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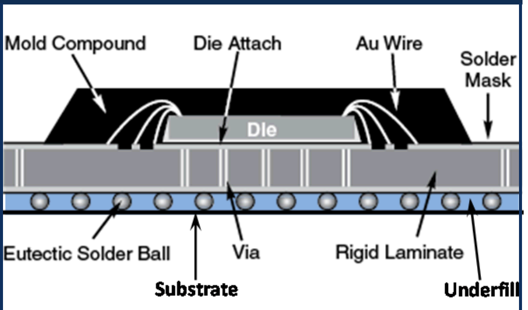

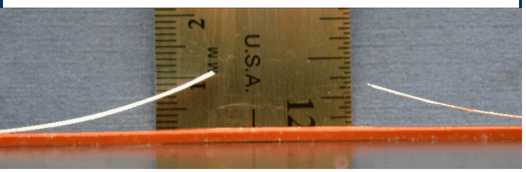

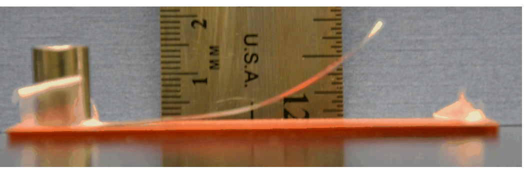

An Empirical Method for Assessing the Significance of Cure Shrinkage Stresses Generated in PBGA Underfills

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Exceptional service in the national interest

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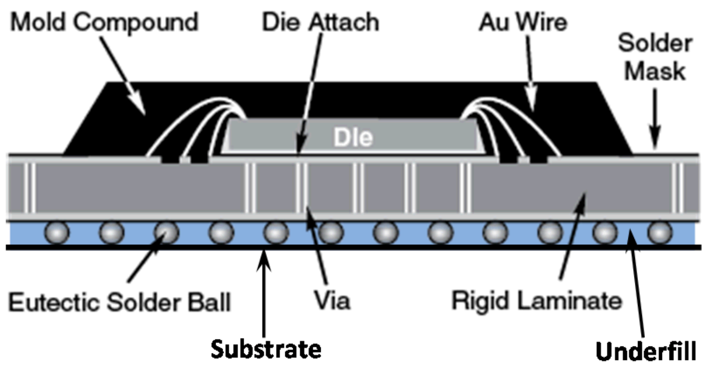
Introduction



After a PBGA (or other surface mount component) is attached to a circuit board, an adhesive underfill is often applied to improve lifetime performance

- Stronger mechanical connection
- Distributes thermal expansion mismatch preventing stress concentration in solder joints

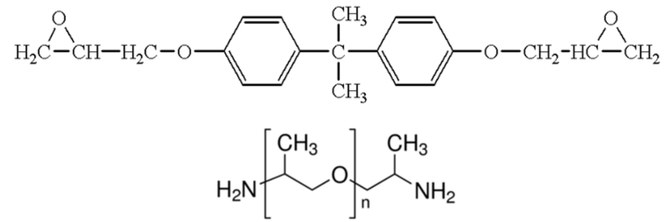
Underfill is applied on 1-2 sides and drawn beneath the package via capillary action

