Characterization of No-Clean Solder Paste Residues: The Relationship to In-Circuit Testing

Many manufacturers have now completed the conversion to no clean solder paste. Many factors governed this initial conversion, among those being cosmetics, solder ability, and process ability. In circuit testing or probing through no clean solder paste residues has topically not been a major factor in the conversion decision for several reasons. Due to board design, solder paste was only used on one side of the board and not subjected to testing. Also, off-site test pads allowed for testing close to, but not through solder paste residue for those manufacturers who had the real estate to have such pads. With changing technology that has led to many boards designs now being double sided reflow (DSDP-double side double pass) and the decline of available real estate for dedicated test probe pads, testing through solder paste residue is now a main concern in the electronics assembly industry.

Each manufacturer has their own board designs, which allow for many different types of in-circuit testing to be performed. There are also hundreds of different probe tip designs to help in testing through paste residues. Companies that are fortunate enough to have the real estate available on their boards to allow for off-site test pads do not have to worry about the residue characteristics of the paste they are using. Also, if the mil spacing between test points is large enough, high-pressure probes can be used to try to break through thick residues. Some assemblers are also fortunate enough to have the time and throughput to do dual probing (testing each board twice-in hopes of getting a board to pass). There is, however, another large and growing percentage of electronic assemblers out in the industry that is not able to test their boards if a no clean paste is used. These manufacturers have boards that are very densely populated using DSDP technology and require test probe that have only 50-mil center spacing. Also, some have board designs where it is necessary to test via holes filled by paste through-hole technology. These present a unique problem to probe testing as concave solder fillets are formed with flux residue pooling on top. It is these two problems, which have led to the thorough scrutinization and characterization of the solder paste residue. This paper will describe the various residues that are now available in the market with their compatibility to in-circuit testing. This paper will also cover a new paste development that has been made to completely address the issue of probe testing for all manufacturers no matter what their testing requirements are. Currently there are four major types of residue that are available in the marketplace. These correspond to the following kinds of solder paste.

Full Residue Air Reflow Solder paste-Solids Content 6 –7 %

Intermediate Residue Air Reflow Solder paste-Solids Content 4%

Intermediate Residue Nitrogen Reflow Solder paste-Solids Content 3%

Super Low Residue Nitrogen Reflow Solder paste-Solids Content <2%.

Please note that each manufacturer has their own moniker for the various types listed. The important information to know is the solids content of the paste to be investigated.

Full Residue Air Reflow Solder paste-Solids Content 6 – 7%

Why It Was Developed:

This was the first viable no clean solder paste available to the industry. It remains today the most popular type of paste, as it requires basically no process changes from RMA or water soluble pastes previously used and has very long stencil and tack lives. These pastes are basically offshoots of modern RMA pastes and contain high amounts of modified or synthetic resins.

Residue Description:

These pastes have behind the most amount of residue in the no clean solder paste family. The residue is typically light amber in appearance and is designed to become hard and non-tacky immediately after reflow. This is so foreign particulates do not adhere to the surface of the residue. The location of the residue is generally all over the joint or pad and in surrounding areas. Because of the high solids content, the residue spreads non-uniformly and can be seen coagulating in large amounts in some areas.

Major Problems or Concerns:

The major problem is the amount of residue left behind with these pastes. Because of the thickness and hardness of the residue, probe testing is extremely difficult. Also, due to its non-uniformity it is difficult to develop a testing program that is capable of testing through the residue.

Compatibility with In-Circuit Testing:

Poor. Only those manufacturers that have 100 mil or greater centers for their probes and who are able to use high pressure probes should attempt testing through this residue. Also, dual probing may be necessary to obtain complete penetration. Dual probing is testing the board once and if there are any failures due to non-contact (open defect), retesting the same board a second time through the fixture to try to achieve penetration.

Test Probes to Try:

A handful of successful attempts have been seen with 11-13 ounce spear tip probes on 100 mil centers through this type of residue. Dual probing is generally also necessary to achieve satisfactory results.

