Tech Talk

Fine Lines in High Yield (Part CXLIX)

Opens and Shorts

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All PWBs, modules, and IC packages consist of conductive features (circuit lines, vias, pads, power and ground etc) insulated from each other by non-conductive (dielectric) material. Therefore, all defects originating in the circuitizing process steps essentially consist of not having insulation where it is required ("short") or having an insulating interruption in the conductive path ("open"), and a number of defects that bring us dangerously close to having opens or shorts such as space violations, copper spots (extraneous copper), minimum line width violations, or dish-downs.

Scope of this Overview

The "column"-format of Tech Talk does not lend itself to an in-depth review of open and short defects, including assignment of root causes, troubleshooting guidelines, and corrective actions. This column will only focus on open and short defects associated with photoresist. An example of a review of open and short defects with a different focus is Michael Barbetta's (Ref. 1) investigation of random opens and shorts due to dirt that includes useful remedial actions. Some time ago, when I tried to cover causes of "excess copper" (Ref. 2, 3, 4), including troubleshooting suggestions, it mushroomed into a three-part series. Likewise, when I dealt with the issue of hole voids, a subset of open defects (Ref. 5, 6, 7, 8), it grew to a four-part opus.

Insufficient or Excessive Adhesion of Photoresist

Since conductors are formed by etching, or plating, or a combination of plating and etching, any obstruction to etching may lead to shorts or near-shorts, and any lack of cover or protection of surface areas that should not be etched can lead to opens or near-opens. Likewise, if plating is obstructed it can lead to opens or near-opens, and if plating happens in non-plating areas it can lead to shorts or near-shorts. If these problems are associated with the photoresist process, one can map out the different problem scenarios that have to do with insufficient or excessive resist adhesion as shown in Figure 1.

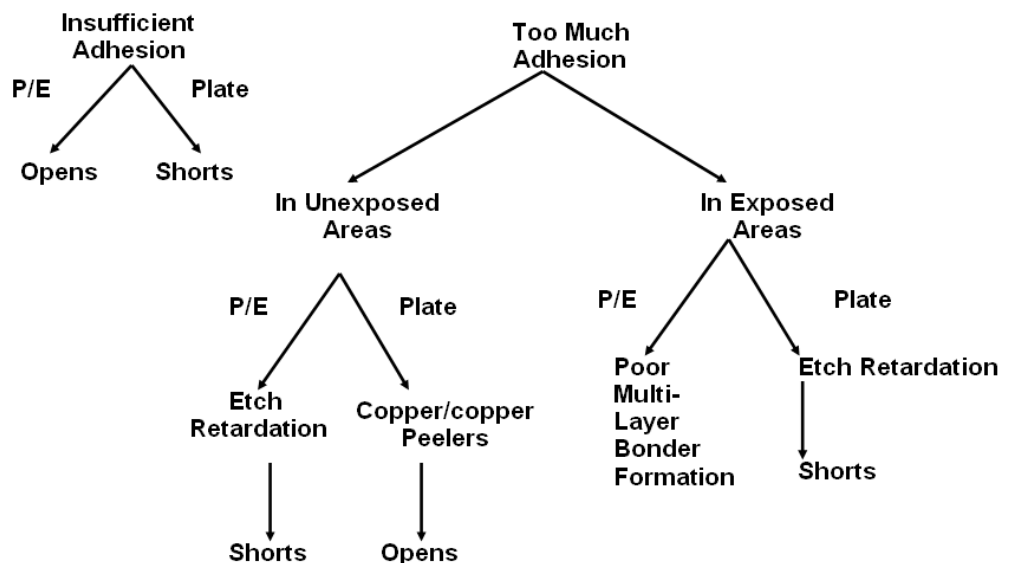

Figure 1: Failure Modes due to Insufficient or Excessive Resist Adhesion

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The failure mechanisms due to "Insufficient Adhesion" are pretty obvious: in the print & etch (P&E) process there is the danger of under-etching the resist which will lead to opens or near-opens such as mouse bites or dish-downs. In the plating process there is the possibility of under-plating so that after copper plating, metal etch resist plating and resist stripping, we have to etch through more copper where under-plating occurred, and since the etching process has been set up in such a way that there is just enough etching to remove the base copper and the thin electroless copper, there will not be enough time in the etcher to remove the excessive copper thickness in the under-plated area.

The failure mechanisms due to "Too Much Adhesion" are more complex as is evident from Figure 1. One has to distinguish between too much adhesion in unexposed areas and too much adhesion in exposed areas. Too much adhesion in unexposed areas in the P&E process will leave development residues on top of the copper that is to be etched. This can lead to etch retardation which in turn can lead to shorts or near-shorts. Too much adhesion in unexposed areas in the plating process can leave resist residues in the area where plating should occur. Such residues may impede plating altogether or, if plating occurs, the resist residues don't allow the plated copper to bond tightly to the base copper which may lead to copper/copper peelers, and ultimately to opens. If there is too much adhesion in the exposed resist areas, this may lead to resist residues in the P&E process after stripping on top of the copper circuit which can interfere with the application of the multilayer bonder treatment which in turn may lead to lamination defects. If there is too much adhesion of the exposed resist in the plating process, there may be resist residues after stripping in areas that should be etched which can lead to etch retardation and shorts between plated lines.

Causes of Insufficient Resist Adhesion

Poor resist adhesion is typically associated with inadequate surface preparation or faulty lamination conditions. Lack of adhesion due to inadequate surface preparation can be caused by insufficient copper micro-roughness or organic contamination (see Ref. 9) or by excessive chromate residues (see Ref. 10, 11). Poor resist adhesion due to lamination problems may be caused by low lamination pressure, low lamination temperature, or fast lamination speed. Under-exposure is another potential cause for poor adhesion. One should also keep in mind that not all resists are formulated to adhere to copper through nickel and gold plating or alkaline etching.

Causes of Excessive Resist Adhesion

This problem is less prevalent than insufficient resist adhesion. It may be due to high lamination temperature, long post-lamination hold times, or it could happen with wet lamination of a dry film resist that is not compatible with wet lamination.

Other Resist Related Causes for Opens or Shorts

The failure mechanisms described under "Insufficient Adhesion" are of course not only applicable for the case of insufficient adhesion of the resist, but also apply to poor resist conformation (interfacial voids), and to the case were resist had good adhesion but was mechanically removed due to handling damage. In addition, it applies to the situation where the questionable area was never covered by resist due to a flaw in the phototool, e.g. opaqueness in the clear area of the phototool, or an obstruction to exposure due to dirt in the exposure unit, scratches in the exposure frame etc. Last not least, the phototool may have been perfect, the exposure unit spotless, but the exposure energy was set too low. In this case we have resist where we expect it to be, but it may not survive the development process.

Over-development could be a cause of shorts or near-shorts. This is due to developer attack on the resist sidewall which can lead to a positive resist foot, or more likely to resist slivers breaking off the "nose" of the resist sidewall and re-depositing on the board surface. Re-deposition of resist may also have other causes. Tacky, partially polymerized resist, e.g. originating from the use of step tablets, may get stuck to transport rollers from where it transfers to the board surface. Poor filtration in the developer can cause an accumulation of resist particles in the development chamber, and may lead to resist particles being pressed onto the board by exit squeegee rollers. Unwanted resist residues on the board surface that don't get removed in the stripper can cause shorts in pattern plating. This problem can occur if boards are overplated ("mushroomed") or with very fine lines and spaces. In the latter case the use of resist that dissolves or partially dissolves in the stripper and the use of amine-based proprietary strippers are recommended.

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