No-Clean Solder Pastes:
The Testing Dilemma

Success “in the lab” may be a poor benchmark for predicting end-product reliability.

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When qualifying a no-clean solder paste, the primary concern is the nature and safety of the flux residue on the board after reflow. This residue may have an effect in three distinct areas:

1. Most critical is current leakage of the residue. If the product is a high reliability device that is subject to extreme conditions involving exposure to high levels of hygroscopic dust, flux residue volume can be a problem should the dust become electrically conductive. As a solution, boards can be conformationally coated; urethane, silicone acryls, and epoxies typically work well with no-clean pastes. Silicones work particularly well under severe thermal cycling conditions since they do not tend to crack from thermal shock.

2. Test points. Testing methods are not designed with environmental concerns in mind. For example, test points are generally off-site from solder joints in surface mount applications. However, mixed technology often entails “bed of nails” testing, in which residue can gum up the pins and falsely signal failure. As a result, pin design and pressures should be examined as part of the no-clean implementation process.

3. Aesthetics. Assuming that a PCB is functionally free from life-threatening defects, appearance should be of no concern. However, some manufacturers prefer to explain the nature and properties of the residue and the effects on field performance and life-span of the finished product. To that end, solder paste suppliers can help manufacturers by providing life studies of pastes and residues.

Testing Reviewed

A number of flux residue tests have been accepted as standards by the electronics industry. These include the Bellcore and IPC tests, although tests performed in-house by manufacturers can be more relevant to a company’s product. For example, copper mirror and silver chromate tests, which form part of the accepted standard tests and which require medium to be extracted from the paste, are of limited use. A copper mirror test indicates whether raw flux is sufficiently corrosive to remove film from a mirror (figure 1).

However, in a typical application of solder paste in an in-line process, it is virtually impossible for raw flux to survive, thus test results are inconclusive. In fact, most no-clean fluxes are designed to remove surface oxides of copper, which compromises the chances of the flux passing such a test. Furthermore, to prevent the flux from failing likely will compromise performance. Therefore, the copper mirror test should only be used as an indicator.

The halides (ionic salt of the halogen) test employs silver chromate paper and is also performed on raw flux. Fluxes containing halogens perform very well and are safe in most applications, and manufacturers can use three to six times less activator in such fluxes compared to organic acid fluxes. If the silver chromate test shows positive for halide, a failure in the surface insulation resistance (SIR) and electromigration tests is likely (figure 2). Many halogens volatilize with temperature, and therefore the test can have negative results.

Similarly, the copper corrosion test should be relied upon only as an indicator. Here, a copper coupon featuring a dimple punched in its center and flux added via a solder slug is subjected to a dry temperature. Since most solder pastes do not contain isopropyl alcohol (IPA), this test does not mimic an actual profile. Therefore, depending on solvents used, volume of flux added, and dwell-time on solder slug meltdown, the test can produce another false alarm.

SIR, on the other hand, may provide meaningful results because comb patterns are fluxed and sent through a proper heat cycle (Class III environments are recommended) to mimic actual reflow. However, most SIR testing is done on bare copper coupons, while fluxing during reflow occurs on tin-lead solder pads.

In terms of the electromigration test, it is important to note that while copper grows a bud-type dendrite, tin grows a needle-type dendrite that looks like a whisker and grows very quickly. One must therefore ensure that tests are performed on tin-lead comb patterns. After a Class III environment, seven-day test is completed, specimens must be examined for changes on the edge of the comb pattern. It is common for many fluxes to pass an acceptable limit for SIR, but also to show evidence of cor-
the effectiveness of raw flux to remove film. But the nature of in-line processing renders this test unrealistic.

Figure 1. Copper mirror test indicate pass (left) or fail (right) the effectiveness of raw flux to remove film. But the nature of in-line processing renders this test unrealistic.

Figure 2. The silver chromate paper test may indicate later SIR or electromigration test failure, but variables such as temperature, can skew initial results.

Solder pastes typically print well in lab environments. Yet it is not uncommon for pastes later to fail once air-flow problems or humidity and temperature extremes are encountered. A wiping solvent used on the bottom of the stencil can dramatically improve printability. However, IPA should not be used since it can speed up dry-out in fine-pitch paste formulations under high humidity conditions.

The solderability of paste is typically related to the reflow profile and the manufacturing process. If variations in solderability occur after a paste has been selected, the reflow profile should be consulted. A long, drawn-out heat-up is detrimental both to paste and components. A ramp of 1.5-2.5" per sec is recommended where possible, although often this will depend on components used and board density. A plateau of 150-160°C is required to remove the temperature factor. Ramp-up should continue to spike in the 210-220°C range (figure 3).

One thing is clear: Shorter dwell time will result in better solderability. This explains why a solder ball test performed on a hot plate or solder bath will show good results compared to one done on a test board run slowly through an oven. It is common in manufacturing for boards to sit idle for extended periods of time, and the only way to assess potential problems is to run real-life tests. Because such testing will not provide a number sufficient for statistical accuracy, some modifications will be required to accumulate useful data.

Environmental safety, cost, and process reliability are all of immediate concern. For example, in a water-soluble process, deionized water and a closed-loop system burn energy, the lead in the paste creates toxic waste, and maintenance and a large capital investment are required. Still, problems may occur depending on flux chemistries and component types used. Clearly, then, some applications require cleaning.

Ultimately, a life test should closely mimic the end-product's environment. Application parameters should be addressed. Paste application and printability are directly related to flux volumes; higher residue translates into better printability. Squeegee materials also play an important role in print definition, with hard materials, high density polymers, and metal squeegees generally offering the best printing quality.

Solder pastes

Inert Environments
Is nitrogen required for no-cleans? Driving the use of nitrogen is the goal of lower residues. Generally, if a paste leaves 40 to 60 percent residue of the initial flux content, nitrogen is unnecessary. However, in very-low-residue applications, nitrogen may be required.

The residue volume and flux type will determine an acceptable oxygen level when soldering in a nitrogen atmosphere. Typically, levels of 300 ppm are sufficient. To achieve extremely low residues (i.e., less than 10 percent), oxygen levels of 50 ppm and lower are necessary.