Probable Results:

For the most part and most manufacturers, attempting to probe through the high solids air reflow pastes is generally not worth the effort. Due to the constraints necessary to get through this residue it is much easier to try probing through lesser (see following) residues.

Intermediate Residue Air Reflow Solder paste-Solids 4%

Why It Was Developed:

This intermediate residue air reflow solder pastes were developed for those manufacturers who did not want to go into nitrogen reflow but wanted the least amount of residue for cosmetic or other reasons. These pastes tend to have a decreased stencil and tack life as compared to their full residue cousins and therefore are not as popular as full residue versions.

Residue Description:

As these pastes have approximately half the solids content of the full residue pastes available, the residue seen is considerably less. Generally, the residue is very light amber to clear in appearance and tends to spread uniformly away from the joint; although this characteristic varies by paste supplier. Some residue can still be found, though, in varying quantities on some joints and pads. The residue is soft after reflow and designed to harden quickly upon cooling. The residue is also non-tacky after it hardens.

Major Problems or Concerns:

Even though half decreases the residue amount, there is still a considerable amount to test through. This residue is also hard which makes probing difficult. Also, though the spread of the residue tends to take it off the joint, there are still some areas with residue on them. This unpredictability causes problems with testing repeatability.

Compatibility with In-Circuit Testing:

Poor. Though the residue is decreased by approximately 50 percent, these residues are still difficult to probe through. Attempts should only be made if high probe pressures can be used and dual probing is not prohibitive.

Test Probes to Try:

As with the full residue paste, and 11-13 ounce spear tip probe should be tried on this residue. Dual probing may also be necessary for consistent results to be seen.

Probable Results:

Unknown. Previous tests with 6-8 ounce spear tip (with both twist and non-twist action) gave inconsistent reading.

Intermediate Residue Nitrogen Reflow Solder paste-Solids 3%

Why It Was Development:

This solder paste type was developed for those manufacturers who were using nitrogen reflow system and required a robust solder paste for their process. These pastes have longer stencil and tack lives than lower solids nitrogen reflow pastes and only require less than 2500-3000 ppm oxygen in the reflow oven. Cosmetics of the residue were also very important to these manufacturers.

Residue Description:

The residue left behind is generally clear in appearance and tends to flow uniformly away from the joint. Due to amount of solids, this residue is extremely thin in most places. This allows for a camouflage effect. Upon visual inspection, the joint looks to be free of virtually all residues. The residue from these pastes are hard and non tacky for reasons given previously.

Major Problems or Concerns:

Even though the residue cannot be “see” (transparent), it is still there. Also, it is designed to become hard immediately upon cooling and some residue may be found intermittently on the pads or joints.

Compatibility with In-Circuit Testing:

Fair. Unfortunately, any hard residue is tough to probe through. Unsuccessful attempts have been made using 6-8 ounce spear tip probes (with both the twist and regular probes). Because the residue is very thin and hard, it tends to “shatter” when being probed which does not allow for complete penetration. This shattering allows for accumulation of particulate debris in the test fixture. Debris also deposits on the probe tips which after subsequent cycles makes probing more and more difficult.

Test Probes to Try:

Probing may be attempted if one uses 11-13 ounce spear tip probes; however the author is not aware of anyone who has tried this or their results.

Probable Results:

Unknown with higher pressure probes. Lighter probes (see above) were not able to consistently break through the residue.

Super Low Residue Nitrogen Reflow Solder paste-Solids <2%

Why It Was Developed:

Super low solids solder pastes became available approximately two years ago to provide the absolute lowest amount of residues for those manufacturers who required it. Typically those manufacturers were in the telecommunications industry where cosmetic concerns were very high. These pastes require the use of nitrogen with extremely low amounts of oxygen (less than 100 ppm) for satisfactory reflow and solder ability. These pastes generally have very short tack and stencil lives and control is very important when using them.

