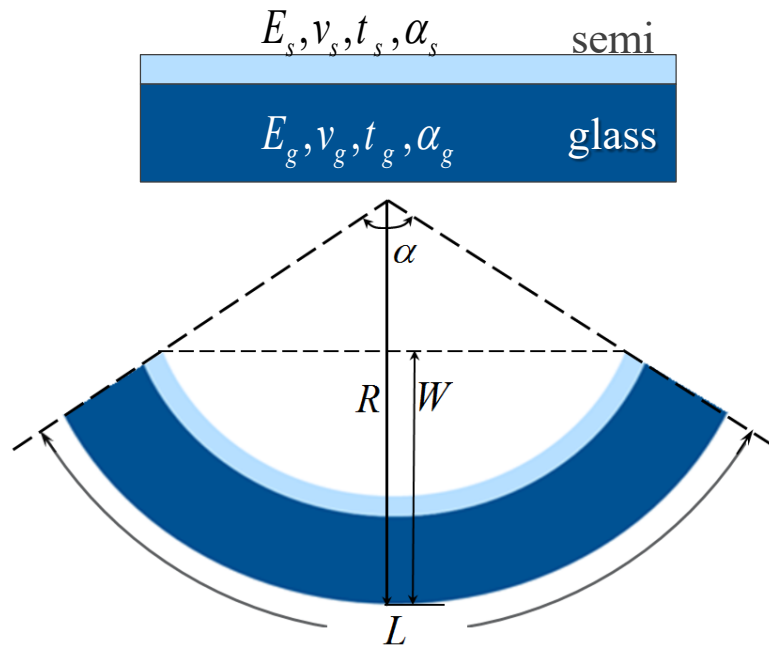


$$R = 1/\kappa \quad \alpha = L/R = \kappa L$$

$E$ : Young's modulus;  $\nu$ : Poisson's ratio;  $t$ : Glass thickness;  
 $\alpha$ : Coefficient of thermal expansion;  $T$ : Temperature.  
 $g$ : glass;  $s$ : semiconductor layers (MC + redistribution layers + die)

## Understanding in-process warp

CTE mismatch in carrier applications induces in-process warp



Under typical fan-out conditions, in-process warp follows a simplified formula showing its dependence on:

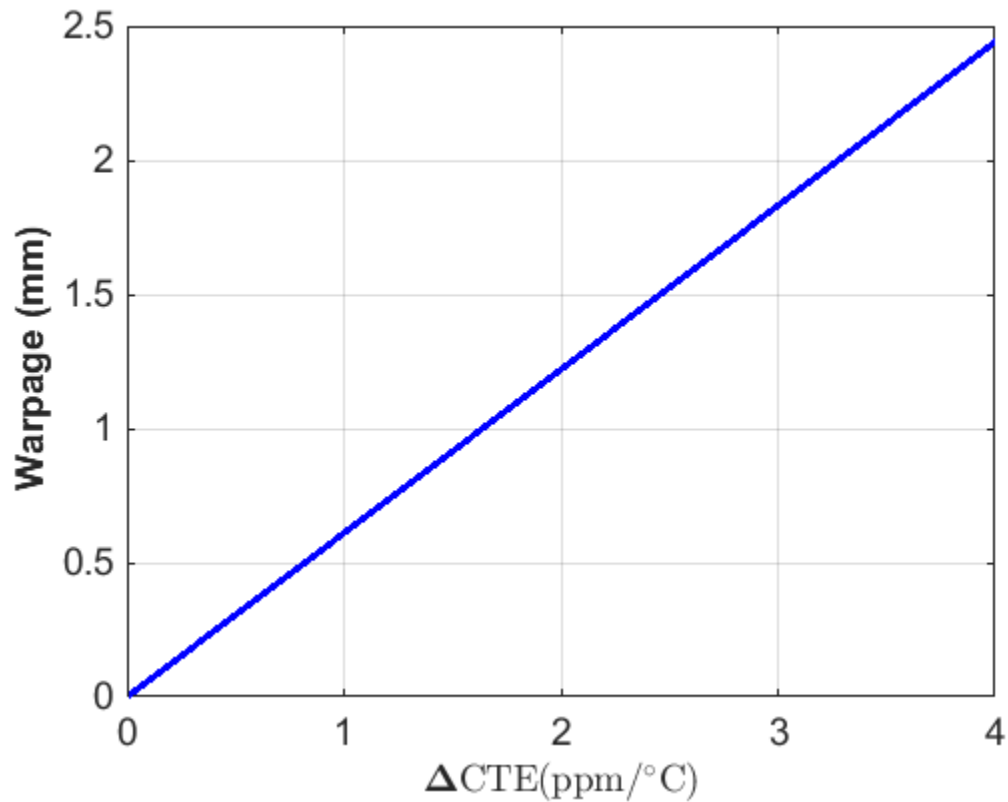
1. CTE mismatch between glass and the composite semi material
2. Glass Young's modulus
3. Square of glass thickness

$$\approx 0.75L^2 \Delta\alpha \Delta T \frac{E_s (1-\nu_g) t_s}{E_g (1-\nu_s) t_g^2}$$



