Agile Manufacturing of Glass Carriers for Fan-Out

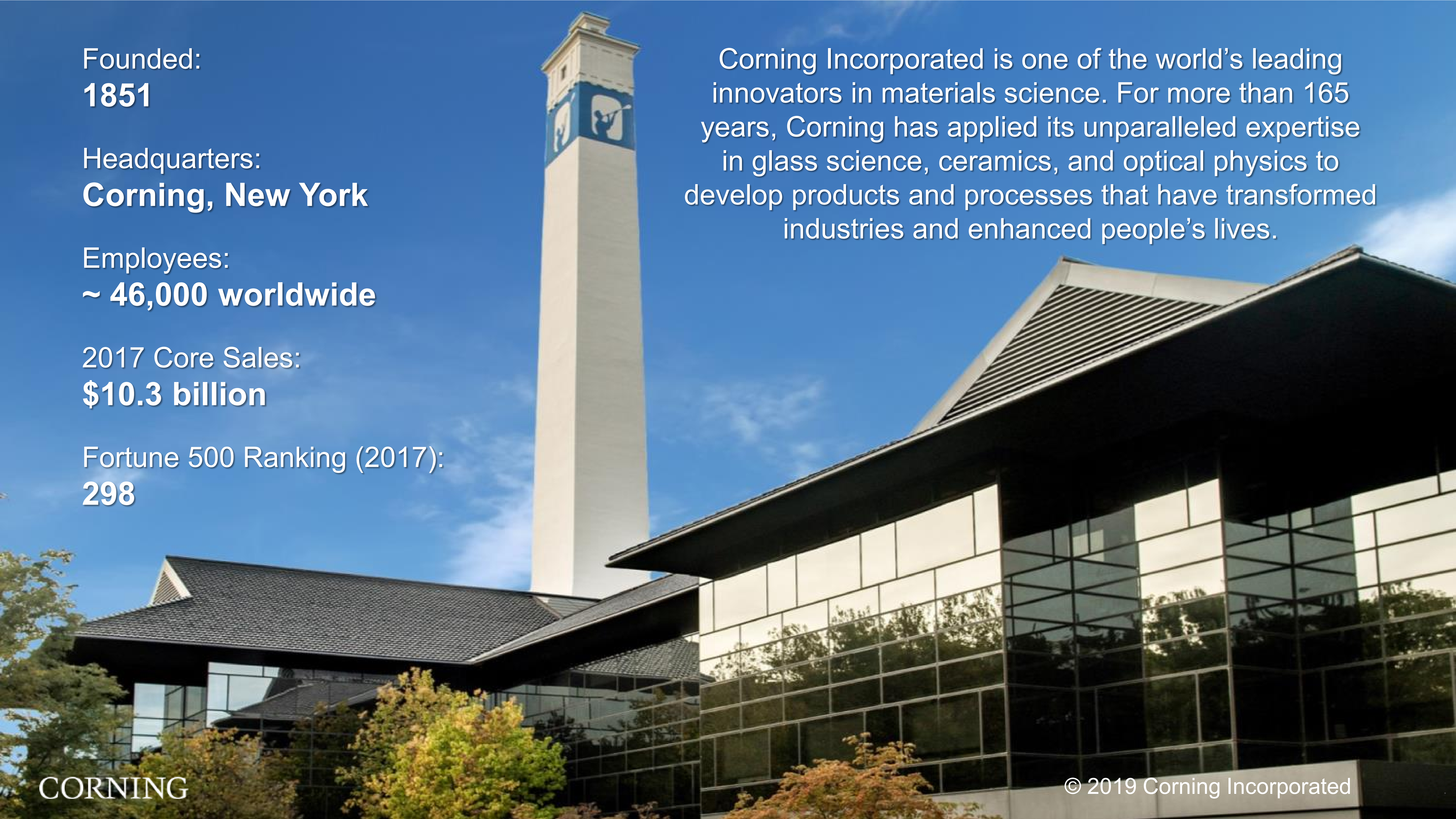
Dr. Jay Zhang

Business Development Director, Corning Precision Glass Solutions

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.

