# sti electronics inc. NEWS

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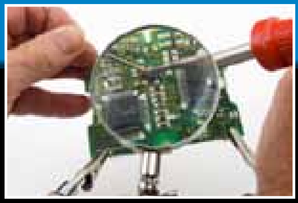
## Leading the way in **electronics**



By: Dave Raby

# March, 2016

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As usual, we've had a busy couple of months at STI. We celebrated Pat Scott's 15th Anniversary in February. I've known Pat since the very early 80's when she was an instructor at China Lake, CA. She was a good instructor then and has only improved over the years. Pat is Director of STI's Training Services Department and has been instrumental in making sure all of our training programs meet and exceed our customers' expectations as well as support the overall philosophy of STI. I made my almost annual pilgrimage to the SMTA's Pan

Pacific Conference in January. This was the conference's 21st year and I think it was my 18th. I thought this year's program was the best one yet with great technical papers from Asia, Europe and North America. The technical papers featured technology that we, our next generation and our competitors will be using in the future. Mark McMeen represented STI well presenting a technical paper titled "Electronic Assembly Warranties Challenge the Industry to Improve Risk Mitigation Test Methods". Mark was able to use data from one of our existing projects to support the presentation. Some very bright minds in our industry from all over the world are put in a close environment for 4 days where they share ideas and meals and make connections that wouldn't happen anywhere else. I'm already looking forward to next February on Kauai.

Prior to the conference, I did get to play in the golf outing and tried something I hadn't done before. Instead of riding in a cart, Mark and I rode a golf board. (We were the only two of the entire group dumb enough to try.) A golf board is a combination surf board/ skate board/snow board and theoretically zips you around the course for a fun filled day. The reality is a 5 or 10 minute safety video, a multi-page liability waiver that I'm pretty sure says "you might die" more than once, and warnings on the board itself "highly recommending" the rider wear a helmet and knee and elbow pads. (It is golf so you don't wear a helmet or knee and elbow pads.) Not included on the advertisement but on a sign I saw after I had committed, were the words "A great core workout". I didn't know I had a core but I learned quickly and the hard way. Mark was able to go out and practice until he felt somewhat comfortable with it. I used to be a skateboarder (approximately 100 years ago) so I took two laps around the cart parking lot and then headed to the first tee where the mountains began. I think it was the philosopher Gallagher who said "two wrongs don't make a right but three rights make a left". It was the 3rd hole before I learned to turn left. The next four hours involved lots of stopping and starting and concentrating on things other than enjoying the great ocean views and hitting a golf ball. It involved hanging on going up and down steep slopes and tight turns (generally to the right) and slowly approaching wild goats and quickly moving away from disturbed wild goats. I did manage to accomplish one of my two goals for the day. I didn't play as well as I would have liked but I did live. It turned out I do have a core and it took a couple of days to recover. Having said all of that, it was fun and I would do it again.

March started off with a visit to the Houston SMTA Expo. It is always good to visit Houston in support of STI's instructors and training operations there. Julio Estrada and Jason Shastri do a great job there and the business continues to grow. We are in the process of expanding our industrial classes which we have previously only offered in Florida to the Texas market. The local SMTA officers always do a great job with the Expo and this year was no exception.

It was then off to Boston for another of my favorite annual events, the MIT Sloan Sports Analytics Conference. This was the 10th anniversary of the conference, which is also somewhat affectionately known as Dork-a -Palooza, and I think my 5th to attend. This year's event had a capacity crowd of 3,900 people which was comprised of 3,899 really smart people (MIT professors and graduate students, professional sports general managers and other personnel) and me. I started going to the conference because of my interest in sports analytics which have always fascinated me. Many years ago I even worked for the legendary Bill James collecting data at professional baseball games before that data was public. "Moneyball" brought attention to the subject and computers that could handle big data have revolutionized how we collect and look at the data. Sports analytics was what got me to the conference the first time but what has kept me coming back is being able to hang around all of these really smart people and get a better idea on how they think about and attack a problem. I'm not on their level but I'm definitely better than before attending. This year's conference also had a few sessions on various aspects of wearable technology. It is a popular topic in many of our industry events and it was interesting to see how in some arenas sports are leading the way to new technology.

From Boston, I was off to Las Vegas for IPC's APEX Expo. APEX is a great place to see people and the latest and greatest equipment from large and small manufacturers. It is also home to the committee meetings that drive the standards we use to build and inspect hardware. I was there for all of the above reasons. I saw two pieces of capital equipment that we will be buying in 2016 and a couple of more that we are looking at for 2017. I had the honor of accepting from Mike Buetow Circuit Assembly's


*David Raby, President & CEO, STI Electronics accepts award from Mike Buetow, Editor-in-Chief, Circuits Assembly Magazine*

New Product Award for Training Materials for our IPC-A-600 PCB Process Sequence Kit. In my slightly biased opinion, it really is a great product, developed by STI's training department, which shows step by step how bare boards are made. Circuits Assembly always does a great job with the awards and donates a good bit of money from the entry fees to the SMTA's Charles Hutchins Scholarship Fund. A couple of hours later at the IPC Annual Luncheon, I was very

*David Raby, President & CEO, STI Electronics accepts award from John W. Mitchell, IPC President & CEO*

honored to receive the IPC President's Award from IPC President John Mitchell. I'm still not sure I deserve it, but it truly was a special honor to be recognized. My father, Jim Raby, received the same award in 1984. This makes us the first father/son duo ever to have received the award. I wish Dad could have been there for the presentation but he was very happy about it. I offer my sincere thanks to John Mitchell and Mark Peo and the entire IPC group.