## Levers to control in-process warp

### Decreasing $\Delta\text{CTE}$ between carrier and semi



$$L = 300\text{mm}$$

$$E_g = 70\text{GPa}; E_s = 20\text{GPa};$$

$$\nu_g = 0.22; \nu_s = 0.35;$$

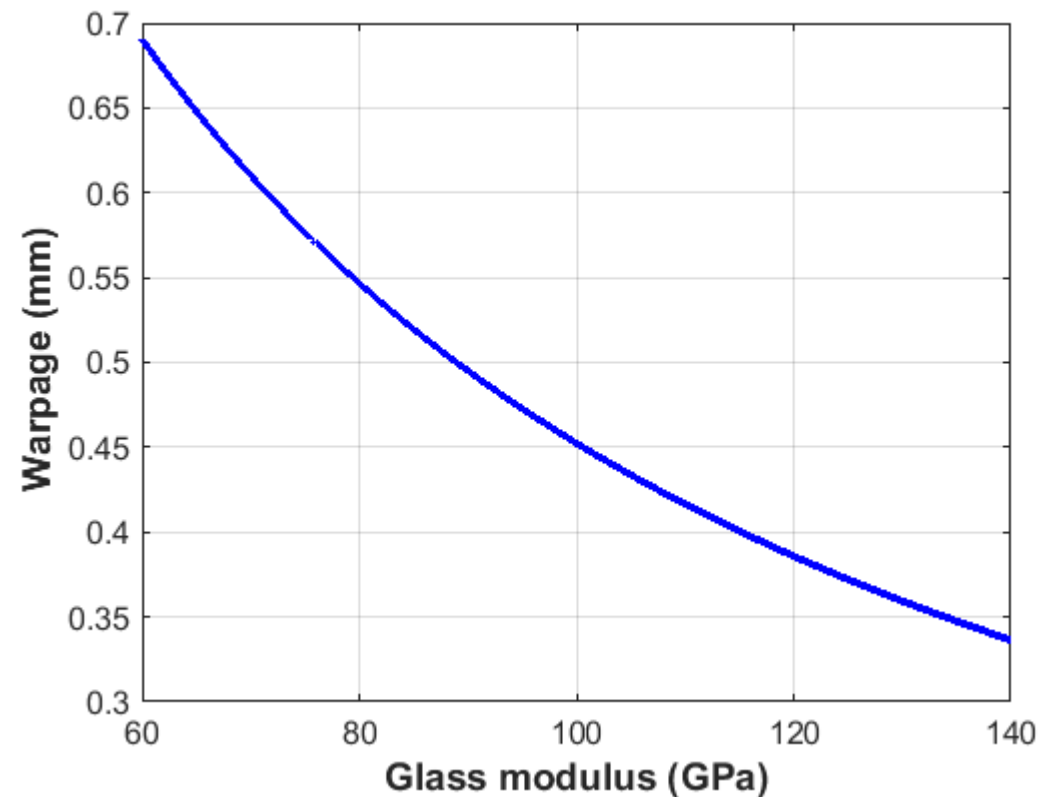
$$t_g = 1.1\text{mm}; t_s = 0.15\text{mm};$$

$$T_{\text{room}} = 20^\circ\text{C}; T_{\text{process}} = 250^\circ\text{C};$$

Perfect CTE match is desirable, but not possible due to composite semi CTE changing in process

## Levers to control in-process warp

### Increasing the modulus of the carrier



$$L = 300\text{mm}$$

$$E_s = 20\text{GPa};$$

$$\nu_g = 0.22; \nu_s = 0.35;$$

$$t_g = 1.1\text{mm}; t_s = 0.15\text{mm};$$

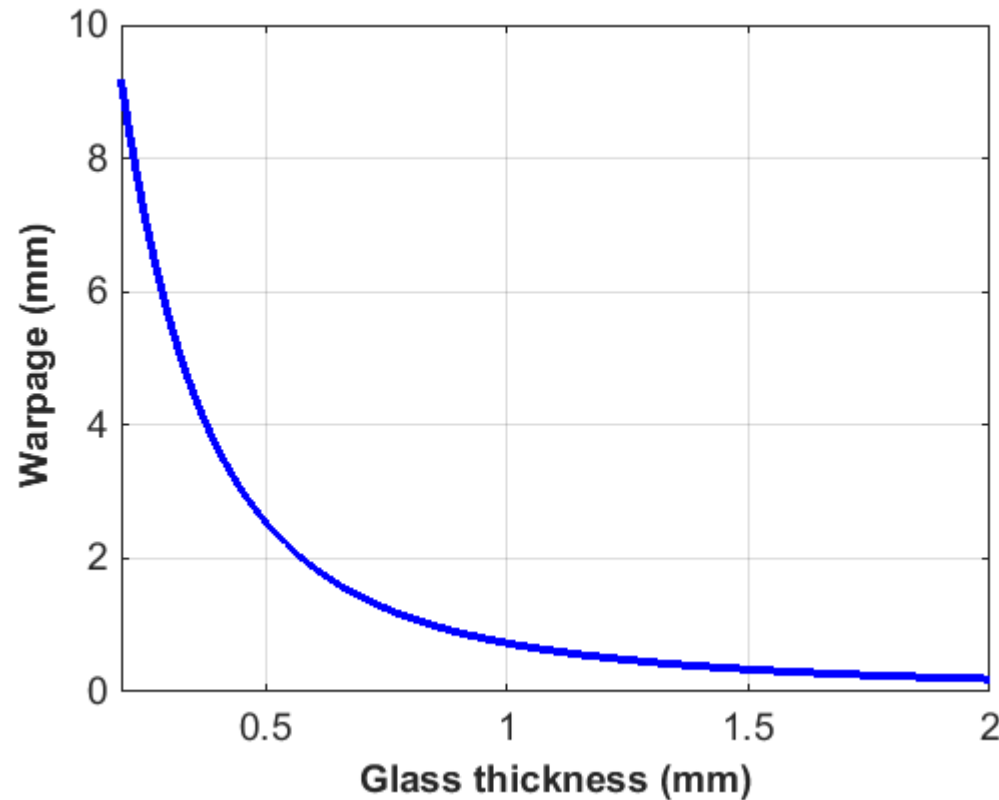
$$\Delta\text{CTE} = 1.0\text{ppm}/^\circ\text{C};$$

