Effect of Lead Free Assembly Reflow Cycles on Base Material Substrate Properties

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Regulatory restrictions and environmental needs are moving the electronics industry towards lead-free solders and other environmentally friendly materials. This massive effort has resulted in numerous efforts across the supply chain – this involves qualifying materials and equipment, designing products and processes followed by exhaustive test procedures and qualification.

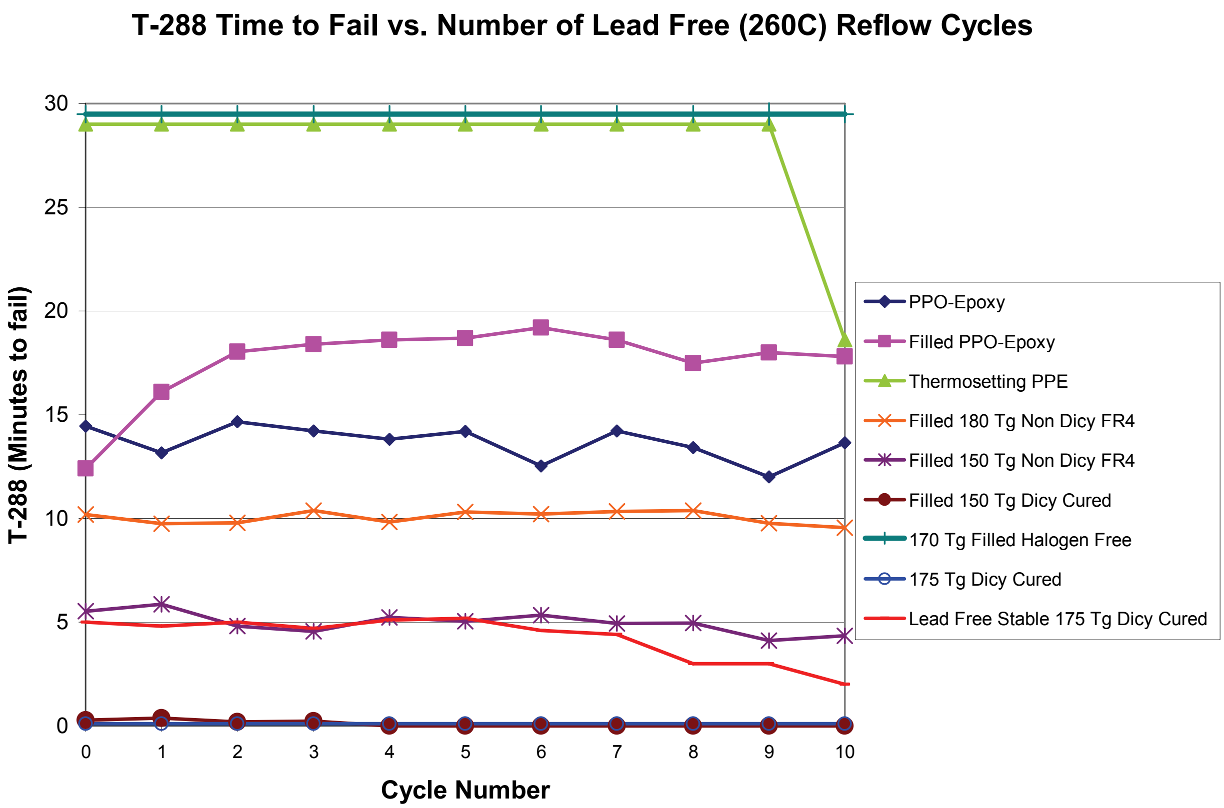
This paper reflects some of the materials characterization efforts performed to accommodate the changes in assembly processes. A look back at the life cycle of a PCB base laminate indicates that the substrate is exposed to numerous thermal cycles at PCB fab houses and final board assemblers. This effort is focused on identifying and quantifying changes due to the same.

