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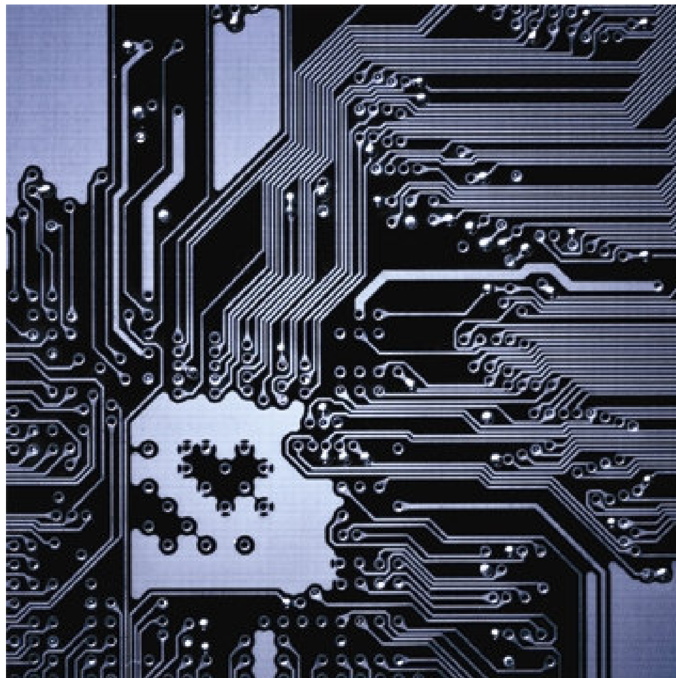

Innerlayer Processing: Process Control and Troubleshooting

An improved awareness of the relationship between key innerlayer process controls and defect modes will drive improvements in product yield and quality.

Whether producing ultra-fine line or more mainstream product, each of the steps within the innerlayer manufacturing process can influence both quality and yield.

Identifying and maintaining the proper controls and procedures for each process step is a critical first step to maintain high quality while meeting process cost targets. This review of the issues associated with a liquid resist based innerlayer process aims to provide an overview of these issues.

Material Preparation and Handling

Whether using liquid photoresist or dry film, the quality of the copper surface over which the resist is applied has a primary impact on process defect level. While liquid resists have better ability to cover surface defects, dents, scratches or burrs on the copper surface may still lead to formation of defects after etching (predominantly opens).

The key to avoiding such issues is to be aware of the different points at which the copper surface can be damaged.

Control of the process starts with clear acceptance criteria for incoming copper clad laminate. This should be combined with appropriate levels of sampling and inspection to confirm that quality targets are being maintained.

Each time clad laminate is handled there is another opportunity for creation of surface damage. Both procedures and equipment maintenance schedules for sheet cutting and edge cleaning operations should be examined to ensure that surface quality is maintained.

Debris formed in these operations is a primary source of contamination in the later resist coating and exposure processes. Elimination of this debris at source with clearly defined work practices is the most effective approach to avoiding problems in later process steps.

Scratch and burr defects are more easily formed on RTF foil, so particular care should be taken when handling these materials.

Surface Pre-Cleaning

Proper pre-cleaning is the key to achieving good adhesion between resist and copper.

Typical process flows employ a cleaning step, followed by a copper microetch and acid rinse. Usual process controls including cleaning uniformity, using such tests as water break, and maintaining bath concentrations and microetch rates based on measurements made at least once per shift are always appropriate. More sophisticated techniques such as contact angle measurement may be useful for troubleshooting purposes, but are less suitable for routine use. Since variations in copper foil grain structure can affect microetch rate, it is important to ensure that coupons used to test etch rate are representative of the product being run in the line.

Cases have been sometimes encountered when preparation of a new cleaner bath led to a significant improvement in resist adhesion, even though the water break test showed no indications of insufficient cleaning. When qualifying a line, data can be obtained to establish a defined dump schedule for the cleaner, based on resist adhesion as a function of cleaner bath age or throughput.

Whether the microetch used is a persulfate or peroxide based material, creation of a consistently rough surface morphology is required. Troubleshooting can be done by correlating surface condition (using a combination of SEM and profilometry) with data for resist adhesion after multiple passes through the subsequent development process.

Liquid Resist Coating and Drying

Maintaining the cleanliness of the environment used for the coating and drying steps is critical. When troubleshooting yield loss, examination of the resist layer after coating and drying can provide information on the nature and source of particulate contaminants.

While 10 +/- 2µm is often described as being the desired coating thickness range for liquid resists; depending on the process control and technology complexity at an individual customer, use of 8 - 9 µm coatings may not always provide acceptable yield.

Figure 1: Example of the Effect of Liquid Resist Thickness on Innerlayer Yield

Resist Coating Thickness (microns)	Number of Layers Evaluated	Panels with Opens or Nicks	Open / Nick Rate (%)
8 – 9	160	27	17
10 – 11	400	8	2

Using this approach to obtain initial baseline data for process capability and updating that information when higher difficulty product is introduced will ensure that the best balance of performance and cost is achieved.

