empfasis

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The EMPF is a U.S. Navy-sponsored National Electronics Manufacturing Center of Excellence focused on the development, application, and transfer of new electronics manufacturing technology by partnering with industry, academia, and government centers and laboratories in the U.S.

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Tin Whiskers: Mitigation With Conformal Coatings | Part II

One of the two basic risks of employing the commercially accepted, RoHS compliant, lead-free (Pb-free) electronics is the threat to the electronics reliability from the growth of tin whiskers. The other basic risk deals with Pb-free solder joint reliability.

Although the risk of whisker-generating electroplated pure tin is commonly found in COTS electronic hardware, it is showing up in military electronic assemblies at an alarming rate. Because of this "inconvenient truth" (as the tin whisker risk has been called) many attempts at mitigation of these risks have been made. An example of a recent tin whisker event, on the NASA Space Shuttle, is depicted in Figure 1-1.

It should be noted that these Space Shuttle tin whiskers were not growing from tin plated electrical components, since the Space Shuttle avionics pre-dated RoHS by a significant time, but from tin plated beryllium copper card guides, and may have been growing for years. Today's lead free electronics would be expected to have far more tin whisker susceptible components, since any tin plated component could be a source of whiskers.

An analogy can be drawn between unwanted tin whisker growths in electronics and weeds in a lawn.

Generic strategies for elimination of weeds involve studying the biological growth mechanism for the weed phenomenon, identifying the critical biological contributors to the growth, and eliminating or arresting these key biological factors as needed to circumvent the growth and not simultaneously harm wanted phenomena (e.g. your lawn).

In the case of tin whiskers, the metallurgy of tin must be studied to identify the critical parameters for tin whisker growth and then eliminate as many of the key metallurgical factors as needed to circumvent the growths (without simultaneously harming the electronics, or the environment, in the case of Pb-free electronics).

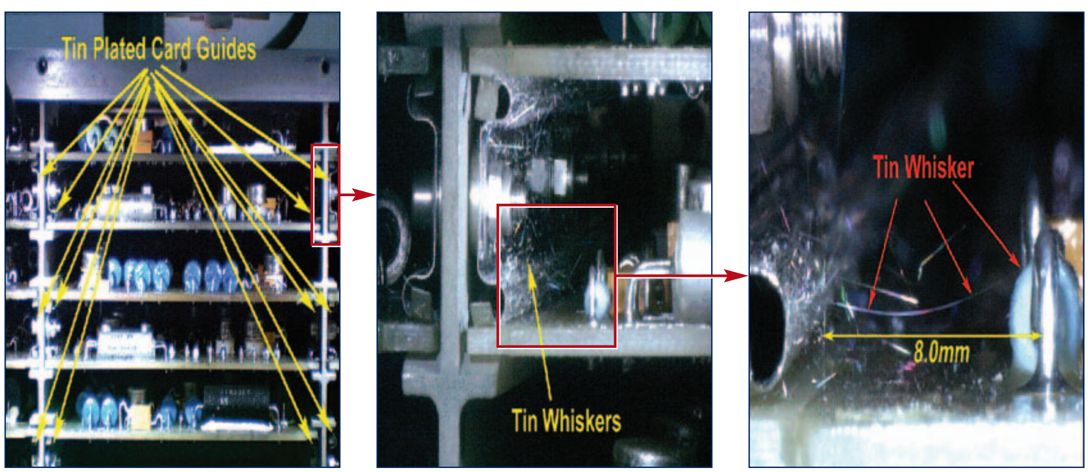

Figure 1-1: Tin whiskers growing on NASA Space Shuttle avionics hardware documented in April 2006. Photos courtesy of NASA.

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Ask the EMPF Helpline!

Improving the Rework and Cleaning Method

Recently, a customer contacted the EMPF and requested advice for replacing two wires on an RTV silicone conformal coated printed circuit board (PCB).

During lot production, two power wires were improperly installed and needed to be replaced (Figure 2-1). The customer reworked some of the PCBs which later failed in the field. On the failed boards, dendrites had grown under the conformal coating and between the solder joints of the reworked power wires. The customer requested help from the EMPF with improving their rework and cleaning method and to confirm the effectiveness of the method.

The EMPF recommended using an RMA core solder wire instead of the no-clean core solder wire and recommended rinsing the rework area after hand cleaning. Mixing no-clean fluxes with other flux types is not recommended. No-clean fluxes contaminated with RMA fluxes cannot be easily brush-cleaned with DI water and isopropyl alcohol (IPA). If left behind, they do not cure properly and can absorb moisture. This enables the migration of ionic residues and the formation of dendritic growths in the presence of a voltage gradient. The recommended cleaning method for no-clean fluxes is the use of a saponifier at 60ºC and rinsing with plenty of low pressure steam and DI water.