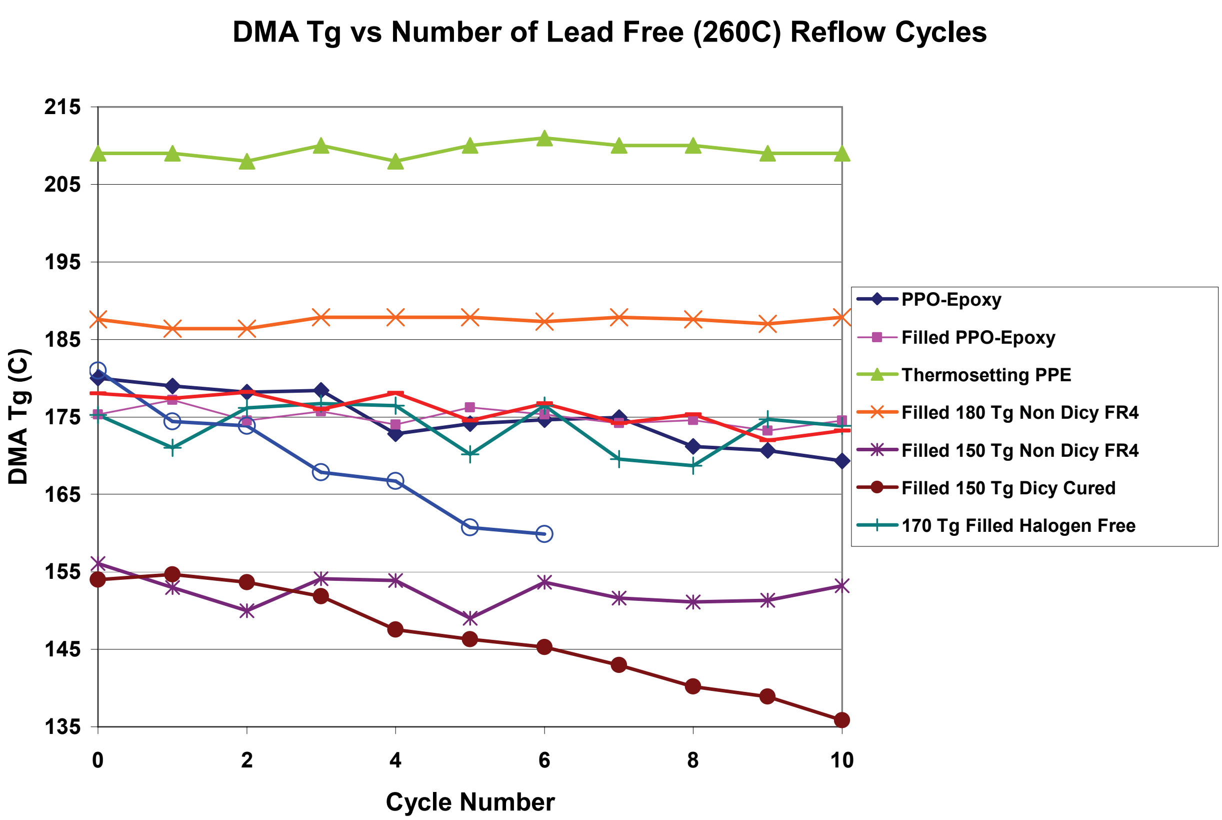
It is crucial to characterize the effects of processing conditions on material properties to predict product performance; the experimental plan involved evaluating changes in base material substrate properties as a function of multiple reflow cycles. The following properties were evaluated – Glass Transition Temperature (T_g), T-288, Decomposition Temperature (T_d), % Expansion (50-260˚C), Temperature of failure by TMA, and Dielectric Constant (DK).