One bad thing about APEX being a little later on the calendar than usual this year was it overlapped with the Army's AUSA show in Huntsville. Mark and his technical crew manned our booth for that one and it sounds like they had a good show.

We try to make STI a good place to work. We try to treat people fairly and do other things to promote a good atmosphere. We expect good hard work but with very few exceptions, our jobs aren't really physically demanding. That's why this past month has been odd with what seems like more than our fair share of illnesses. We've also had at least 5 surgeries in our group (from gall bladder to open heart and various stops in between). I'm very happy to say everyone is recovering as they should. I'm also happy to say Pat has done a great job keeping classes covered and AJ has done a great job continuing to build hardware through some interesting times. I look forward to a healthier team going forward.

Additionally while on the health topic, Travis Wease is an instructor for STI's Crane, Indiana Training Facility. Travis's wife, Amanda, has been diagnosed with Stage 4 cancer and has been undergoing treatment for the last 18 months. The treatments require considerable expense and travel making this an extremely stressful burden. STI employees have been contributing to help in a variety of ways including T-Shirt sales. If you would like information on purchasing a T-shirt or like to make a donation, please contact Pat Scott (pscott@stielectronicsinc.com) and she can make it happen. Please keep Travis & Amanda and their family in your thoughts and prayers.

Thank you for your support and please let me know how STI Electronics can serve you better.

**Amanda Stemler Wease**

# Fundraiser

T-Shirts | T-Shirts | T-Shirts

This is Amanda Stemler Wease, wife of Travis Wease, she has been diagnosed with cancer & has been fighting this battle for 18 months. (She has Merkel Cell Carcinoma). They have her currently labeled as Stage 4 since they have discovered the cancer in her hand, arm, lymph nodes and lungs. These shirts don't have her name on them, so they are great if you have a friend or family member who has battled cancer. There are 4 designs to choose from. So please, order a shirt, donate, pray, whatever you are able to do right now! Thank you all so very much from the bottom of our hearts!

**All Proceeds will go towards Amanda's Medical Bills.**

**Shirt Order Information**

| Name | Shirt #1 Qty/Size | Shirt #2 Qty/Size | Shirt #3 Qty/Size | Shirt #4 Qty/Size | Total |
|---|---|---|---|---|---|
| *John Doe* | *1 / XL* | *1 / 2XL* | | *1 / YL* | *$48.00* |
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YL – Youth Large
AS – Adult Small
AM – Adult Medium
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XL – Extra Large
2XL – Double Extra Large
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➡ **Shirts are all printed on Gildan Brand T-Shirts.**

To purchase a T-Shirt
contact Pat Scott
pscott@stielectronicsinc.com

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# TRAINING MATERIALS

## PCB SURFACE FINISH FOR BGAs

### BGA SOLDERING KITS

While circuit board surface finish is commonly dictated by the design envelope, the surface finish plays a more significant role in the success or lack thereof regarding Ball Grid Array (BGA) attachments.

*Figure 1*

Initially, the unique properties of the BGA package must be considered. BGAs have no lead compliancy and therefore the flatness of the surface is a critical perspective for successful attachment. If one of the BGA lands is slightly higher than others, it may result in adjacent solder spheres not contacting the solder paste or land (see Figure 1).

The pitch of the BGA solder spheres has a more significant impact as the pitch (and corresponding solder sphere diameter) decrease. Coplanarity is improved when the PCB has a plated surface finish when compared to a finish such as Hot Air Solder Level (HASL). When the solder is leveled during the HASL process it tends to build up or crest on the trailing edge of some pads and flatness or coplanarity suffers (Figure 2).

This will typically not be an issue for common pitch dimensions around 1.27mm or 50 mil pitch. Electroless Nickel Immersion Gold (ENIG) is a very flat surface finish and is compatible with most Lead Free and Tin Lead BGA spheres. A potential drawback of ENIG is the possibility for Black Pad failures at the nickel interface. This may require tighter quality control of the plating process or very careful consideration of the design and component interconnects. Another common finish that has good coplanarity is Organic Solderability Preservative (OSP) since it is placed directly on the exposed copper surfaces. One of the disadvantages of OSPs is the reduced shelf life when compared to HASL or ENIG.

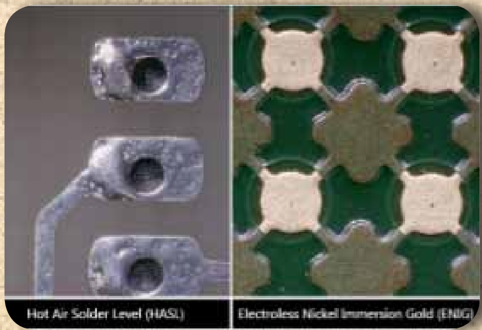


*Figure 2*

Solder paste deposits on the BGA lands can provide some compensation for lack of coplanarity of the board surface since it compresses slightly during component placement, and levels at the surface of the stencil as it is applied to the board. Solder paste application does require a lot of process control as a result of the number of variables in the process. Poor process control of the solder paste application process can lead to other issues such as bridging and dispersed solder fines which can have a significant impact on the finished quality.

