Effectiveness of Substrate Modeling Techniques On Package Warpage Prediction

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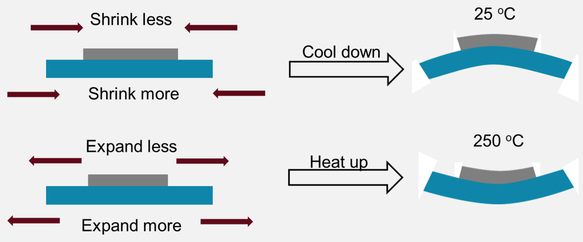
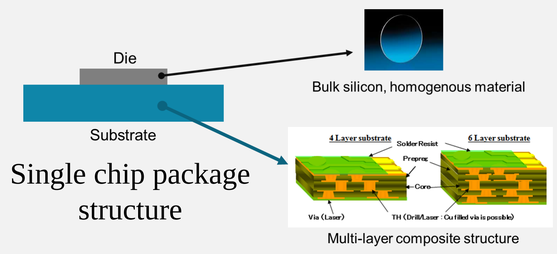
Objectives

Why does a package warp ?





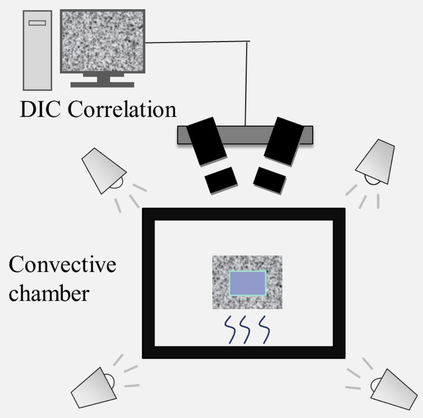
Single chip package structure

✓Techniques to model the package substrate
- ✓One effective layer
- ✓Three major layers
- ✓Multi-layer structure

Sample Preparation

✓Three layer model:
- The top and bottom build up
- The core layer.

✓Lenses: 50 mm focal lenses
✓Aramis system: 5M resolution
✓Convection chamber:
Temp. range: -55 ^{0}C to 320 ^{0}C
Max ramp rate: 15 ^{0}C/min.

