Improved Flatness of RO4000/FR4 Hybrid Multi-layer Boards

Designing Rogers' high performance RO4000 dielectric materials with FR4 cores and prepregs into hybrid multi-layer circuit boards has been a common practice since the introduction of the RO4000 product family. Initially, hybridization was necessary as RO4000 core materials were available before a complimentary prepreg system was fully developed. But, many designers still opt for a mixed dielectric approach even though the introduction market of RO4403 prepreg has made homogeneous RO4000 MLB's possible. The logic is simple. Designing RO4000 materials into layers with high performance requirements while forming the signal routing layers with epoxy/glass cores and prepregs results in a cost-effective performance upgrade.

Our experience has indicated that most hybrid MLB designs can be manufactured within standard tolerances for warp without making modification to the materials used in the construction or to the manner in which the boards are processed. It is not unrealistic to expect most hybrid designs to be processed within ¼% of the warp that would be expected from a design had it been manufactured as a homogeneous RO4000 or epoxy/glass construction.

However, warp is a concern with some hybrid designs. The warp might result from design and processing issues or simply from the use of dissimilar dielectric material systems. Whatever the cause, there are practiced ways of reducing warp.

Through designed experimentation and collaborative processing studies with our circuit facility partners, we have identified the following list of options that can be implemented to improve the flatness of hybrid MLB designs when warp is an issue. Choosing which option or options might best be implemented to improve the flatness of a particular design is dependent upon the cause of warp and the cost impact. Some of the options have little or no cost impact and perhaps should be considered as specifications during design.

High Tg FR4 Cores: All evaluations have strongly indicated that high Tg FR4 (>165C) cores are a major benefit to the manufacture of flat RO4000/FR4 constructions. The higher Tg materials provide improved stability through the temperature exposures associated with multi-layer bonding, circuit fabrication, and component assembly. The benefits provided by the use of high Tg epoxy/glass laminates are such that their use should be specified by the designer.

Low Tg FR4 Prepreg: The flatness of low layer count (4-6 layers) MLB designs can benefit from the use of low Tg (125-135C) epoxy glass prepregs and their associated bonding conditions. While the reason for this is not fully understood, the flatness of several hybrid designs has been improved upon by combining high Tg cores with low Tg prepreg. The benefit may lie in the improved temperature stability of the high Tg cores through the low temperature bond cycles required by the low Tg prepreg.

Balanced RO4000 Layers: Higher layer count (8+ layers) hybrid constructions can benefit from being balanced with respect to the distribution of the high performance material layers. For example, a ten layer construction might use equal thickness RO4000 cores to support metal layers 1-2 and 9-10.

Metal Distribution: Warp often results from dimensional changes due to temperature-induced stress relief of dielectric materials following the removal of restraining copper layers. For this reason, copper cladding should be left in any areas where circuit performance would not be affected.

Reduced Ramp Rate to Temperature: Different rates of heat rise through a book of multi-layer boards can result in process-induced warp. It is quite common, especially through in-hot press cycles, for a multi-layer in the top of a book to cup down toward the bottom platen while a multi-layer from the bottom of the book cups up toward the top platen. The multi-layers in between transform from cupped-down to cupped-up depending upon position in the book. The temperature differential through a multi-layer book can be reduced by using a cold start with a controlled ramp rate or by increasing the thickness of press pad and temperature lagging layers.

Step-Down Pressure Profile: Most epoxy/glass prepreg materials require a sixty to ninety minute dwell at temperature with an average applied pressure of 200 to 250 PSI even though the fill/flow potential of the prepreg is realized during the first ten minutes at temperature. The remainder of the time at temperature serves no purpose other than to advance the cure of the resin system.

The flatness of several hybrid designs has been significantly improved by incorporating a step-down pressure profile where the applied pressure is reduced to 50 PSI during the final 20 to 30 minutes at temperature. The step-down pressure profile incorporates a stress-relieving flat bake into the original bond cycle.

Pre-Baked RO4000 Cores: As mentioned earlier, stresses residual from copper cladding by the laminate manufacturer are relieved in the form of dimensional movement through copper etch and exposure to elevated temperature. A mis-match of the dimensional stability of dissimilar dielectric materials can contribute to the warp of hybrid constructions. Naturally, greater mis-matches result in greater levels of warp.

Most of the stresses residual to RO4000 materials can be removed by baking incoming cores for four hours at 350F. Virtually all of the stresses can be relieved through a four hour bake at 400F. Either bake can be done in air and either bake provides improved dimensional stability of the RO4000 cores through inner-layer preparation and multi-layer bonding.

Post-Process Flattening: Some warp can be removed from hybrid constructions through a four hour flat bake at 350F. The bake can be done by stacking multi-layers between flat metal plates and oven baking for four hours. But, the preferred approach is to hold the MLB’s in a 350F press for four hours under 50 PSI applied pressure. The press approach eliminates the presence of air at the surface of the circuits and results in less temperature-induced discoloration of the solder masks and dielectric materials.