Highly confined geometry – cure shrinkage and stresses can become significant

- Excessive stress in underfill may lead to premature failure

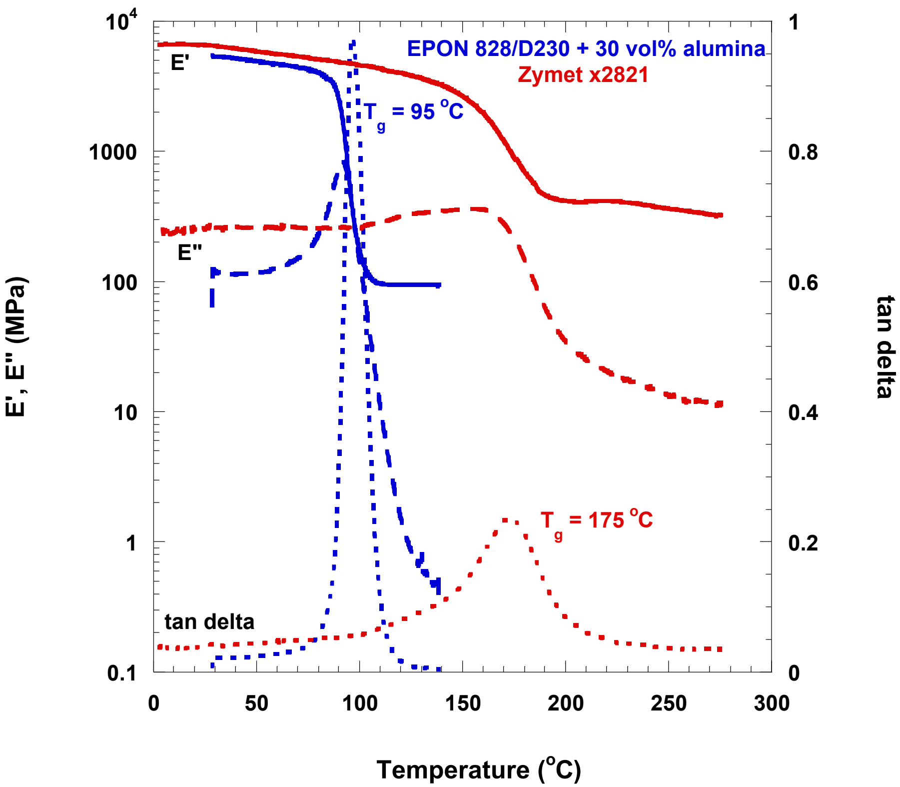
This study – needed a quick method of comparing *relative* behavior of two materials

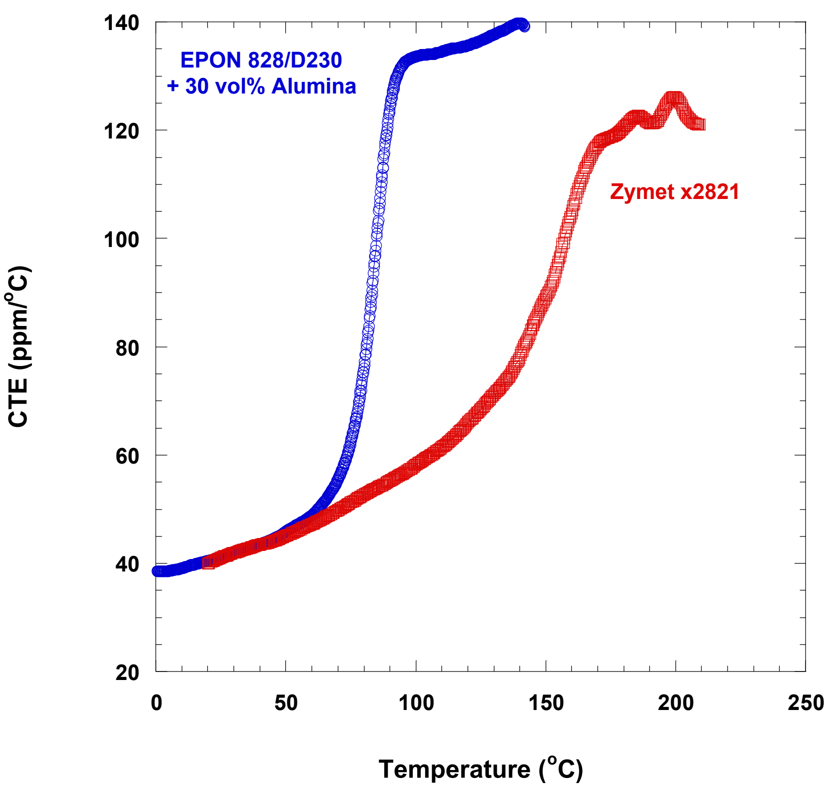
Materials of Interest



	Zymet X2821	EPON828 + Jeffamine D230 + 30vol% Alumina
Material	Commercial “snap-cure” underfill material	Sandia developed formulation
Cure	Recommended cure is 120 °C for 10 minutes	5 hour cure at 50 °C and 80 °C
Advantages	Very short cure time – good for production Low room temperature viscosity Long pot life/working time Commercially available - convenient	Mild cure temperature Known constituents Potential to obtain premixed/frozen Suitable working time
Disadvantages	High cure temperature Fast, highly exothermic reaction Unknown constituents	Much longer cure time Higher room temperature viscosity Must be mixed in house

