

Non-functional lands: keep them vs. remove them

The common assumption that removal of non-functional lands has no reliability impact needs to be rethought in light of the higher lead-free soldering temperatures.

The threat to the reliability of printed circuit boards (PCBs) comes primarily from one source - the temperatures required during the soldering processes for the assembly of the components onto the PCB. These reliability threats were first discussed in this column in the October 2001 GSMT&P 1.3 issue, and more recently with emphasis on the high lead-free soldering process temperatures in the September 2005 GSMT&P 5.8 issue.

In neither column was the issue of non-functional lands (NFLs) addressed. The reason for this came from the assumption that it was essentially a non-issue.

This common assumption that removal of non-functional lands has no reliability impact needs to be rethought in light of the higher lead-free soldering temperatures. As was shown in my column of May 2003 (GSMT&P 3.4), the PCB reaches temperatures of 265 to 280°C when soldering with LF-solders.

Early work showed that there was no significant impact on barrel stresses when NFLs were removed, as can be seen in *Figure 1*.

Experience has shown that the reliability issues primarily related to plated-through hole (PTH)/via copper barrel fractures for small-diameter holes or inner-layer separation

(ILS) for larger-diameter holes^[2-5]. 'Resin recession,' as illustrated in *Figure 2*, did not have any real reliability consequences.

Further, studies and testing concentrated on the long-term threat to reliability from the cyclic operating conditions^[1,3,5], and assembly conditions, to the extent considered at all, where simply pre-conditioning to the main effort.

However, recent experience shows things to be nowhere near as benign for assemblies undergoing soldering processes utilizing the lead-free solders as had been tacitly assumed. *Figure 3* shows some recent industry experience with PTHs in PCBs that reached nowhere



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the 'Red Flag'-level of an aspect ratio of 4-to-1.

In *Figure 4*, the same PCB is shown with a full complement of non-functional lands (NFLs) and showing no wall separation or 'resin recession.'

The physical processes that cause what is seen in *Figure 3*, and to a lesser degree in *Figure 2*, need to be understood. For an understanding of what is going on, it is perhaps best to visualize the PTH as a submerged submarine. The surrounding resin is the equivalent of the ocean water surrounding the sub: as the temperature is increased to soldering temperatures, the 'hydro'-static pressure on the copper barrel 'submarine' increases.

In Physics 101 we learned that if one drills a hole in a plate of steel and then heats the plate, the size of the hole increases with the thermally expanding steel. Unfortunately, the isotropic steel plate is not the equivalent of the PCB, with its glass-fiber sheets constraining the resin in the x/y-directions. This makes the PCB highly anisotropic, and as the resin thermally expands almost exclusively in the z-direction, it tries to expand into the space of the PTHs as well.

Coming back to our *Gedankenbild* of the submarine, clearly a 'sub' with a smaller diameter is stronger than one with a larger diameter, a 'sub' with closely spaced reinforcement ribs is

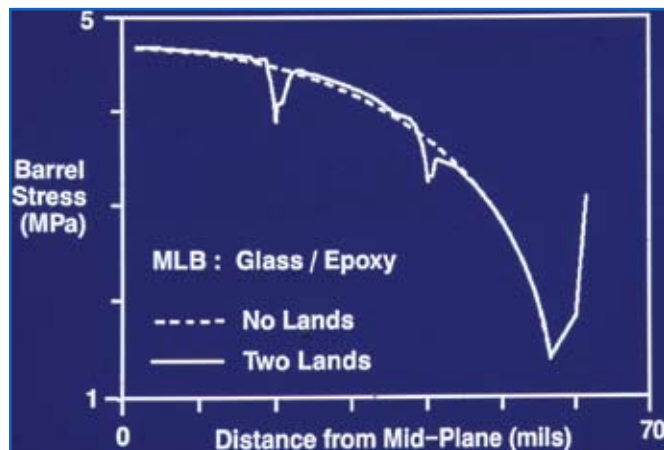


Figure 1. Graph showing the z-direction tension stresses on the copper barrel of a plated-through hole^[1].

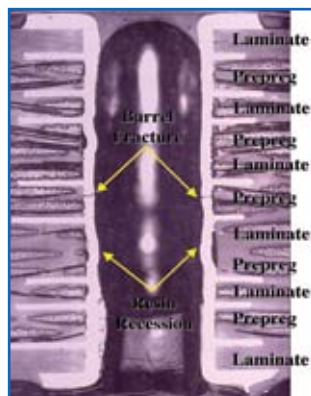


Figure 2. Micro-photograph of plated-through hole copper barrel crack and some 'resin recession'^[2].