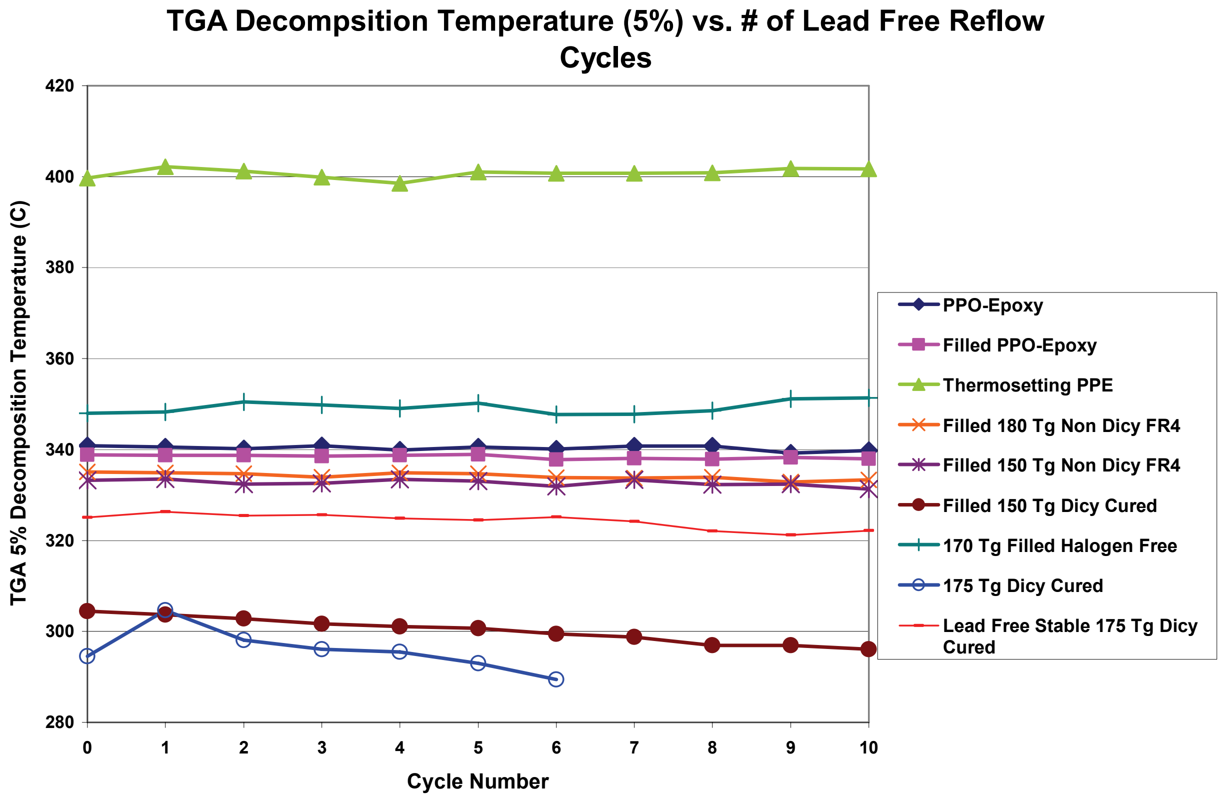
Test vehicles were built with the same glass style and had the same construction. The reflow profile used was a typical "Lead Free" cycle used for the qualification of substrates and PWB's. The Lead Free profile used had substrate exposure time above 260C of 20 seconds, exposure above 220C for 110 seconds, with a peak temperature of 266C.

Each substrate material was exposed to 1 through 10 reflow cycles unless there was premature decomposition. Furthermore, a range of base materials (Low – High T_g, Enhanced electrical, Filled substrates, different curing agents and resin chemistries), were evaluated for this study. All laminate tested were 0.062 inches in thickness and clad with 17 micron thick copper foil on both sides.