Thermal and Mechanical Properties

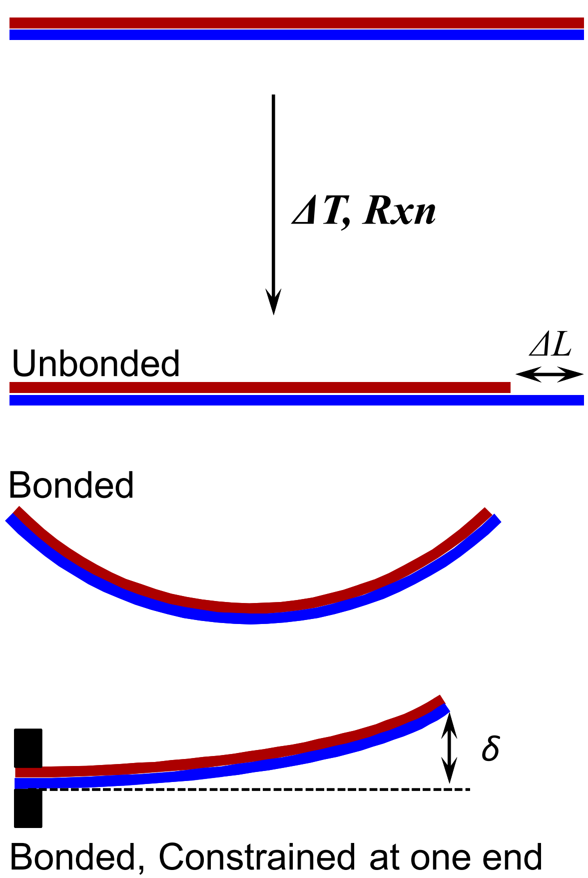




- Comparable moduli in glassy regime
- Zymet rubbery modulus is significantly higher
- Tg difference is about 80 °C

- CTE for temperatures < 50 °C are comparable
- Zymet has lower rubbery CTE
- Use temperature range is likely in the glassy regime for both materials

Bi-material Strip



Bi-material strip composed of a laminate of two dissimilar materials

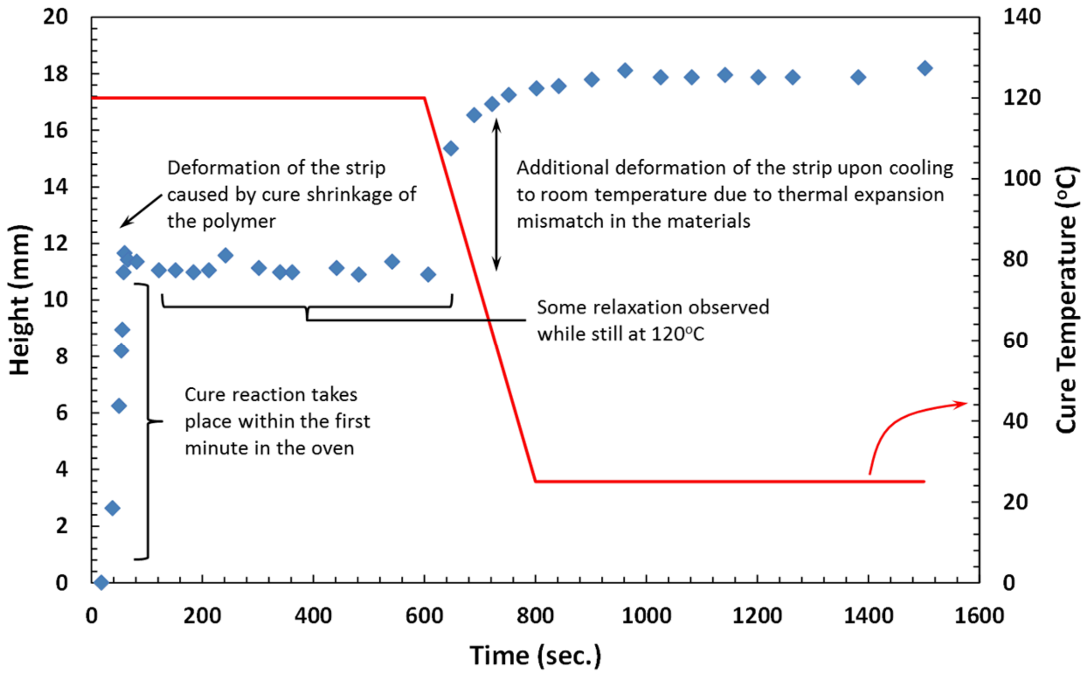
If not bonded, materials are free to contract independent of one another