$$T_{\text{room}} = 20^\circ\text{C}; T_{\text{process}} = 250^\circ\text{C};$$

Warp is inversely proportional to the Young's modulus of the carrier

## Levers to control in-process warp

### Increasing the thickness of the carrier



$$L = 300\text{mm}$$

$$E_g = 70\text{GPa}; E_s = 20\text{GPa};$$

$$\nu_g = 0.22; \nu_s = 0.35;$$

$$t_s = 0.15\text{mm};$$

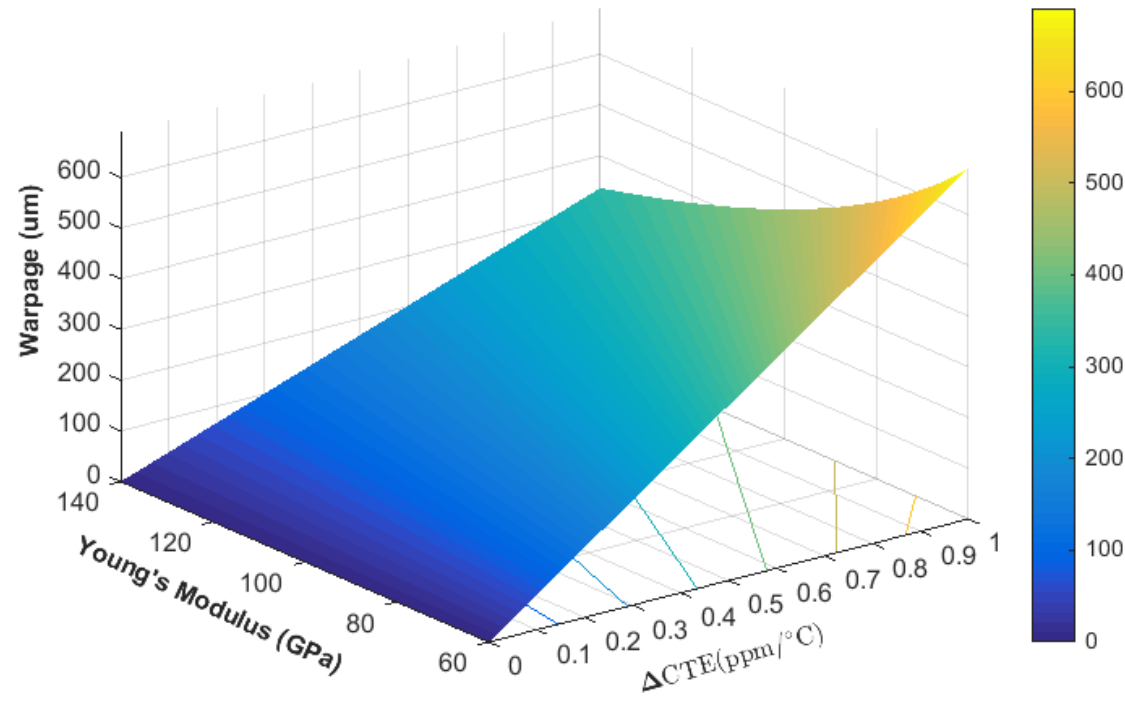
$$\Delta\text{CTE} = 1.0\text{ppm}/^\circ\text{C};$$

$$T_{\text{room}} = 20^\circ\text{C}; T_{\text{process}} = 250^\circ\text{C};$$

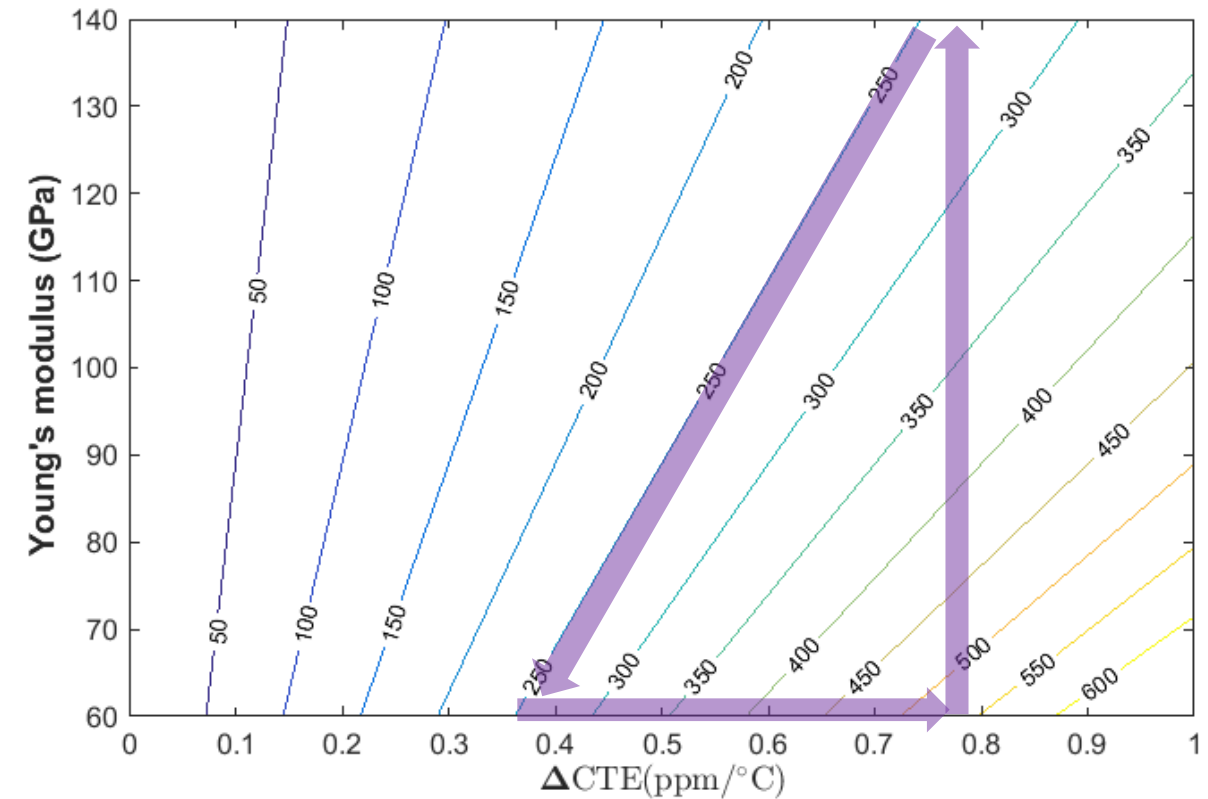
Warp is inversely proportional to carrier thickness squared, but returns diminish beyond 1mm