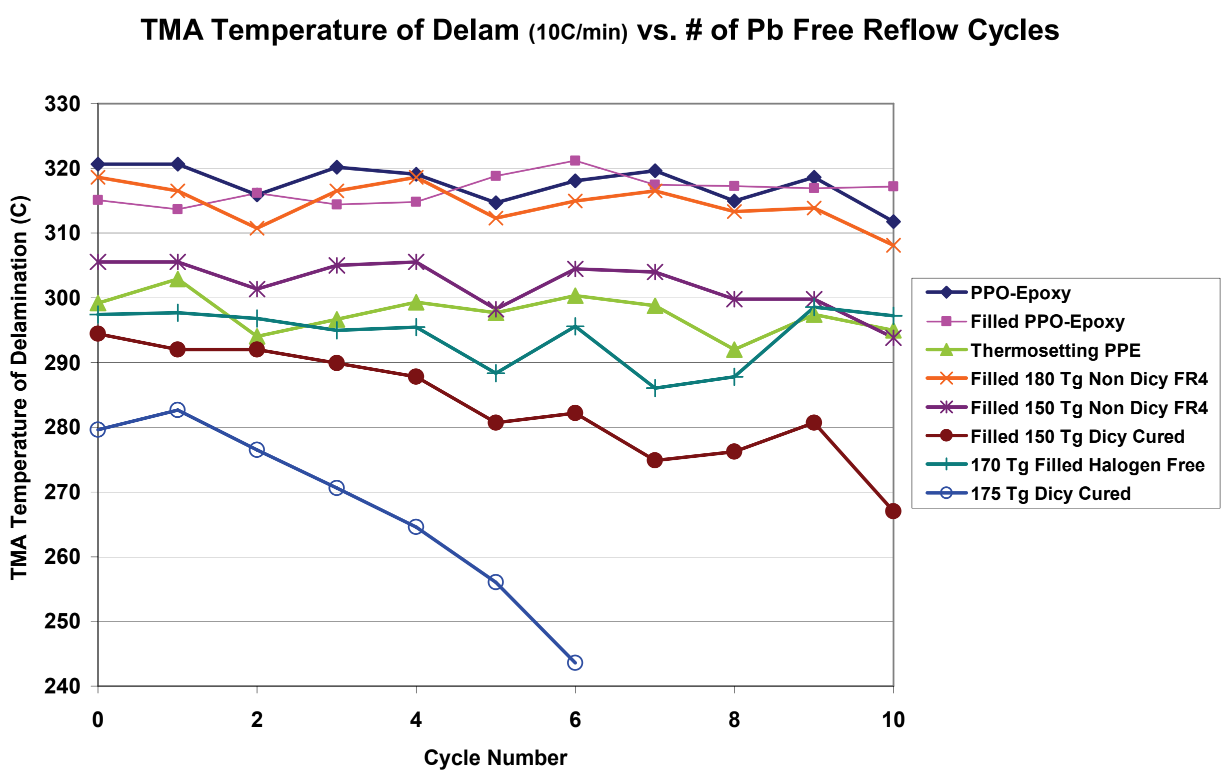
Below are a series of graphs depicting the results of the testing performed on the laminates cycled through the assembly reflow process.


T-288 Time to Fail vs. Number of Lead Free (260C) Reflow Cycles
T-288 (Minutes to fail)
Cycle Number
PPO-Epoxy
Filled PPO-Epoxy
Thermosetting PPE
Filled 180 Tg Non Dicy FR4
Filled 150 Tg Non Dicy FR4
Filled 150 Tg Dicy Cured
170 Tg Filled Halogen Free
175 Tg Dicy Cured
Lead Free Stable 175 Tg Dicy Cured

