Thermo-Mechanical Characterization of Next Generation Substrate Like Printed Circuit Board (SLP) Materials

Devanshu Kant, Shane Bravard, Arnold Andres
Multek - Interconnect Technology Center,
Milpitas, CA

Abstract

Internet of Things (IoT) adoption pushes the boundaries of Printed Circuit Board (PCB) miniaturization and speed employing more hybrid stack-ups. The complexity of PCB stack up designs, material selection, advanced processing, and subsequent assembly requirements are driving novel approaches to accelerate engineered solutions. To support the aggressive PCB product development cycle times, the accuracy of physics-based predictive modeling must improve, and the number of lengthy Design of Experiments (DoE) minimized. To facilitate this, effective material characterization techniques and modeling capabilities of these complex systems have been developed, with the goal to mitigate risk, increase reliability and reduce engineering time while ensuring a manufacturable solution. In general, the stress induced on interconnects increases as the interconnect size decreases. However, to accurately model the physical behavior (stress and strain) of PCB interconnects in design stack ups during a reflow or lamination processes requires material property information which necessarily is not present on a typical materials' supplier datasheet. Some parameters are also not readily available using standard measurement techniques. Additionally, typical numbers in a laminate datasheet only apply to a standard glass style and resin content. Glass style and resin content have a dramatic influence on the end product mechanical properties. Also, the composite nature of PCBs not only result in its thermomechanical behavior to differ along the X, Y, and Z directions, but also relax over time due to the viscoelastic nature of the epoxy resin. Therefore, the anisotropic and viscoelastic properties of PCB materials must be measured. The measurement techniques discussed here are not part of any formal IPC testing protocol currently. However, they capture properties of PCB materials at the small scale very effectively. They rely on using a Dynamic Mechanical Analyzer (DMA) instrument for measurement purposes. These advancements in material characterization and modeling provide insights into micro-via reliability for next generation PCB miniaturization and high-speed signals.

Introduction: PCB material terminology

Manufacturing multi-layer printed circuits with High Density Interconnects (HDI) involves combining dielectrics and copper foil. Dielectrics are produced in two major forms – fully cured cores with copper foil bonded to the top and bottom, and bonding sheets (or prepregs) without copper foil. Prepreg is B-stage, while core is C-stage. The terms B-stage and C-stage refer to the degree to which the resin system is polymerized or cured. B-stage refers to the state of partial cure. B-stage prepregs are designed to flow and continue polymerizing when exposed to sufficient temperatures. C-stage refers to a state of 'full' cure (a state where the overwhelming reactive sites on the resin molecules have cross-linked).

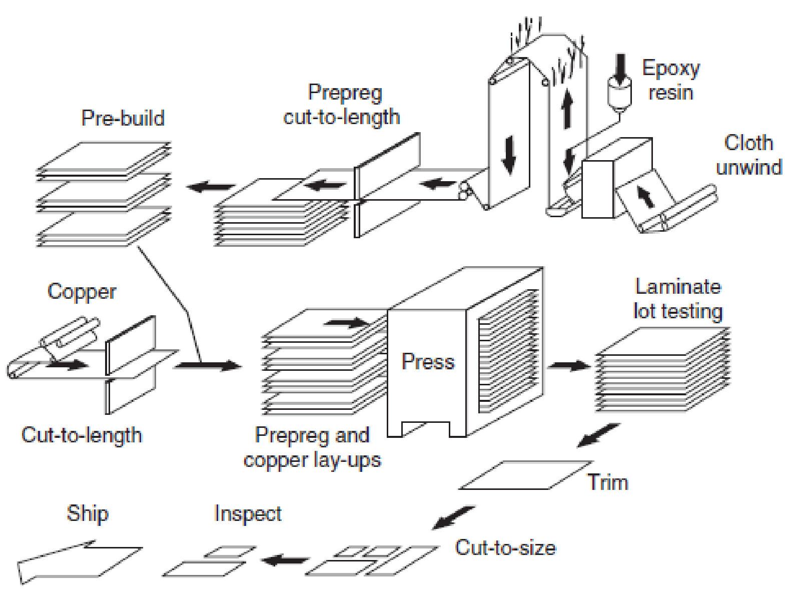

Figure 1: Conventional PCB laminate/prepreg manufacturing

PCB manufacturing

The first step in most of these processes involves coating a resin system onto a woven fiberglass cloth (Figure 1). Rolls of fiberglass are run through equipment called treaters. The fiberglass cloth is drawn through a pan containing the resin system and then precise metering rolls help control thickness and also push resin into the yarns of the glass cloth. Next, the cloth is pulled through a series of heating zones. These heating zones utilize forced air convection (most common), infrared heating, or a combination of the two. The different heating zones are dedicated to partially curing the resin system, or B-staging the resin. Because the resin system at this point is only partially cured, prepregs must typically be stored in temperature and humidity-controlled environments to prevent further curing.

The process of copper clad laminate manufacturing begins with the prepreg material. Prepregs of certain fiberglass cloth styles and specific resin contents are combined with the desired copper foils to make the finished laminate. First, the prepregs and copper foils are sheeted to the desired size. These materials are then laid up in the proper sequence to produce the desired copper laminate. Several of these individual sandwiches of prepregs and copper foil are stacked on top of each other, separated by stainless steel plates (typically). These stacks are then loaded into multi-opening lamination presses, where temperature, pressure, and vacuum are applied (Figure 2). The specific press cycle used will vary depending upon the particular resin system, the degree of cure of the prepregs and other factors. The presses themselves have many platens that can be heated by steam or hot oil (typical) that flows through the platens.

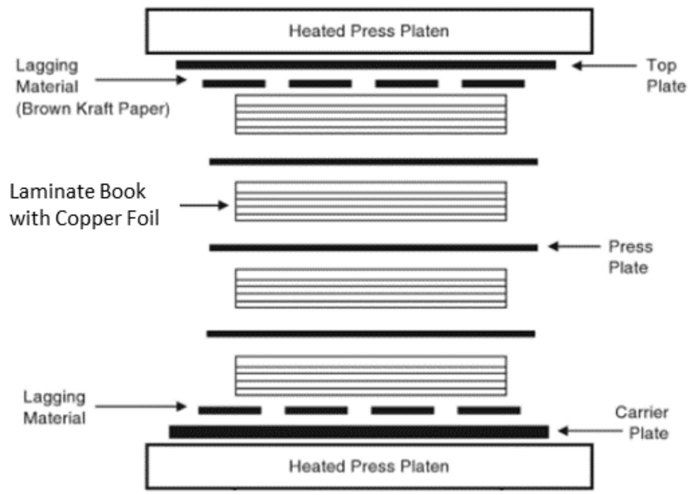

Figure 2: Laminate pressing

Process induced thermo-mechanical behaviors

Prepregs and cores are composite structures by nature, due to the fusion of different materials (woven fiberglass, epoxy resin and copper foil) during their manufacturing. Their processing results in process induced distortions that affect the final shape of the laminate. The basic reason behind the distortion is the process induced residual stresses occurring during manufacturing processes. The non-uniform distribution of residual stresses inside the composite material can result in deformation, matrix cracking and even delamination. These distortions manifest as warpage in flat parts like PCB laminates. Problems occur during and after assembly of components due to poor solder joint formation between the PCB and mating components unless the magnitude of these distortions are predicted within tolerances. In manufacturing, a trial and error approach is often used to compensate for geometrical variations like warpage, but this method is time consuming and expensive. If distortions are predicted accurately in advance, the investment in the trial and error modification and labor-intensive reworking task during assembly can be prevented. Hence, increasing simulation capacity for manufacturing processes is an important step towards a more cost-efficient development and manufacturing of PCBs.

Residual stresses can be categorized according to the scale (micro/macro) at which they originate and whether they are thermoelastic or non-thermoelastic. Micro scale residual stresses develop between the fibers and resin as a consequence of (i) thermal expansion mismatch between the fibers and resin, (ii) chemical shrinkage of the resin during polymerization, and (iii) moisture absorption. Residual stresses at this scale do not cause any large distortions of the composite laminate because they are self-equilibrating. On the other hand, residual stresses at the macro scale are the source of large dimensional changes. Anisotropic behavior of individual plies, the constraint effect of individual plies, and tooling constraints are the main sources that trigger the residual stresses at this scale. Thermoelastic residual stresses are reversible, so distortion can be eliminated by heating the part to its polymerization temperature. The source of these stresses in thermoplastic composite materials is the difference between in-plane thermal strains and through-thickness thermal strains. Non-thermoelastic residual stresses, on the other hand, are irreversible and the mechanisms behind them are more complex. They can be listed as (i) the tool-part interaction (Figure 3), (ii) chemical shrinkage during polymerization, (iii) consolidation, (iv) through-thickness degree of cure (crystallinity) gradients, and (v) fiber volume fraction gradients (Figure 4).

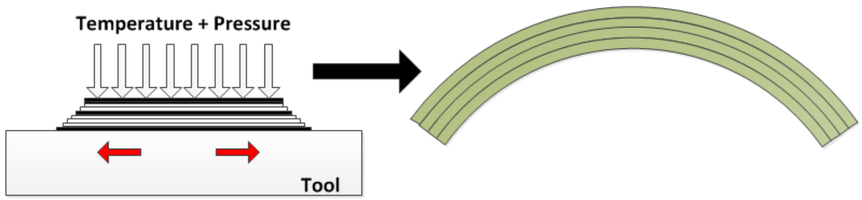

Figure 3: Effect of tool-part interaction on distortion (exaggerated) of flat laminates

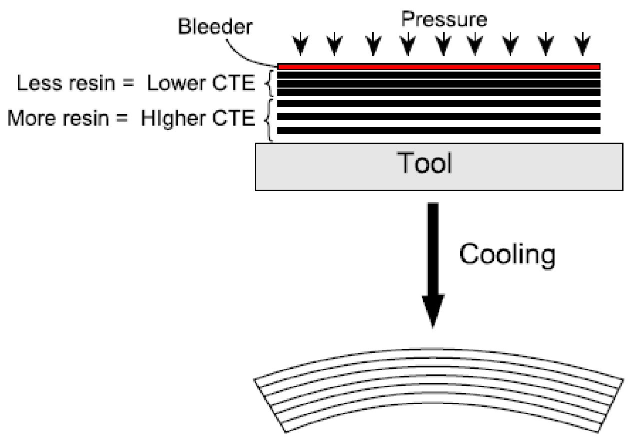

Figure 4: Effect of resin flow on the warpage in flat laminates

Thermo-mechanical experimental methods

Cores and prepregs manufactured with plain woven fiberglass as reinforcement possess thermo-mechanical properties that are orthotropic in nature. A general three-dimensional orthotropic material has three mutually perpendicular planes of symmetry that coincide with the coordinate planes. Fiber composites are orthotropic materials that exhibit symmetry of their elastic properties with respect to two orthogonal planes. Hooke's law can be used to connect the stress and strain in the material with a general linear relationship. To describe the composite material using Hooke's law in 3D, nine independent constants are required (Figure 5).