Over or under drying a liquid resist can lead to a variety of different issues. Underdrying may lead to defects associated with damage during handling and stacking, loss of resist adhesion and changes in resist exposure and development properties, such as excessive photospeed or formation of a negative or positive resist foot. In contrast, overdrying can lead to loss of photospeed and difficulty in achieving proper development. Sublimation of resist components can also be an issue if drying is too severe, leading to issues with debris build-up within the equipment.

Resist Exposure

Although collimated sources (in which the light radiation from the source follows a parallel rather than a diverging path) may be used, non-collimated equipment is the norm for liquid resist exposure. The combination of higher exposure sensitivity of liquid resists with a collimated exposure source leads to an increased sensitivity to particulate contamination, with increased open / nick defects and lowered yields. Therefore the use of non-collimated light is much preferred. The equipment used must be capable of delivering sufficient light energy in an exposure duration that gives acceptable production throughput.

Enough exposure energy must be provided to allow the resist to be fully crosslinked, but excess energy will lead to lateral growth of the exposed area with consequent loss of resist line width control.

Optimum exposure energy for a particular resist may be identified using a Stouffer Step tablet (1).

Since the artwork must be tightly held against the resist coated substrate, insufficient delay time between vacuum application and exposure can adversely affect resolution. To confirm proper settings, evaluate resolution as a function of vacuum delay time.

Artwork damage and contamination is also an ever-present concern. Repeating defects appearing at the same location on a panel is an indication of this issue.

Resist Development

The developer process is required to remove unexposed resist (for a negative resist) so as to allow an accurate transfer of the image from the artwork to the final etched panel.
Residual resist left in areas that were intended to be completely cleared will prevent the subsequent etch step from properly removing copper from those locations.

Issues of this type may be associated with deficiencies in control of developer concentration or temperature, failure to ensure that horizontal equipment is properly maintained, for example, blocked spray nozzles or contamination of transport rollers.

Even if the developer chemistry and equipment is properly maintained, inadequate time, temperature, water cleanliness or spray pressure in the post-develop rinse step may also lead to residuals being left on the panel surface.

Optimum developer speed is established using breakpoint testing, where breakpoint is defined as the point at which the unexposed resist is first washed away revealing the copper substrate. Breakpoint should be sufficiently early in the developer chamber that complete pattern formation, with no residual material is guaranteed, but not so early that resist feature line width is reduced by dissolution in the developer chemistry.

While the exact breakpoint settings used in different
processes vary, typical values range from 30 – 60%

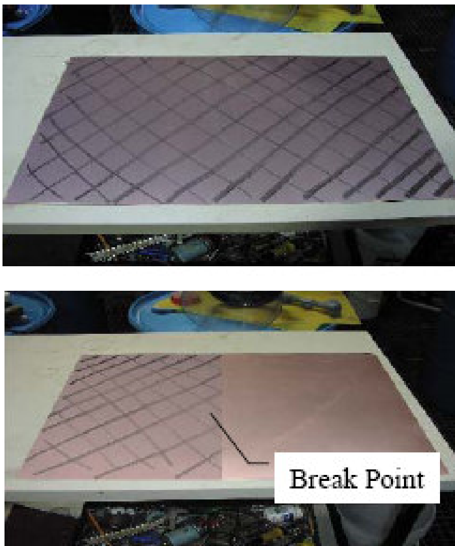

Figure 2: Development of resist coated over a water soluble marker pattern, allowing clear identification of developer breakpoint

Etching and Resist Stripping

Proper control of etch rate and etching factor is achieved through a combination of chemical concentration management and equipment maintenance. For most etching, temperature and spray pressure far outweigh any other factors in determining etch rate.

Although resist stripping does not directly affect the pattern formation, it may sometimes have an indirect impact on process yield. Incomplete stripping or copper surface oxidation after stripping can lead to a non-uniform surface appearance. When finished innerlayers are examined by AOI, these surface irregularities can trigger false defects. If the equipment settings are adjusted to eliminate the false signals, actual defects may fail to be detected by the AOI step, leading to scrapped panels at final, a very expensive and undesirable problem.

Adhesion Promotion

As global assembly has shifted towards lead-free processes and with more complex product often requiring multiple laminate operations, the increased stresses placed on the innerlayer copper / laminate interface have in many cases exceeded the capability of existing laminate materials.
Even when new materials designed for lead-free assembly processes are used, unexpected failure modes have been experienced lead to the need to re-evaluate material qualification and test methods.

As an example, delamination failures of boards have been reported in assembly after storage in ambient conditions for 3 - 6 months. Prior to lead-free, storage for this period of time would not have been considered a potential problem. For these applications, some laminate systems based on dicy cure have been found to not perform as well as novolac systems.

In addition, surprisingly complex interactions between adhesion promotion systems and laminate material formulation have been reported for oxide, reduced oxide and oxide replacement.

Overall, this has led to new approaches to adhesion promotion process qualification, including the evaluation of adhesion performance on a wider range of copper substrates and use of more severe screening tests.

Test combinations must certainly include copper foil and plated copper (as would be seen on plated innerlayer products) combined with the full range of laminate material types that will be processed.

Performance tests should include assembly simulation testing immediately after lamination, after pressure cooker exposure and also after extended room temperature storage.

References

1) http://www.stouffer.net

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