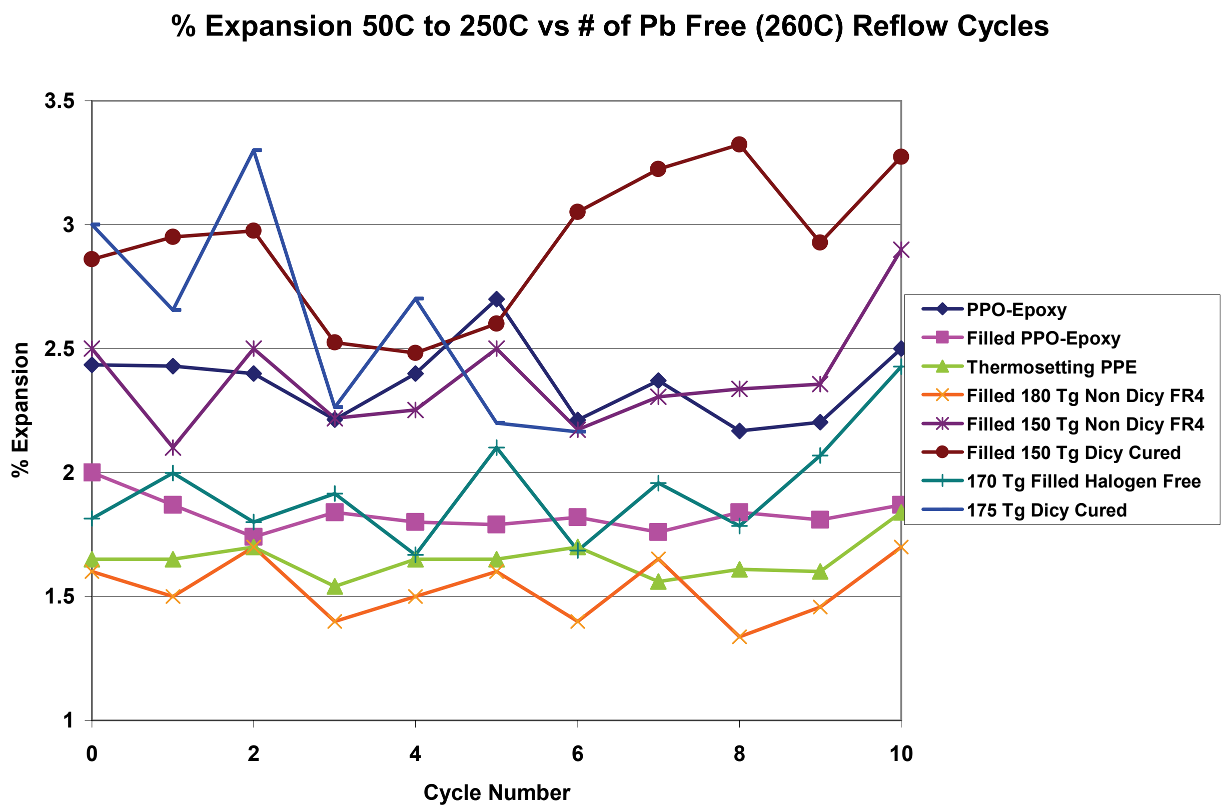

DMA Tg vs Number of Lead Free (260C) Reflow Cycles
DMA Tg (C)
Cycle Number
PPO-Epoxy
Filled PPO-Epoxy
Thermosetting PPE
Filled 180 Tg Non Dicy FR4
Filled 150 Tg Non Dicy FR4
Filled 150 Tg Dicy Cured
170 Tg Filled Halogen Free