Residue Description:

As there are less than two percent solids in these formulas, the residue is very minimal. However, because of the low solids content, the residue does not exhibit very good spreading characteristics and tends to ball up in one area or corner of the joint or pad. This leaves a small area of thick residue on the joint. The residue is typically very light yellow to clear in appearance and is designed to be hard and non-tacky.

Major Problems or Concerns:

Probing the joints or pads is not a concern if the probe hits an area of the pad that does not have the residue. However, as the residue balls up in one area, if the probe hits that area it will be unsuccessful in penetrating it.

Compatibility with In-Circuit Testing:

Fair. Probing has been attempted with 6-8 ounce spear tip probes (both twist and non-twist) with inconsistent results. This one small area of residue is just as difficult to penetrate as the 6-7% solids no clean pastes are.

Test Probe to Try:

Due to the variability of the placement of the residue, it would be necessary to try high-pressure spear tip probes (8-13 ounces) to penetrate the residue.

Probable Results:

Unknown with higher pressure probes.

The above information gives a very bleak prognosis for successful probing through solder paste residue. However, keep in mind that these paste types were never designed to be probed through. Each was designed to fit a certain market need at the time. Upon review of the information it would seem that a paste in order to be probed would have to have special characteristics unlike any solder paste available to date. This paste type has now become available; the information is listed below.

Intermediate Probe-able Residue Nitrogen Reflow Solder paste-Solids 3%

Why It Was Developed:

This solder paste type was developed for those manufacturers who needed a probe-able residue material. Testing through this material had to be accomplished using low pressure probes (4-6 ounces) as the worst case required testing 50 mil spacing. The paste was designed to have a good tack and stencil life (approximately 4-6 hours) and easily printable on 16 mil pitch. Currently technology requires the uses of nitrogen with this type of paste however the oxygen content in the oven can be quite high (up to 6000 ppm).

Residue Description:

From previous experiments done on currently available formulas, it was determined that this paste had to retain soft residue through two reflow profiles (for DSDP boards) and remain soft for an extended period of time to allow testing. The residue also had to be non-tacky to allow for easy and clean penetration of the probes for thousands of cycles. Also, the residue was designed to spread evenly away from the joint in a thin coating. As the residue was soft and non-tacky, even if some remained on the joint it would not interface with the test probes. The residue also is clear in appearance for cosmetic concerns.

Major Problems of Concerns:

As the residue is soft and non-tacky, testing with standard probes in not a problem. However, when one tests on vias where the residue tends to coagulate in the bottom of the concave fillet formed by the solder, a special probe design is necessary.

Compatibility with In-Circuits Testing:

Excellent. Testing has been successfully demonstrated with this type of residue, although some probe changes may be necessary to achieve 100% penetration.

Test Probes to Try:

Probing can be accomplished on typical pads or joints using a variety of low pressure probes (4-6 ounces). Testing on vias can be accomplished using a three point chisel tip probe which tests through the annular ring of the via and not directly through the large amount of pooled residue in the concave fillet formed.

Probable Results:

Successful probing can now be accomplished using the above probes.

Summary

Probing through solder paste residues is now an important factor if a complete conversion to a no clean process is to be made by electronic assemblers. The impetus for this change is the move to miniaturization of electronic products such as lap top computers, modular phones and personal digital assistants (PDA's). This has spurred the development of an increased amount of double-sided reflow boards, along with more populated board designs, which via holes. Solder pastes currently available have not been designed for in-circuit testing and therefore successful probing is difficult to accomplish. A new solder paste has been developed to address the probing issue. This paste has a soft, non-tacky residue that is designed to spread out uniformly around the joint. This paste currently requires the use of nitrogen for reflow.

As solder paste technology evolves, the use of nitrogen to obtain acceptable levels of soft residue will probably not be necessary. Development work is currently underway to achieve this goal. The final obstacle to achieving a complete no clean process for all electronic manufacturers has now been removed.