BGA soldering kits are available from STI with HASL finish for common pitch dimensions and ENIG finish for fine pitch. It is a cost effective way to evaluate BGA production capability without expensive production material loss. Gerber data can be supplied to forward to your preferred source for stencil fabrication.

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**IPC-A-610 and J-STD-001 STATUS**

The IPC soldering standards are continually evolving and we are collecting input for the next revision to the IPC-A-610 and J-STD-001 series which will be Revision "G". The process takes a couple of years to complete but we have some newer technologies that need to be incorporated and we have committed to being more responsive in getting the latest information out to the community as soon as possible. If you have any suggestions for the new revisions, now is the time to submit those to the appropriate committee. Please contact me if you need any assistance with your submission. I'll be able to provide you with more detail of the revision efforts and status in our next newsletter.

Our feature Training Kit for this newsletter remains the updated J-STD-001, Revision F, Solder Training Kit.

Mention this newsletter article and receive a **10%** discount for your next Revision F kit order.

# ORDER NOW!

## New Staking and Conformal Coating Board for Hands-On Training

## *No Assembly Required*

STI'S Training services department is constantly looking for ways to improve the training process. This past year we have developed the J-STD-001/IPC-A-610 Inspection Kit, and the IPC-A-600 Process Sequence Kit. STI is pleased to unveil its new Staking and Conformal Coating Board for Hands-On Training.

**The Kit Contents Include:**

- Staking
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If you're looking for a standardized training kit to use when teaching staking, bonding and conformal coating this board is the answer.

This fully assembled board comes ready for component staking, bonding, underfill, torque (witness) stripe and conformal coating. Use this kit for training programs such as J-STD-001, IPC-A-610, NASA-STD-8739.1 or company specific standards. Evaluate your student's proficiency using actual hardware.

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# Electronic Assembly Warranties Challenge the Industry to Improve Risk Mitigation Test Methods

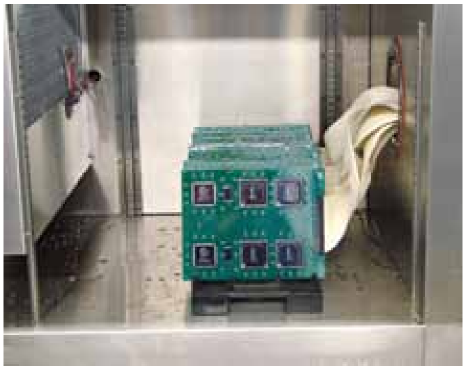
*As originally published in the 2016 SMTA Pan Pacific Microelectronics Symposium Proceedings.*

Mark McMeen and Jason Tynes, STI Electronics, Inc. | Mike Bixenman, DBA and David Lober, Kyzen Corporation

## Abstract

Circuit/System PCB designer's objective is to increase device functionality in a smaller form factor with a higher density electronic layout. Higher density and smaller form factor components are driving the industry toward a higher risk situation in intermittent electronic performance. Voltage leakage and even current leakage can lead to signal integrity loss and even flip bit issues or drops in processing commands. As the density increases and the miniaturization drops in size and spacing so does the increase in failure mode opportunities for signal integrity/signal loss. The spacing between conductors and pads in the past has been our friend and saving grace by giving us greater insulation between these conductors and pads. Even the standoff heights within the Z-Axis of miniaturized components are approaching one mil. This drop in z-axis means there is smaller cubic volume area to outgas volatiles or insure the volatization/boil off effect of flux additives such as inhibitors (against oxidation/corrosion), activators (promotes wetting) and thermal stabilizers (insures fluxing action at peak reflow temps) during reflow, flux residues can become entrapped under the component itself in a state that has not fully deactivated. Mobile ions within the flux residues form leakage currents and/or voltages, especially when the device is operating within humid environments. Flux residue can contain halide/ionic materials which, when trapped under a part can lead to shorts across adjacent pads, or voltage/current leakage pathways.

Companies who require devices to meet long term reliability/warranty expectations need an improved industry test specification that allows for an accurate risk assessment. The problem is that the risk assessment is a multi-variable issue influenced by flux type, flux make up (activators and inhibitors), activation temperature, component type and placement; the type and criticality of the circuit in which the component is operating



in, wash characteristics if not a no-clean flux system, solder paste volume, PCB cleanliness and component contamination. Current measures of "clean" do not indicate if the product is clean enough in a critical area, which is what we hope to do. The goal is to design a test and test vehicle which encompasses the challenges of today so the System Design Engineer can define and characterize risk within his/her electronic assembly for long term reliability associated with cleanliness of the finished electronic assembly and final system warranty expectation. This is a tall order but there is a concern within critical industries such as Military, Medical, Automotive, Aerospace and safety critical industrial applications and industries to better define the risk and measure the risk associated with cleanliness. Cleanliness is a broad term for the mitigation and measurement of Electrochemical Migration (ECM) and pitting and creep corrosion, and general surface insulation breakdown due to free ionics.

This paper will report ongoing research to study these multi-variant issues using a new test vehicle with sensors placed under and near bottom terminations such as QFN and LGA components. The test vehicles are designed to track impedance where it matters most. The goal of this research is to develop an improved method for studying multi-variables that may impact circuit/component reliability. This is not a single event/variable equation but a very complex multi – variable problem with varying degrees of interaction. Some of the main variables are processing equipment temperature controls/profiles; construction of the flux system and its chemical formulation; volume of flux residue remaining; and the type of component and its design as well as the plating finishes used on pads as well as the type of solder alloys used. This list was not all inclusive but gives an insight to the multi-variable problem statement. Data findings, inferences from the data findings, and recommendations will be documented and presented.