$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{13} \\ \tau_{12} \end{Bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\ C_{12} & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} \\ C_{13} & C_{23} & C_{33} & C_{34} & C_{35} & C_{36} \\ C_{14} & C_{24} & C_{34} & C_{44} & C_{45} & C_{46} \\ C_{15} & C_{25} & C_{35} & C_{45} & C_{55} & C_{56} \\ C_{16} & C_{26} & C_{36} & C_{46} & C_{56} & C_{66} \end{bmatrix} \begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \gamma_{23} \\ \gamma_{13} \\ \gamma_{12} \end{Bmatrix}$$

(a): anisotropic material

$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{13} \\ \tau_{12} \end{Bmatrix} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & 0 & 0 & 0 \\ C_{12} & C_{22} & C_{23} & 0 & 0 & 0 \\ C_{13} & C_{23} & C_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{66} \end{bmatrix} \begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \gamma_{23} \\ \gamma_{13} \\ \gamma_{12} \end{Bmatrix}$$

(b): orthotropic material

Figure 5: Hooke's law in three dimensions

Using stiffness ([C]) matrices works in an analytical setting when deriving mathematical relationships between stress and strain. Traditionally, material response has been characterized by "engineering constants" rather than elements of a stiffness matrix. For example, Young's modulus, E, is used to describe the ability of a material to transfer a pure extensional strain into a pure extensional stress; Poisson's ratio, ν, is used to indicate the extent to which the lateral dimensions of a body decrease (or increase) in response to a pure extensional (or compressional) strain; and shear modulus, G, is used to describe the ability of a material to transfer pure shear strain into pure shear stress. As a result, the constitutive behavior of the composite can be expressed as:

$$\begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \gamma_{23} \\ \gamma_{13} \\ \gamma_{12} \end{Bmatrix} = \begin{bmatrix} S_{11} & S_{12} & S_{13} & 0 & 0 & 0 \\ S_{12} & S_{22} & S_{23} & 0 & 0 & 0 \\ S_{13} & S_{23} & S_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66} \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{13} \\ \tau_{12} \end{Bmatrix} \qquad \begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \gamma_{23} \\ \gamma_{13} \\ \gamma_{12} \end{Bmatrix} = \begin{bmatrix} {}^{1}/_{E_{11}} & {}^{-\upsilon_{12}}/_{E_{11}} & {}^{-\upsilon_{13}}/_{E_{11}} & 0 & 0 & 0 \\ {}^{-\upsilon_{12}}/_{E_{11}} & {}^{1}/_{E_{22}} & {}^{-\upsilon_{23}}/_{E_{22}} & 0 & 0 & 0 \\ {}^{-\upsilon_{13}}/_{E_{11}} & {}^{-\upsilon_{23}}/_{E_{22}} & {}^{1}/_{E_{33}} & 0 & 0 & 0 \\ 0 & 0 & 0 & {}^{1}/_{G_{23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & {}^{1}/_{G_{13}} & 0 \\ 0 & 0 & 0 & 0 & 0 & {}^{1}/_{G_{12}} \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{13} \\ \tau_{12} \end{Bmatrix}$$

Figure 6: Hooke's law for orthotropic composites expressed with "engineering constants"

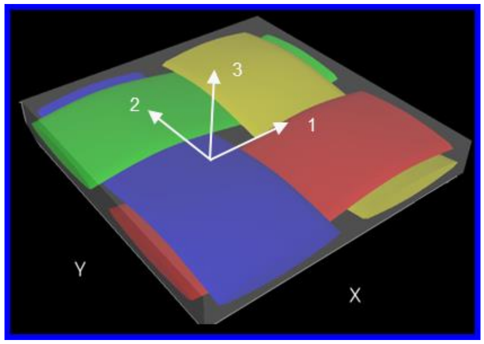

Figure 7: Material directions in orthotropic woven composites

For application cases that involve understanding composite behavior during reflow, these engineering constants were quantified for C-stage cores as a result of characterization experiments. Specific engineering constants are associated with each unique direction of the orthotropic material (Figure 7). For example, Young's modulus along the warp direction of the fabric (E_{11}) is different from Young's modulus perpendicular (E_{22}) to this direction. Furthermore, Young's modulus perpendicular to the laminate, E_{33}, differs from both E_{11} and E_{22} (because response to strain in this direction is resisted primarily only by the epoxy resin). Similarly, three distinct shear moduli were determined. The respective tests conducted on a production Dynamic Mechanical Analyzer (DMA) apparatus captured mechanical behavior of the material through its glass transition. A representative sample of test data is shown in Figure 8.

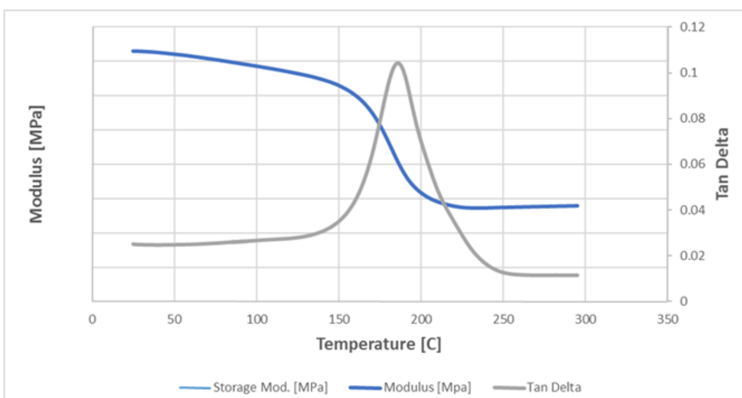

Figure 8: Mechanical characterization of C-stage composite

In addition, post cure stress relaxation of the C-stage laminate was characterized by conducting stress relaxation experiments in shear or tensile mode. Stress relaxation was measured by quickly deforming the material by a specified amount. The state of deformation was maintained, and the stress required to hold the fixed deformation was measured as a function of time. The decaying stress was divided by the constant strain to obtain the stress relaxation modulus. The relaxation modulus of the resin matrix thus obtained was then fit to a Prony series approximation for modeling purposes (Figure 9).

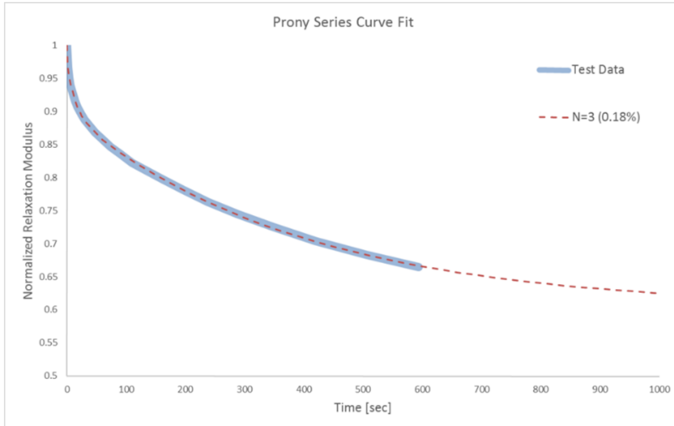

Figure 9: Stress relaxation characterization and Prony series approximation of C-stage composite

Finally, for laminates subjected to reflow temperature loads, three engineering constants (since free expansion produces only normal strains) – coefficients of thermal expansion (CTE) were experimentally determined for quantifying thermal strains.

For application cases that involve process induced warpage and distortion, a fundamental understanding of how properties of the thermoset resin and composite develop during cure becomes vital because of the long cure times and very thin parts involved. Characterizing the stress relaxation behavior via insight on the development of mechanical properties (of B-stage prepreg) through the manufactured recommended cure cycle (MRCC) served as a practical option. In these tests, the modulus measurements were carried out in a production DMA on prepregs in shear and tensile mode. Stress relaxation was carried out as follows: The specimen was loaded at a constant strain rate up to 0.1% strain and held at that strain. Then the stress was allowed to relax to an asymptotic value and the relaxed modulus recorded. This measurement was repeated every 10 minutes throughout the cure cycle (Figure 10). The relaxed modulus is the relevant material property for residual stress modeling because the curing processes are slow enough to allow the built up stresses to relax to a minimum value.

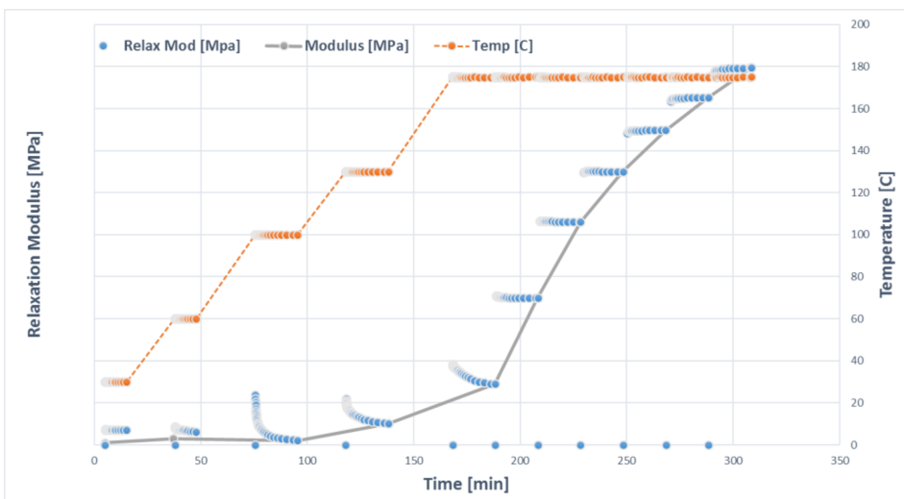

Figure 10: Modulus development (stress relaxation characterization) of composite during cure

Viscoelastic (stress relaxation) modeling

The basic assumption for viscoelastic modeling in this work is that the material behavior can be idealized as a step transition from the rubbery state to a glassy state with constant mechanical properties within each material phase. This approach is similar to the path dependent model proposed by Svanberg and Holmberg [5]. Time dependence due to the viscoelastic nature of the resin system is replaced by the resin exhibiting its relaxed rubbery modulus in the rubbery state, and the unrelaxed glassy modulus in the glassy state. The assumption requires the use of two different sets of modeling parameters for the rubbery and glassy states of the composite in finite element modeling.

The constitutive model can be illustrated by considering the behavior of the composite in a direction dominated by the resin. Consider the stress-strain behavior during a loading – unloading cycle (Figure 11). Based on the approximation described earlier, the time dependence is neglected and the resin is considered to exhibit its relaxed rubbery modulus in the rubbery state and full unrelaxed glass modulus in the glassy state. The line joining from point 1 to point 2 corresponds to the loading condition where stiffness is low due to the resin being in a rubbery state. Then the resin vitrifies at point 2 whereas the stress state remains unaffected by the state transformation. When the load is removed, the composite will now follow the line from point 2 to point 3, because its modulus is higher in the glassy state.