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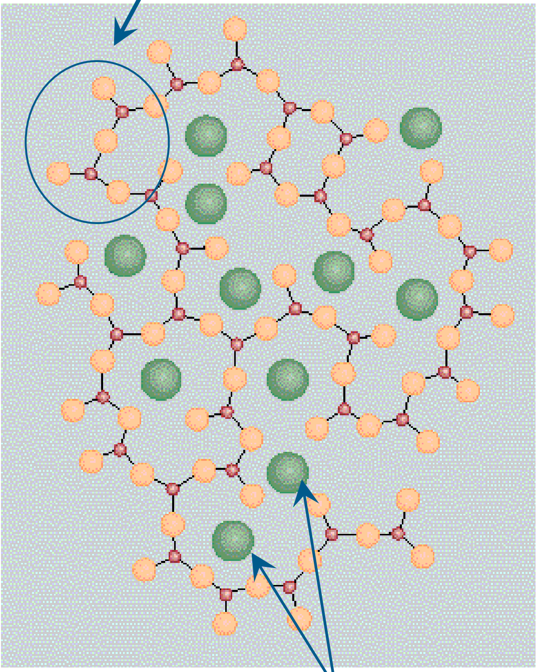
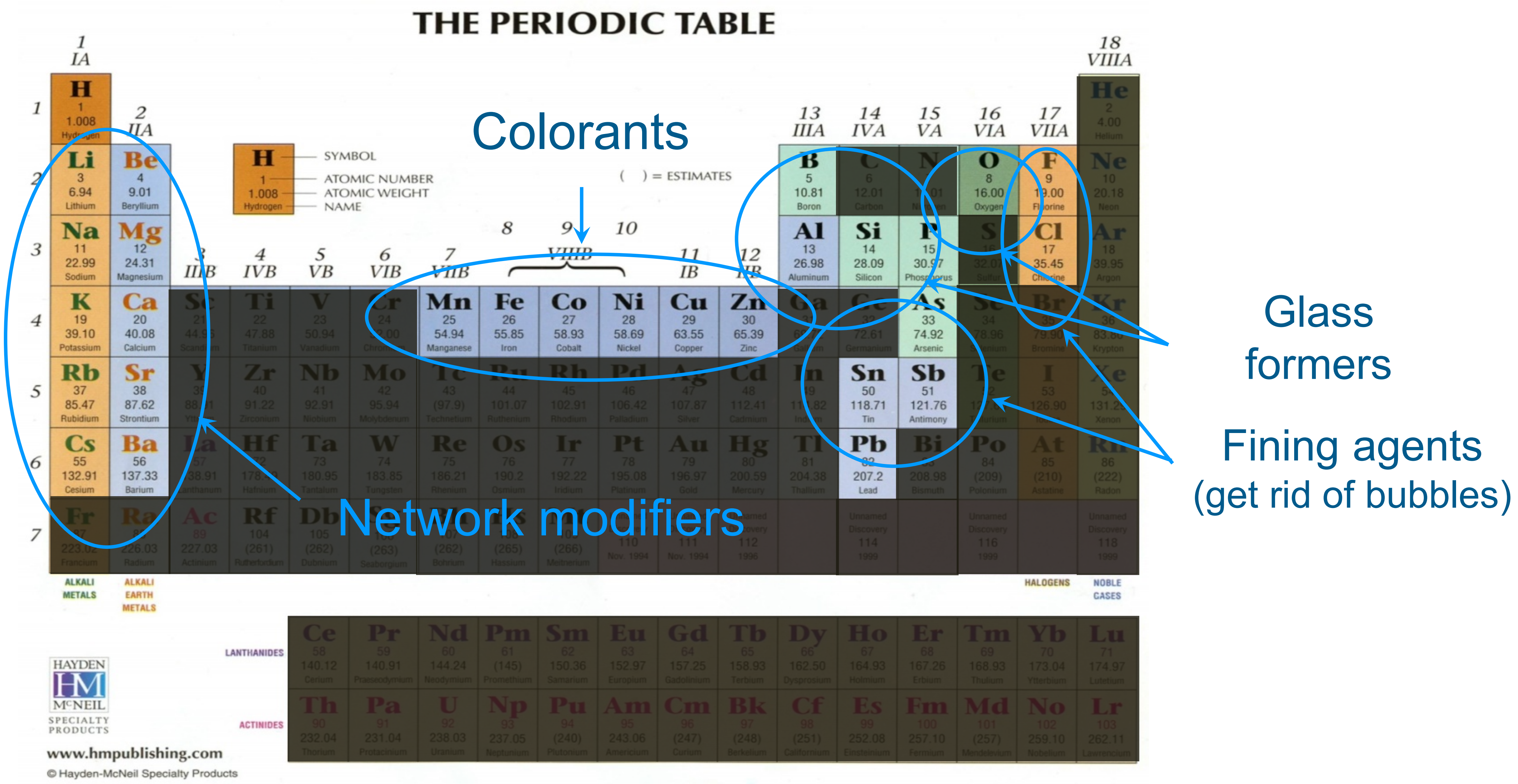
Introduction to Corning

We understand the Periodic Table of a glass scientist

'Backbone' or network formers



Network modifiers e.g. sodium or calcium



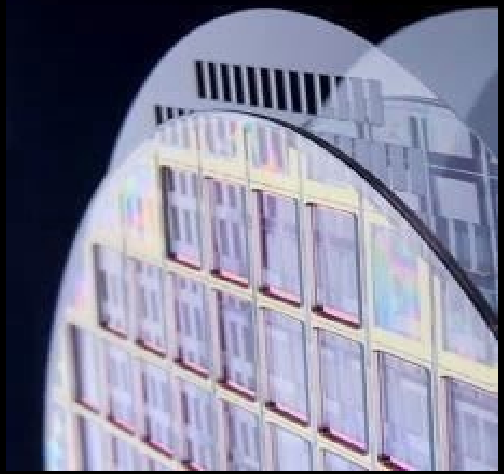
Corning Precision Glass Solutions offers industry leading wafer and panel format glass-based solutions.

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

Augmented Reality Solutions

Wafer-Level Optic Solutions

Wafer-Level Capping Solutions



Carrier Solutions

Custom Glass Solutions

*Through Glass Via Solutions**

**Development program*

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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:

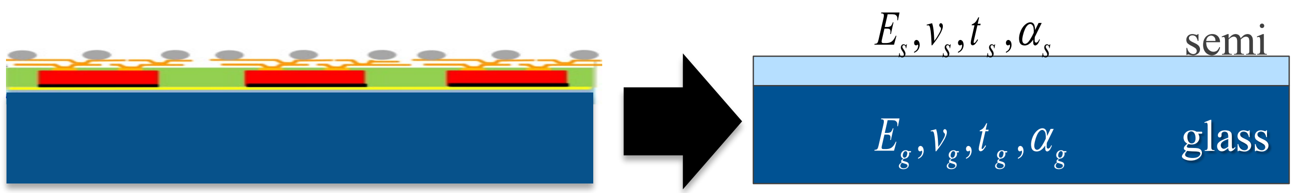
$$\kappa = \frac{6(\alpha_s - \alpha_g)(T_{\text{process}} - T_{\text{room}})(t_g + t_s)t_g t_s}{\left[\frac{E_g(1-v_s)}{E_s(1-v_g)}t_g^4 + \frac{E_s(1-v_g)}{E_g(1-v_s)}t_s^4 + 2t_g t_s\left(2t_g^2 + 3t_g t_s + 2t_s^2\right)\right]}$$

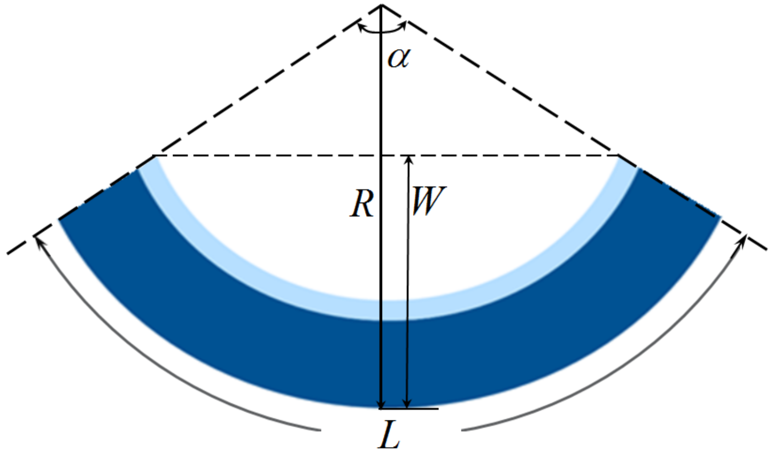
and the warp is:

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

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

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



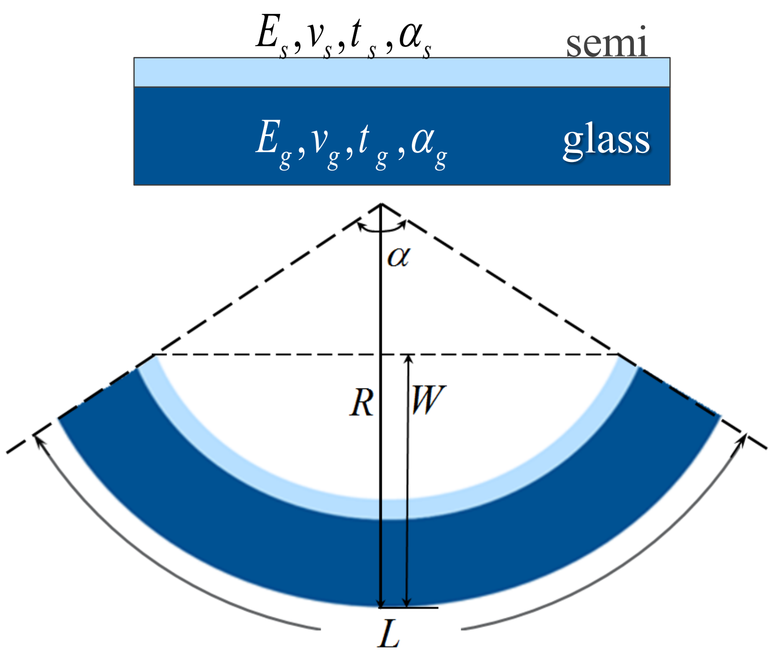


$R = 1/\kappa \qquad \alpha = L/R = \kappa L$

E : Young's modulus; v : Poisson's ratio; t: Glass thickness;
α : 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



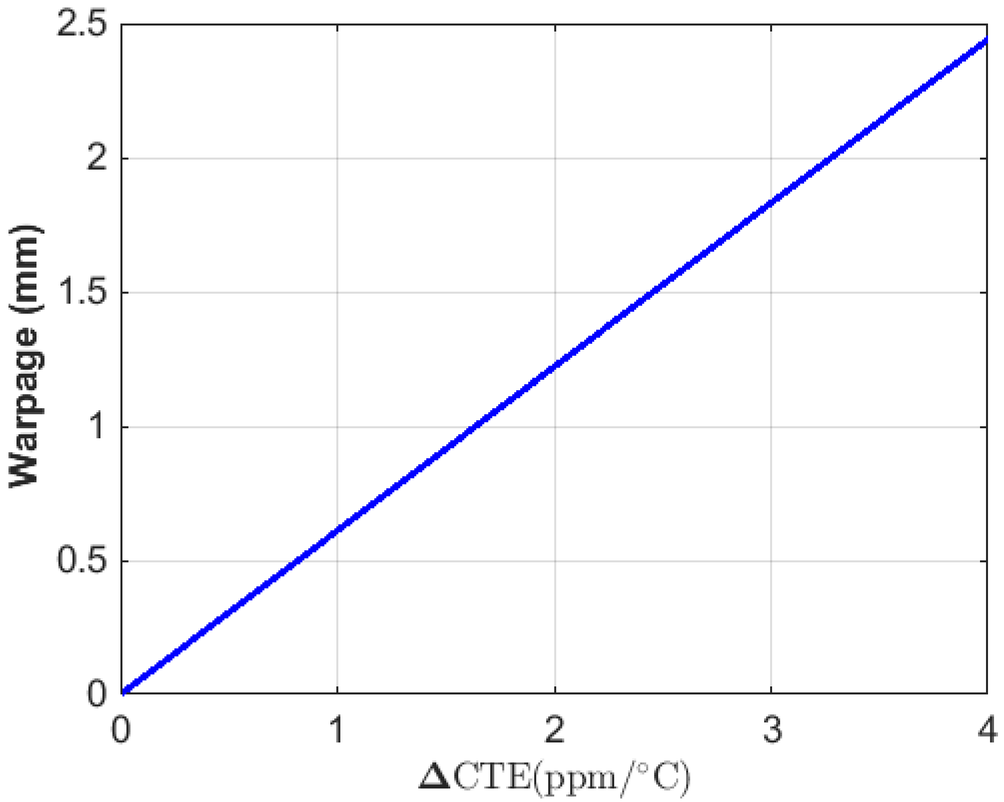
$$\approx 0.75 L^2 \Delta\alpha \, \Delta T \, \frac{E_s\left(1-v_g\right)}{E_g\left(1-v_s\right)} \frac{t_s}{t_g^2}$$

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

Levers to control in-process warp

Decreasing ΔCTE between carrier and semi



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

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

$$v_g = 0.22;\ v_s = 0.35;$$

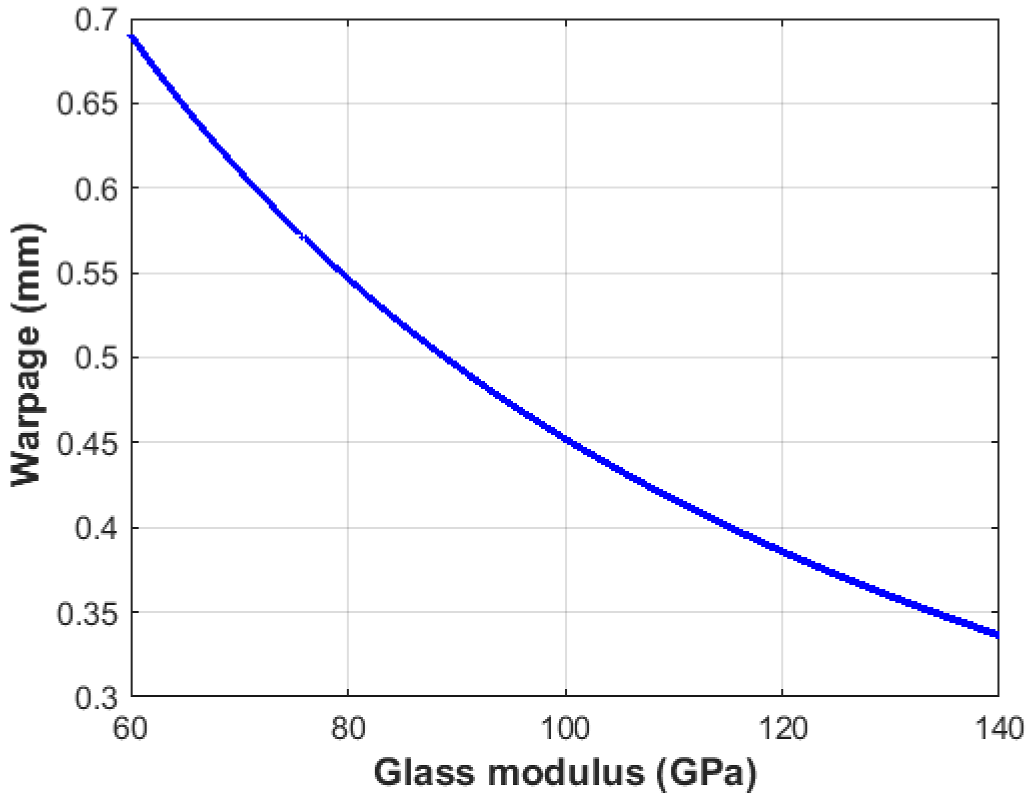
$$t_g = 1.1\text{mm};\ t_s = 0.15\text{mm};$$

