Measurement of Epoxy Molding Compound Properties for The Prediction of the Warpage Using FBG

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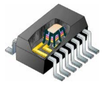
LOMSS

Sponsor: calce

What is Warpage?



- **Warpage** is the deviation from uniform flatness of a package; It can cause potential failure of the package, especially during solder reflow process at which the package is exposed to very high temperature (>240 °C)

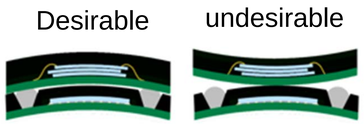


Figure 1. Schematic illustration of a warpage in PoP component

- Warpage of the package is induced during the manufacturing is attributed to following two process;

(1) Curing of the polymer (shrinkage of the polymer)

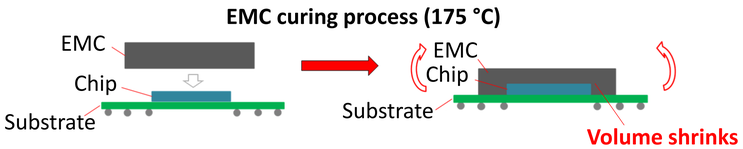


Figure 2. Schematic illustration of the warpage induced by the curing process of EMC

(2) Temperature change (CTE mismatch)

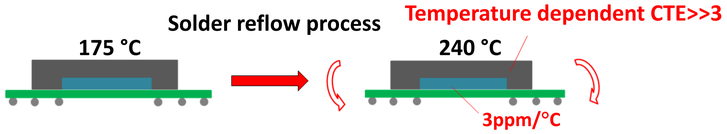


Figure 3. Schematic illustration of the warpage induced by temperature excursion during solder reflow process

- Warpage worsens as package thickness reduced and the package thickness is getting thinner and thinner.

Objectives

- To develop an experimental procedure to measure the polymer properties for the prediction of the warpage in electronic packages accurately.
- Properties required for modeling:
  - (1) Curing process : effective chemical shrinkage and equilibrium modulus
  - (2) Temperature excursion : temperature dependent CTE and viscoelastic properties

Approach

- **Fiber Bragg Grating (FBG**) is embedded in the center of the polymer. It deforms together with the polymer during the curing process and works as a strain sensor.

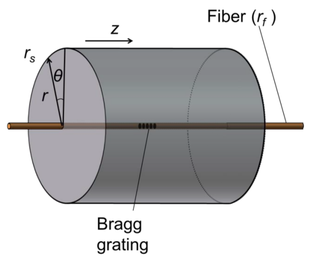


Figure 4. Schematic illustration of a FBG embedded in a polymer specimen

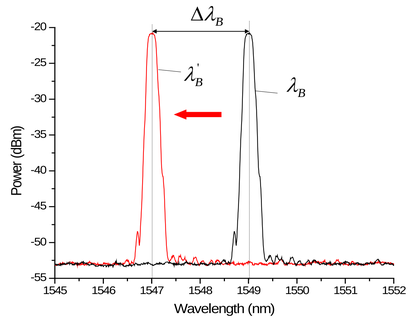


Figure 5. Bragg Wavelength (BW) changes of FBG as the chemical shrinkage happens during the curing

- **The single cured specimen** is used to measure **two required properties** (E and K)

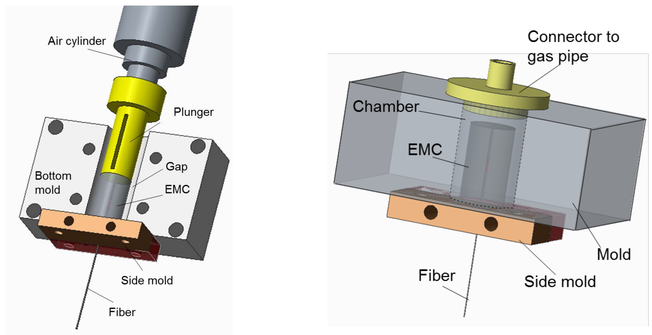


Figure 6. Schematic illustration of experimental setup for uniaxial and hydrostatic creep test to measure Young's and bulk moduli

Experimental Result

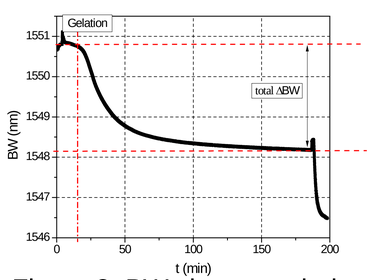


Figure 8. BW changes during the curing process to measure effective chemical shrinkage

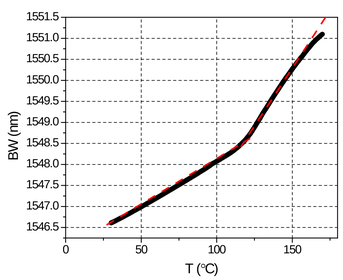


Figure 9. BW changes to measure temperature dependent CTE

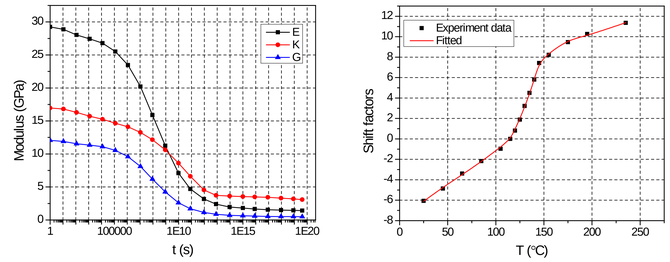


Figure 10. Obtained master curves for viscoelastic properties and Shift factors

Numerical Verification (FEM and T/G test)

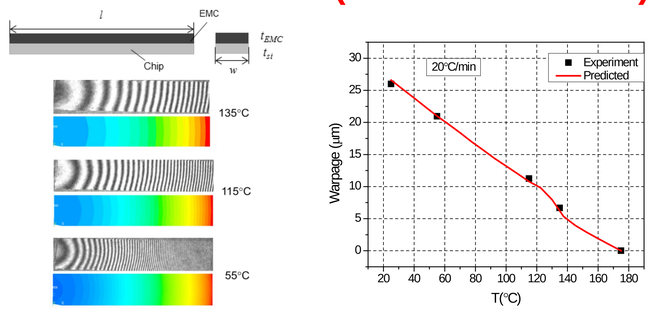


Figure 11. Comparing the warpage of a bi-material specimen obtained by T/G test and FEM.

- **The results match well confirming that the measured properties can be used for the prediction of the material behavior.**

Impact

- **A novel experiment setup using FBG is developed to measure all required properties for the warpage modelling with a single specimen.**
- The result of the measurements are verified by comparing FEM result with obtained properties and T/G test.

Related Publication

- Sun, Y. et al., "Dual-configuration fiber Bragg grating sensor technique to measure coefficients of thermal expansion and hygroscopic swelling.", *Experimental Mechanics* (2014) 593–603
- Sun, Y. et al., "Measurement of Elastic Properties of Epoxy Molding Compound by Single Cylindrical Configuration with Embedded Fiber Bragg Grating Sensor." *Experimental Mechanics* (2016): 1-12.
- Gromala, P. et al., "Non-Linear Viscoelastic Modeling of Epoxy Based Molding Compound for Large Deformations Encountered in Power Modules.", submitted for *ECTC* (2017)