With respect to the material coordinate system shown in Figure 7, where the 1- and 2- directions correspond to the warp and fill direction, and the through thickness direction is the 3-direction, the constitutive relation for the composite in the rubbery (B-stage) or glassy (C-stage) stage can now be expressed using the Hooke's law relationships described earlier, leading to two sets of modeling parameters.

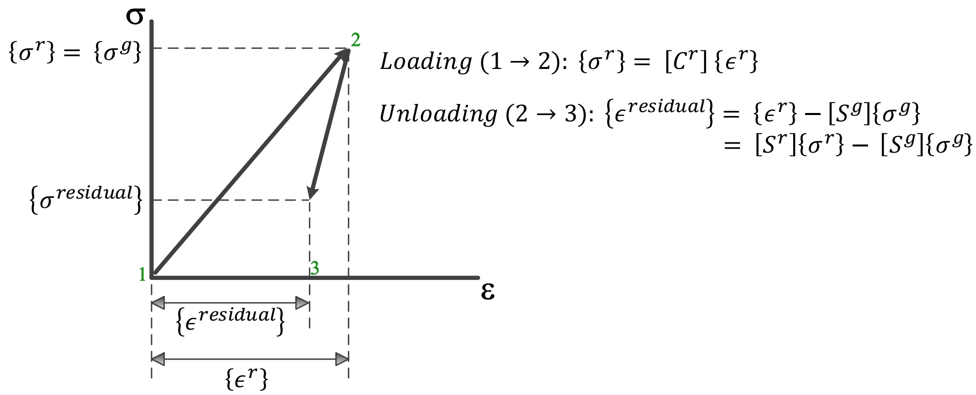

Figure 11: Stress-strain curve during loading-unloading cycle

Case study outcomes

Material characterization methods described earlier enabled development of post cure three dimensional simulation models of next generation Substrate Like Printed Circuit Board (SLP) Assemblies. These assemblies consisted of flip chip packages with Ball Grid Array (BGA) attachment mechanisms undergoing reflow. The simulation goal was to gain insight into (i) the effect of prepreg and core material choices on the structural integrity of hybrid miniaturized microvia systems , (ii) compare and contrast response of the system with conventional structures, (iii) ensure an overall robust manufacturable solution.

Figure 12 shows snapshots of the results from the simulation models. Figure 12(a) shows principal stresses in the materials around the microvia regions for different stack up design choices. Evaluation of these responses helped in screening riskier material sets that could potentially compromise structural integrity of the microvia systems. In 12(b), the stress impact of a hybrid construction is compared with the conventional microvia construction, indicating a 13% difference between the two configurations.

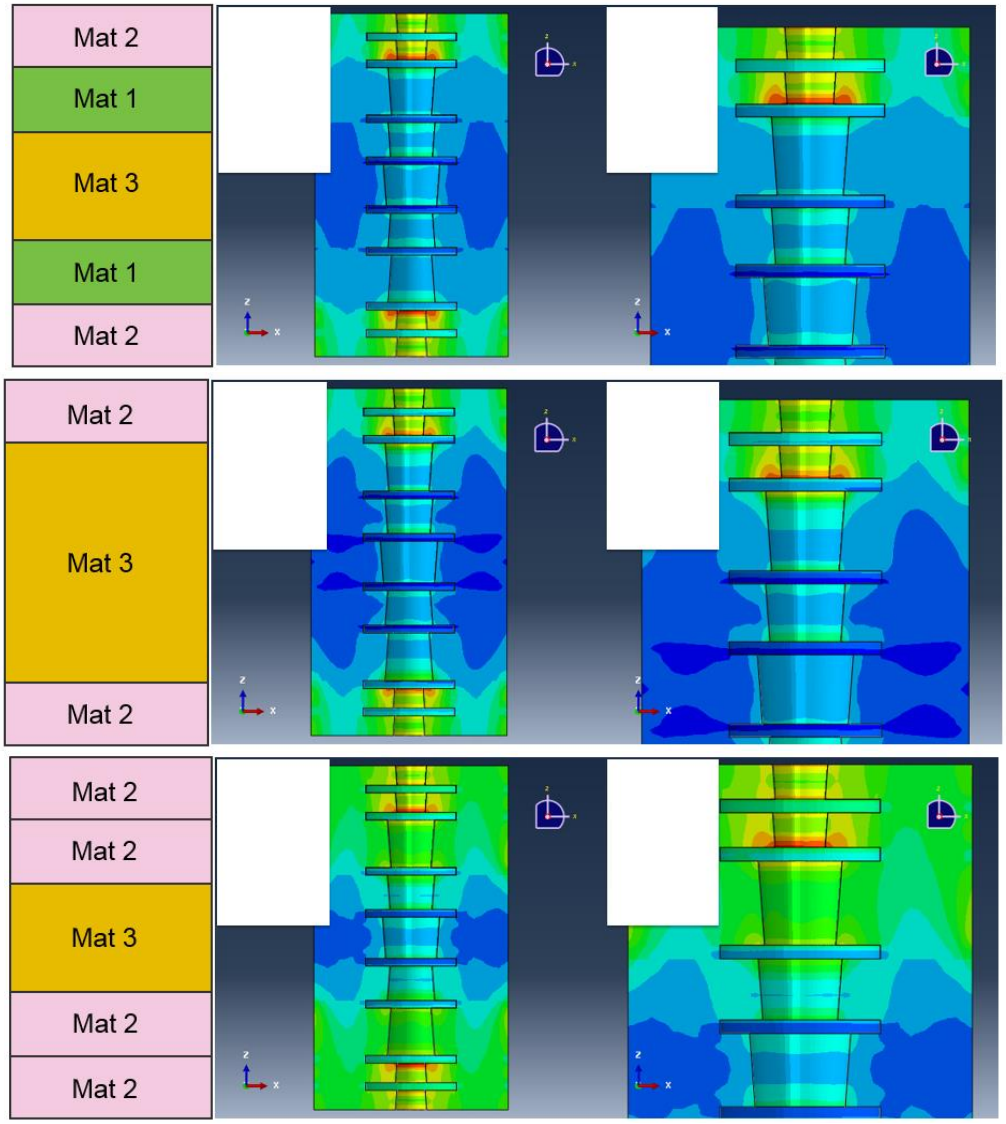

Figure 12(a): Principal stress contours

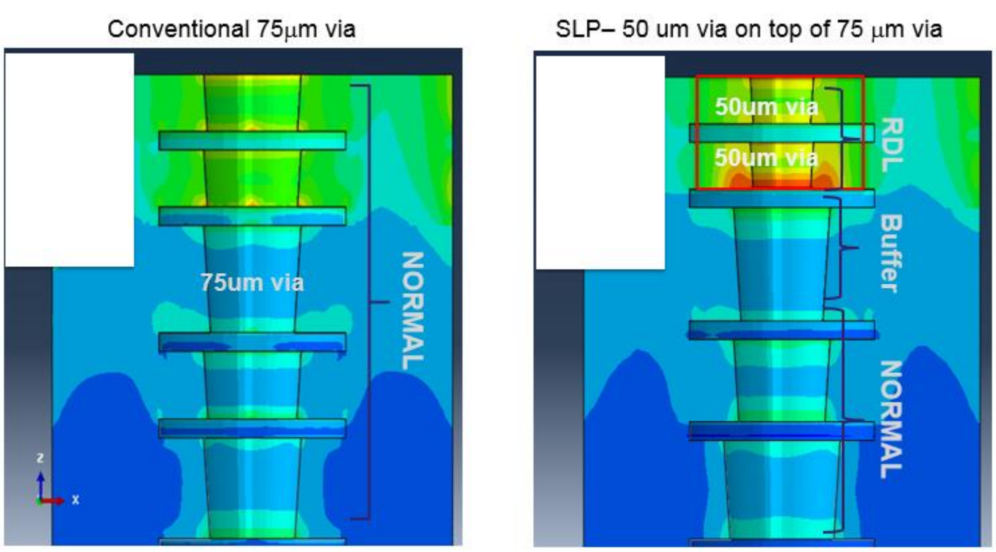

Figure 12(b): Comparison between traditional and hybrid microvia constructions

Figure 13 shows a snapshot of very good correlation of structural integrity failure between a simulation model and reliability testing of an Interconnect Stress Test (IST) coupon. Again, the model was built in advance to screen material choices for the design.

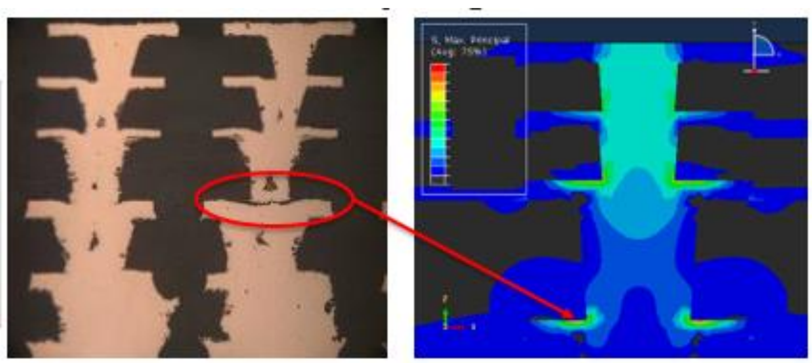

Figure 13: IST Thermal cycling correlation

Summary/ Conclusions

Practical methods were discussed to characterize the mechanical and thermal behavior of B-stage and C-stage materials undergoing lamination and post processing reflow. Results from the characterization were used in the analytical modelling of SLPs with conventional and hybrid microvia constructions using the finite element method. Analyses of the results from simulation shows very good correlation with test vehicle coupon testing. These observations and insights suggest that the methods outlined in this work are a reliable and effective way to characterize SLP materials.