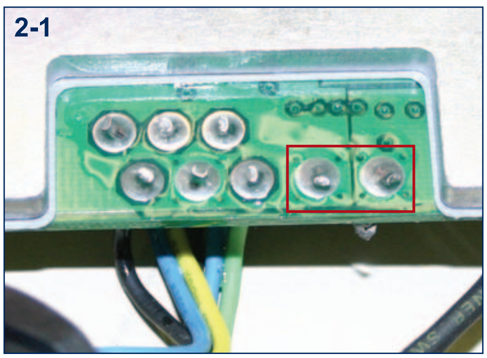
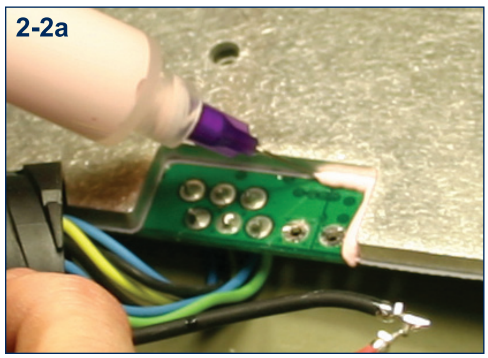


Figure 2-1: Conformal coated rework area next to aluminum heat sink (showing two power wires to be replaced).



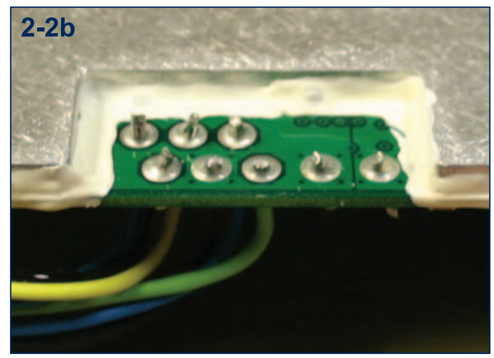


Figure 2-2: Peelable mask applied at the edge of the heat sink to prevent contamination.

The PCB was conformal coated with a non-corrosive, one-part, fast moisture curing, RTV silicone elastomer (Dow Corning 3-1965). This coating offers good dielectric properties over a wide frequency range and resists high humidity and other harsh environments. The silicone can be applied by spraying, dipping, brushing, and flow coating. The coating in the rework area was carefully removed with a cotton tip swap and the application of a commercially available stripping agent such as Amtex-CCR or Envirosol.

Conformal coating is only effective at preventing dendritic growth if there are no ionic residues trapped under the coating. If residues are present under the coating, small amounts of moisture will penetrate the conformal coat, facilitate the migration of metallic ions, and affect PCB performance. Thus, all residues must be removed from the rework area prior to reapplying the conformal coating.

The EMPF reviewed the customer's rework and cleaning process. An aluminum heat sink located next to the rework area presented a challenge to cleaning this PCB after rework. Since the heat sink could not easily be removed, and to reduce the possibility of capturing residues under the heat sink, the customer required that the PCBs be hand cleaned instead of cleaned with a batch cleaner. The original rework process called for RMA flux applied to a copper solder wick to remove the SnPb solder from the original solder joints. The replacement wires were then soldered with RMA flux and no-clean flux core SnPb wire. After installing the new wires, the rework area was hand cleaned with a brush and the conformal coating was reapplied.

A third recommendation was the application of a peelable mask, such as Chemtronics' Chemask,® to the heat sink/board interface around the rework area (Figure 2-2). The mask creates a barrier to minimize pulling residues under the heat sink through gravity or capillary action. IPC rework methods (Class 3 guidelines for wire attach) were used to remove and replace the wires. During rework, care was taken to keep the PCB at an angle to encourage excess flux to flow away from the heat sink. Maintaining this angle is especially important while cleaning the rework area prior to reapplying the RTV conformal coating. The rework area was rinsed several times to remove ALL contaminants (Figure 2-3). Finally, the peelable mask was removed and the conformal coating was reapplied.

To confirm the effectiveness of cleaning method, local area ion chromatography (IC) was used per IPC-TM-650, method 2.3.28 using the C3 Localized Extraction Method and Dionex ICS 2000 ion chromatography (IC) system. This method can test the cleanliness of a dime size area (0.1 in^2) instead of the whole PCB. The localized IC test results indicated that the weak organic acids (WOA), anions, and cations in the rework area were below the maximum EMPF recommended limits.

After reapplying the conformal coating, the EMPF subjected five reworked boards to 500 hours of temperature (85ºC), humidity (85%RH), and bias (12V, 1 amp) testing (THB). The goal of THB testing is to confirm that there were no deleterious effects of the cleaning and re-attach process. After testing, the reworked areas were microscopically examined with an Olympus SZX12 microscope, using 7X to 50X

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Five Types of Conformal Coatings

Conformal coatings are polymeric materials which protect electronic assemblies from environmental contamination, and serve as insulative protection and a physical barrier. There are five main types of conformal coatings categorized by their chemical composition: acrylic (AR), epoxy (ER), urethane (UR), silicone (SR), and poly(para-xylylene) (XY). Fluorescent compounds are incorporated into the coatings for ease of inspection under UV light, as shown in Figure 3-1. Each coating has advantages and disadvantages in terms of their deposition method, chemical properties, physical properties, reworkability, and affordability.