## *Introduction to the Problem*

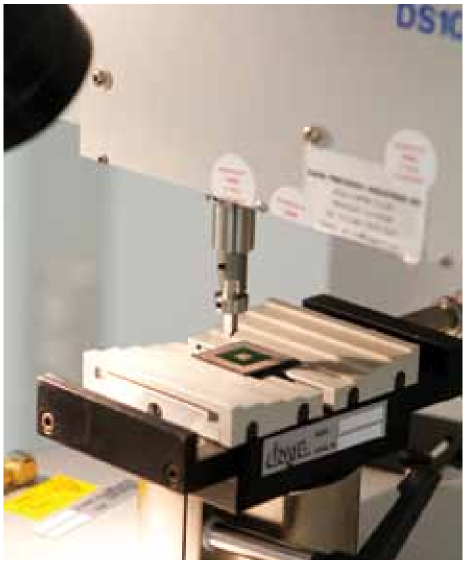
Field failures on highly critical systems are not acceptable for some industries such as military where there is a son, daughter, father, and/or mother depending on that electronic system to protect them from harm's way. Automotive and aerospace applications have the ability for loss of life and in multiples depending on when and where it happens. Medical reliability is critical at the personal level as well as to the person counting on everything to optimally work and not produce false readings or complete failure which can drive wrong conclusions or death in the worst case. All of these have personal accountability but also business liability concerns. Product designs that are faulty or do not meet consumer expectation will ultimately go out of business, but equally important is the failure mode or warranty failure of products not meeting design life expectations or warranty expectations. This business risk via liability is essential to company's long term success or failure.

System designers first test performance factors in an effort to screen in reliability and then once those factors are understood, design in reliability. To properly screen in reliability, definition of end product life expectancy is critical. What is the finished product designed to do? What are key performance objectives such as size, speed, cost, mass, style and efficiency? Having a good feel or understanding for the product warranty objective up front from a reliability standpoint, helps to properly meet the definition stage for screening and designing in reliability.

A critically important factor during the reliability screening stage is to properly consider and design the product for the environment in which the device will be exposed and used. This is usually overlooked or performed too late in the design cycle. If the environment subjects the device to moisture/humidity above 60% RH, ions can be mobilized. Ion mobilization is one of the critical attributes to a number of failure modes associated with creep and pitting corrosion and electrochemical migration and a breakdown in surface insulation due to free ionic mobility. The issue today is that few system designers worry about environmental conditions such as humidity but concentrate on larger environmental conditions of temperature and CTE movement extremes which are important but the most basic concept for ion mobilization and metal dissolution is overlooked. Humidity is an ever changing constant in all environments and water is the greatest solvent of all solutions which aids in dissolution of metal ions and ion mobility. This area of concern is what this paper is designed to address, cleanliness and its multifaceted/multivariable interaction and how design engineers need the data and test specification to determine how to design in safety measures to insure defect free products that meet their warranty and long term reliability objectives when cleanliness and contamination under components interferes with the circuit/component performance.

Designing in reliability for cleanliness starts by defining the assembly process conditions and material sets used and their interaction. Characterizing risks due to material choices and their interaction with processing parameters provides the OEM/design engineer with data for defining component types, solder material selection, processing/ building requirements, cleaning conditions and protective sealants. Designing the product layout is not trivial and processing rules and requirements help to accurately build a risk assessment. At this point, having test data that defines the optimal material choice and processing steps along with cleaning specification that defines handling, cleaning and coating levels required for a product that works as promised and meets its long term objectives. By minimizing and understanding the risks of the multivariable issues associated with cleanliness where it counts the most in the electronic circuitry and under its individual components that make up and operate at the electronic system is essential to meeting long term reliability and warranty expectations. Any mistake in this realm could jeopardize the long term reliability of the product and thus jeopardize human life as well as the OEM's financial viability.

The last part of the equation after the process specification is in place and material choice is chosen is to minimize cleanliness risk by process monitoring and traceability. The ability to monitor and verify processes and traceability needs to be captured to insure lot to lot repeatability. This allows the OEM to monitor and perform design verification and product reviews as well as periodic audits to insure that everything is still in control and no variable has deviated from the norm or process control parameters. This process of monitoring insures electronic designs meet its reliability expectation by understanding quantitative failure rates, evidence of product and test capabilities, sound procedures for process control and a defined material control policy to insure product and corrective action plans for identified weaknesses on a lot by lot basis. Taking this level of discipline enables sound procedures for building products that will meet and exceed expectations. Again the goal of this research is in defining test methodologies and techniques that gives system design engineers the data necessary to choose the right solder alloy and solder paste system as well as a way of measuring process controls to insure and address the cleanliness objectives of the final electronic assembly.