Acknowledgements

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Multek ITC

Milpitas, CA, USA

Agenda

- Drivers of SLP Manufacturing
- Why Computational Modeling?
- PCB Material Characterization Measurements
- SLP Case Study - Modeling Post Process Assembly Reflow
- SLP Case Study - Modeling Outcomes
- SLP Case Study - Interconnect Reliability
- Summary

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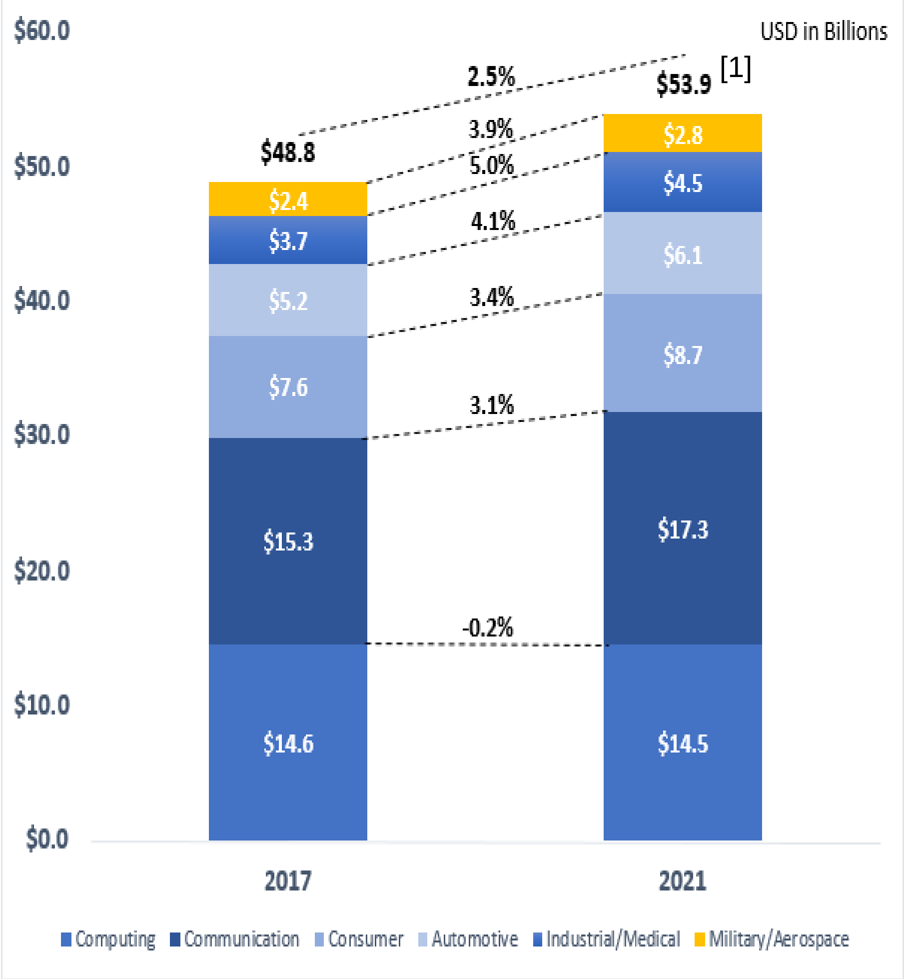
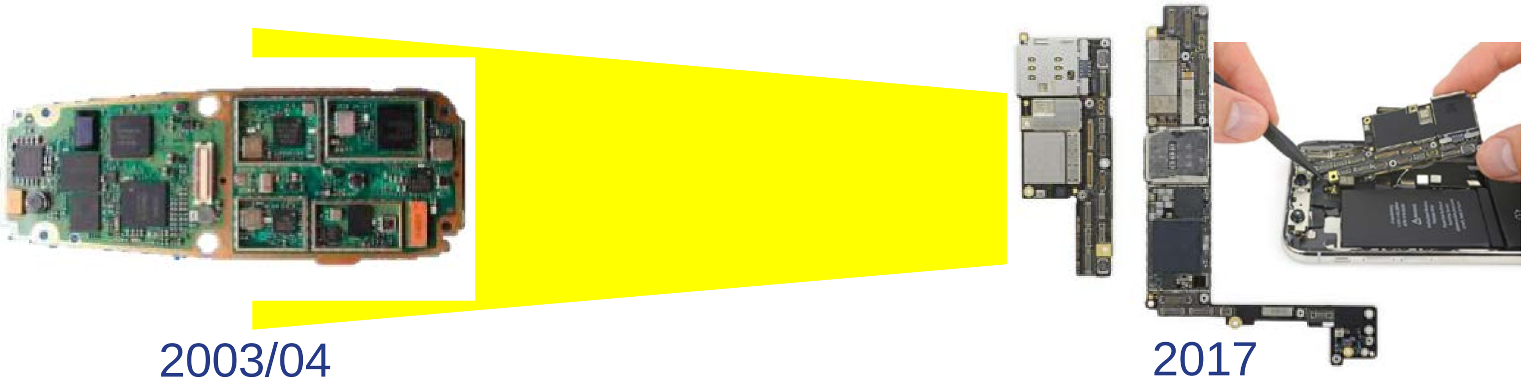
Drivers of SLP Manufacturing

Moderate 2.5% CAGR forecast for PCB industry till 2021. IoT/wearables as enablers



Miniaturization and modularization as drivers



2003/04
PCB: 125mm long

2017
PCB: 55mm long
(Production smartphone)

- HDI supports significant routing density increase in the evolution of PCB manufacturing.
  - *laser drilled vias, new via metallization technologies, revised etching methods, etc.*
- Substrate-like PCB (SLP) is the next evolution of HDI PCB manufacturing allowing much higher routing density.
  L/S < 30um - 35um

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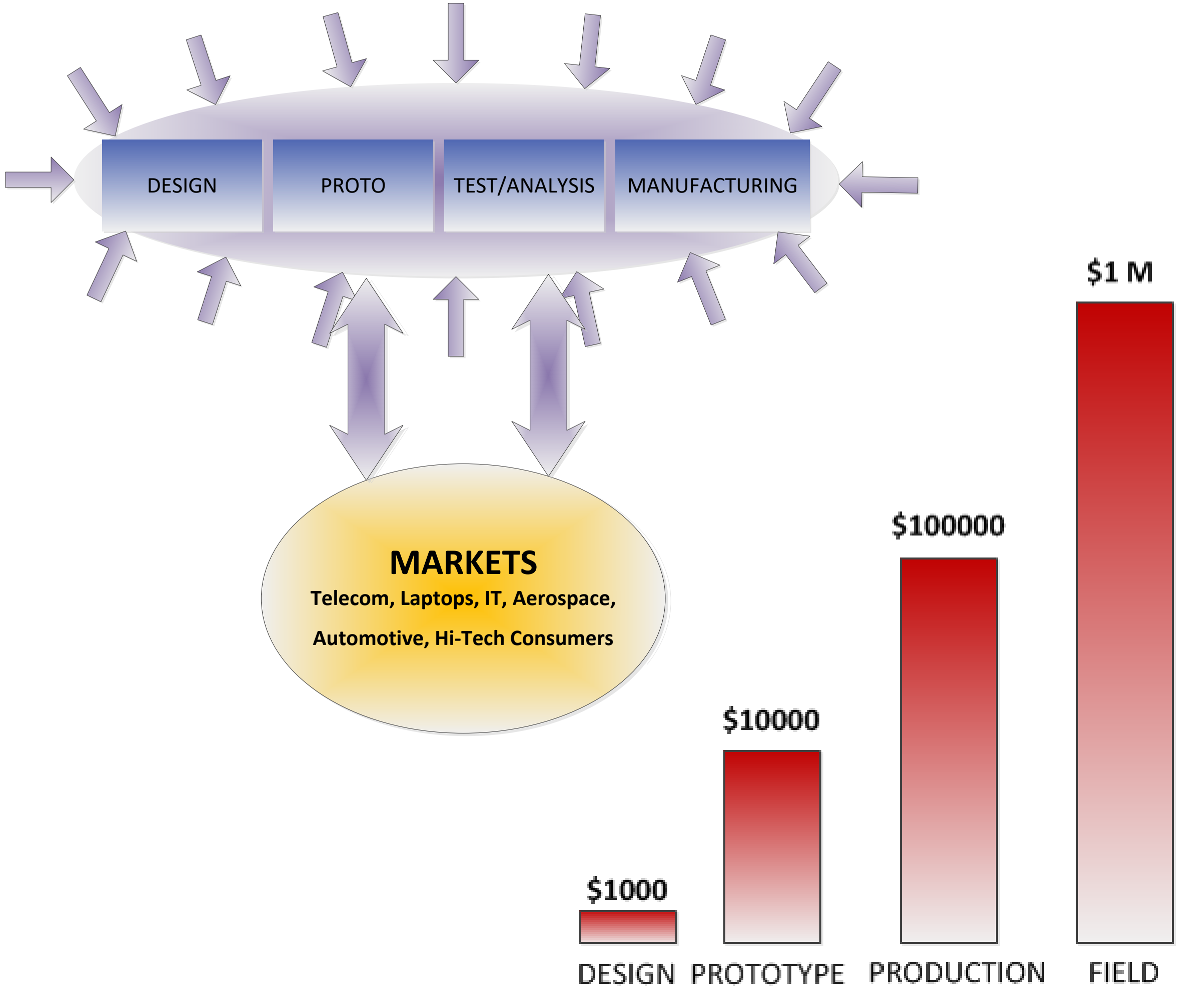
Why Computational Modeling?

- "Electronics industry would necessarily need to rely more and more heavily on MS&DT over experimental prototyping during product and technology development due to increasing cost and time pressures." [2]
- High End (HE) systems (high-speed, high-bandwidth products) market innovation provides a compute environment and platform that has revolutionized the level of detail and size of the problem that can be analyzed.
- In addition, increased expectation of accuracy level from analysis drives need for improved material properties to use in modeling and link with experimental techniques.



Spiraling cost of mistakes in product design

Agenda

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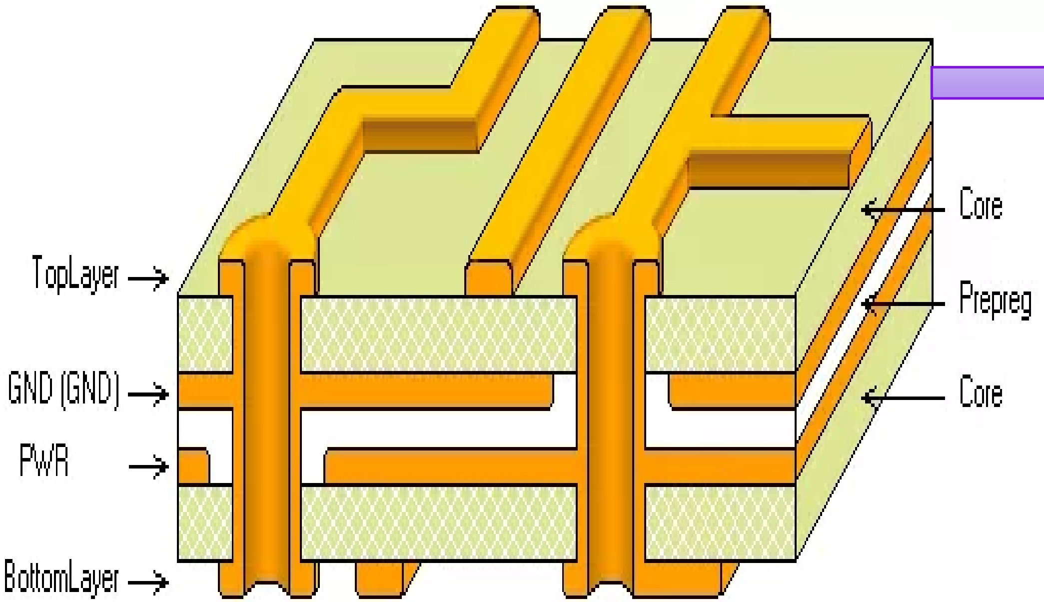
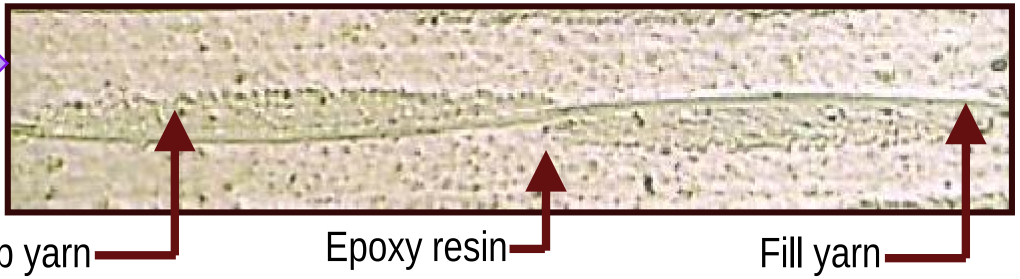
PCB Materials Characterization Measurements

