Promoting Proper Solderability: 
PCB Fabrication Issues Which Can Impact Solderability

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During the worldwide introduction and acceptance of Sterling™ Silver Solderability Preservative, there have been some occurrences of less than optimum assembly results. These types of issues are anticipated with the implementation of new technology. MacDermid’s investigation of these occurrences was performed utilizing solderability testing such as wave solder and IR reflow, as well as the Multicore wetting balance tester. Visual and analytical analyses were performed to better understand the soldered surface. The following report documents MacDermid’s findings and explicates the negative impact of several PCB fabrication areas and processes on the solderability of Sterling™ Silver finished printed circuit boards.

1. Copper Plating

The Sterling™ Silver deposit will mimic the underlying copper surface. Rough and porous copper surfaces provide a conduit for heavy silver deposition. This kind of surface may impede the silver dissolution during soldering, yielding non-wetted areas.

Figure 1. SEM of Copper nodules
2. Tin Stripping
Incomplete tin stripping will leave residues along feature edges, which form a copper-tin intermetallic. This intermetallic layer may prevent solder from wetting to the feature edge. In addition, these residues will inhibit Silver deposition in these areas, allowing for less than the 6µ” (0.15 micron) minimum thickness necessary for optimum solderability.

3. Solder mask
A. Solder mask registration:
Mask on pads and features, or in PTHs, is a common cause for poor solderability. Mask infringement on clearances also allows for entrapment of chemical solutions and hinders proper rinsing.

B. Incomplete developing of solder mask:
Heavy loading of the developer solution, or a delayed break point in the developer, may leave residues on the copper surface that are a common cause of solderability issues. These residues are not easily removed in the Sterling™ cleaner.

Figure 2. Solder mask residues after Sterling™ Silver Process

C. Solder Mask cure:
Under-cured solder mask will leach contaminants during subsequent chemical processes.
This is a vital concern with mask-plugged micro vias. The density and mass of the mask in the vias precludes the possibility of a complete cure of all the material. In addition to the potential for leaching from this mask plug, it is a probable site for chemical entrapment.

Rinse assists such as eductors may be required in the Sterling™ vertical process. Solution impingement will be critical for adequate rinsing in the horizontal process mode. Prototype equipment designs are currently under evaluation to address the unique challenge of solution displacement in these partially plugged vias.

After silver deposition, contaminants from under-cured mask can seep from the mask boundaries during bakes and other thermal excursions, causing staining and discoloration. These contaminants will have a negative impact on solderability, causing de-wetting or non-wetting.

4. Sterling™ Silver Process

A. Cleaning:

The Final Finish Acid Cleaner (vertical mode) and the Final Finish Spray Cleaner (horizontal mode) are intended to remove oils, fingerprints and light copper oxidation. They will not remove residues from the solder mask or the tin strip process(s). A clean active copper surface is required for proper silver deposition.

B. Surface Prep:

An etch rate of 0.5 - 1.0 micron yields the most favorable copper topology for optimal solderability. Etch rates > 1.0 micron may impede speedy silver dissolution during soldering. Etch rates < 0.5 microns may not be sufficient to yield the oxide free copper surface required for consistent silver deposition. The etch rate should be checked every 4 - 8 hours of production using the test method detailed in the MacDermid Sterling™ Silver Process Operating Guide.

C. Silver thickness:

A minimum silver thickness of 6µ" is recommended for optimal solderability. Sterling™ is an immersion replacement reaction, and therefore larger features and land areas may have a thinner deposit than smaller isolated features. Due care should be used to insure that the silver thickness in all areas is at least 6µ" to insure a minimum of 6 months shelf life for the coating properties. Silver thickness > 30µ" may require extended contact time with solder for complete and uniform dissolution. The optimal range for the silver thickness is 6 - 25µ"

The primary Sterling™ process attributes that affect silver thickness are:

- **Solution movement:** Vigorous solution movement will increase the silver thickness, but
may compromise the distribution uniformity.

- Contact time in the silver solution: Recommended contact time is 60 – 90 seconds.
- **Temperature of the Sterling™ Silver solution:** Higher temperature increases the deposition rate. Recommended temperature range for the silver solution is 110° - 130°F (43° - 54° C)

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**Fig. 4. De-wetting after soldering. FTIR detected the presence of an aliphatic material, attributed to inadequate final rinsing in the Sterling™ Silver Process.**

**D. Rinsing:**

Incomplete final rinsing can adversely affect solderability and Ionic Contamination or SEC testing (see Fig. 4). Some of the recommendations for the Sterling final rinses:

- Do not allow foam to build up in the rinses.
- Provide adequate water flow to insure 2 to 3 tank turns per hour to maintain clean rinses.
- DI water conductivity < 20 microsiemens.
- Do not use soft water for the final rinses.
- Allow sufficient contact time in the final rinses.
- Keep squeegee rollers clean of any contamination (horizontal process).
- Ensure sufficient water pressure in all manifolds (horizontal process).
- Incoming DI water temperature should be > 20°C (68° F) for optimum rinsing efficiency.