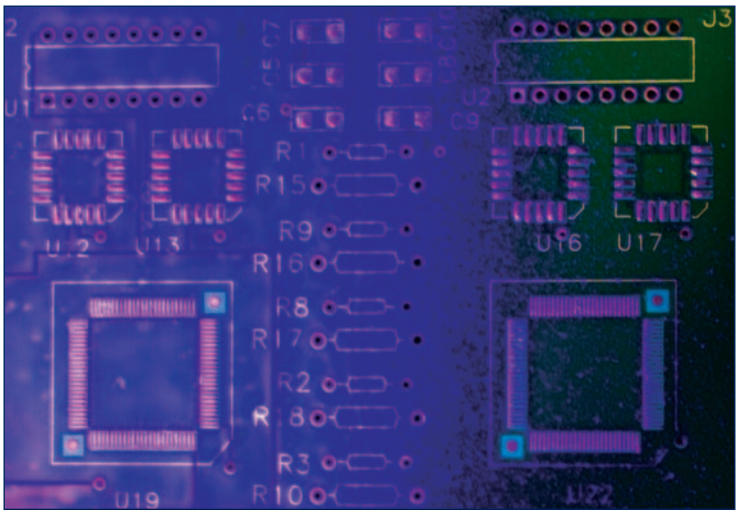

Figure 3-1: Image of a board under UV illumination with conformal coating only on the left side.

Coating Types

Acrylic resins (AR) are preformed acrylic polymers dissolved in a solvent. The "curing" process really drives off solvent (which can be either organic or water-based) forming a dried film. Acrylic coatings can be easily dissolved in many organic solvents for repair work and provide only selective chemical resistance. Acrylic coatings dry rapidly, have good fungus resistance, have long pot lives, give off little or no heat during cure, do not shrink during cure, and have good humidity resistance. At elevated temperatures, they soften more readily than other polymers. They also have low abrasion resistance, easily leading to scraping, chipping, and flaking. Acrylic resins can be applied by brush, spray, or dip coating. Figure 3-2 shows an example of acrylic polymerization, where one of the reactive C=C double bonds of the acrylic monomer on the left connects with a neighboring monomer repeatedly to form a polymer chain.

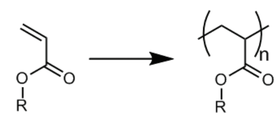

Figure 3-2: Synthesis of acrylic resin.

Epoxy resins (ER) are usually available as two part compounds that start curing upon mixing, but single part coatings that can be cured thermally or with UV exposure, are also available. Epoxy resins exhibit good abrasive and chemical resistance, as well as reasonable humidity resistance. The coating is virtually impossible to remove and rework requires burning through with a soldering iron. A buffer is recommended around delicate components, since film shrinkage occurs during polymerization. The shrinkage can be minimized by curing at a low temperature. Epoxy resins can be applied by brush, spray, or dip-coating. Figure 3-3 shows an example of epoxy polymerization, where epichlorohydrin on the left reacts with a dialcohol to form an epoxy resin.

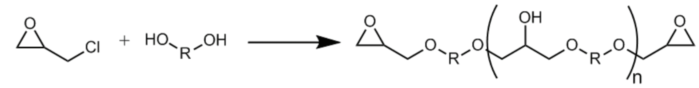

Figure 3-3: Synthesis of epoxy resin.

Polyurethane resins (UR) are either single or two-component compounds, which provide good humidity and chemical resistance, with high sustained dielectric properties. Due to their high chemical resistance, removal of the coating requires the use of stripping agents which may leave ionic residues. These need to be thoroughly cleaned to prevent corrosion on the underlying board. Polyurethanes can be soldered through for rework, but usually results in a brownish residue, which affects the appearance of the assembly. Polyurethanes have medium bond strength and tend to peel or flake off in large pieces. Polyurethane resins can be applied by brush, spray, or dip-coating. Figure 3-4 shows an example of urethane polymerization, isocyanates reacting with alcohols to form urethane linkages in polymer chains.

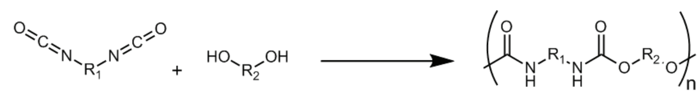

Figure 3-4: Synthesis of urethane resin.

Silicone resins (SR) are usually single component compounds that begin curing upon exposure to moisture in the air, along with temperature. Silicones can endure extreme temperature cycling environments with a useful operating range from -55°C to +200°C. They have high humidity resistance, good thermal endurance, good UV resistance, low dissipation factor (useful for high impedance circuitry), and very good adhesion to most PCB materials. For those low surface energy PCB materials, such as polyimides, adhesion can be improved with primer agents or surface treatments of chemical or plasma etching. Silicon resins can be applied by brush, spray, or dip-coating. Figure 3-5 shows an example of silicone polymerization where water reacts with the silicon-containing monomer to form poly(dimethylsiloxane) (PDMS) chains and acetic acid as a byproduct.

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Tech Tips: Coating Application Methods

Conformal coatings are applied to Printed Circuit Board Assemblies (PCBAs) using a variety of different methods. There are six main methods of applying conformal coatings[1]: manual spraying, automated spraying, dipping, brushing, selective coating, and vacuum deposition.