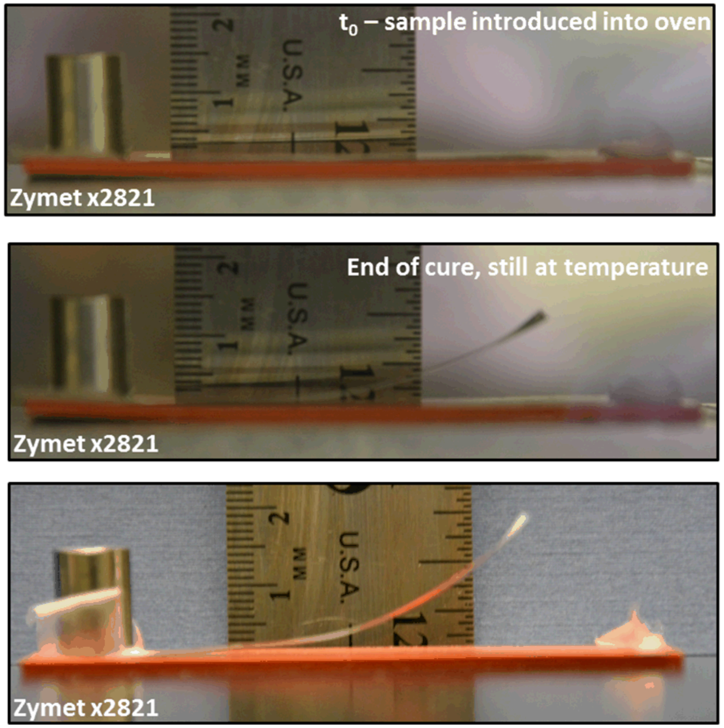
If bonded, curvature results from one material contracting (or expanding) more than the other material

Constraining one end allows measurement of deflection at the other end

Application of beam theory allows calculation of a stress

Zymet Material





Zymet snap cures within the first 60 seconds in the 120 °C oven, accompanied by strip deformation

While at 120 °C, some relaxation may occur

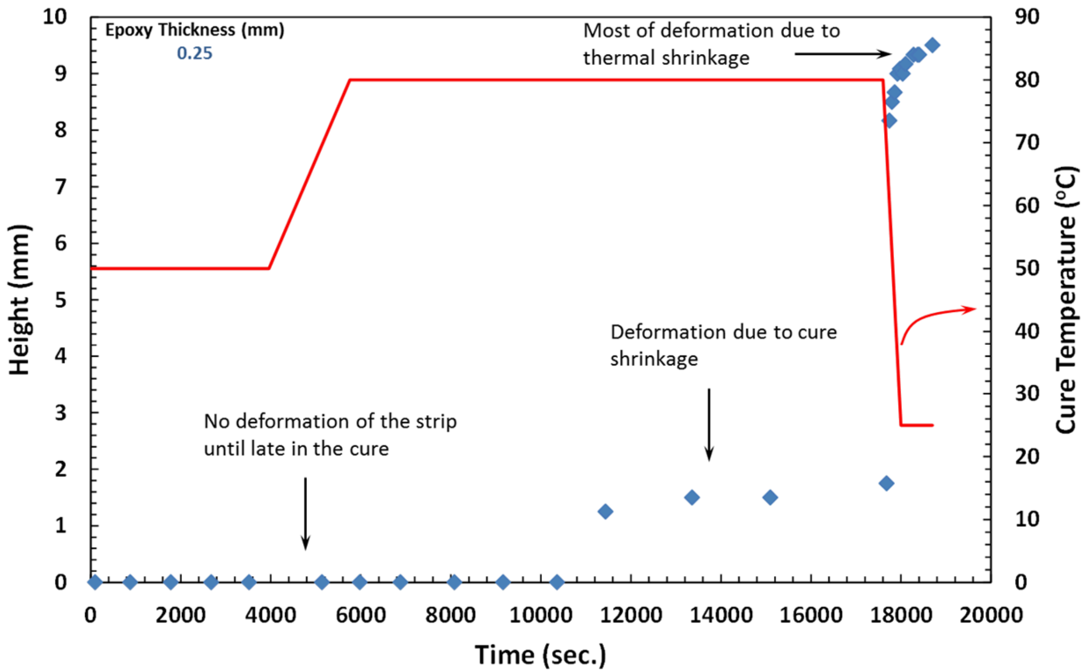
Sample then removed from oven (after 10 minute) and allowed to cool to room temperature