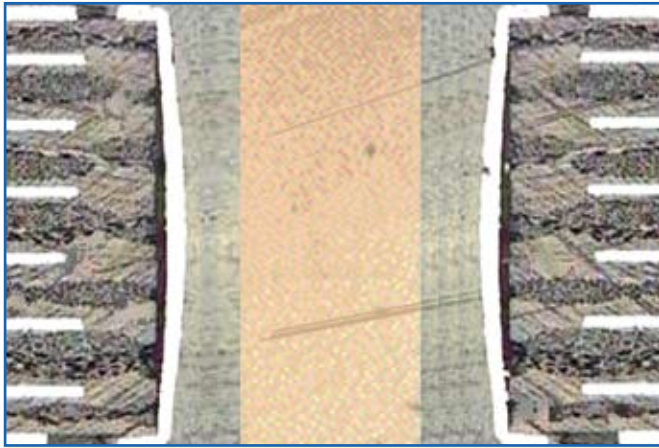


Figure 3. Micro-photograph of plated-through hole without any inner-layer connections/lands and resulting full hole-wall pull-away after lead-free wave soldering process^[2].

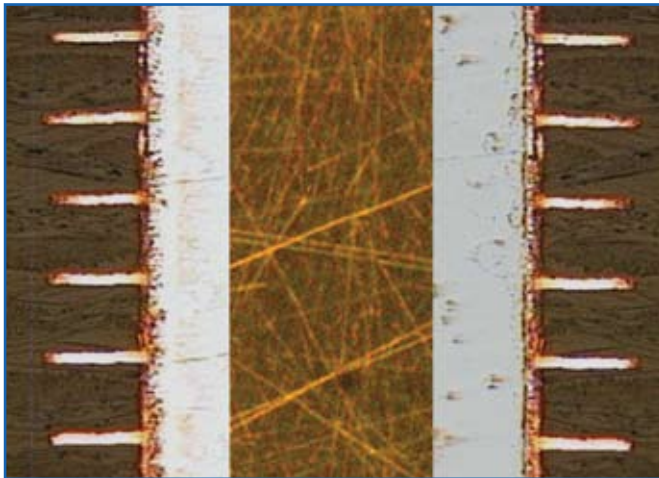


Figure 4. Micro-photograph of plated-through hole with full complement of inner-layer connections/lands^[2].

stronger than one with wider spaced ones or none at all. For a PTH, the functional and non-functional lands serve as 'reinforcement ribs;' thus, removing them clearly weakens the PTH barrel against collapse - not against barrel cracks, however - as can be seen in Figure 3. The higher temperatures required for lead-free soldering clearly exceeded the maximum 'dive depth' of this PTH.

What is actually happening is that on heating the PTH copper barrel wall bulges inward and plastically deforms more or less depending on the inner-layer land separation and the copper plating thickness for a given maximum temperature and PCB resin content.

When one looks at micro-photographs of PTHs with barrel cracks and/or resin recession, one notices that the vast majority of these occurrences are at prepreg layers and not laminate layers within the PCB (see Figure 2, also Ref. 5).

On cooling, when the resin thermally contracts to its original volume, the plastically deformed barrel walls cannot return to their former geometry, particularly if the inner-layer 'anchor points' are missing - the result: 'resin recession' or even full hole-wall separation, as illustrated in Figure 3.

Thus, the conclusion is clear: in order for PCBs to be compatible with the higher

soldering temperatures required for lead-free assemblies, non-functional land should not be removed.

I have just finished a multi-client study/white paper: "WHITE PAPER REPORT: Recommendations for PCB FAB Notes and Specifications in Printed Circuit Board Drawings for SnPb and Lead-Free Soldering Assemblies, the Qualification of PCB Shops and Activities to Assure Continued Quality." As indicated by the title, in this report recommendations are made regarding appropriate specifications and 'FAB Notes' on drawings for printed circuit boards (PCBs), general procedures to qualify PCB shops and to assure they would be producing PCBs of good quality, and testing procedures to verify quality and reliability. It contains examples - one for SnPb solder assemblies and one for RoHS-compliant Pb-free solder assemblies - of 'FAB Notes' serving as general specifications on PCB drawings, a basic questionnaire for new PCB shops to be qualified meant as a supplement to IPC-1710, as well as recommendations for ongoing activities to assure that qualified PCB shops maintain the quality of the PCBs produced by them. All the recommendations are fully researched and referenced.

References:

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- [4] IPC-TR-486 "Report on Round Robin Study to Correlate Interconnect Stress Test (IST) with Thermal Stress/Microsectioning Evaluations for Detecting the Presence of Inner-Layer Separations," The Institute for Interconnecting and Packaging Electronic Circuits, Northbrook, IL, July 2001.
- [5] Birch, B. "Discussion on Non Functional Pad Removal/Backdrilling and PCB Reliability," Monograph, PWB Interconnect Solutions Inc., www.pwbcorp.com, 2005.

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