Manual spraying is a common practice for a process where a high mix is employed, where low volumes are produced, a low cost process is desired, or where the expectation exists for frequent design changes (such as early prototype production). The biggest problem with manual spraying is inconsistency from one operator to another, which may require hand touch-up by brushing. Spraying requires the use of sufficient ventilation due to the high solvent content typical of aerosols as well as the typically low flash point of the solvents. This combination can create a fire hazard if the solvents are allowed to build up in the spray area. Depending on the solvent used, respiratory equipment may be required for the operator.

PCBAs should be sprayed in the horizontal position to help ensure a consistent thickness across the assembly. Masking may be required if any keep-out areas exist. In order to ensure a consistent application, assemblies should have a thin coating applied during each pass and then be rotated 90 degrees between each spray.

Manual spraying can be further subdivided into aerosol spraying and handheld gun spraying.

- Manual aerosol spraying is analogous to graffiti painting. It has a low startup cost – all it requires is a ventilated area, a few cans of coating, and an operator – but efficiency is a concern as there is a significant loss of coating (40% or more) due to over-spray and spray of masked areas.
- Handheld gun spraying is similar to auto body shop painting. The process has a finer degree of control of variables (fluid and air pressure) when compared to aerosol spraying. Another advantage is the ability to use coatings with higher viscosities than can be used with aerosol techniques. A disadvantage is that coating may begin to cure in storage, especially coatings that use moisture as a cure catalyst. If curing occurs in the system, the clean up can be quite difficult. The use of pressurized dry air or nitrogen in the storage tank can prevent this from occurring.

Automated spraying refers to a reciprocating spray system in a process that is like applying icing to donuts. Parts on a paper belt move directly under a reciprocating spray head that applies the coating. Machines of this type may incorporate ovens directly after the spray area. The oven is used to cure the parts to a state where they can be handled without concerns about tacky coating. Masking is still required as the spray head continuously coats the belt and everything on it while the machine is running. Through control of variables (fluid and air pressure, belt speed, spray reciprocating speed), the required skill of the operator is reduced and the process can achieve better uniformity than a purely manual application method.

Dipping is the coating method of choice for many high volume processes and is similar to making chocolate covered strawberries. It is an efficient method with very little wasted material. Dipping also has good repeatability once properly set up and controlled. The main variables that are the immersion speed, withdrawal speed, dip dwell time, and coating viscosity. Immersion speed is set to ensure that the coating can displace air around components as they are dipped into the bath. The dwell time should be set so that all bubbles have stopped. The withdrawal rate is set to a slower speed than immersion and to a speed that provides for the proper coating thickness as the PCBA is removed from the bath. The viscosity is controlled by adding solvents to the storage tank to ensure operation within the recommended application range.

Brushing is a low-cost, labor intensive application method that uses a brush to apply the coating to the PCBA surface similar to how Picasso would have applied oil paint to canvas. Brushing is most often used for repair and rework applications, where the originally applied coating needs to be replaced or supplemented. It can be difficult to cover an entire PCBA of any reasonable size with a consistent thickness by brushing. This method benefits from a reduced need for masking, as the operator can carefully control the specific locations where coating is required. The use of an open air container requires care to prevent materials from curing or changing viscosity on the workbench by using the proper solvents with the material.

Selective coating is an automated coating process that is similar to painting in an automotive assembly factory. Instead of a reciprocating head as described in the automated spraying process, the selective coating process uses a programmable robot outfitted with a spray nozzle and programmed to spray the exact locations required. Depending on the precision of the spray nozzle and the accuracy of the robot, the need for masking can be reduced or eliminated. This process lends itself to a high degree of control, resulting in a very repeatable process.

The final coating application method uses Chemical Vapor Deposition (CVD), a vacuum deposited coating process. Used only for Type XY poly (para-xylylene) or Parylene, this process requires special equipment and training but provides an extremely accurate and consistent application. Like the Mythbusters say, "Do not try this at home, unless you are a trained professional." Expect to invest heavily for this technology or let experienced subcontractors handle the job.

When assessing a need to apply conformal coating, each of the methods described above can be suitable in the right situation. It is up to the technician or engineer to determine you need to be a graffiti artist, a body shop painter, a donut shop, a candy maker, Picasso, an automotive factory paint shop, or a Mythbuster. Many of these techniques are available at the EMPF. For more information, please visit www.empf.org or call the technical staff at 610.362.1320.

[1]IPC - Association Connecting Electronics Industries. IPC-HDBK-830 "Guidelines for Design, Selection, and Application of Conformal Coatings". Oct. 2002:, 28 - 33.

Jason Fullerton | Senior Product & Applications Engineer

Manufacturer's Corner: RPS Automation

Selective soldering is emerging as a necessary technology for companies that produce circuit boards with a mix of SMT and through-hole components. In the past, the choices for soldering through-hole components have been limited to hand soldering, masked wave soldering, and single/multi tube nozzles for dedicated selective soldering equipment.