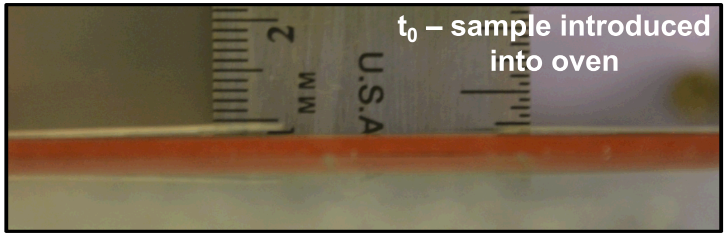
- This thermal change is accompanied by further beam deformation due to thermal expansion mismatch

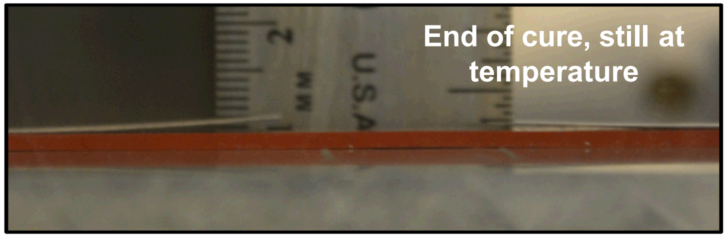
More than half of total deformation occurs during cure

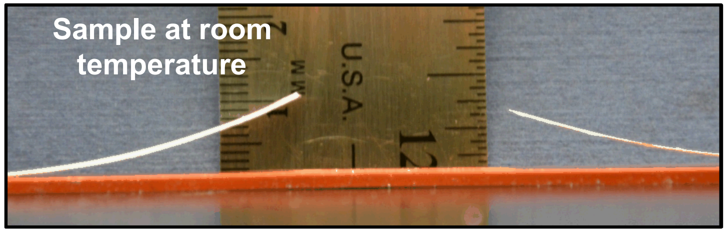
Able to clearly distinguish between deformation during cure and cool down