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

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



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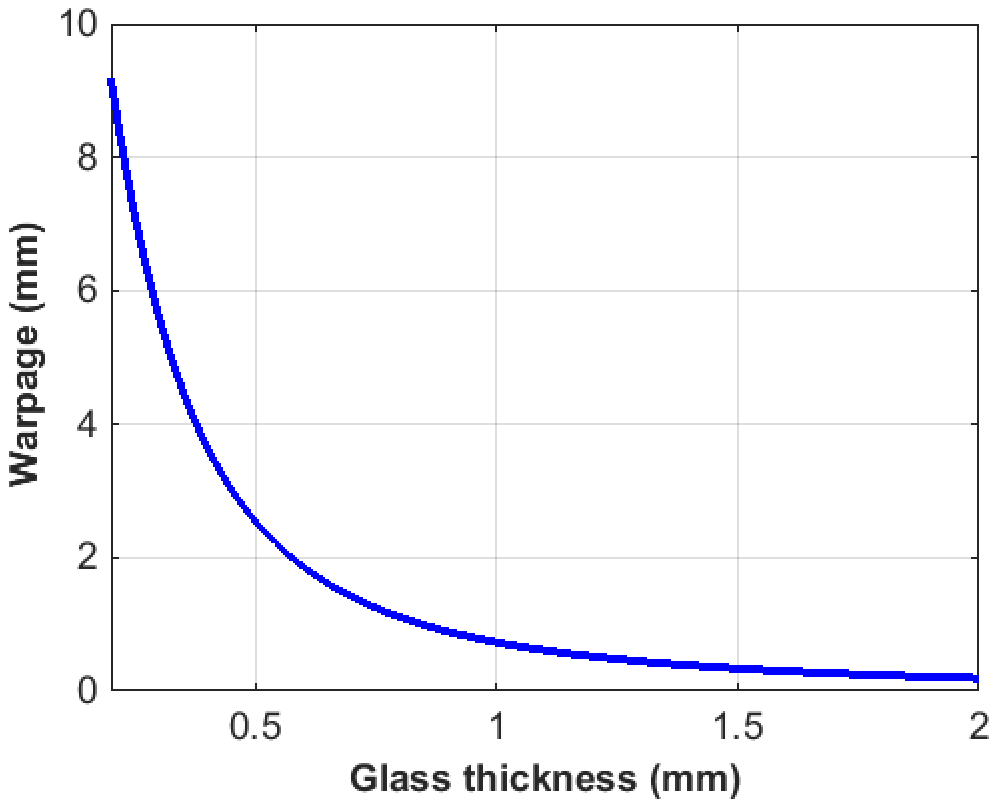
$$\Delta\text{CTE} = 1.0\text{ppm}/^\circ\text{C};$$
$$T_{room} = 20^\circ\text{C};\ T_{process} = 250^\circ\text{C};$$

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

Levers to control in-process warp

Increasing the thickness of the carrier



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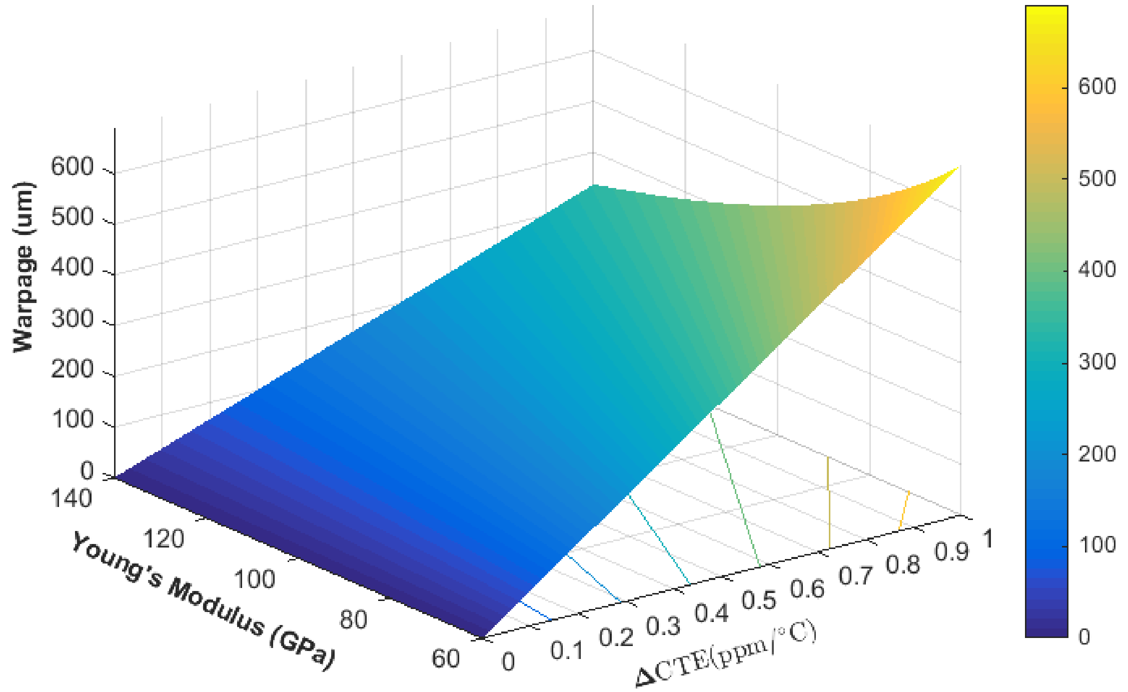
$$\Delta\text{CTE} = 1.0\text{ppm}/^\circ\text{C};$$