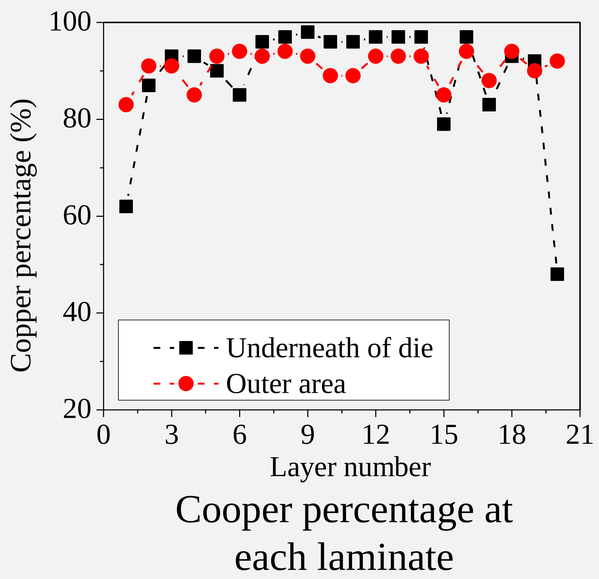


Digital Image Correlation setup

Table: Specimen properties

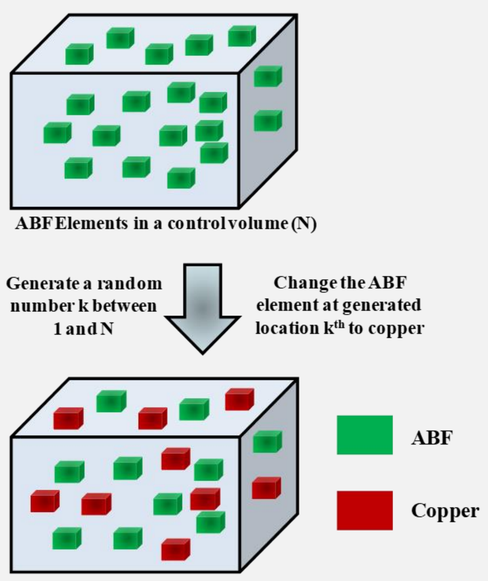
Model	Layers	Thickness (mm)	Area (mm²)
1 effective layer	Die	1.000	26x26
	Underfill	0.075	
	Substrate	1.652	75.6x70
3 major layer model	Die	1.000	26x26
	Underfill	0.075	
	Top build up	0.416	75.6x70
	Bottom buildup	0.416	
	Core	0.820	
Multi-layer model	Die	1.000	26x26
	Underfill	0.075	
	Solder Resist	0.021	75.6x70
	9 x (Cu + ABF)	0.015	
	9 x ABF	0.025	
	Cu layer near	0.035	
	Core	0.820	
	Cu layer near	0.035	
	9 x ABF	0.025	
	9 x (Cu + ABF)	0.015	
	Solder Resist	0.021	

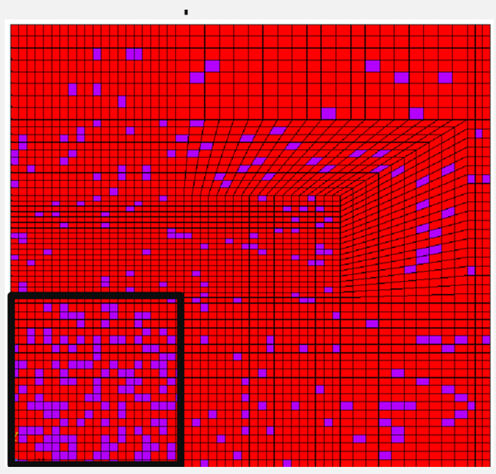
Finite Element Method



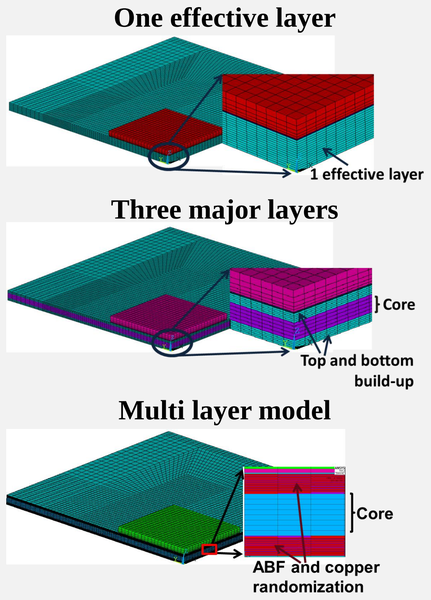
Cooper percentage at each laminate

Copper randomization method



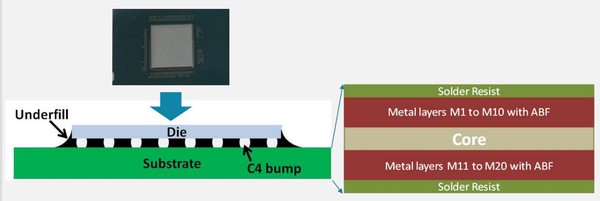


Copper implementation at one layer



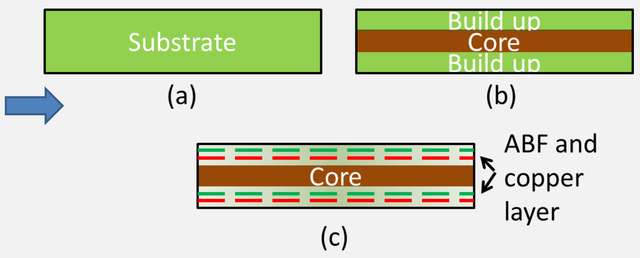
✓The copper randomization is generated in ANSYS: right underneath of the die area (62 %) and out of die area (83 %)
✓The randomization process has been done for 20 layers.