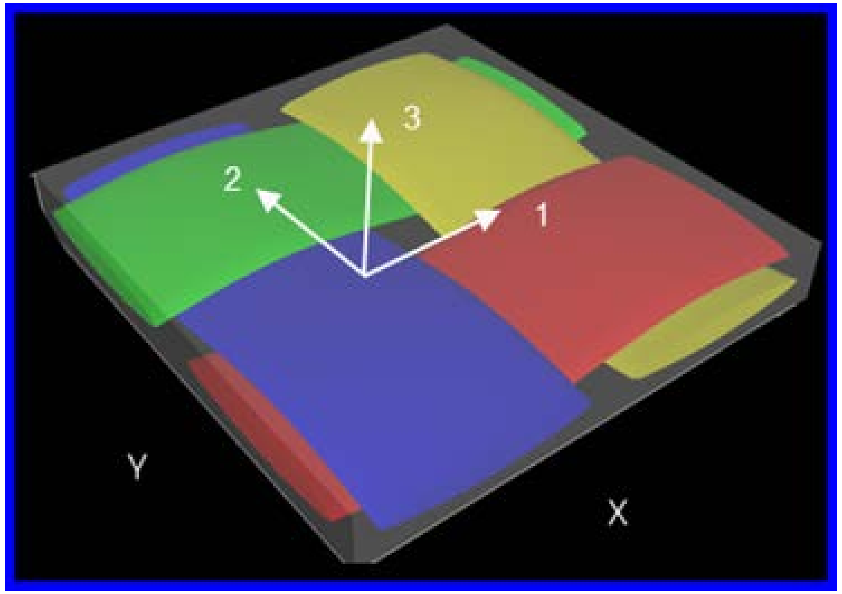
PCB cross-section
layered construction



- Core/prepreg & copper multi-layered construction
- Core/prepreg materials orthotropic in thermo-mechanical nature

Prepreg/Core cross-section





PCB Materials Characterization Measurements

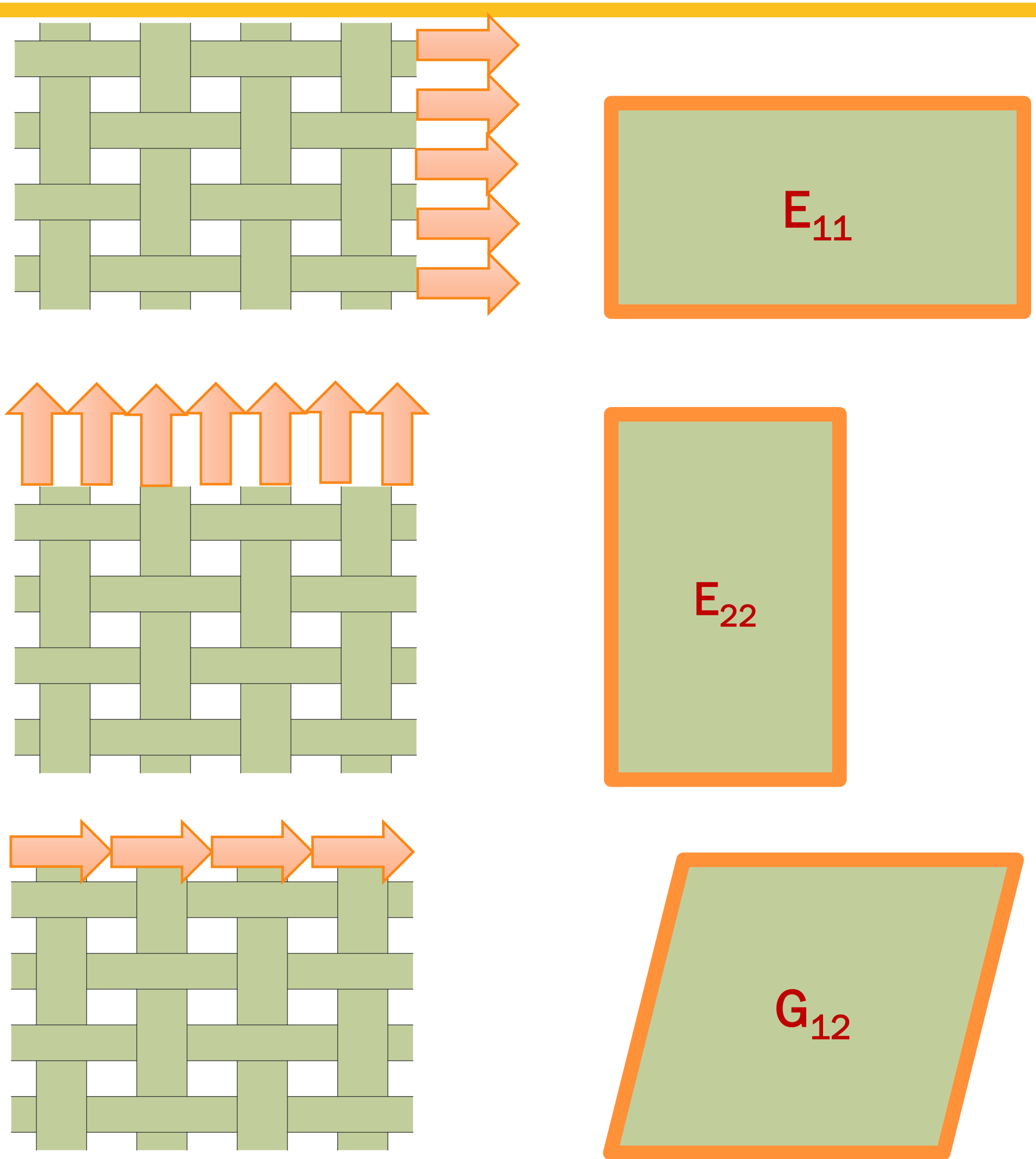
Hooke's Law for orthotropic materials

$$\begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \epsilon_3 \\ \gamma_{23} \\ \gamma_{13} \\ \gamma_{12} \end{Bmatrix} = \begin{bmatrix} {}^{1}/_{E_{11}} & {}^{-\upsilon_{12}}/_{E_{11}} & {}^{-\upsilon_{13}}/_{E_{11}} & 0 & 0 & 0 \\ {}^{-\nu_{12}}/_{E_{11}} & {}^{1}/_{E_{22}} & {}^{-\upsilon_{23}}/_{E_{22}} & 0 & 0 & 0 \\ {}^{-\nu_{13}}/_{E_{11}} & {}^{-\upsilon_{23}}/_{E_{22}} & {}^{1}/_{E_{33}} & 0 & 0 & 0 \\ 0 & 0 & 0 & {}^{1}/_{G_{23}} & 0 & 0 \\ 0 & 0 & 0 & 0 & {}^{1}/_{G_{13}} & 0 \\ 0 & 0 & 0 & 0 & 0 & {}^{1}/_{G_{12}} \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \\ \tau_{23} \\ \tau_{13} \\ \tau_{12} \end{Bmatrix}$$