EPON828/D230 + Alumina









Two-stage cure, 50°C followed by 80°C

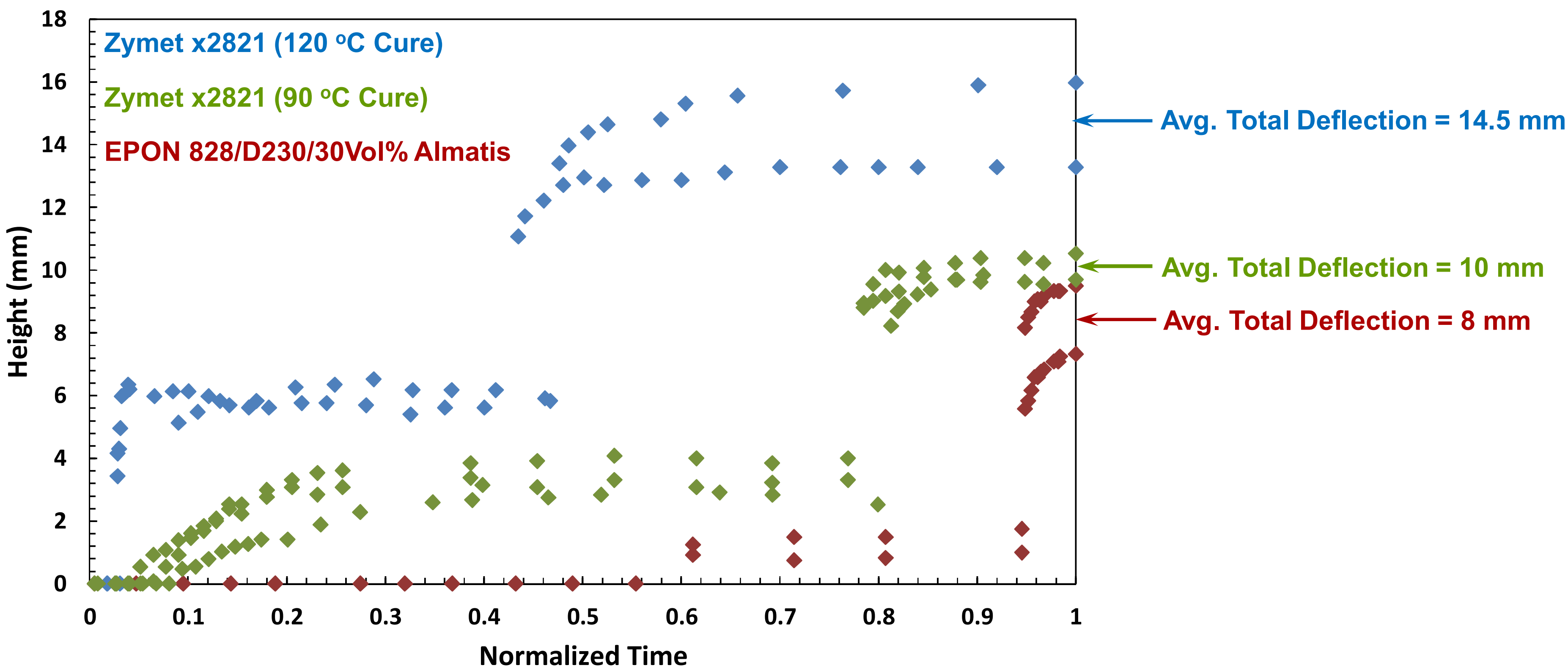
No significant deformation observed until late in the cure cycle

Thermal expansion mismatch results in addition significant curvature as sample cools to room temp

Most of the cure occurs while the epoxy is in the rubbery state

Deformation during cure only accounts for about 20% of total deformation

Results Comparison



Decreasing cure temperature for Zymet from 120 °C to 90 °C results in a milder cure and lower total beam deflection

At 90 °C, cure is not complete (missing some cure shrinkage) and more of the cure likely takes place in the rubber (vitrifies later)

828/D230/30 Vol% Almatis material shows the lowest amount of total beam deflection

Deflection during cure drastically lower than for Zymet

Majority of cure occurs in the rubber

Remaining Questions

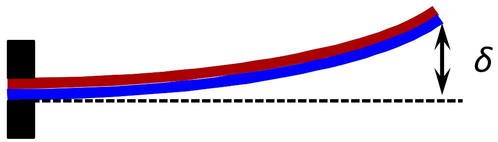
This method gives a convenient way to measure *relative* differences

Not yet quantitative in terms of stress – HOW TO QUANTIFY?

- Quantification of stress would allow better performance predictions
- Beam theory may give an estimate, but not entirely accurate
- Modulus evolves during cure

Can we determine stress-free temperature? Then calculate stress

- Ensure the substrate is only elastically deformed (no yielding)
- Yield in the substrate will make a determination impossible



Summary

- Empirical test was used to compare *relative* cure and thermal shrinkage between two underfill materials
- Able to distinguish between cure and thermal effects for each
- Zymet (snap cure) material shows more beam deformation both during cure and during cooling
  - Higher cure temperature
- EPON 828/D230 material showed a much milder response to cure
- Good start, but method is qualitative only. Would like to extend to be more quantitative
  - Actual stress values?
  - Stree-free temperature? How different from cure temperature?

Questions/Suggestions?