## *Why Do Electronics Fail?*

Failure mechanisms/modes can be classified into four categories:[3]

1. Chemical/Contaminant
    a. Moisture Penetration
    b. Electro-Chemical Migration
    c. Pitting/Crevice Corrosion
    d. Free ionics not bound or cross linked
2. Electrical
    a. Electro-Migration
    b. Conductive Filament Formation
    c. Thermal Degradation
3. Mechanical
    a. Fatigue
    b. Creep
    c. Wear
4. Over Stressed Issues
    a. Supplier compliance to material specs
    b. Field loading
    c. Product durability

The nature of the research within this paper focuses on Chemical Contaminants. When ions are mobilized, the corrosion process is initiated through oxidation and reduction of metal ions. When the device is biased, mobilized metal ions migrate from the cathode to the anode. The metallic ions plate out until a dead short occurs. The corrosion rate tends to be dominated by the mobility of the ions which depends on temperature, ionic concentration, and the material that the ions are dissolved in, among other factors. In most cases water will be the mobilizing fluid although in certain circumstances boards may be exposed to other fluids, such as organics.

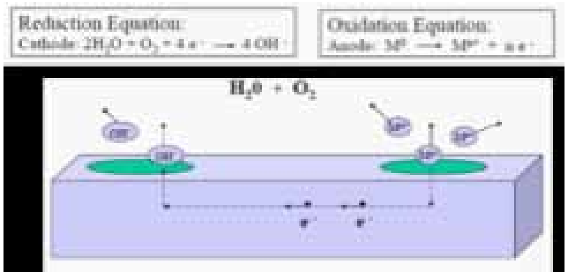



*Figure 1 Mobilizing Ions Initiates Oxidation/Reduction[4]*

There are two categories of ions: cations and anions. Cations are atoms or molecules that have a positive charge due to the atom or molecule "donating" one or more electrons to another chemical species. The most common cations encountered in electronics are metal cations. Anions are atoms or molecules which have an abundance of electrons. In electronics the most common anions are halogens as well as weak organic acids.

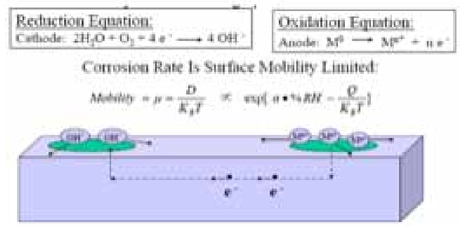



*Figure 2 Corrosion rate versus surface mobility[3]*

Ionic residues are mobilized based on the strength of the ion-dipole forces of attraction with water. The intermolecular bond with water creates an electrolytic solution, which can be acidic or basic but can be neutral as well. The ions present in the monolayers of water form an electrolytic solution.

When the electrolyte solution comes in contact with solder alloy, component metallization and plated PCB pads, metal oxides can dissolve into the electrolyte. Some ions are more active, meaning they are more reactive and likely to dissolve metals than others. The activity of an ion depends on the environmental conditions as well as the electrochemistry of the materials that it is exposed to. These positively charged metal cations are attracted to the negative pole when the part is biased.

The metals mobilized within the electrolyte can plate out in the form of dendrites. The leakage current from these dendrites reduces resistivity. Over time the dendrite can migrate until the metal migration creates a dead short causing the device to fail or cause intermittent operation Thus, voltage leakage from one circuit to another becomes the failure mechanism. In a power circuit, current leakage is the mechanism that triggers failure.


*Figure 3 Ions Dissolve in Water*

Some ions are more active than others. For example, the Cl- ion forms coordination complexes with metals and metal ions. These coordination complexes tend to be positively charged. When biased, the positively charged metal complex is attracted to the negative pole. Over time the metal ion plates from the anode back to the cathode (Figure 4). These metal fragments form leakage currents which reduce resistivity. Over time the metal fragments will short the component, which leads to performance failures.

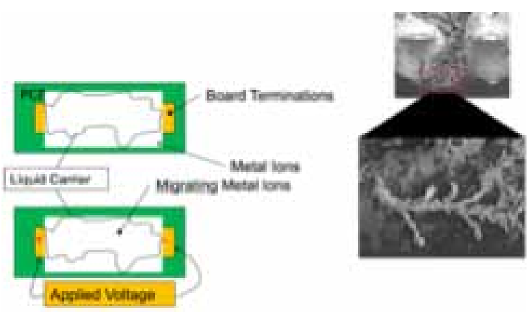



*Figure 4 Metal Migration forming Dendrites*

ANSI/ASRAE water standards finds that 3 monolayers of adsorbed water will mobilize an ion.[6] They also report environmental conditions require roughly 50-60% RH (relative humidity) to obtain 3 monolayers of moisture (Figure 5). As circuits continue to miniaturize, the distance between conductors narrows. This has relevance in that shorter distances results in lower levels of ions needed to be mobilized in ≥3 monolayers of water to create a reliability issue. As such, residues residing under Bottom Terminated Components (QFN and LGA style components) increase reliability risks.

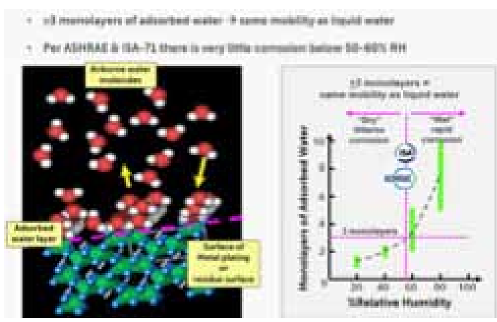


*Figure 5 ANSI/ASHRAE Monolayers as a function of RH[5]*

The driving forces for mobile ion diffusion depends on several factors:6

- Diffusing species
- Medium through which the mobile ions diffuse
- The concentration of the contaminant

- Temperature
- Bias

Momentum exchange between current-carrying electrons and metal ions drift in the direction of the electron current. In the presence of flux, a stress gradient is induced that is proportional to the current density. Pitch reduction between conductors creates increased electric field strength causing leakage currents that can impact product performance. The acceleration factors can lead to a shorter mean time to failure.