**E. Drying:**

- The dryer should be dedicated to the Sterling™ Silver process.
- A process such as OSP or HASL may leave contaminants, fluxes, or copper metal on the
dryer rollers that can contaminate the silver surface and adversely affect solderability.

- Incomplete or delayed drying may allow oxidation, water spots, stains, or tarnish to form on the silver deposit that will impede soldering.
- Vertical mode drying may be in-line, or horizontal off-line, as long as the drying is accomplished immediately and completely.
- Oven drying is not recommended.

5. Measurement of Silver Thickness:
- Sterling™ Silver thickness may be measured by weight gain method, or by XRF. Both methods are described in the Technical Section of the Sterling™ Silver Process Operating Guide.
- When using XRF instruments, software and hardware designed specifically for measurement of thin immersion silver deposits are required. Standardization with thin foil coupons is necessary to compensate for the copper base and topology, as well as the dielectric background.
- The pad or feature being measured should always be at least 3X the collimator diameter. A 12-mil diameter collimator should not be used to measure any feature or pad < 36-mil in diameter.
- Measurement time should be at least 30 seconds for a 12-mil collimator, and 60 seconds for collimators of less than 12-mil diameter.

6. Handling and Packaging:
- The silver finish is susceptible to tarnish caused by oils, fingerprints, sulfur (S) and chloride (Cl) contamination. Operators must use clean gloves when handling silver finished boards.
- Any interleaving or wrapping paper used with silver finished boards must be certified as acid / sulfur free.
- Most plastic materials have a high sulfur content, and should not be allowed to contact the silver surface. Use a barrier ply of acid /sulfur free paper between the plastic and the silver surface.
- Rubber bands, desiccants, and cardboard are also very high in sulfur, and should not be in contact with the silver surface.
- All post - Sterling™ wet processes such as board washers must use only DI water, and if needed only MacDermid approved post-cleaners. No use of detergents, or cleaners is allowed.
- Care should be taken to insure that proper handling and packaging practices are enforced in the work place. The importance of these simple procedures is illustrated in the testing noted below.
- Figures 5.1, 5.2, 5.3, on the following page are coupons which were fabricated through the Sterling™ Silver process and separated into 2 groups:
  - One group was wrapped in sulfur /acid free paper and stored for over 21 months. The surface of these wrapped coupons was tarnish free after 21 months. (Figure 5.1)
  - The other group was set, unwrapped, on an angle against a wall in an “office environment” for the same period of time. The visual appearance of the silver surfaces on the unwrapped coupons were as follows:
    - **Side A**, the side exposed to the most air circulation developed a heavy layer of yellow/gold colored tarnish film over all. (Figure 5.3)
    - **Side B**, which was partially shielded from direct air circulation developed a layer of yellow/gray colored tarnish film over all. (Figure 5.2)
SERA of the discolored areas showed the level of sulfur contamination as a combination of silver sulfide and sulfate.

- On the wrapped boards, the depth of the tarnish film was from 0 to 50Å.
- Side B of the unwrapped coupons (shielded from direct air circulation), with the yellow/gold tint: the tarnish film was slightly over 500Å thick.
- Side A of the unwrapped coupons (open to direct air circulation), with the yellow/gray tint: the tarnish film was over 1000Å thick.

Figures 6.1, 6.2, and 6.3, below, show that the solderability results of these coupons correspond to the levels of contamination as determined by SERA.

- The wrapped coupons showed 100% wettability, with no evidence of de-wetting after 21 months storage. (Figure 6.1)
- The Side B of the unwrapped coupons had some de-wetting with a few areas of non-wetting. (Figure 6.2)
- The Side A of the unwrapped coupons had heavy de-wetting with many non-wet areas. (Figure 6.3)

This document discusses the relationship between the various PCB fabrication processes and the quality of the Sterling Silver metallic solderability preservative applied as a final finish. In addition, this document may serve as a guide to resolving failures encountered in PCB solderability testing, or during assembly operations.

As always, the MacDermid Sterling™ Silver Process Operating Guide provides the prevailing operating specifications.