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

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

Levers to control in-process warp

ΔCTE is part of fan-out reality



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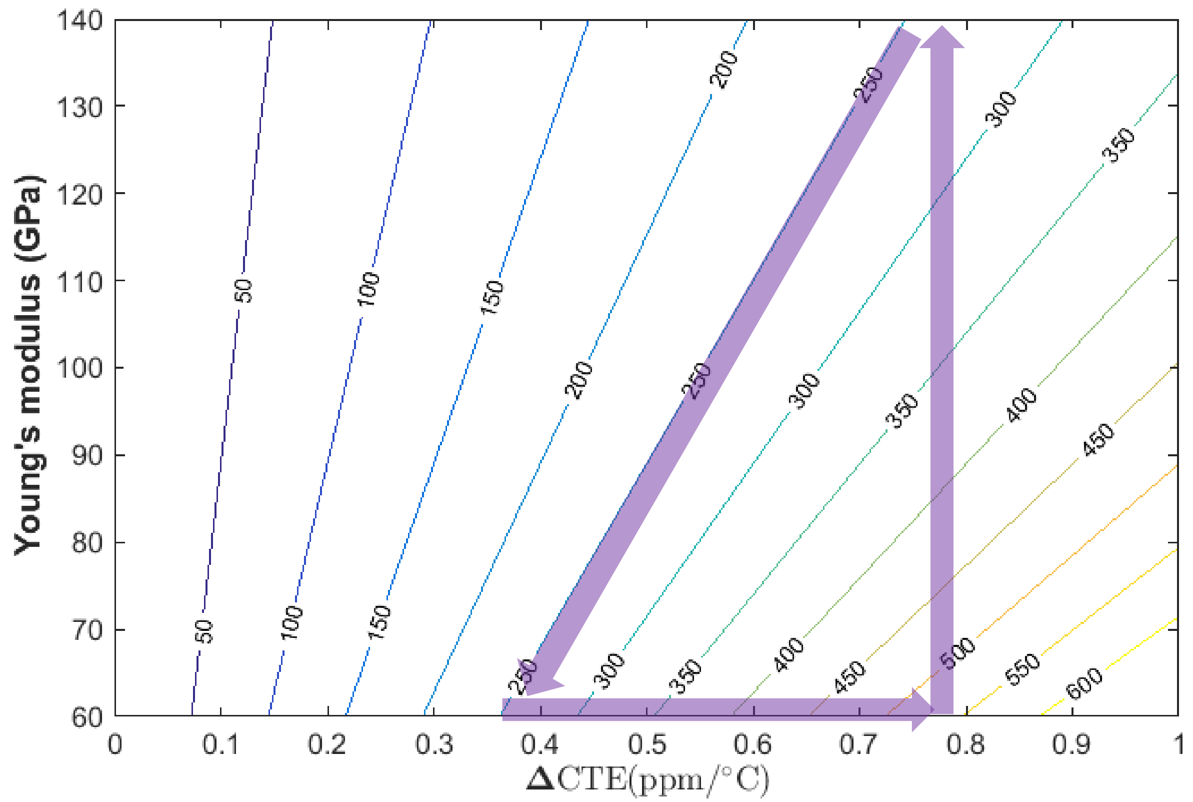

Higher Young's modulus helps overcome the ΔCTE mismatch challenge

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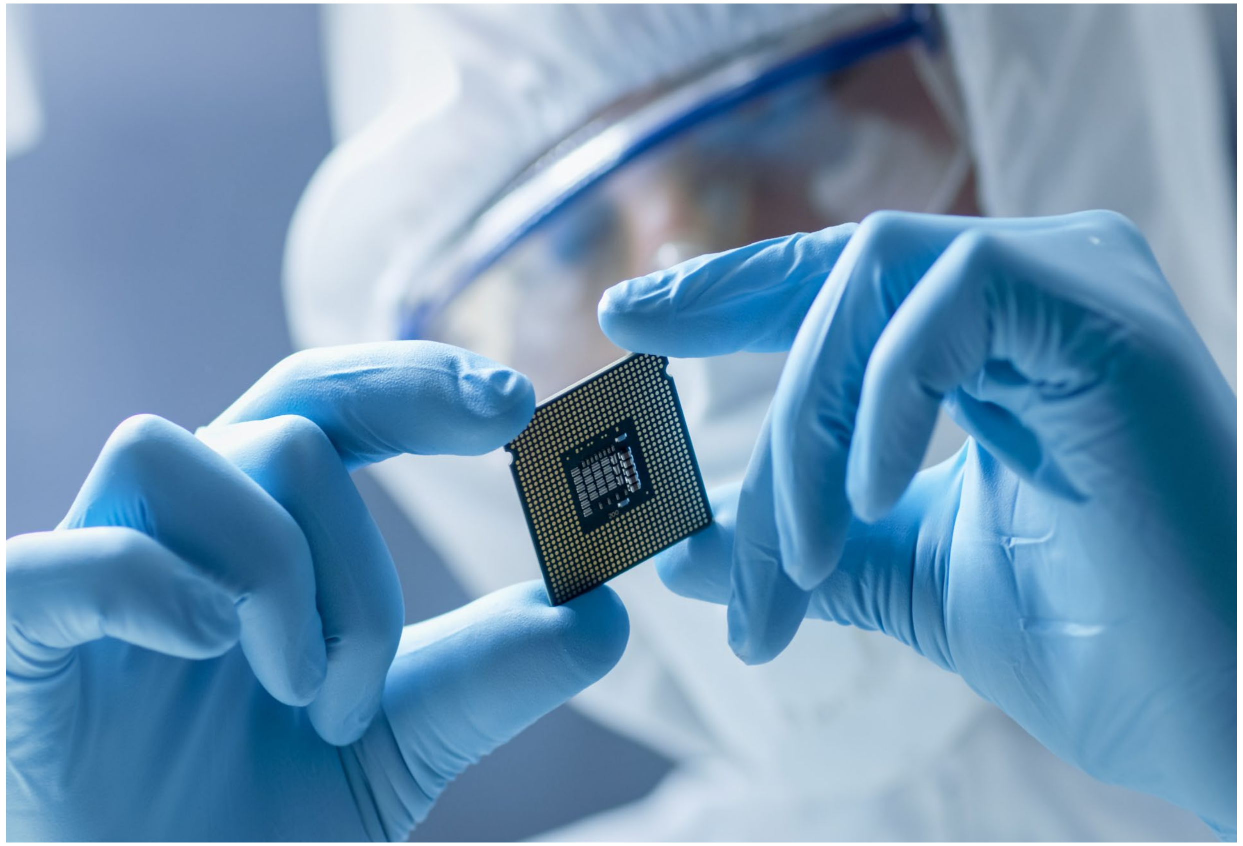
Real-world customer challenges

