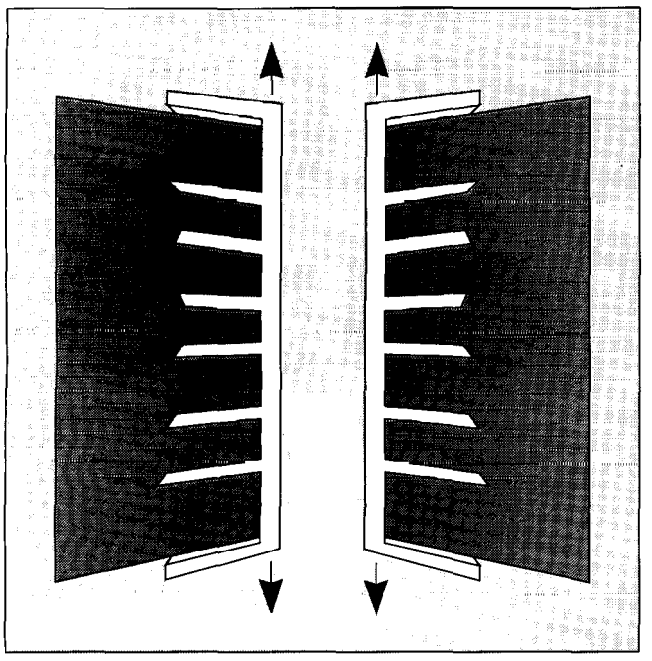

Figure 2. Stresses imparted to a PTH *due to thermal Z-axis expansion* conditions.

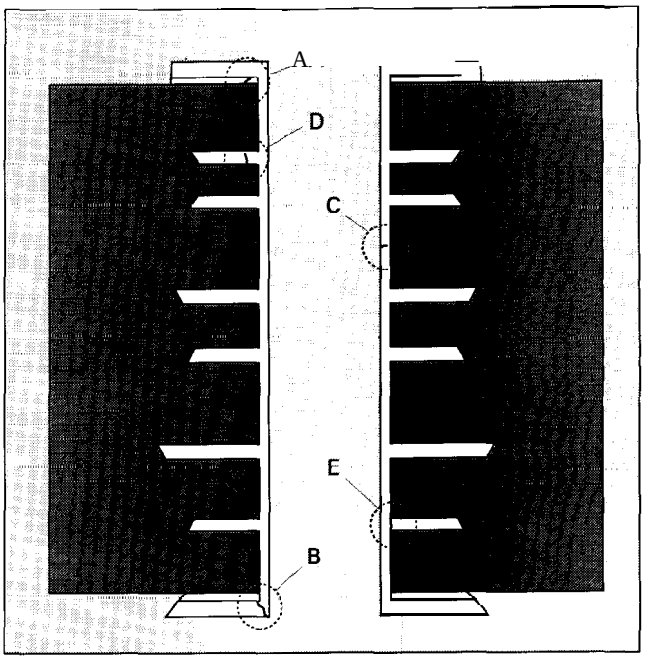

Figure 3. A) vendor foil pad *cracking, B)* pad cracking, C) hole *barrel* cracking, D,) innerlayer foil cracking, and E) barrel-to-innerlayer cracking.

multilayer printed circuit boards. Thermal expansion of the printed circuit board places stress on the plated through-hole because the rate of expansion of the resin/glass base *material is* much higher than that of the copper in the plated through-hole barrel. The copper PTH barrel is therefore forced to extend, placing significant stress on the inner-layer foil-to-barrel connections, the external foil-to-barrel connections, the pads, and the barrel itself (Figure 2). If no consideration is given to the differentials in expansion, then barrel cracking, pad lifting, foil cracking, or layer-barrel separation will eventually occur, ultimately causing circuit opens and failure of the electronic product. Figure 3 illustrates various PTH failures related to Z-axis thermal stress on a PCB.

Product Tests

Two mil-spec tests have gained widespread acceptance in the non-military PCB sector. Outlined in MIL-P-55110, para. 4.8.6.1 and 4.8.6.3, respectively, the thermal stress and thermal shock tests have become a standard means by which PTH reliability is judged for acceptance. The thermal stress test is a lot-by-lot test based on a PTH coupon solder float for 10 seconds at 550°F, followed by cross-section analysis. The thermal shock test, which is most often used as a qualification-type test, consists of the thermal cycling of PTH samples at —65°C for 15 minutes, followed by 15 minutes at 125°C (FR-4 specifications). This cycle is repeated 100 times. The acceptance of these rigorous tests as the benchmark for PCB quality, as well as the increase of thick, high-layer count multilayer printed circuit boards with higher-aspect-ratio holes and high resin content, has placed the need for reduced Z-axis expansion at a premium.