Analytical Method



Bare die package

9-2-9 structure



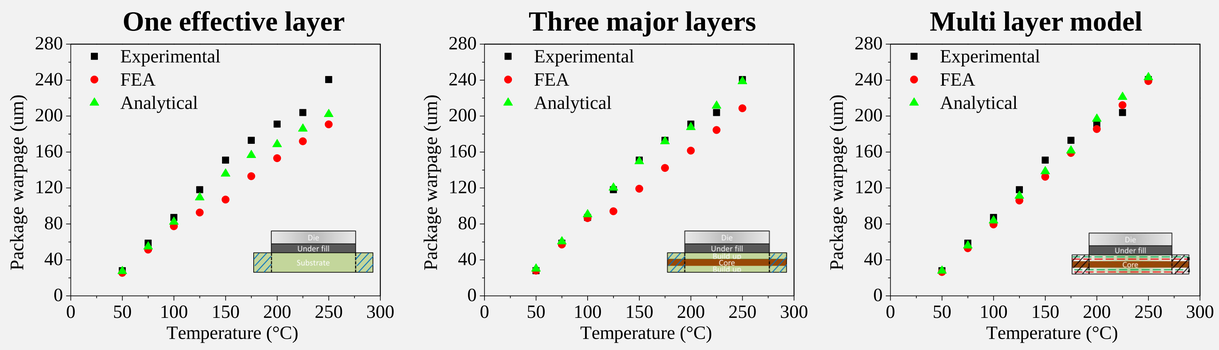
✓Classical Laminate Theory is applied to predict package warpage
✓One effective layer (a) : die, effective underfill, and substrate
✓Three layer model (b): die, effective underfill, top buildup, core, and bottom
✓Multi-layer model (c) : 43 laminates

$$w = -\frac{1}{2}\left(\kappa_x x^2 + \kappa_y y^2 + 2\kappa_{xy} xy\right)$$

- k_x, k_y are curvature at mid-plane
- w are the mid-plane warpage

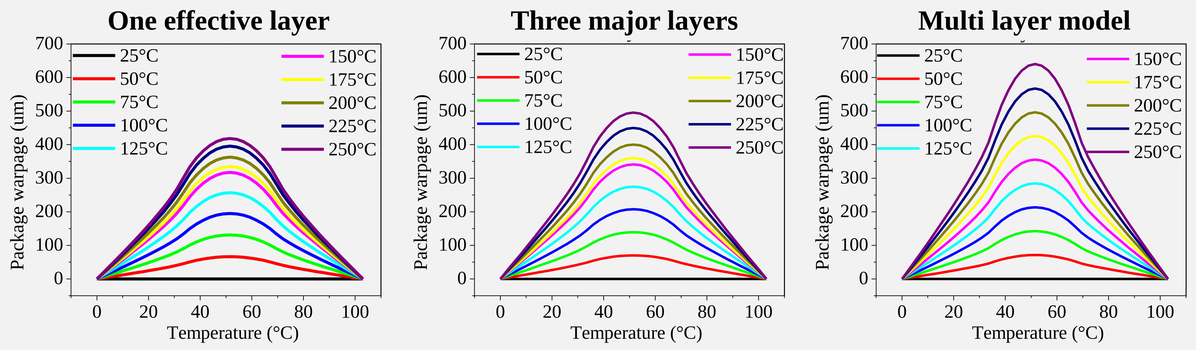
Results and Discussions

Analytical result

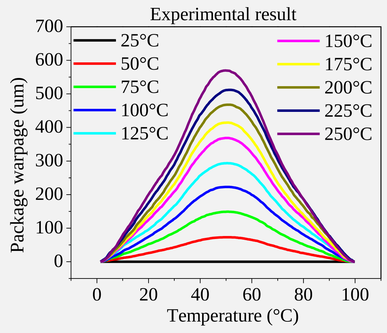


✓FEA shows smaller warpage amount for all cases.
✓Multi-layer, three major layers, and experiment results match well
✓One effective layer model predicted worse.

FEA result



Experimental data



✓Experimental results show same features as these by FEA approach.
✓The three-layer model, and the multi-layer model show better warpage prediction than the one effective layer in all cases.

Conclusion

✓The warpage prediction from multi-layer model is the best among these, then the three-layer model and the last is one effective layer.
✓For better warpage estimation, a FEA model of the package substrate should be considered as three layers to avoid the complexity of the multilayer modeling and the oversimplification of the one effective layer

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