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**

Research & Development | *Mass Production (MP)*

Small volume test cycles	*CTE finalization*	
6-9 months	+3-4 months	>6 months

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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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

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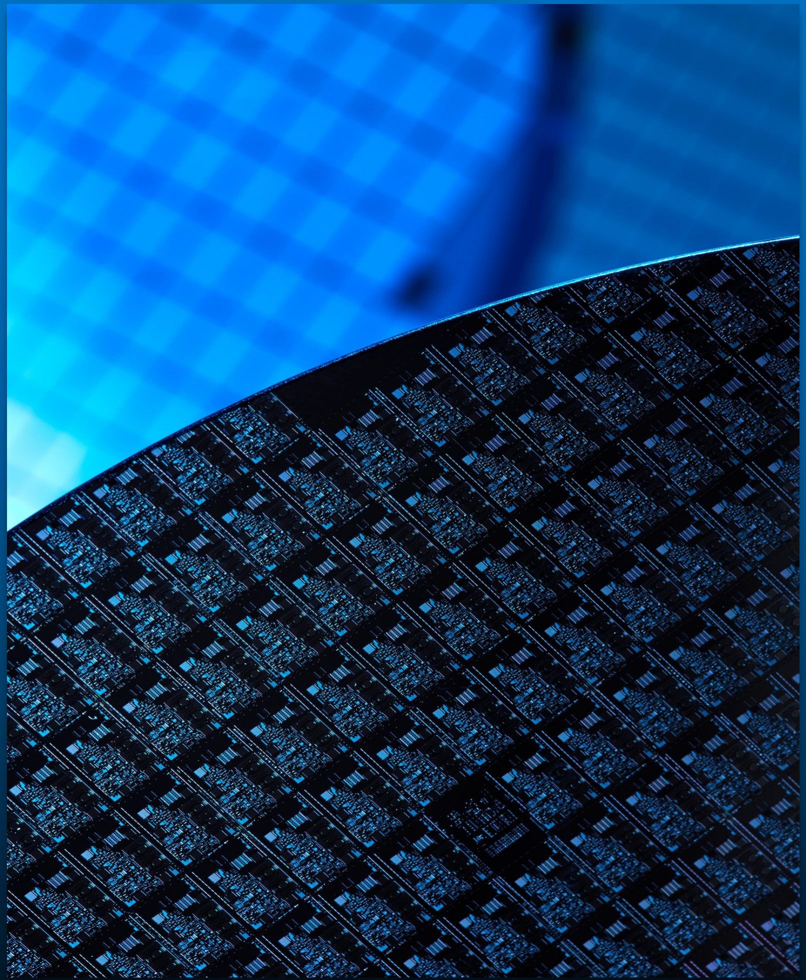
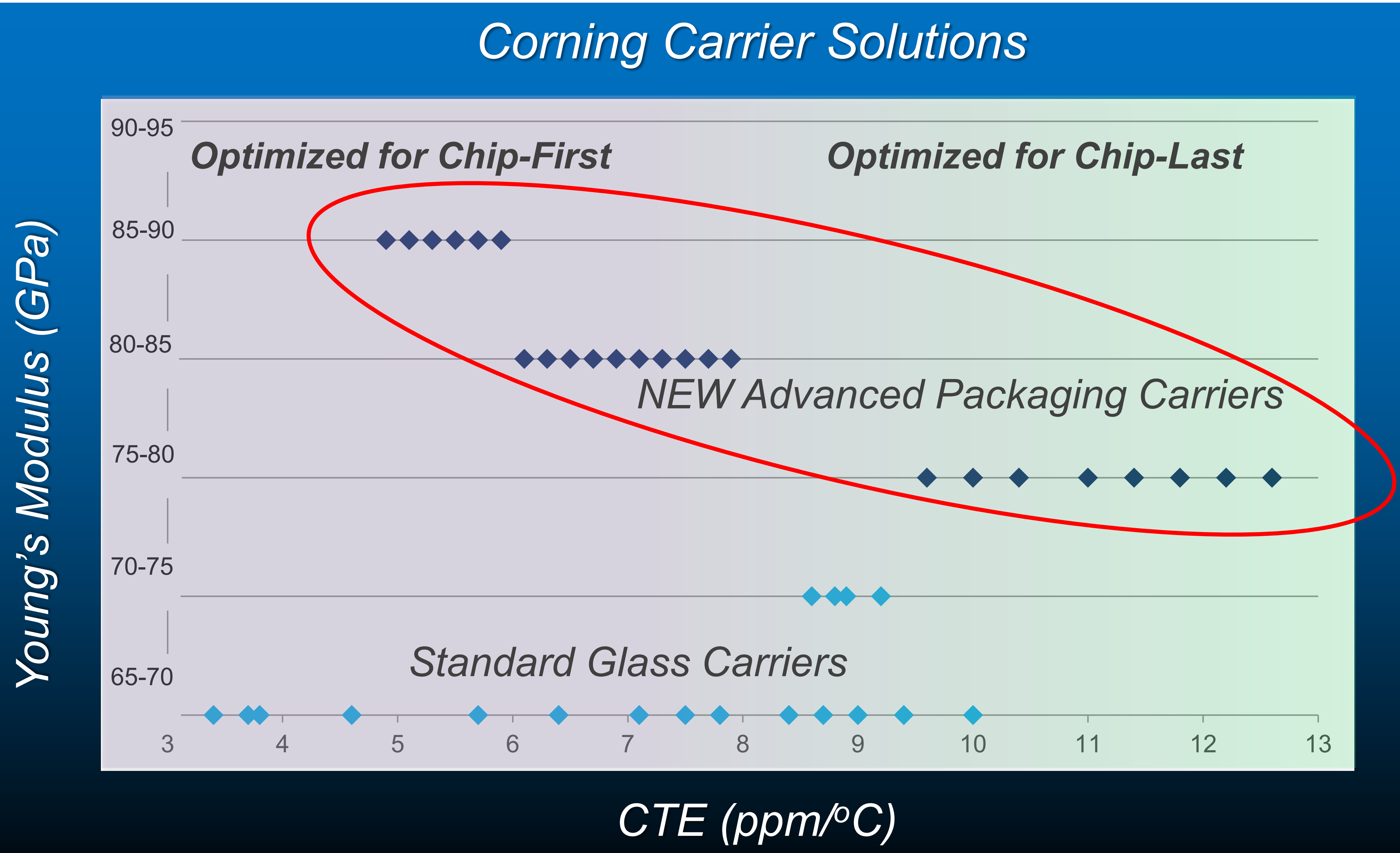
We've tailored our glass carriers by Young's Modulus and CTE to meet customers' requirements for advanced packaging