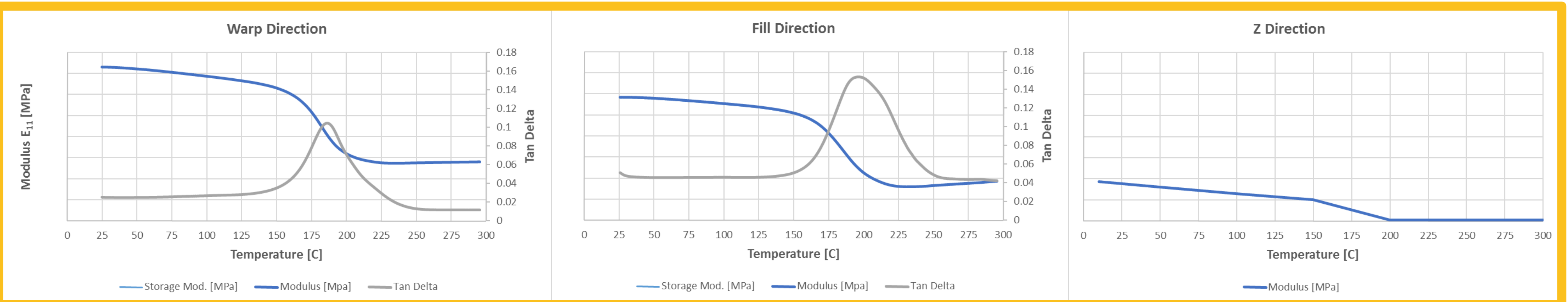
DMA instrumentation

Tension

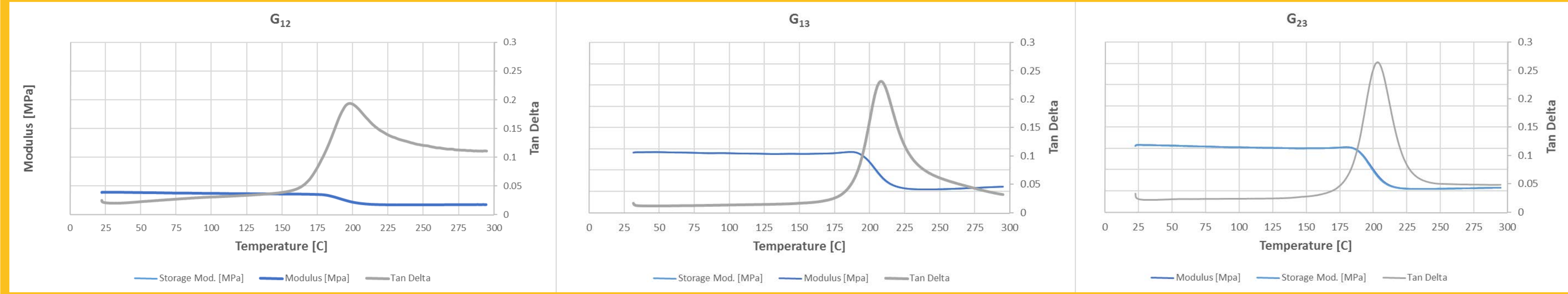
Shear Sandwich



PCB Materials Characterization Measurements



Young's Moduli



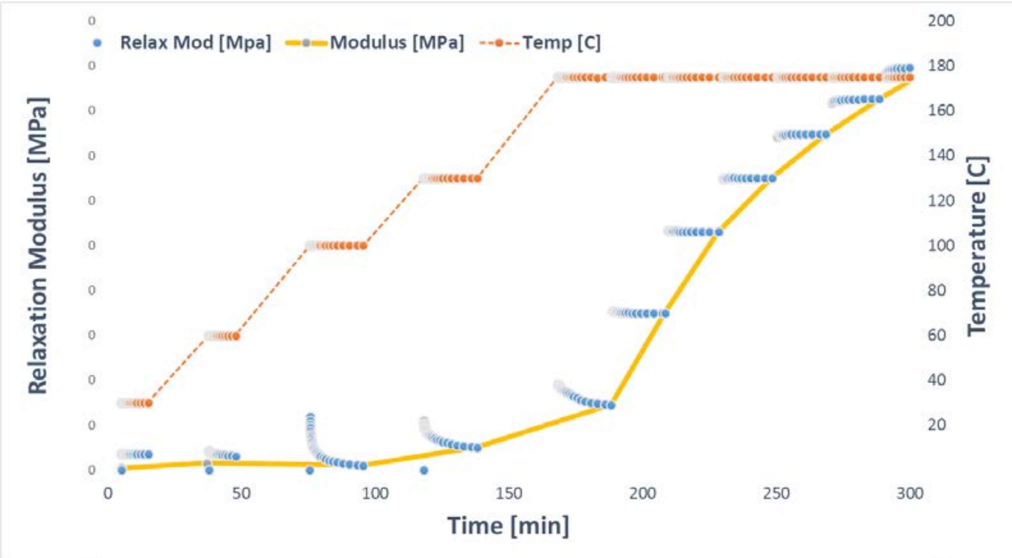
Shear Moduli

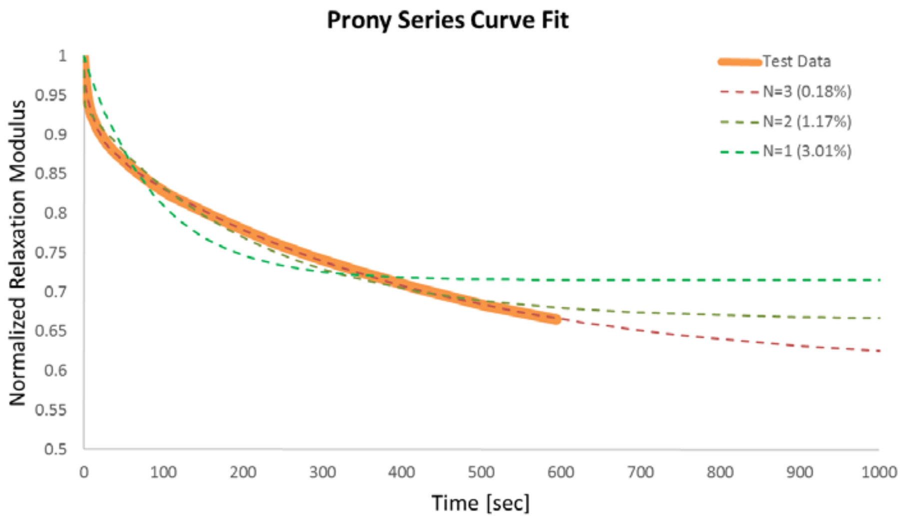
PCB Materials Characterization Measurements

Resin stress relaxation behavior

- Process induced residual stresses have detrimental effect on laminate dimensional stability & distortions
- Distortions manifest as warpage in flat PCB laminates
- Modulus development during long cure times pathway to quantifying material ability to release residual stress

DMA instrumentation



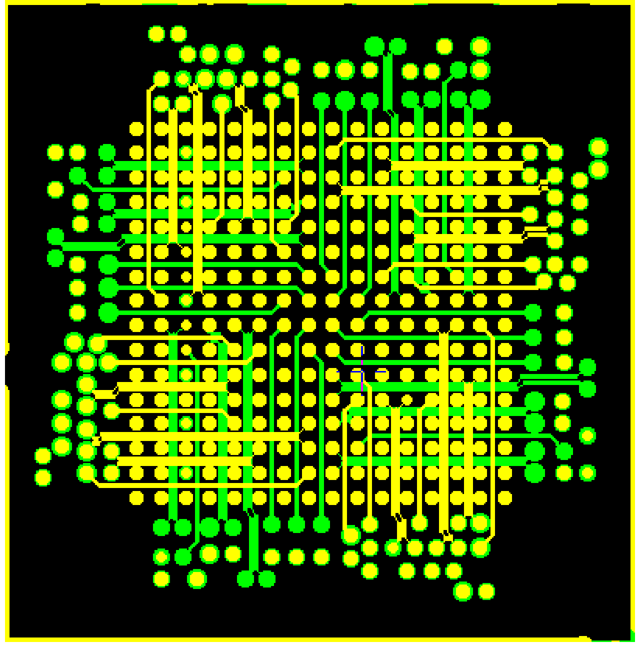


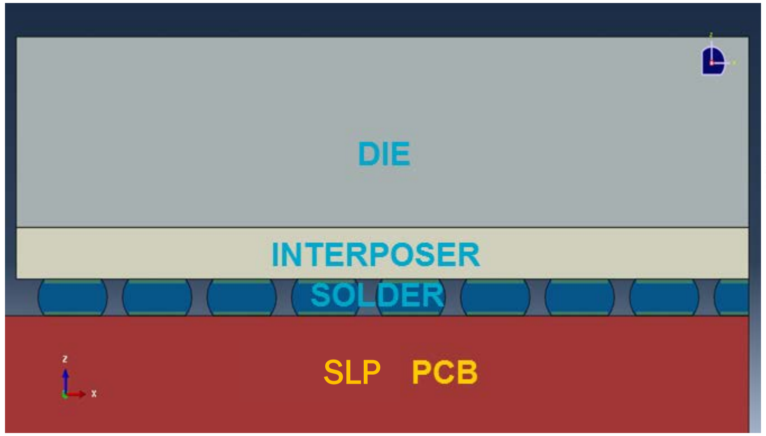
Agenda

- ✓ Drivers of SLP Manufacturing
- ✓ Why Computational Modeling?
- ✓ PCB Material Characterization Measurements
- SLP Case Study - Modeling Post Process Assembly Reflow
- SLP Case Study - Modeling Outcomes
- SLP Case Study - Interconnect Reliability
- Summary

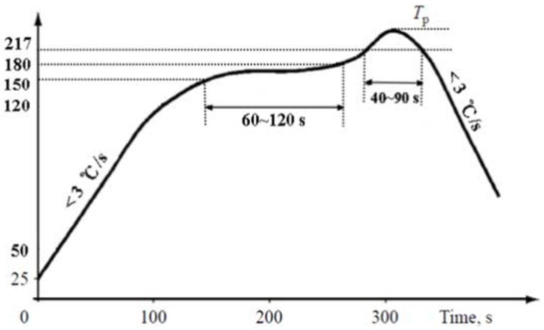
SLP Case Study - Modeling Post Process Assembly Reflow

- Test Vehicle developed with flip chip package
  - *mSAP process*
  - *10 layer metal interconnect PCB*
  - *BGA pitches - 200um, 254um, 300um*
  - *Microvia diameters - 50um, 75um*
  - *Overall PCB thickness - 0.58mm*

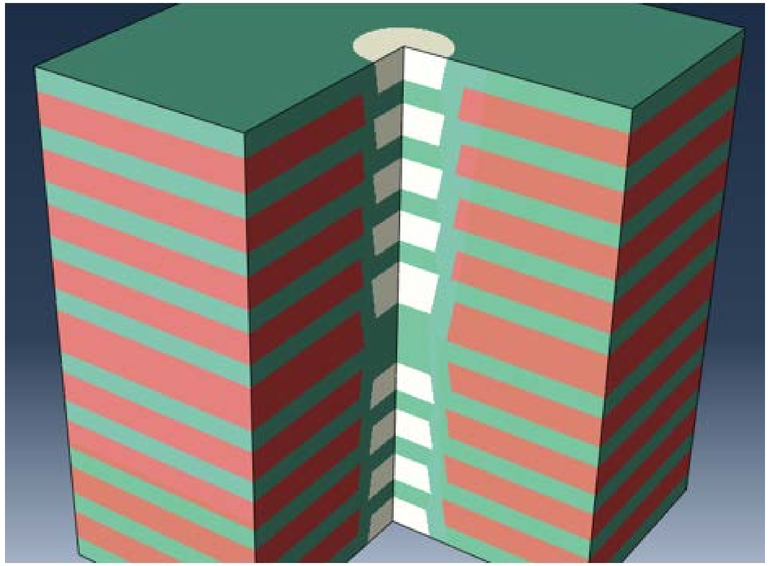




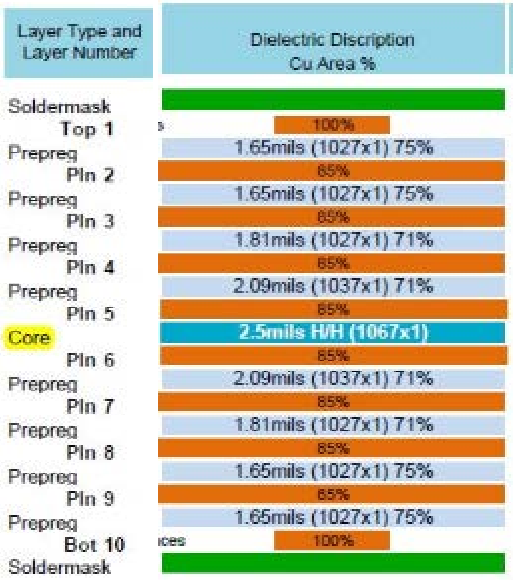
PCBA cross-section



PCBA reflow profile



PCB cross-section (microvias)