Tighter spacing, active flux residues, higher voltage and end use environment create higher risk of electrical leakage. As OEMs work to develop a risk profile, better information and knowledge of residues residing under Bottom Terminated Components is needed. The purpose of this research is to develop research methods for quantifying the activity of residues under the bottom termination and to improve the ability to make risk assessments.

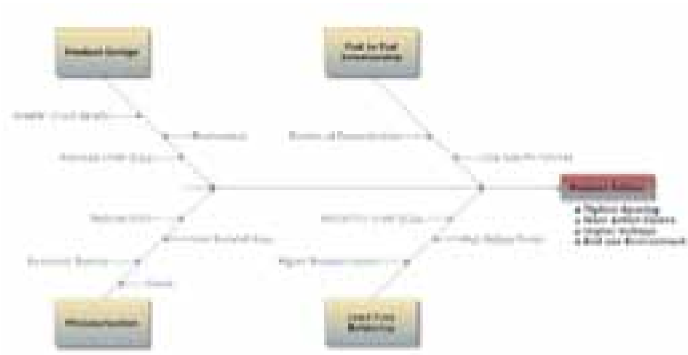


*Figure 6 Product Failure Factors*

## Defining Cleanliness Specifications

Cleanliness specifications are needed to assure that a high reliability product can meet the engineering drawing; be produced with the candidate material set and assembled using defined manufacturing parameters.  The objective is to meet the contractual requirements and customer expectations for quality and reliability. Customers want assurances that they can meet their warranty and long term reliability goals.  From a cleanliness perspective, key questions should be considered:

- How clean is clean?
- Is the assembly clean enough to meet long term reliability?
- Who warrants the product over time?
- What is the definition of clean electronics?
- What is the level of cleanliness needed?

The research in this document presents new test methods designed to quantify the level of contamination that may be problematic at specific line spacing. The test method evaluates the drop in resistance levels from residue under a bottom terminated component.

## EXPERIMENT Round 2 Results as well as Initial Results

***Bottom Terminated Componenets (QFN/LGA Style)***

Real Time Surface Insulation Resistance (RT SIR) test vehicles were used to evaluate the cleanliness levels of a quad flat bottom termination (QFN) component. These component packages are increasing in popularity due to their versatility in size, pin count, and power dissipation capabilities. BTCs present a challenge to cleaning practices in that the pin pitch (or spacing) decreases, while the proportional volume of solder pastes increases. The challenge comes in the form of effectively removing solder flux residues trapped under the part. Due to the component style (QFN), the Z-axis standoffs height inhibits proper flux outgassing, which in turn traps unactivated flux residue. Though they are undetectable to the naked eye, these residues have measurable electrical properties that can be characterized using the RT SIR Test vehicle.

The electrical properties of paramount concern are the resistive and capacitive effects of any residue trapped between the part and the board. The presence of mildly conductive residues tends to drop the resistance between adjacent pins, permitting current/voltage leakage during operation. The presence of mildly capacitive residues tends to provide a potential source of charge storage that undermines the integrity of high frequency circuits. Any foreign substance will have some potentially measurable electrical property that deviates from that of air and/or PCB dielectric substrate material. This deviation is what the real time SIR test vehicle seeks to isolate and illuminate.

The test vehicle utilizes a QFN package with a large ground lead in the center. The part is 7mm square with 0.5 mm pin pitch. The ground lead serves as an electrical reference, and commonly as a thermal path for the part. A relatively large volume of solder paste is used to connect the ground lead/lug to the PCB. As a consequence, the flux within the solder paste must activate, vaporize, and evacuate/outgas in order to render the volume devoid of flux residues and activators/inhibitors. Given the quantity of flux, short reflow duration and relatively long route to evacuation, it is not uncommon for flux residues to be trapped between the ground lead and perimeter leads. The impact of conductive or capacitive material in this area can adversely affect any of the pins on the perimeter of the component.

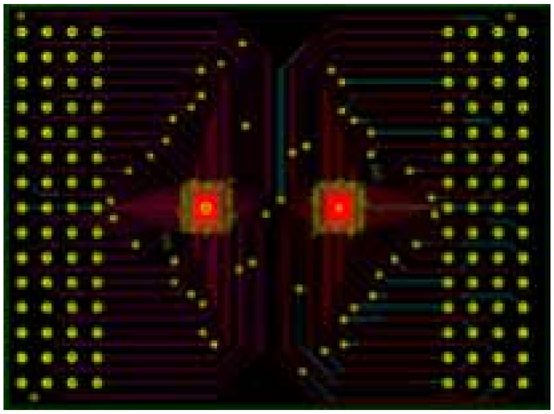


*Figure 7 RT SIR Test Vehicle*

The test vehicle employs an exposed sensor trace that circumscribes the area between the ground lead and perimeter leads. This trace is 20-mil wide on two (2) sides and 10-mil wide on the adjacent sides, leaving a 10- and 15-mil space to adjacent conductors, respectively. The spaces are exposed to any materials in the area, allowing remote electrical access to the volume. With equal spacing between the traces, ground lead and perimeter leads, these traces provide information regarding conductivity and capacitance between any combinations of leads.