The most typical process is hand soldering, which often produces upwards of 1000 defects per million opportunities (DPMO). The defects range from insufficient fill due to varying solder dwell times, to cold solder joints and missed joints. While labor intensive and hampered by defects, hand soldering is the most widely accepted method for soldering the through-hole leads in heavily populated double-sided circuit board assembly

The EMPF has the OPUS-3 miniature wave selective soldering system from RPS Automation (Figure 5-1). It is a multi-axis Cartesian Robot designed specifically for selectively soldering through-hole and odd-form components into mixed-technology PCBs, molded modules, and other odd-form assemblies without any special tooling. It has a top-side gantry robot that moves the board above the flux and solder for highly controllable precision and flexibility. The system conforms to SMEMA in-line manufacturing standards, is CE labeled, and is ideally suited for applications where the product is manufactured in small or large lot quantities and high product mix.

The board handler is an optional manual load EF or edge-conveyor (In-Line operation) mounted to the robot, expanding between 4"-18" under program control. The PCB is processed through the fluxing and soldering operation with no operator intervention. The robot then delivers the processed PCB back to the operator, or alternatively to the down stream conveyor, completing the cycle.

The solder station features miniature wave Gaussian soldering technology for exceptional keep-away, lead protrusion clearance and thermal-demand capability. The solder pot is lead-free capable and features automatic level sensing, solder make-up, and PID temperature controls (Proportional-Integral-Differential), including independent N_2 heating also with PID temperature controls. Solder nozzles are magnetically coupled and can be quickly changed.

The unique and innovative features of the OPUS-3 Selective Soldering System enable the system to solder almost any thermal demand without requiring special tools such as vision, or pre-heating. The exceptional flexibility, performance, and productivity of the OPUS-3 make it a powerful tool to add to your post-reflow production soldering solutions.

The Windows software is easy to learn and very functional. The user builds a script file by selecting the commands required from a menu. When completed, the script file is executed, controlling all motion and processes. Commands are contained in four classes: System, Motor, Inputs, and Outputs.

- System commands include subroutine calls, IF statements, dwells, and repeats.

Figure 5-1: OPUS-3 Miniature Wave Selective Soldering System from RPS Automation.

- Motor commands include a variety of commands that initiate or configure motion. The software can logically link up to four axis to produce linear interpolated motion.
- The Input and Output sections allow for checking input states, toggling output states, and configuring the names of each I/O point. These names can be user defined depending on the function.

The software can create, teach, and store an unlimited number of location points in the database. The motion commands can then recall these points and move to any one of them. The motors can be put into jog mode for the purpose of checking and teaching points. An unlimited number of script files can be stored on the computer hard disk. I/O and new move commands can be issued while axis are in motion, making the machine ideal for multi-tasking. Alternatively, a scan of the board can be used at your desktop and a file created remotely that can be downloaded into the Opus for executing a selective soldering pattern.

To learn more about the OPUS-3 from RPS Automation or to schedule a demonstration at the EMPF, please contact Ken Friedman, 610.362.1200, extension 279 or via email at kfriedman@aciusa.org.

Ken Friedman | EAB Coordinator

IPC 7711/21B Conformal Coating Removal and Replacement

With the economy being what it is today, manufacturers have been forced to find more efficient ways to produce their products. In the field of Electronics Manufacturing this has led to a variety of solutions. Everything from company consolidations, to the updating of older technologies, to the elimination of obsolete product, has been considered and instituted. Some of these changes bring about the growing reality of working upon pre-existing assemblies for the purpose of Modification, Rework or Repair. This becomes particularly difficult when the assembly is Conformal Coated. The EMPF offers training for the technician and engineer alike, which may help to eliminate this concern. The IPC-7711/7721B course offers an entire section devoted to the identification, removal, and replacement of conformal coating during the rework/repair or modification processes.

This course utilizes the characteristics of the five basic types of conformal coating to help identify the unknown coating and offer suggestions on the most effective methods for removal and replacement. An identification flowchart and two tables identifying common characteristics and removal techniques are described in Sections 2.3 and 2.4 of the IPC-7711/7721B standard. Some of the characteristics that are considered include (but are not limited to): hardness, transparency, solubility, thermal reactivity, surface bond strength, and surface appearance. The identification of characteristics specific to the material to be removed will dictate the most cost effective and safest method to perform the task at hand. Harder coatings (such as acrylic or epoxy resins) may be more suited to abrasive removal techniques, where as softer coatings (such as silicone or polyurethane resins) may be suited to removal by brushing or peeling procedures.

Coating Types

The specific chemistries of modern conformal coatings can be engineered to suit almost any circumstance in today's manufacturing landscape, yet almost all coatings can be classified into one of five categories. They are as follows:

- Type AR - Acrylic resin
- Type ER - Epoxy resin
- Type SR - Silicon resin
- Type UR - Polyurethane resin
- Type XY - Poly(para-xylylene)

Acrylic Resin: Acrylics are usually glossy and smooth in appearance. They provide good electrical protection to the covered area and generally have good dielectric qualities. They are also usually hard and may be mistaken for an epoxy. Like epoxy resins, they have a reaction to heat and will soften forming a gummy residue when heat is applied. Unlike epoxy, these coatings form a surface bond that often yields to chipping and flaking. Because of this physical characteristic, these coatings are NOT recommended for assemblies that require a high abrasion resistance.