# Levers to control in-process warp

## $\Delta\text{CTE}$ is part of fan-out reality



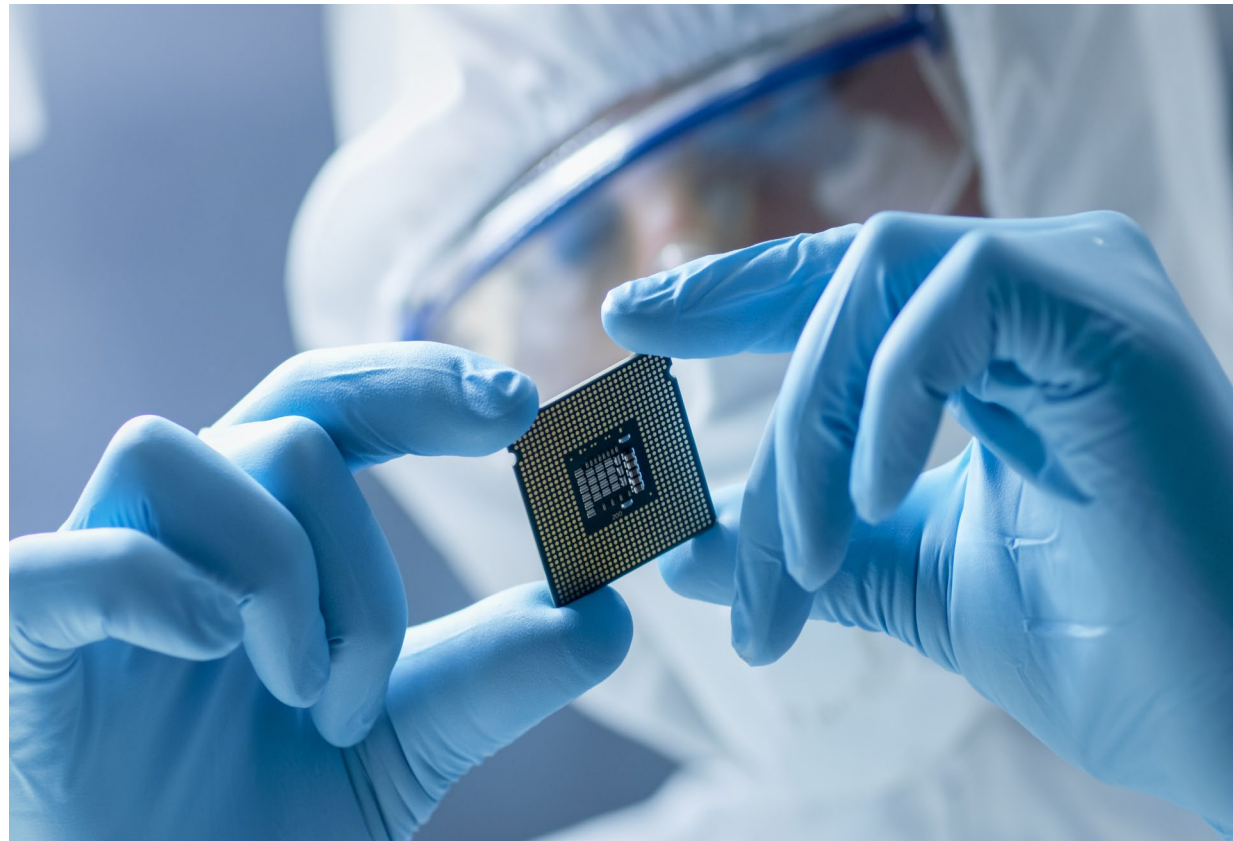
$E_s = 20\text{GPa}$ ;  
 $\nu_g = 0.22$ ;  $\nu_s = 0.35$ ;  
 $t_g = 1.1\text{mm}$ ;  $t_s = 0.15\text{mm}$ ;  
 $T_{\text{room}} = 20^\circ\text{C}$ ;  $T_{\text{process}} = 250^\circ\text{C}$ ;  
 $L = 300\text{mm}$ .



**Higher Young's modulus helps overcome the  $\Delta\text{CTE}$  mismatch challenge**

## *Real-world customer challenges*

# Additional considerations



### **Product**

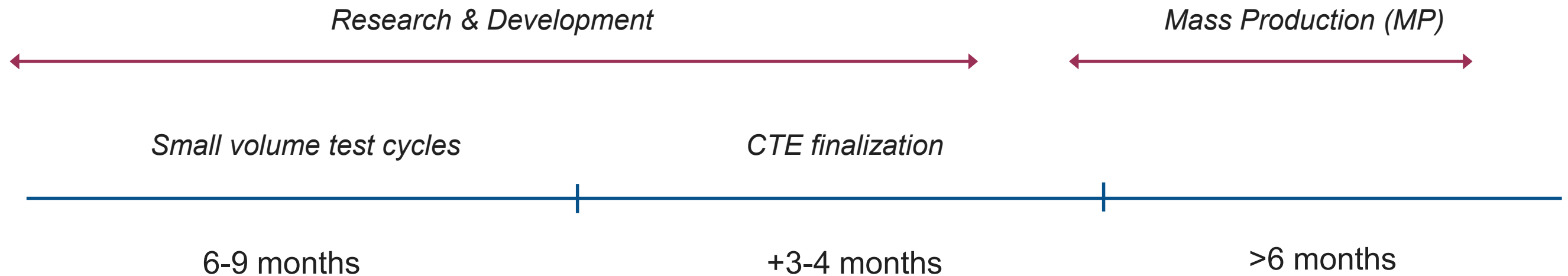
- CTE mismatch is unavoidable due to different materials added during fan-out
- Very high YM may introduce failure modes not yet well understood
- Too high a carrier thickness limits the Z-height of the package

### **Material availability and consistency**

- Long lead times for carrier samples result in delayed package development
- Changes in carrier material during MP ramp may create issues

## Real-world customer challenges

# Customer selection of ideal carrier CTE may take **more than a year**



### Customer Challenges

- Identifying CTE
- Iterate design

- Finalize CTE
- Lock in design

- Reliable supply of MP volume with consistent material properties

### Vendor/Material Requirements

- Multiple CTEs fast
- Fine granularity of available CTEs

- Quick turnaround of chosen CTE
- Flexibility to go back to small volume design changes

- Ability to ramp quickly
- Ability to work with customer to finalize and deliver the specs

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**CORNING**

Precision Glass  
Solutions

# Introducing Advanced Packaging Carriers

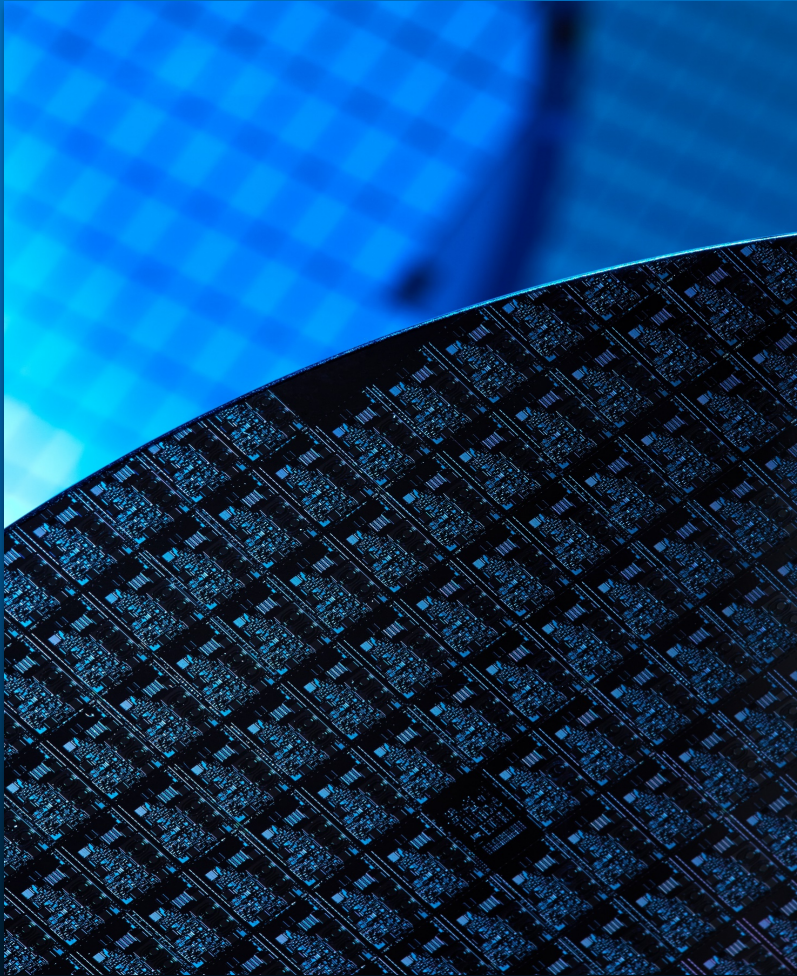
*Up to 40% reduction in customers' in-process warp*