Perimeter leads are connected in an alternating pattern, permitting an understanding of residue characteristics between conductors on the perimeter of the component. The test vehicle includes two configurations of plated through holes beneath the ground lead/lug. One configuration (U1) has an open plated through hole, while the adjacent configuration (U2) is plated shut. As it turns out in this case post analysis showed the open plated hole to fill with solder and minimize the outgassing affect and thus the results were not discernible in our initial test results.  Because both configurations are contained on the same test vehicle, they undergo nearly identical manufacturing processes and materials, and thus minimize processing variability.

## *DOE Factors: The factors considered in this phase of testing included*

1. The influences of humidity on resistance measurements
2. The performance of varying no-clean flux types (Halogen-Free vs. Standard Halide ) as test vehicles are exposed to similar test protocols
3. The propensity of test vehicles to return to baseline conditions after exposure to environmental accelerants (hysteresis)
4. Document the effectiveness of outgas-encouraging design features as it relates to flux residue

The testing was conducted using two (2) circuit boards described previously, differing only in flux type. These boards were built using pick-and-place and screen printer machines capable of precisely locating solder paste and components without unintended solder connections. The boards were then run through a reflow oven using thermal profiles recommended by the solder paste manufacturer.

The boards were subjected to a series of extended environmental stresses, in order to induce any flux residue-related electrochemical changes.

The environment used to accelerate these changes was 40°C and 95% relative humidity (non-condensing) for 168 hours (1 week). A 5VDC voltage bias was applied between the ground terminal and perimeter leads, in order to provide a consistent and prolonged electromotive force to the residue. The intent was to coax the alignment of ionic compounds using a persistent electric field. High impedance measurements were taken prior to, during, and after the environmental exposure, at regular time intervals, in order to identify any degradation. After the 168 hour exposure, the boards were return to ambient conditions (25°C and 40% RH) to dry out. Measurements were again taken at regular intervals to capture any subsequent recovery of electrical properties. After stabilization, the boards were returned to the environmental chamber for a final round of identical stresses and regular measurements.

## *Data Findings: INITIAL TESTING*

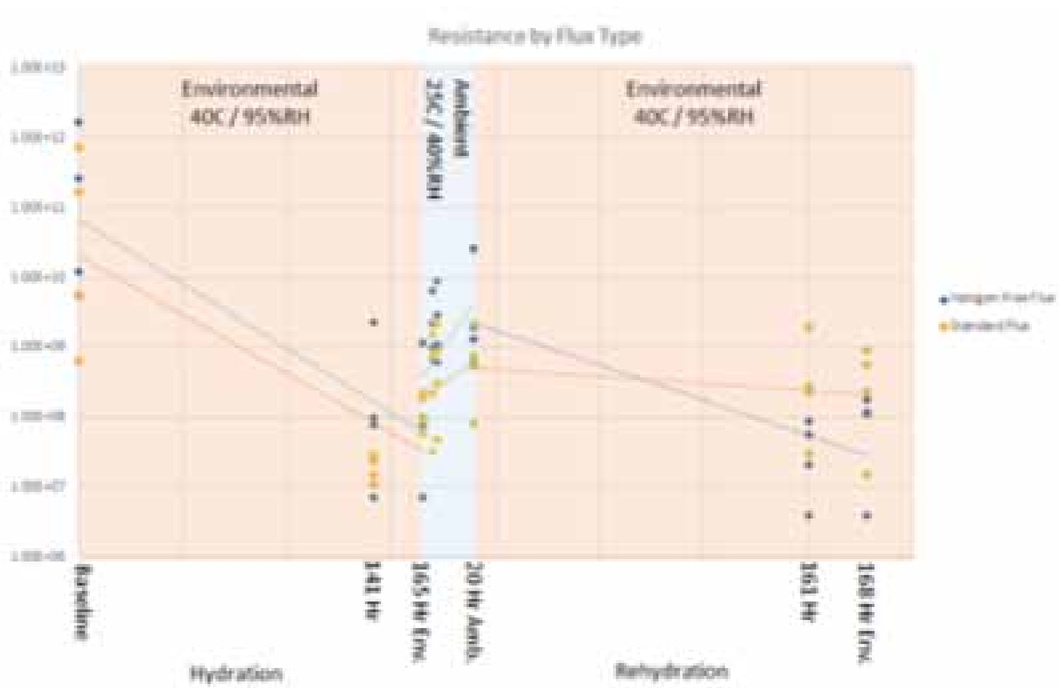



*Figure 8: Resistance by Flux*

Figure 8 shows the data generated during each phase of environmental testing, delineated by flux tape. The straight lines depict the best-fit trend of the data. Because the resistance is on a log-scale, the straight line indicates an exponential rate of change. The decline in resistance occurs at a dramatic rate, while recovering at similar rates while it dries out.