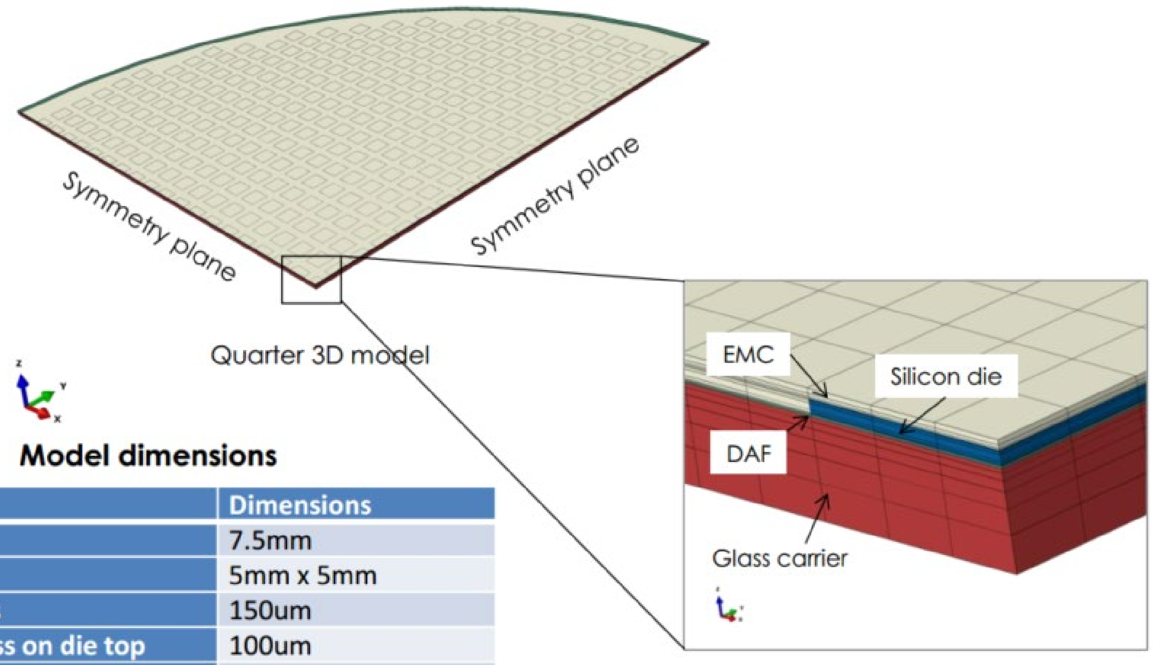


Demonstration of high stiffness in Corning’s carriers

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



Model dimensions

Structure	Dimensions
Unit pitch	7.5mm
Die size	5mm x 5mm
Die thickness	150um
EMC thickness on die top	100um
DAF thickness	25um
Carrier thickness	1000um
Molding KOZ	2.5mm

Source: ASMPT

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'

20% reduction in in-process warp

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

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Precision Glass Solutions

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*

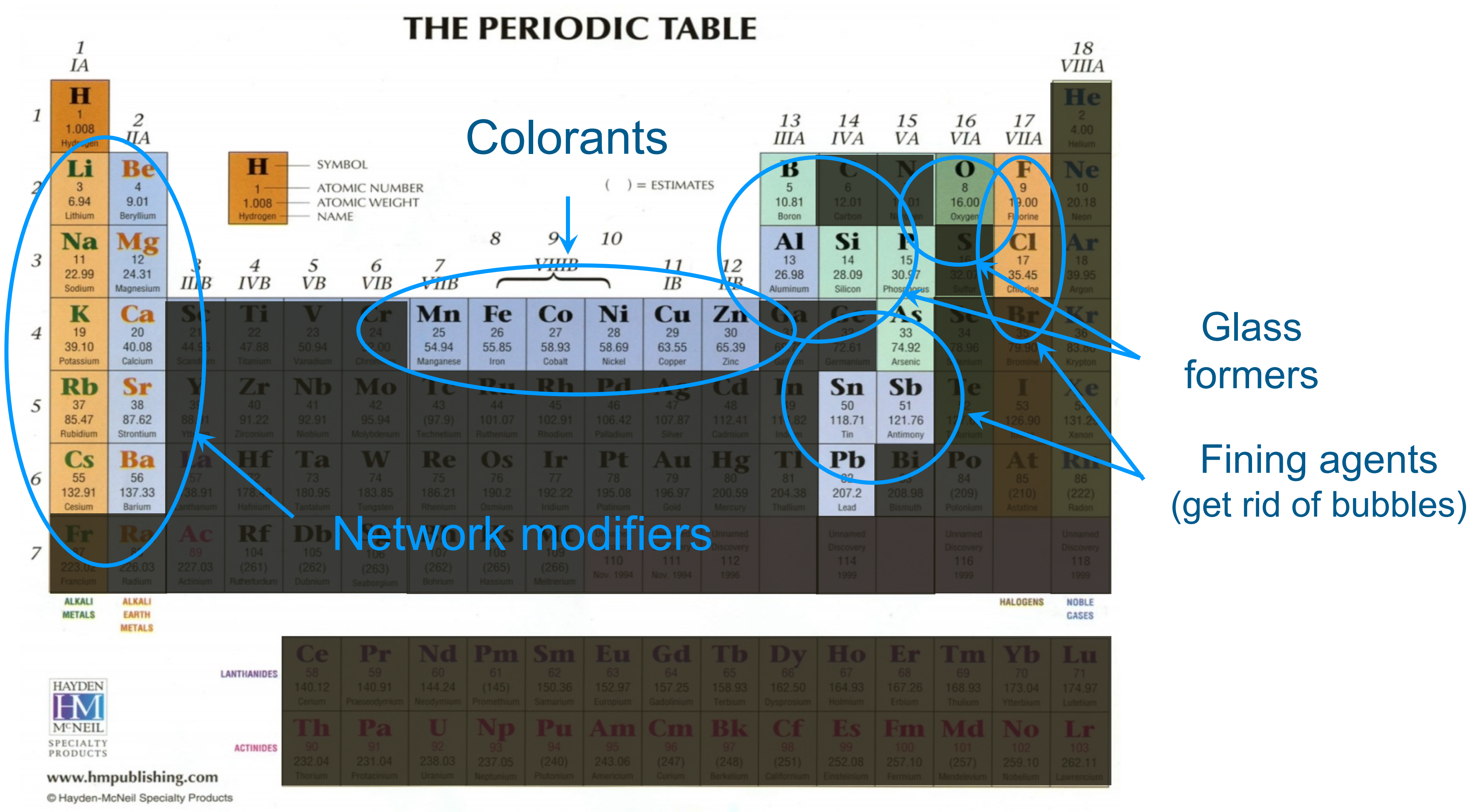
Customer Stage → *Research & Development* *Mass Production*