- ✓ Fine granularity of CTEs
- ✓ High stiffness
- ✓ 4-6 week sample lead time

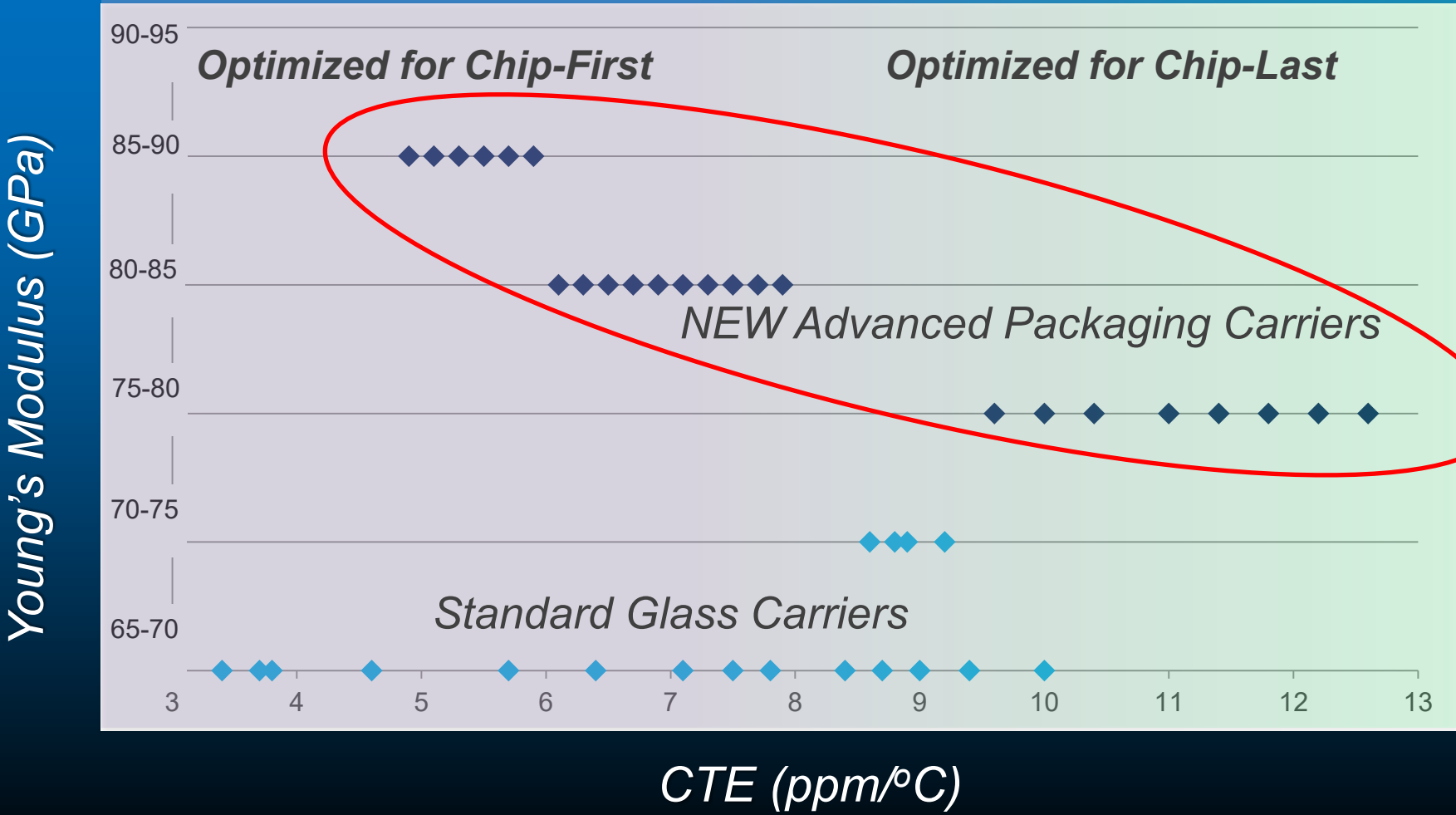




We've tailored our glass carriers by Young's Modulus and CTE to meet customers' requirements for advanced packaging