Epoxy Resin: Epoxy resins are usually characterized by a hard, smooth, and nonporous surface. The two biggest advantages of these coatings are 1) a strong surface adhesive bond and 2) a strong resistance to most solvents. Unlike acrylics, this type of resin is a good choice when high abrasive resistance is needed. The main drawback of this coating is the strong adhesive bond of this type of coating makes it very hard to rework. With a high temperature, epoxy can break down into a white powdery substance; however, the man-hours involved may be costly.

Silicon Resin: Silicone resins can vary greatly in their characteristics, but they are often rubbery and pliable. Their adhesive strengths range from readily detachable to tightly bonded, and thickness of application is also variable over a wide range. Silicone coatings are most useful when an excellent dielectric or high arc resistance property is required. Resistant to normal heat and most solvents, rework can be difficult, however, there are some chemicals available that will break down silicone coatings.

Polyurethane Resin: Polyurethane coatings are intended for use where good resistance to moisture and abrasion is required (although they can be dented or scratched with light pressure). Their appearance is usually smooth, glossy, and nonporous. These coatings range from extreme hardness (similar to epoxies) to a relatively soft consistency (like a silicone). They normally form a medium bond that peels or flakes in large pieces and heat at solder melt temperatures tends to soften and make them pliable.

Poly(para-xylylene): Also called Parylene, these coatings have good dielectric strength, low thermal expansion, good abrasion resistance and outstanding chemical resistance. They form a strong surface bond and provide a thin uniform coverage that conforms fully to the PCB contour. They are used to protect circuits against high humidity, intermittent immersion, salt fog, pollution and aggressive solvents. They are FDA approved for use in medical applications. They are effective in high voltage applications because they can coat sharp edges. However, Parylene coatings are applied by a vacuum deposition process and can be very costly.

By attending the IPC-7711/7721B course, participants will be better equipped to incorporate recognition, removal and replacement techniques into their current manufacturing regimens. In addition, they will better understand the constraints associated with specific materials, designs and processes, while learning the principles associated with electronics manufacturing.

If you would like to experience the challenge of IPC-7711/7721B, please call 610.362.1320 or email registrar@empf.org to enroll.

Ross Dillman | Technician / Instructor

Tin Whiskers: Mitigation With Conformal Coatings | Part II

(continued from page 1)

It is commonly accepted that whisker growth follows a two part mechanism:

1. Diffusion of tin from anywhere in the tin plate to the site of the whisker, and
2. Incorporation of the tin atoms into the crystal lattice of the tin whisker.

Diffusion is encouraged by 1) a temperature high or low enough to be a significant fraction of the melting temperature at the high end, and absolute zero at the low end, and 2) a stress gradient whereby the tin atom diffuses from a place of high free energy (compressively stressed tin plated surface finish) to low free energy (a perfect crystal of β tin) within the tin whisker.

Neither of the diffusion enhancing/impeding parameters can be readily mitigated. First, temperatures at which electronics operate are rarely high or low enough to affect the diffusion coefficient of tin (melting point 231°C) appreciably.

Second, even though the internal compressive stress in the plated tin can be eliminated or caused to become tensile at the initial deposition of the tin coating film, the long term generation of intermetallic compounds in the tin coating on any of the electronic component leadframe alloys can eventually, often over very extended times, re-generate internal compressive stress in an initially stress-free tin finish coating. So diffusion is not something that can be controlled on a practical, long term basis.

The second half of the mechanism for whisker growth – incorporation of the tin atom into the whisker crystal – could possibly be prevented by coating the whisker, or the recrystallized grain of the tin plate that provides the first few layers of perfect crystal in the whisker, with a conformal coating of a high elastic modulus material. If the elastic modulus of the conformal coat is higher than the modulus of tin, then the incorporation of the additional tin atoms may not be possible, because the elastic modulus of pure tin would have to be exceeded to add additional tin atoms (and therefore whisker crystal volume, to the whisker) thus "stretching" the coating. Of course, the elastic modulus of the standard conformal coating materials (acrylics, silicones, epoxies, Parylene, and urethanes) are all thousands of times lower than tin. Only ALD Cap is documented to exhibit higher elastic modulus than tin metal applied to the completed circuit card assembly as a conformal coating by Atomic Layer Deposition. The ALD Cap is a ceramic material with a much higher elastic modulus than tin metal.

A third approach possible to mitigate whisker risk is also the subject of an MDA Phase II SBIR. This would conformally coat the electronics with a tough viscoelastic conformal coating that tents the growing tin whisker and causes Euler buckling of the whisker rather than allowing the growing whisker to puncture the coating. Tin whiskers have been shown to puncture and grow through all standard conformal coatings in a matter of months or a few years.

Both Whisker Tough P1 and ALD Cap conformal coatings show promise in mitigating tin whiskers, and are candidates in an EMPF ManTech project evaluating conformal coatings for electronics.

Fred Verdi | Senior Manufacturing Engineer

Upcoming Courses

IPC 7711/7721

June 1-5 Certification | July 13-14 Recertification

Attain proficiency in the rework and repair of printed circuit board assemblies. Utilize the industry's latest tools, materials and technology in hands-on lab work as well as reviewing all applicable procedures outlined in the IPC 7711/7721A Specification.