Defenses

Although there are myriad possible causes for barrel-cracking plated through-holes (including poor design and poor process control in lamination, desmear/etchback and plating processes), one common defense against cracking has been to decrease the differential of the copper-hole barrel/laminate material Z-axis expansion. Numerous plating additives and hole pretreatments, as well as IPC-CF-150E Class 3 (HTE) copper foil for innerlayers, have become more common in the fight for plated through-hole reliability. One of the most accepted defenses against hole barrel cracking, however, is increasing the robustness of the material/PTH system by using a laminate material with low Z-expansion properties. Figures 4 and 5 illustrate the TMA curves for two high-Tg FR-4 products, an epoxy multifunctional and a polyphenylene oxide (PPO)/epoxy. The former exhibits a 4.25% Z-expansion and the latter a 3.93% Z-expansion value. Note that the PPO/epoxy curve shows the least thickness growth over the same temperature range, illustrating why it is the fabricator's choice when high plated through-hole reliability is required,

Conclusion

The growth of the multifunc-

(Continued on page 56,)

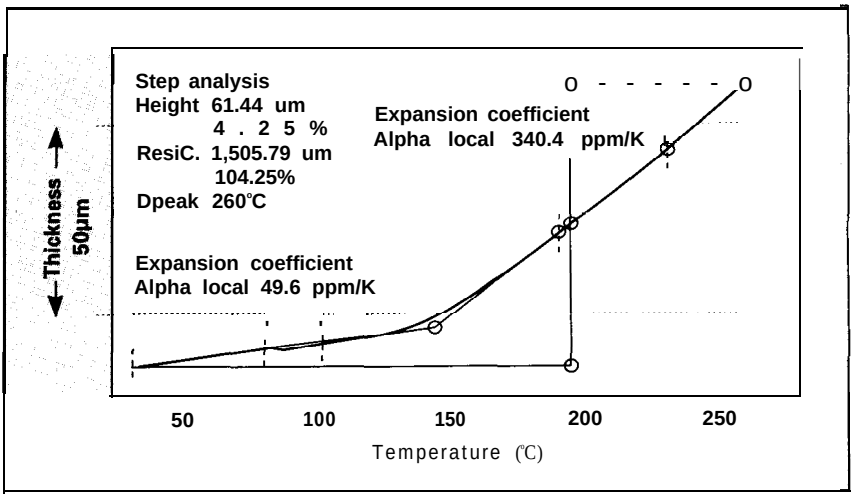

Figure 4. Thermomechanical *analysis curve for an epoxy/multifunctional laminate (expansion=4.25%).*

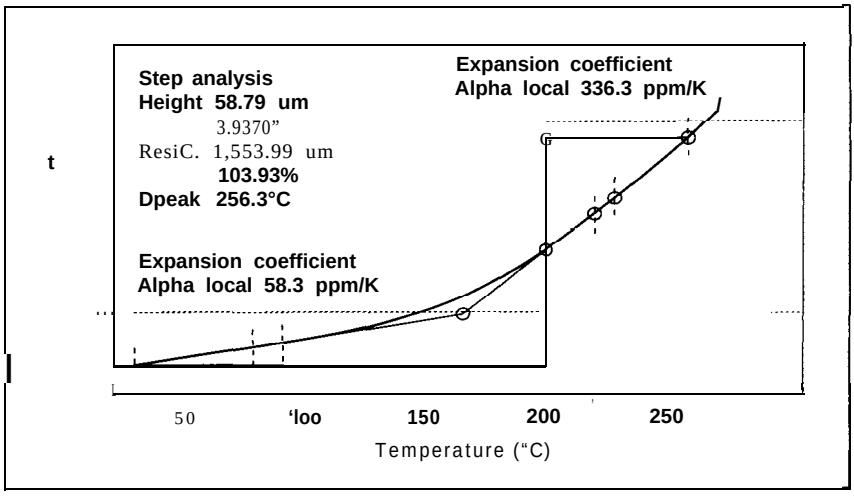

Figure 5. Thermomechanical analysis curve for a PPO/epoxy *laminate system (expansion* = 3.93%).

(Continued from page 50)

tional and other high-glass-transition laminate systems in recent years is mainly attributable to the printed circuit board community's search for plated through-hole reliability through minimized Z-axis expansion. Although these materials have addressed some of the fabricators' concerns about Z-axis expansion and associated barrel cracking, the basic physics involved with materials and printed circuit board manufacturing dictate that Z-axis expansion and reliability can be managed through proper materials, design, and process control—but not totally eliminated. FAB

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