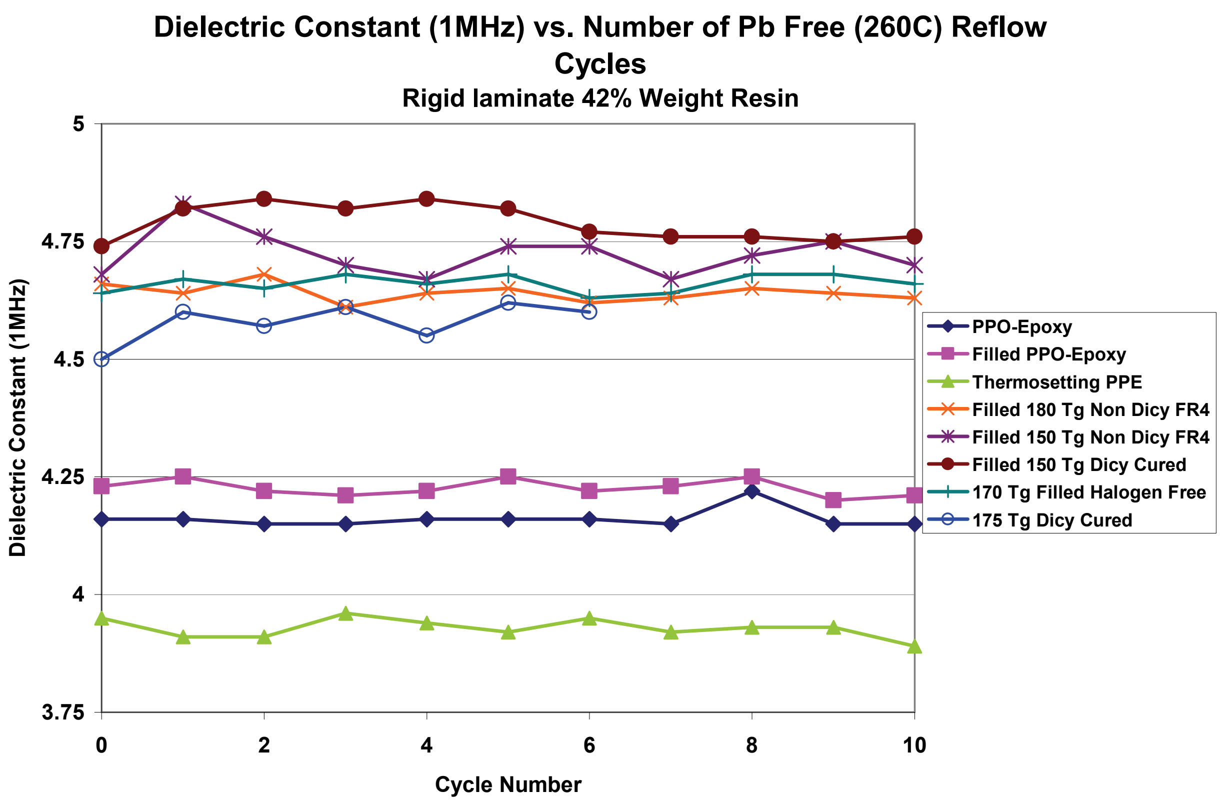


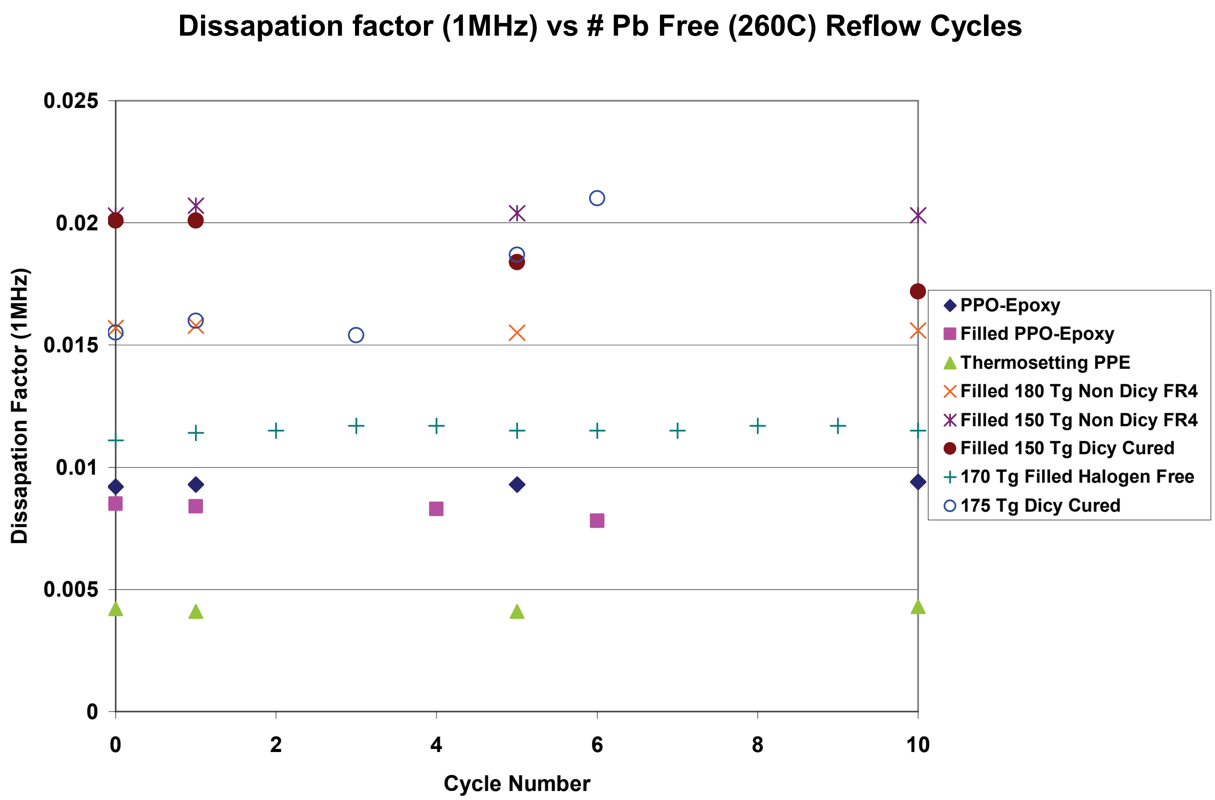
TGA Decompsition Temperature (5%) vs. # of Lead Free Reflow Cycles
TGA 5% Decomposition Temperature (C)
Cycle Number
PPO-Epoxy
Filled PPO-Epoxy
Thermosetting PPE
Filled 180 Tg Non Dicy FR4
Filled 150 Tg Non Dicy FR4
Filled 150 Tg Dicy Cured
170 Tg Filled Halogen Free
175 Tg Dicy Cured
Lead Free Stable 175 Tg Dicy Cured



TMA Temperature of Delam (10C/min) vs. # of Pb Free Reflow Cycles
TMA Temperature of Delamination (C)
Cycle Number
PPO-Epoxy
Filled PPO-Epoxy
Thermosetting PPE
Filled 180 Tg Non Dicy FR4
Filled 150 Tg Non Dicy FR4
Filled 150 Tg Dicy Cured
170 Tg Filled Halogen Free
175 Tg Dicy Cured


% Expansion 50C to 250C vs # of Pb Free (260C) Reflow Cycles
% Expansion
Cycle Number
PPO-Epoxy
Filled PPO-Epoxy
Thermosetting PPE
Filled 180 Tg Non Dicy FR4
Filled 150 Tg Non Dicy FR4
Filled 150 Tg Dicy Cured
170 Tg Filled Halogen Free
175 Tg Dicy Cured


Dielectric Constant (1MHz) vs. Number of Pb Free (260C) Reflow Cycles
Rigid laminate 42% Weight Resin
Dielectric Constant (1MHz)
Cycle Number
PPO-Epoxy
Filled PPO-Epoxy
Thermosetting PPE
Filled 180 Tg Non Dicy FR4
Filled 150 Tg Non Dicy FR4
Filled 150 Tg Dicy Cured
170 Tg Filled Halogen Free
175 Tg Dicy Cured



Conclusions

Traditional dicy cured FR4 laminates do not survive more that a few lead free assembly reflows before severe performance degradation is observed.

More thermally stable non-dicy cured FR4, halogen-free FR4, PPO-Epoxy, and Theromsetting PPE are very thermally stable and do not degrade significantly even after 10 lead free reflow cycles.

Products with a range of dielectric performance are available that are compatible with lead free assembly processes.

Low Z-axis % thermal expansion products such as filled PPO-Epoxy, Thermosetting PPE, and non dicy cured FR4 are available that can survive the lead free reflow temperatures and reduce z-axis stress on plated though holes for improve PWB reliability.

New high Tg dicy cured epoxy chemistry has been developed that has thermal stability adequate for use lead free assembly processes.