IPC A-610

June 8-11 Certification | June 15-16 Recertification

Achieve the highest quality and most cost-effective productivity by knowing how to correctly apply the IPC A-610 acceptability criteria.

Boot Camp

June 15-19 Boot Camp A | July 22-26 Boot Camp B

Boot Camp is designed to provide electronics manufacturing personnel with two weeks of intense, hands-on training in every aspect of the electronics manufacturing process.

Contact the Registrar for details:

phone **610.362.1295**

e-mail **registrar@empf.org**

Ask the EMPF Helpline!

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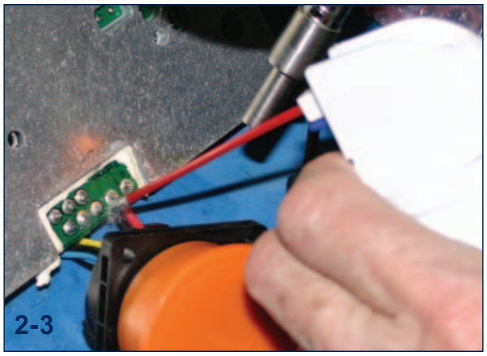
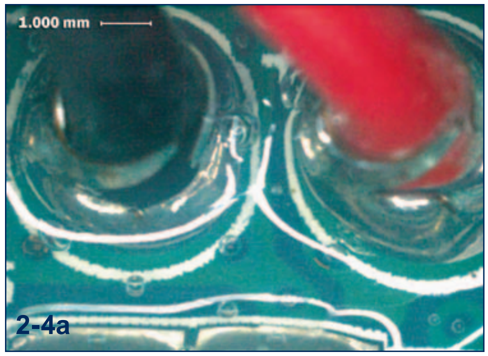




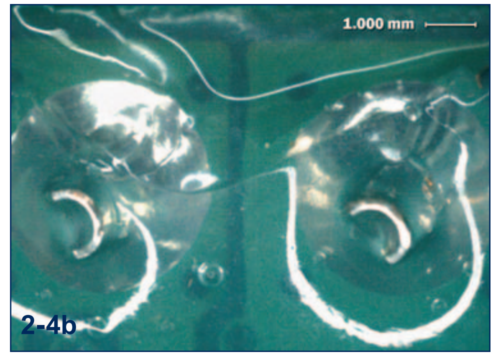


Figure 2-3: Rinse several times to remove all residues.

Figure 2-4: After 500 hours of THB testing.

magnification. No residues, dendritic growths, or conductive anodic filaments (CAF) were observed in the rework area during optical microscopy (Figure 2-4). The lack of residues and the results of the THB test show there is minimal risk of leakage current and corrosion problems with the rework method developed by the EMPF and the customer.

In conclusion, ionic residues left under conformal coatings can lead to corrosion or leakage currents due to dendrite growth. Moist ionic residues are common causes of electronic opens and shorts. When reworking a conformal coated board, it is important to use compatible flux chemistries for all stages of the rework process and to clean and thoroughly rinse the rework area prior to reapplying the conformal coating. The EMPF offers various analytical techniques (THB, IC, ROSE, and FTIR) to determine the root cause of contaminant problems and to evaluate the effects of rework processes on reliability. More information about these services can be found on the EMPF website, www.empf.org or by calling the EMPF technical staff at 610.362.1320.

References:

Munson, Terry. "Does Conformal Coating Stop Electrical Leakage Problems?" Circuitnet. Nov. 2004.

"Terry Munson." Can You Clean a No-Clean Assembly?. 2008. <http://www.residues.com/pdfs/Clean_No_Clean.pdf>.

Rebecca Morris | Materials Engineer

Five Types of Conformal Coatings

(continued from page 3)

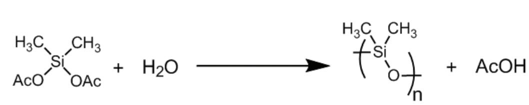


Figure 3-5: Synthesis of silicone resin.

Poly(para-xylylene) (XY), also known as Parylene, is a coating that is vacuum deposited in a process called Chemical Vapor Deposition (CVD). It has consistent thickness with true conformance to the board assembly contour, as well as being pinhole and bubble free. Parylene has a good dielectric, low thermal expansion, good abrasion resistance, and outstanding chemical resistance. It has been used to protect circuits from harsh environments, such as high humidity, intermittent immersion, salt fog, atmospheric pollutants, and aggressive solvents. They have been approved by the FDA in medical device applications. They are very effective in high voltage applications, due to its ability to coat sharp edges. They do not adhere well to boards that have ionic residues, so thorough cleaning should be performed prior to coating. It is an expensive process that exhibits poor repairability in comparison to other coatings. The higher cost associated with Parylene is attributed to the vacuum deposition process. This process is very engineering intensive, requiring control of the deposition rate to assure adequate coverage in the areas of interest, while preventing dielectric contamination with difficult and expensive masking of the board assemblies. Figure 3-6 shows an example of Parylene polymerization, where the starting material dimer is opened up and formed into chains.

continued on page 9

Five Types of Conformal Coatings

(continued from page 8)

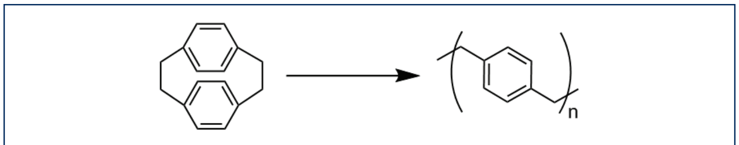


Figure 3-6: Synthesis of Parylene.