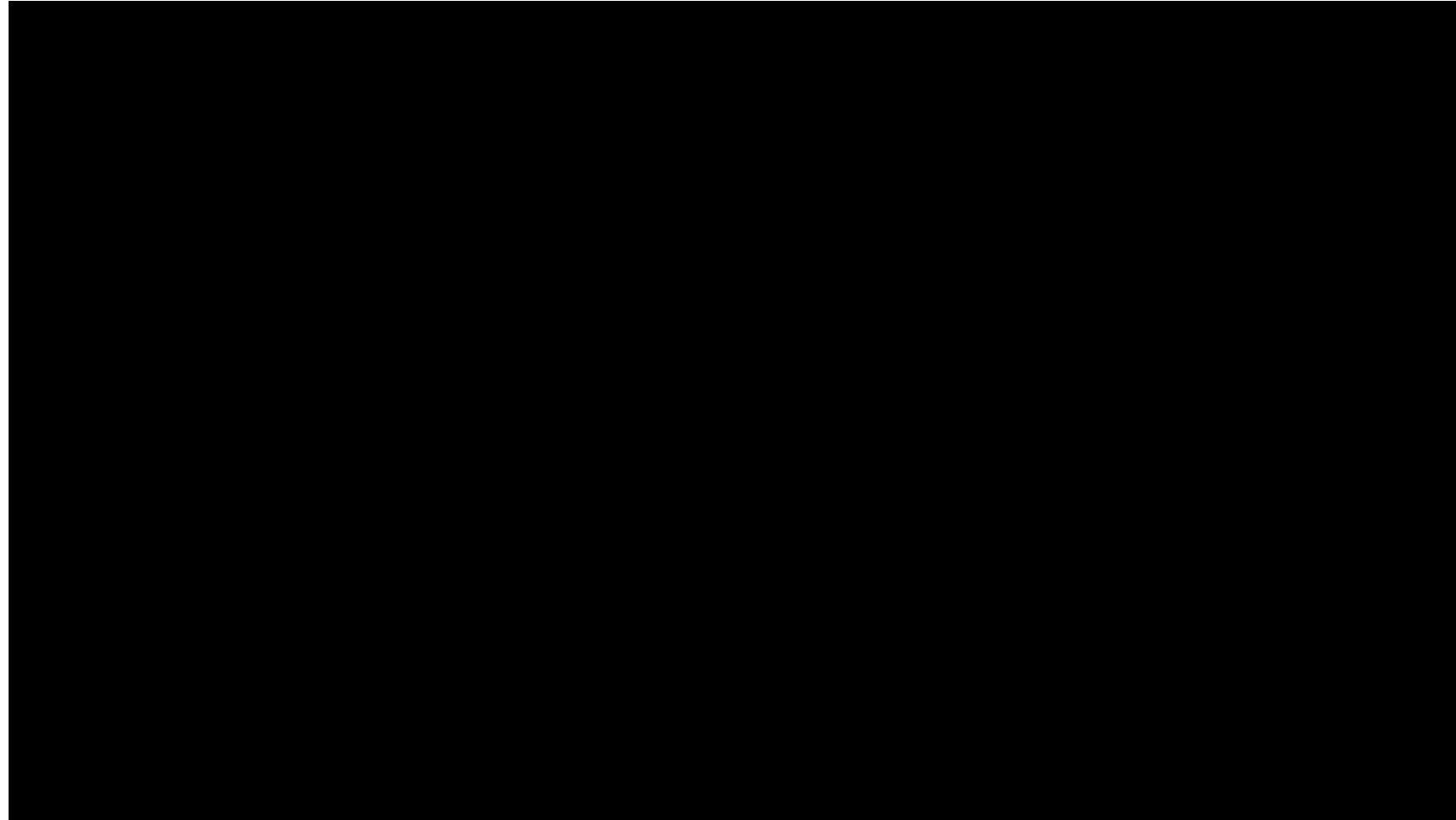


### Corning Carrier Solutions



## *Introducing Corning Advanced Packaging Carriers*

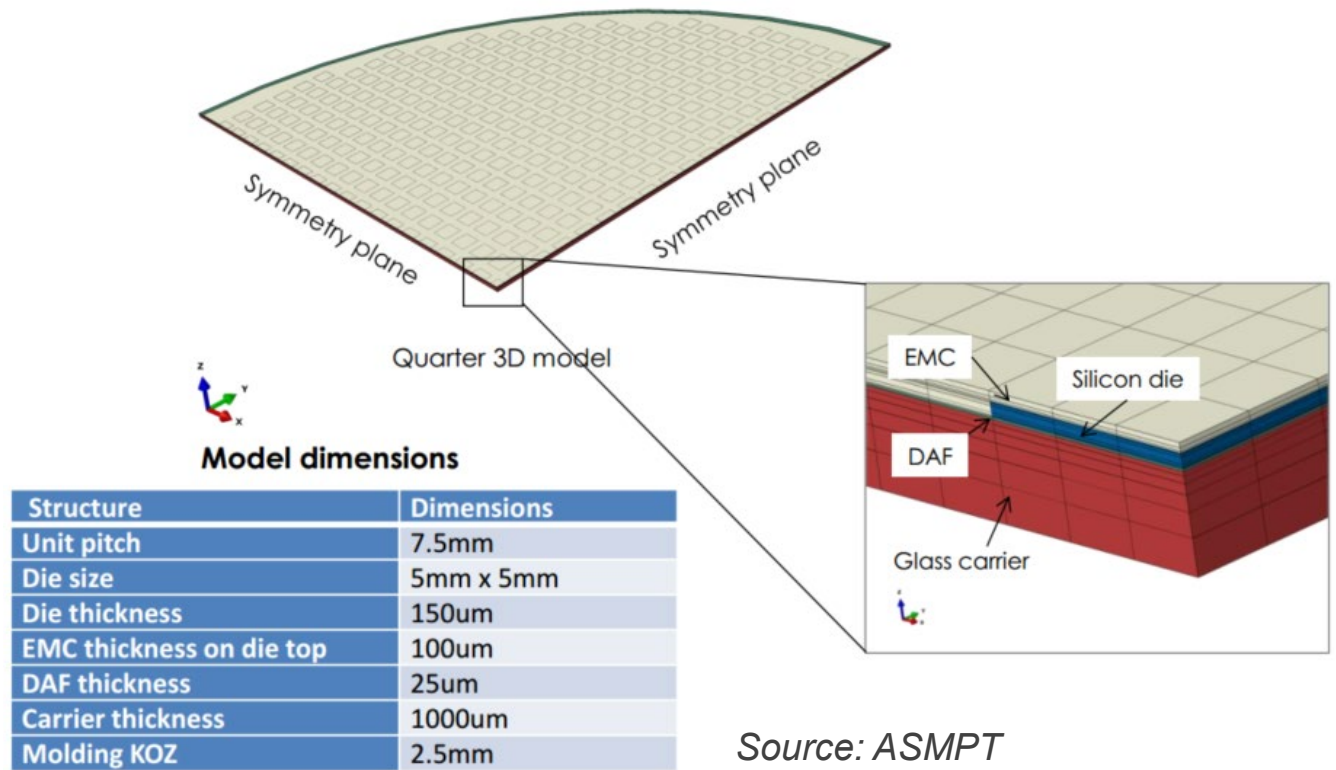
# Demonstration of high stiffness in Corning's carriers



Watch this video at: <http://www.corning.com/worldwide/en/products/advanced-optics/product-materials/PrecisionGlassSolutions/advanced-packaging-carriers.html>

# Introducing Corning Advanced Packaging Carriers

## Simulation results after PMC: Typical vs. Corning Advanced Packaging Carrier



**20% reduction in in-process warp**

Typical carrier



**Predicted warpage results after PMC**

	Simulated
Max. warpage (mm)	1.08
Warpage type	'smile'