Corning glass science expertise

These components determine the properties of glass for fan-out

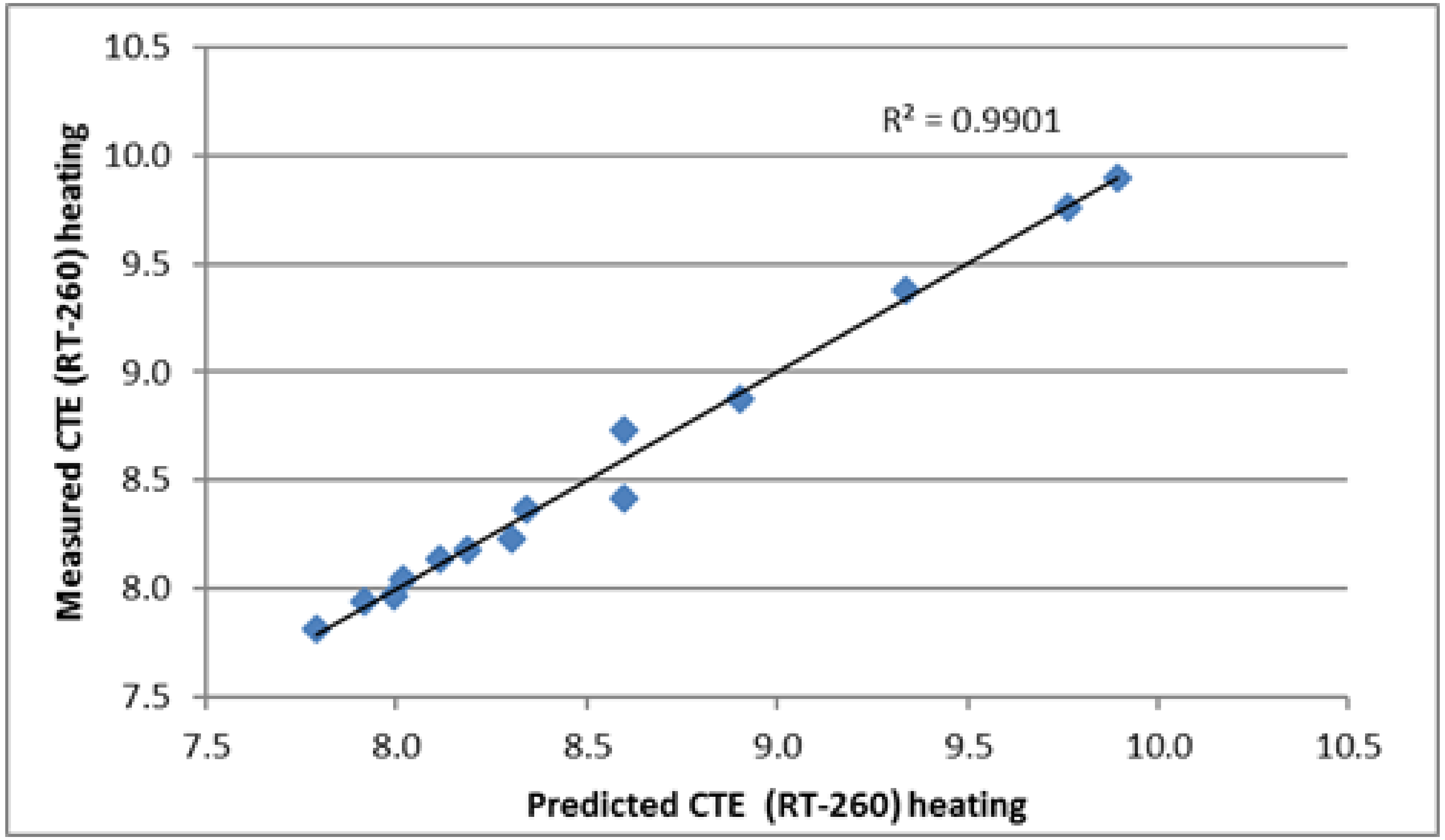
Component	Expansion	Modulus
SiO_2	↓ (yellow)	↓ (red)
Al_2O_3	↓ (yellow)	↑ (green)
B_2O_3	↓ (yellow)	↓ (red)
Li_2O	↑ (yellow)	↓ (red)
Na_2O	↑ (yellow)	↓ (red)
K_2O	↑ (yellow)	↓ (red)
MgO	(yellow)	↑ (green)
CaO	(yellow)	↑ (green)
TiO_2	(yellow)	↑ (green)
ZrO_2	(yellow)	↑ (green)

- Green: *Positive impact for FO*
- Yellow: *Neutral impact for FO*
- Red: *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

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- ✓ High stiffness
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Thank you! Contact me at zhangjj@corning.com for more information