Specifications and Standards

MIL-I-46058C – Insulating Compound, Electrical (for Coating Printed Circuit Assemblies)[1]: MIL-I-46058C is an older military specification that lists the technical criteria for conformal coating characteristics. It also lists the quality assurance tests and how they are to be performed. A companion document, QPL-46058,[2] lists coating materials that are in compliance with MIL-I-46058 and is used by the federal government for acquisition purposes. On November 30, 1998, MIL-I-46058C was declared "Inactive for New Design" with no superseding specification.

IPC-CC-830B (with Amendment 1) – Qualification and Performance of Electrical Insulating Compound for Printed Board Assemblies[3]: IPC-CC-830B was derived from MIL-I-46058C and establishes qualification and performance requirements for conformal coatings. This standard allows manufacturers to qualify conformal coating products and define product performance characteristics to the standard.

IPC-HDBK-830 – Guidelines for Design, Selection and Application of Conformal Coatings[4]: IPC-HDBK-830 was designed to assist in the selection of a conformal coating. It outlines typical properties of each coating type and how they impact performance considering the intended end use.It also outlines processing steps to assure proper coating application.

Coating Acceptance Criteria

In IPC-CC-830B, conformal coatings fall under two classes: Class A and Class B. Class A is for non-hydrolytically stable conformal coatings, where lower moisture insulation resistance is permitted, and the temperature and humidity aging test is not required. Class B is for hydrolytically stable conformal coatings, where higher moisture insulation resistance is required, and the temperature and humidity aging test is required. These classes do not directly correlate to the Class 1, Class 2, and Class 3 in other IPC documents.

There are many testing requirements in IPC-CC-830B that a conformal coating must undergo to be qualified and accepted for use. These requirements and their respective test methods from ASTM, IPC, and UL, fall under thirteen categories:

- Materials
- Viscosity
- Fluorescence
- Flexibility
- Dielectric Withstanding Voltage
- Shelf Life
- Appearance
- Fungus Resistance
- Flammability
- Thermal Shock
- Moisture and Insulation Resistance
- Fourier Transform Infrared (FTIR) Spectroscopy
- Temperature and Humidity Aging (Hydrolytic Stability)

Coating Process

A board assembly must be cleaned and dried eight hours before conformal coating. Removing any water in the assembly may be accomplished by an oven bake at 93°C +/- 5.5°C, for a minimum of four hours. The coating material is applied using a method that will yield complete coverage without excessive filleting or runs. Common coating methods include spraying, brushing, dipping, or chemical vapor deposition (in the case of Parylene).

The EMPF uses a Gen3 Systems DC-2002 Dip Coater and Gen3 Systems SB-2900 Conformal Coating Spray Booth for applications of conformal coating. The Dip Coater works with the controlled extraction rate of the board assembly from the conformal coating bath. The entire board assembly is dipped into the holding tanks with a controlled removal from the conformal coating to obtain uniform thickness. The Spray Booth works with the operator spraying the board assembly on a turn table, under UV illumination, and a ventilation system to minimize exposure.

The following is a list of considerations to keep in mind when choosing a conformal coating:

- Raw material characteristics: viscosity, VOC free, one-part/two-part, cost
- Final cured material characteristics: dielectric, chemical resistance
  - Methods of application: capital equipment cost, speed/throughput
  - Cure methods available: heat/thermal, ultraviolet (UV), vacuum deposition (Parylene)
  - Cost of curing equipment: in-line heaters, deposition chambers
  - Environmental impact: volatile organic compounds (VOCs)
  - Cleanliness of board assembly prior to coating
- Ease of rework
  - Compatibility
  - End use application

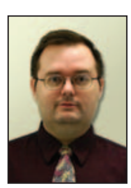
The EMPF facilities are well equipped to assist with the qualification of conformal coatings. In addition, the EMPF offers different deposition methods and techniques for conformal coating application and board assembly inspection.

[1] Insulating Compound, Electrical (for Coating Printed Circuit Assemblies) FSC 5970. <http://www.dscc.dla.mil/Programs/MilSpec/ListDocs.asp?BasicDoc=MIL-I-46058>.

[2] MIL-I-46058 Qualification Information. <http://www.dscc.dla.mil/Programs/QmlQpl/QPLdetail.asp?qpl=46058>.

[3] Qualification and Performance of Electrical Insulating Compound for Printed Wiring Assemblies - Includes Amendment 1. <http://portal.ipc.org/Purchase/ProductDetail.aspx?Product_code=88f063ef-b486-db11-a4eb-005056875b22>.

[4] Guidelines for Design, Selection and Application of Conformal Coatings. <http://portal.ipc.org/Purchase/ProductDetail.aspx?Product_code=64b52656-b586-db11-a4eb-005056875b22>.



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