Corning Advanced Packaging Carrier

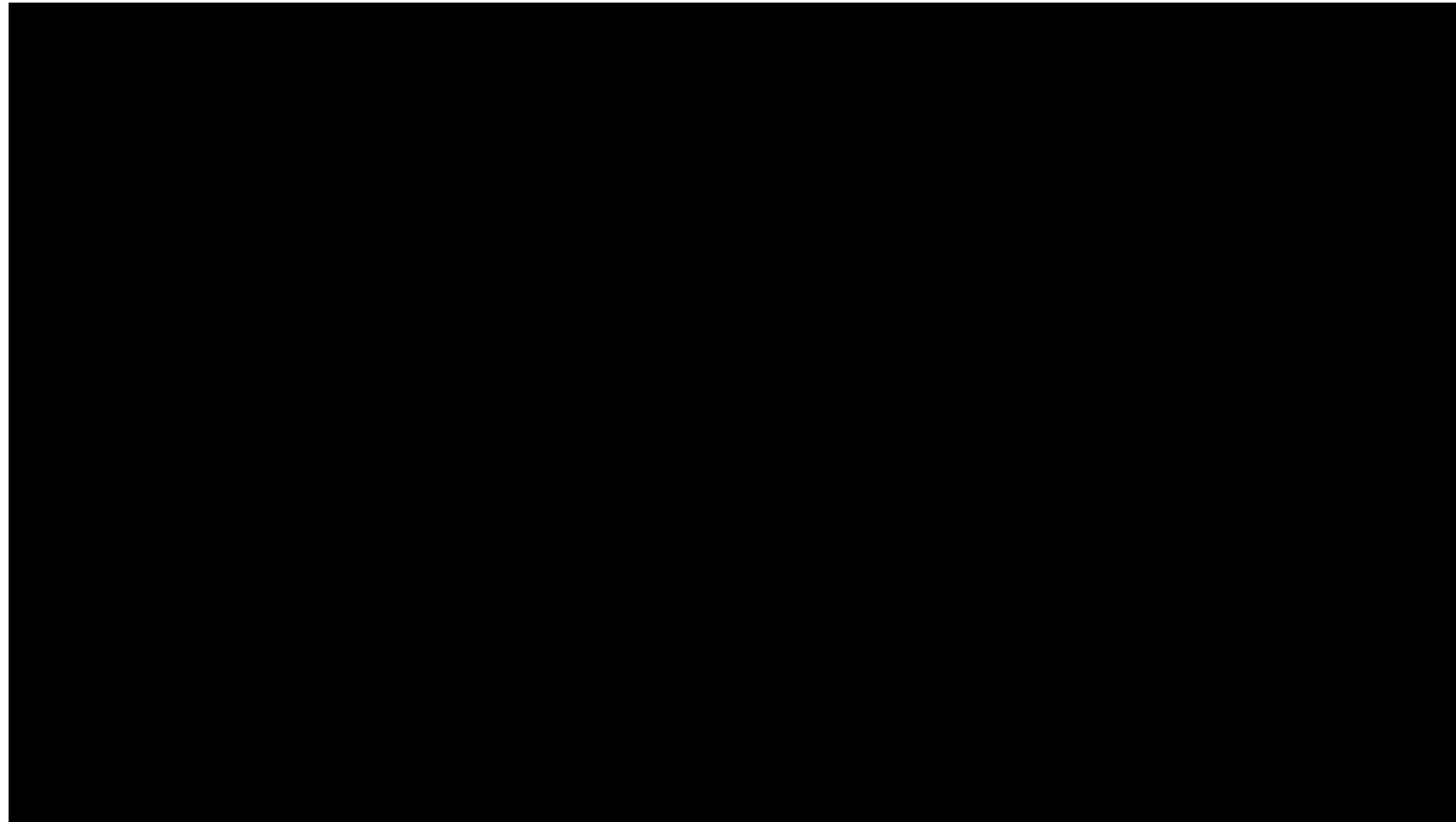


**Predicted warpage results after PMC**

	Simulated
Max. warpage (mm)	0.85
Warpage type	'smile'

## *Introducing Corning Advanced Packaging Carriers*

# Demonstration of the impact of in-process warp on chucking



Watch this video at: <http://www.corning.com/worldwide/en/products/advanced-optics/product-materials/PrecisionGlassSolutions/advanced-packaging-carriers.html>

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# Introducing Corning Advanced Packaging Carriers