Layer Type and Layer Number	Dielectric Discription Cu Area %
Soldermask	
Top 1	100%
Prepreg	1.65mils (1027x1) 75%
Pln 2	85%
Prepreg	1.65mils (1027x1) 75%
Pln 3	85%
Prepreg	1.81mils (1027x1) 71%
Pln 4	85%
Prepreg	2.09mils (1037x1) 71%
Pln 5	85%
Core	2.5mils H/H (1067x1)
Pln 6	85%
Prepreg	2.09mils (1037x1) 71%
Pln 7	85%
Prepreg	1.81mils (1027x1) 71%
Pln 8	85%
Prepreg	1.65mils (1027x1) 75%
Pln 9	85%
Prepreg	1.65mils (1027x1) 75%
Bot 10	100%
Soldermask	

PCB stackup

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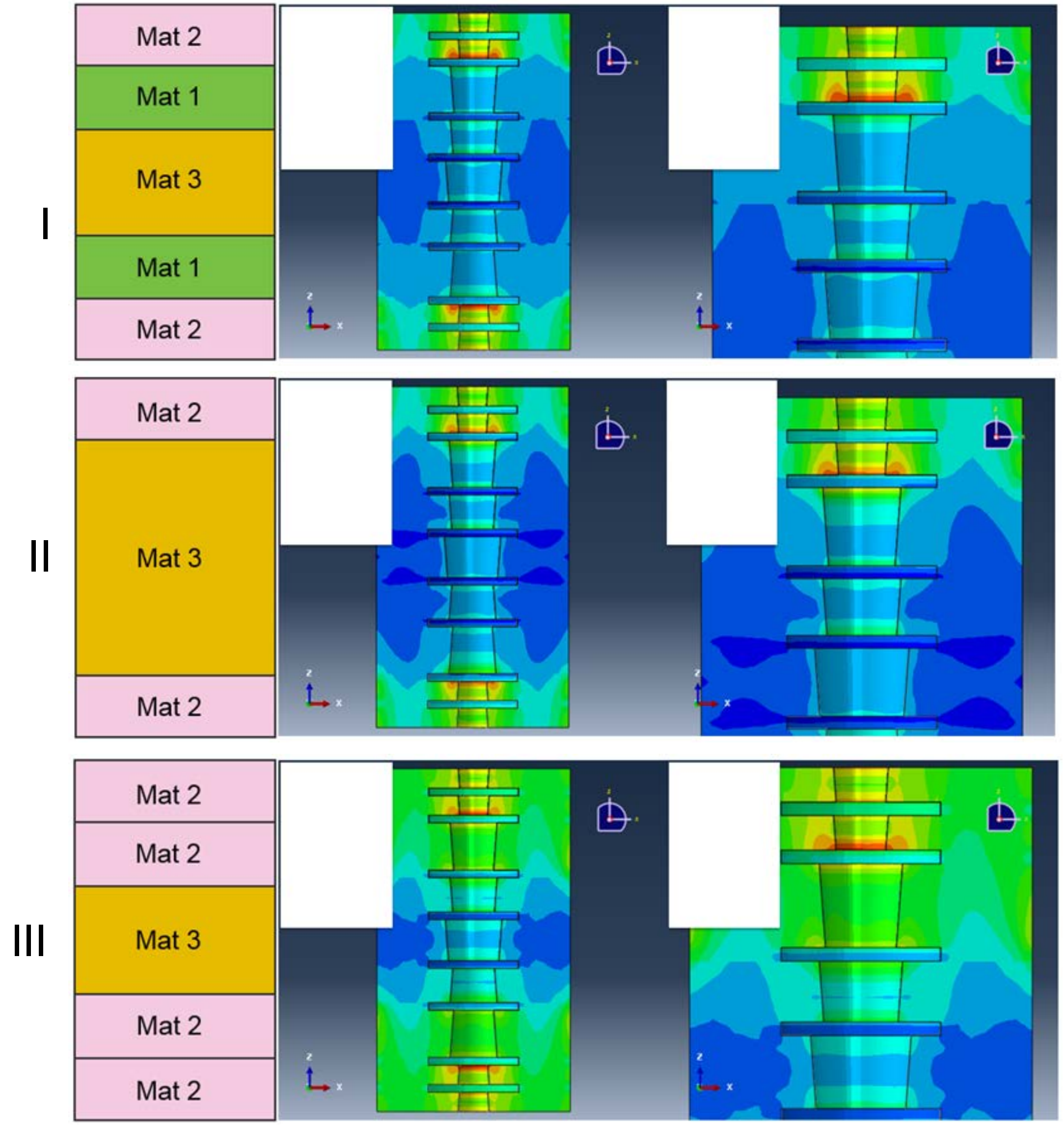
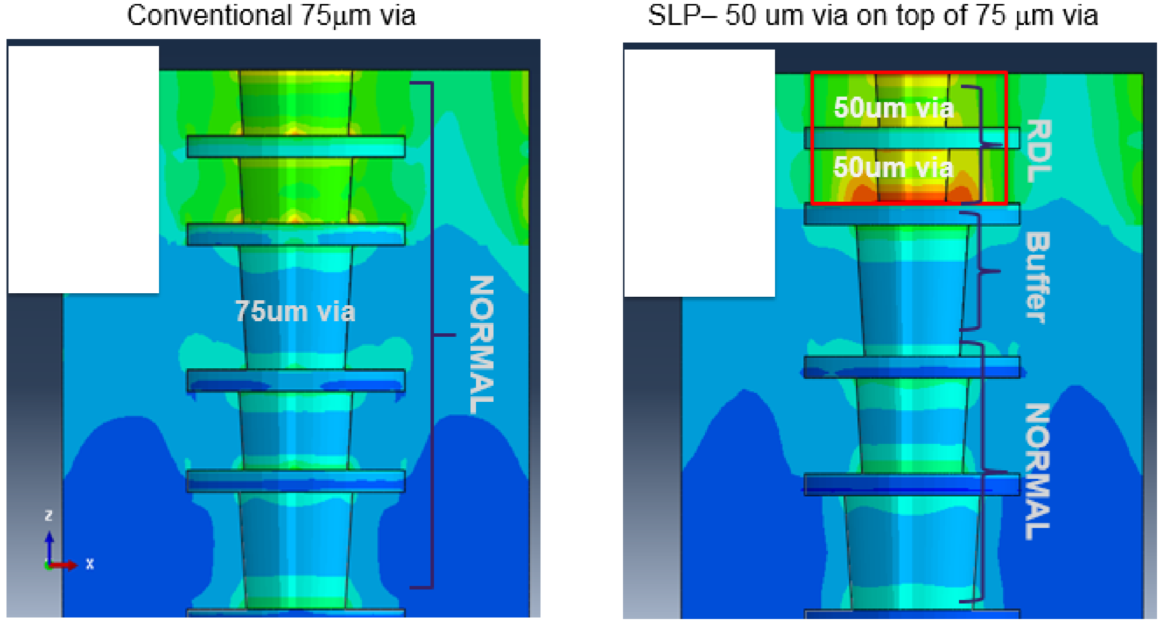
SLP Case Study - Modeling Outcomes

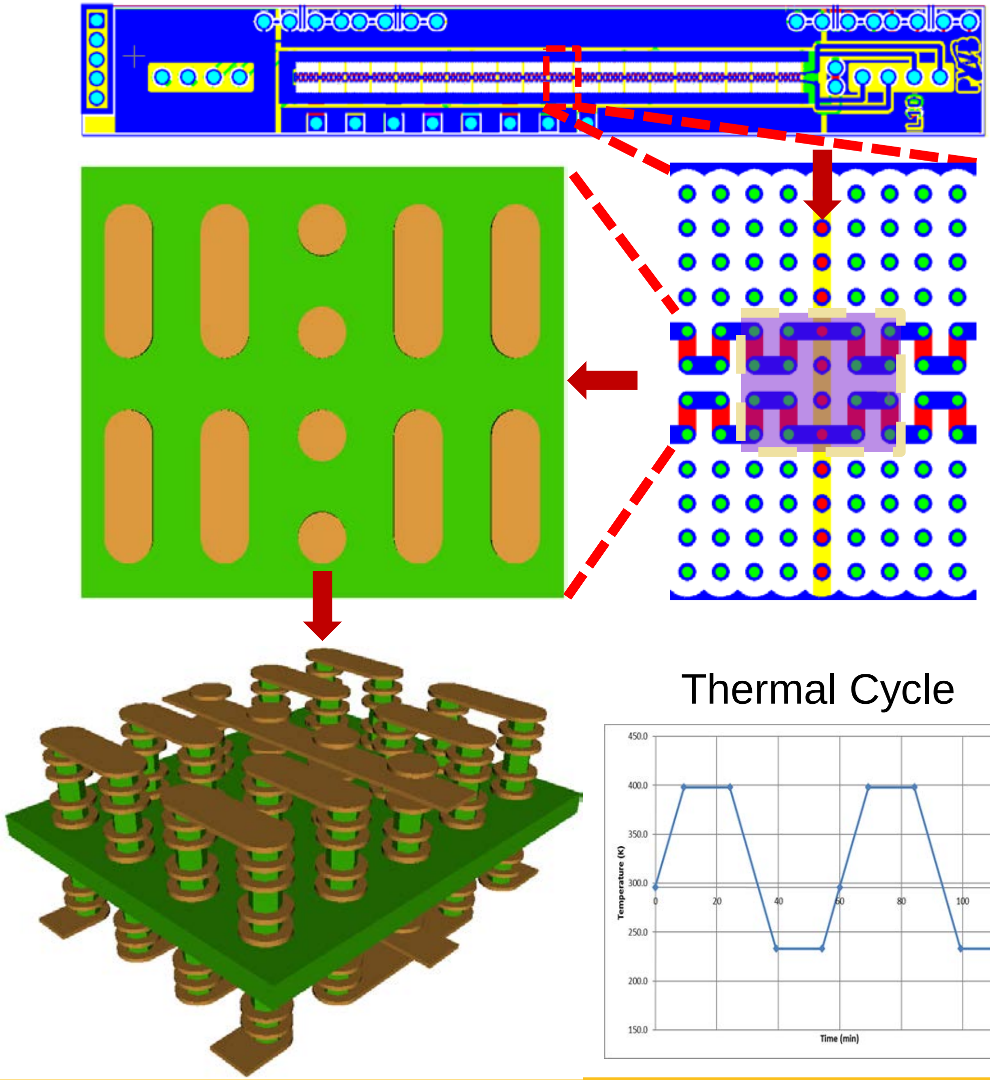




- Simulation goals
  - *Structural Integrity insight of microvia system (II best overall)*
  - *Compare and contrast response with conventional microvia structure*

SLP Case Study - Interconnect Reliability

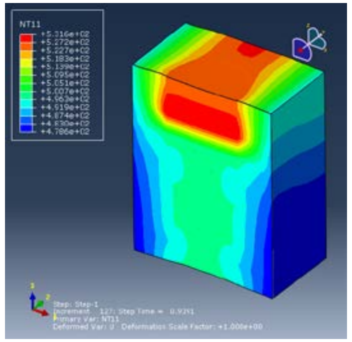
IST (Interconnect Stress Testing) Modeling