Combining core strengths to support fan-out industry requirements

Glass science expertise



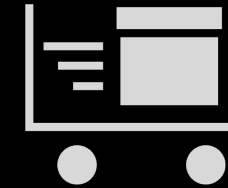
Agile Manufacturing Platform



*Understand material requirements*



*Develop high YM glass in multiple CTEs*



*Deliver multiple CTE samples in 4-6 weeks*



*Supply high quantity of selected carrier*



Customer Stage →

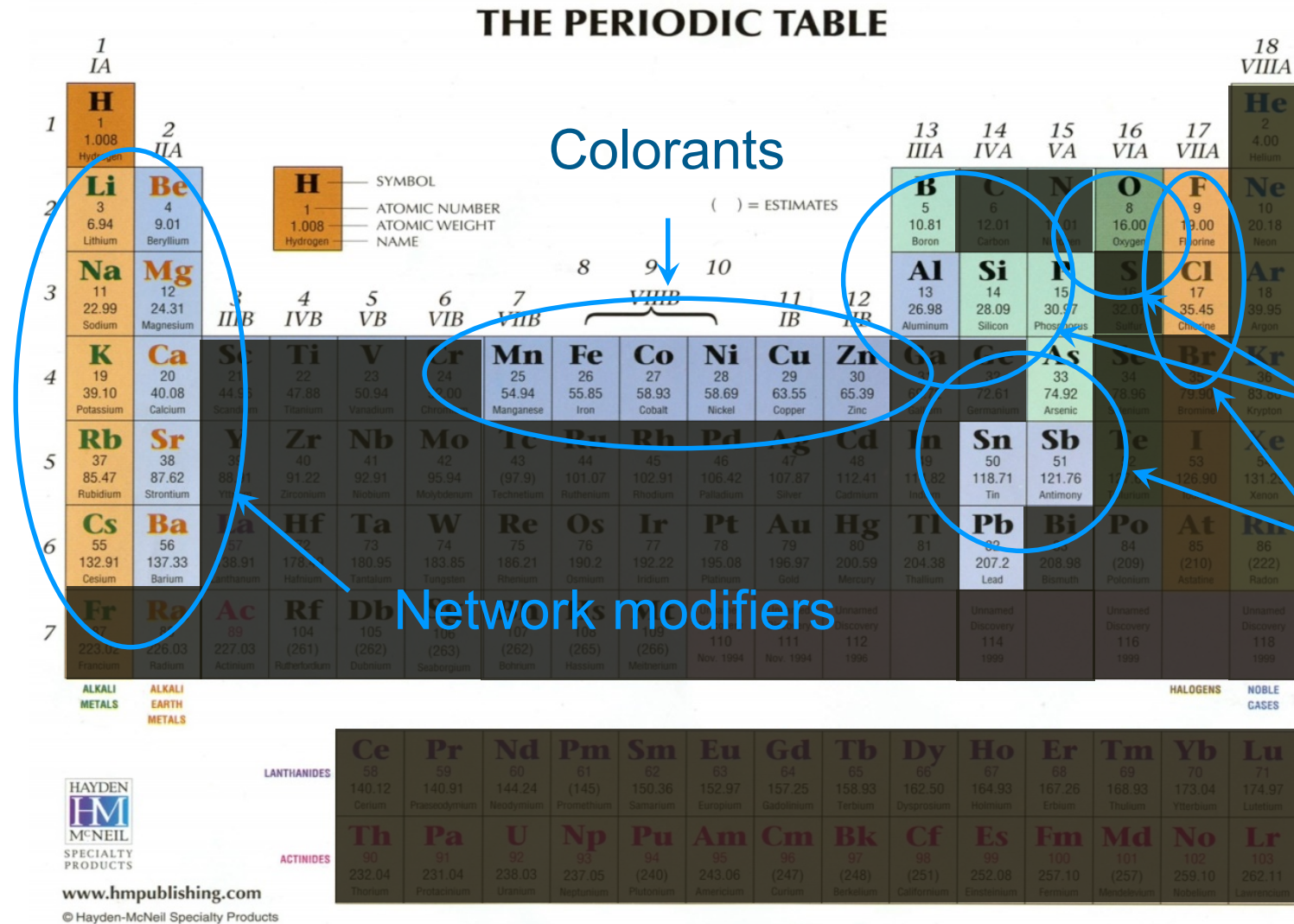
*Research & Development*

*Mass Production*

# These components determine the properties of glass for fan-out

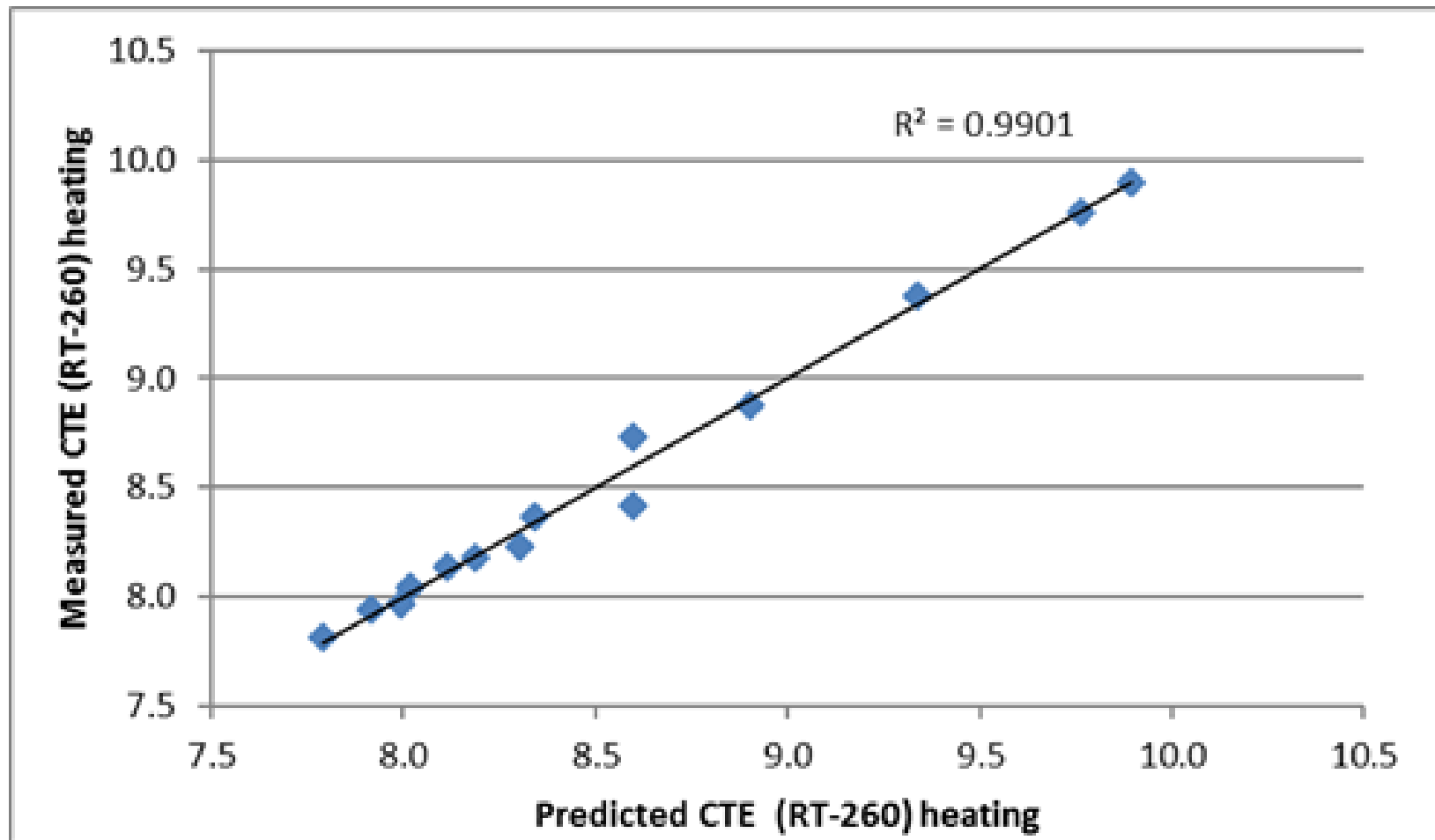
Component	Expansion	Modulus
SiO <sub>2</sub>	↓	↓
Al <sub>2</sub> O <sub>3</sub>	↓	↑
B <sub>2</sub> O <sub>3</sub>	↓	↓
Li <sub>2</sub> O	↑	↓
Na <sub>2</sub> O	↑	↓
K <sub>2</sub> O	↑	↓
MgO		↑
CaO		↑
TiO <sub>2</sub>		↑
ZrO <sub>2</sub>		↑

- Positive impact for FO
- Neutral impact for FO
- Negative impact for FO



## Corning glass science expertise

# Example of glass development for CTE range of 7.5-10 ppm/°C



- High accuracy of regression model designed for CTE space provides high confidence in predicted CTE based on glass composition
- We can control batch materials to hit CTE within +/- 0.1 ppm/°C



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Precision Glass  
Solutions

# Introducing Advanced Packaging Carriers

*Up to 40% reduction in customers' in-process warp*

Thank you! Contact me at  
[zhangjj@corning.com](mailto:zhangjj@corning.com) for more information

- ✓ Fine granularity of CTEs
- ✓ High stiffness
- ✓ 4-6 week sample lead time