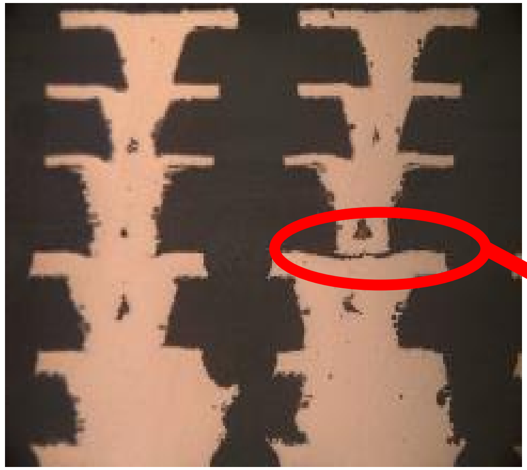


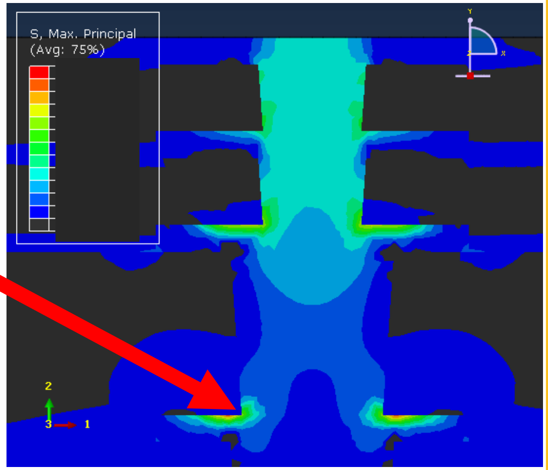
Thermal Cycle

Thermal Cycling Correlation

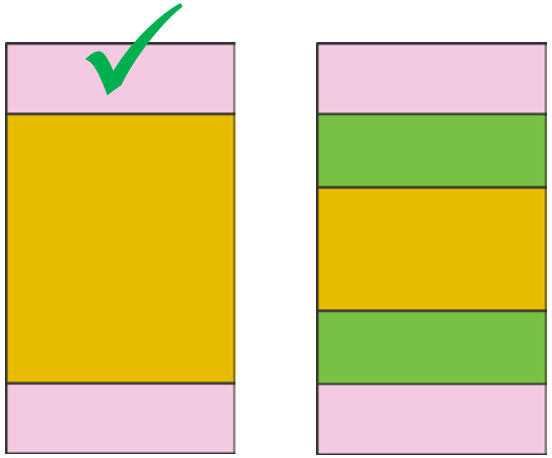
Thermal Gradients







Test Item	Coupon Name	Total Oty	Test Status	PASSED
Reflow 10X	Stackup1_2mil Laser/200pitch	10	Done	10
	Stackup1_2mil Laser/250pitch	10	Done	2
	Stackup1_2mil Laser/300pitch	10	Done	1
	Stackup2_2mil Laser/200pitch	10	Done	8
	Stackup2_2mil Laser/250pitch	10	Done	9
	Stackup2_2mil Laser/300pitch	10	Done	5
LLTS	Stackup1_2mil Laser/200pitch	10	up to 700X	10
	Stackup1_2mil Laser/250pitch	10	up to 700X	4
	Stackup1_2mil Laser/300pitch	10	up to 700X	5
	Stackup2_2mil Laser/200pitch	10	Done	0
	Stackup2_2mil Laser/250pitch	10	Done	0
	Stackup2_2mil Laser/300pitch	10	Done	0
AATS	Stackup1_2mil Laser/200pitch	10	up to 400X	10
	Stackup1_2mil Laser/250pitch	10	up to 400X	8
	Stackup1_2mil Laser/300pitch	10	up to 400X	9
	Stackup2_2mil Laser/200pitch	10	Done	0
	Stackup2_2mil Laser/250pitch	10	Done	1
	Stackup2_2mil Laser/300pitch	10	Done	0



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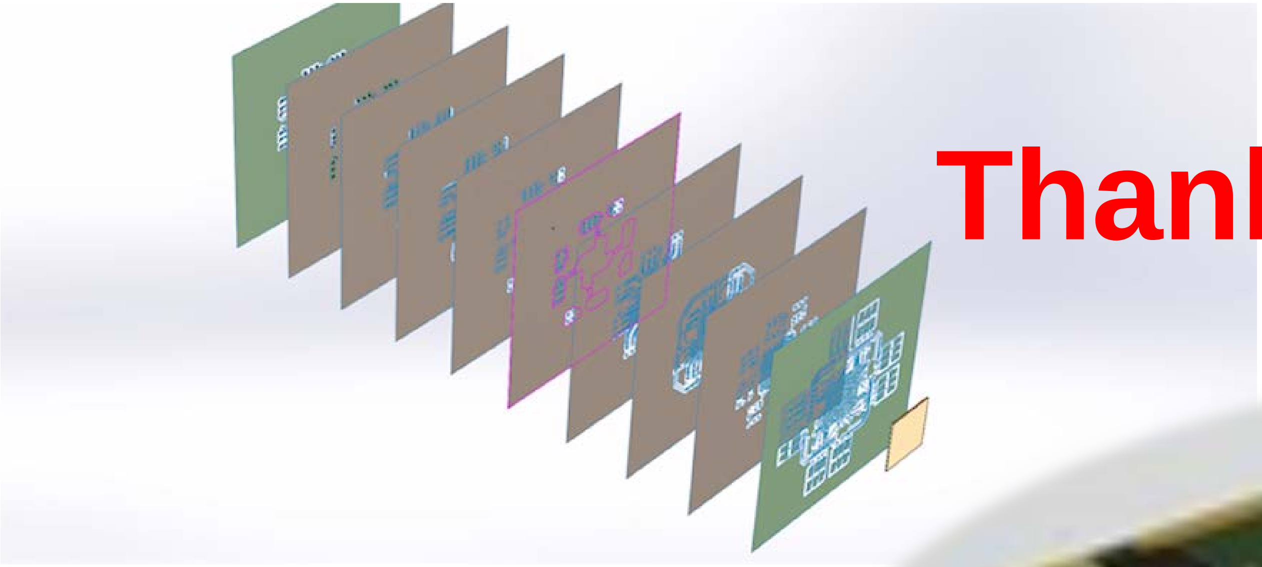
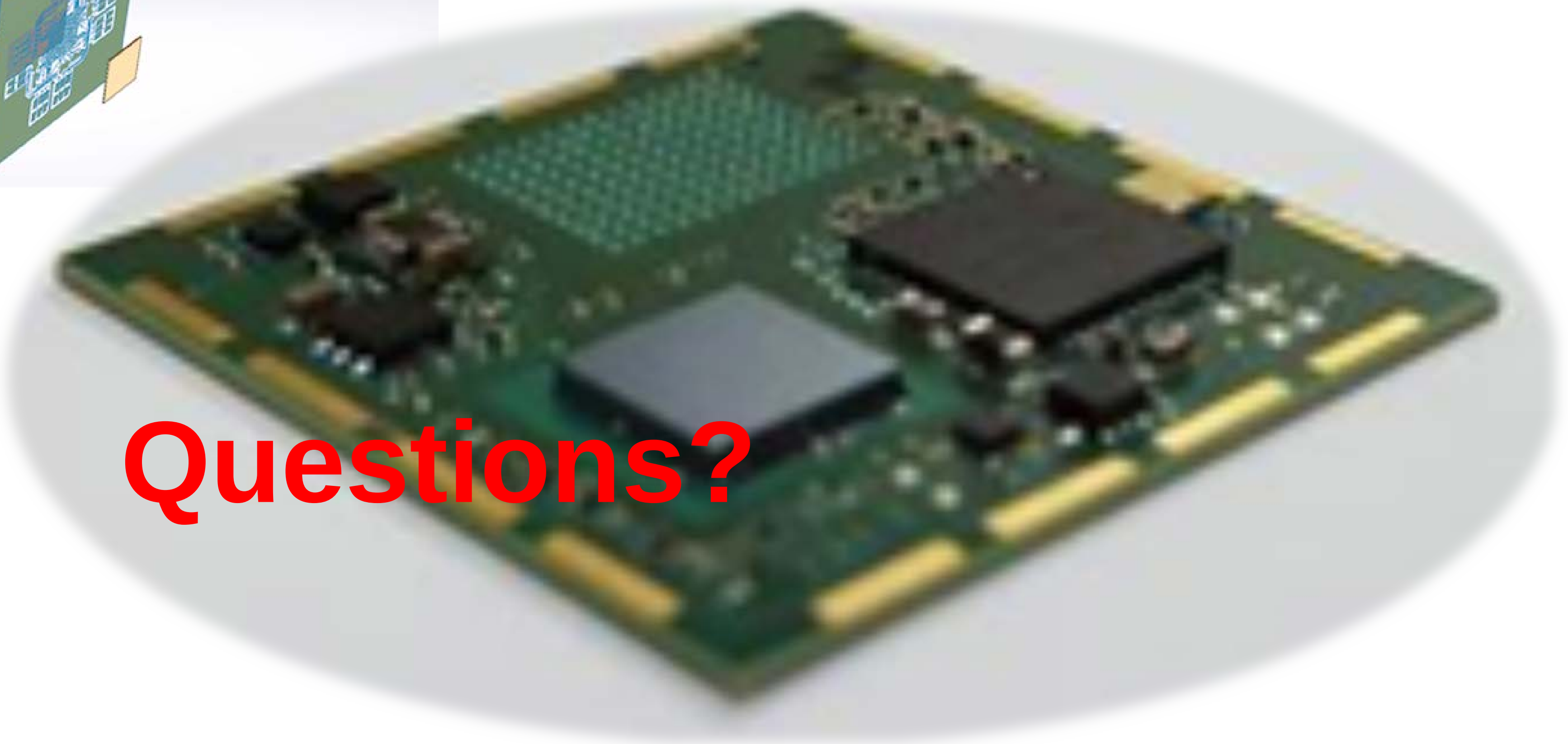
Summary

- Effective methods discussed to characterize mechanical and thermal behavior of B-stage and C-stage PCB materials undergoing lamination and reflow.
- Results from characterization used in analytical modeling of SLPs using Finite Element Method.
- Analyses results shows very good correlation with test vehicle failure mode. Insight helped in material selection and process optimization path for robust manufacturable solution.



Thank You



Questions?

References

- [1] AT&S Annual report 2017; Prismark Feb 2017; Yole Apr 2017
- [2] iNemi Modeling, Simulation and Design Tools (MS&DT) Roadmap. 2013, 2015, & 2017