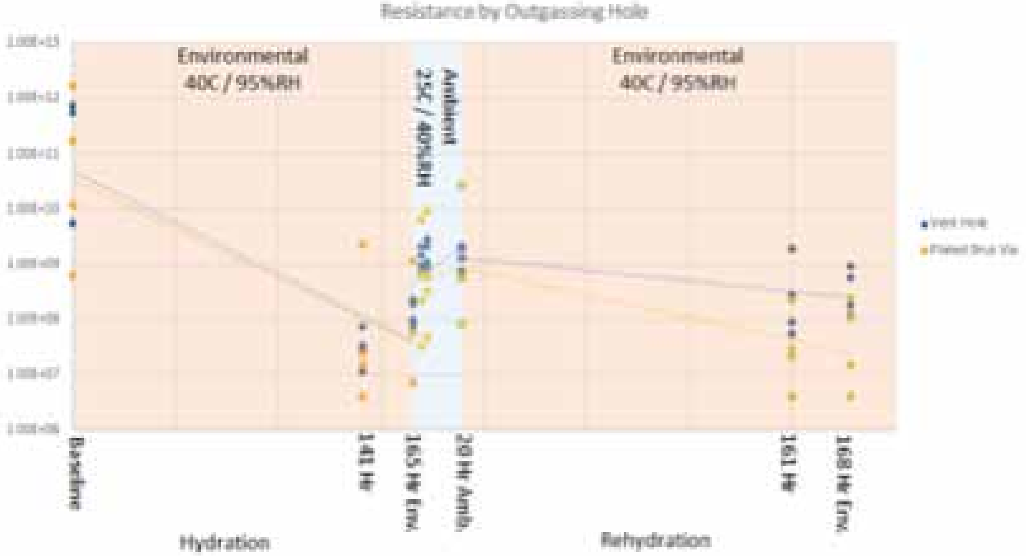



*Figure 9: Resistance by Outgassing Hole*

Figure 9 shows the data generated during each phase of environmental testing, delineated by vent hole. The vent hole, in theory, would have provided a means for volatile flux gasses to escape during reflow, resulting in presumably less volatile flux residues. The absence of this vent hole would have the effect of impeding proper outgassing, thus resulting in more volatile flux residues. Post analysis showed via holes filled with solder and thus eliminated the outgassing effect thus minimizing the expected effect of reducing the inhibitors/ activators inside the flux residue.

## *Second Test: Halogen Free vs. STD Halide*

(More in depth review of flux system type)

### Halogen Free HF Study

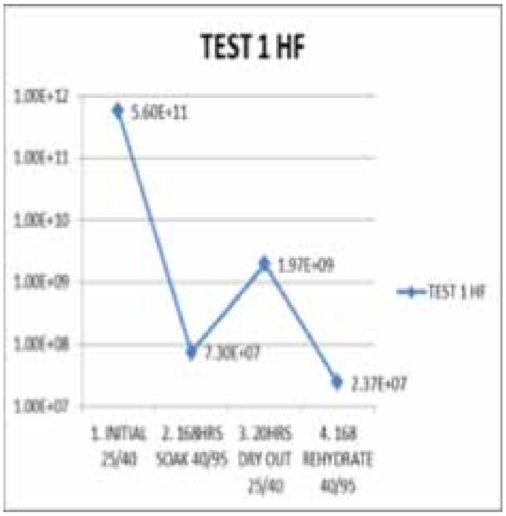



*Figure 10: Test 1 Halogen Free Flux Test 1 Sensor 1*

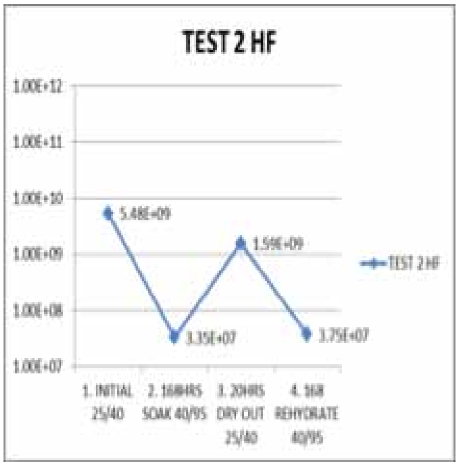



*Figure 11: Test 2 Halogen Free Flux Test 2 Sensor 2*

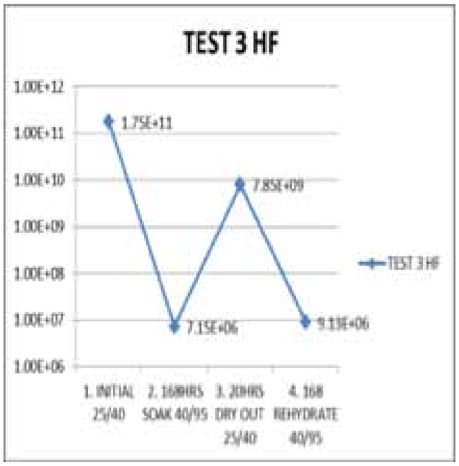



*Figure 12: Test 3 Halogen Free Flux Test 3 Sensor 1*

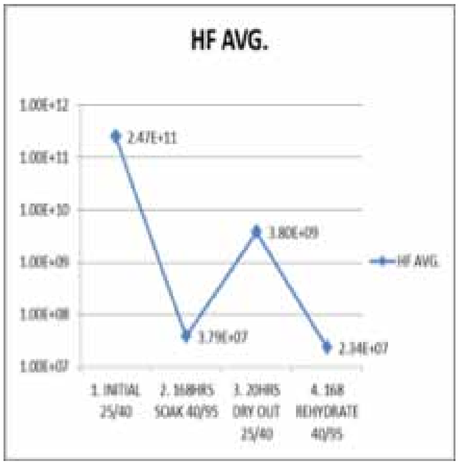



*Figure 13: HF AVG. Halogen Free Flux average of Test 1 thru 3*

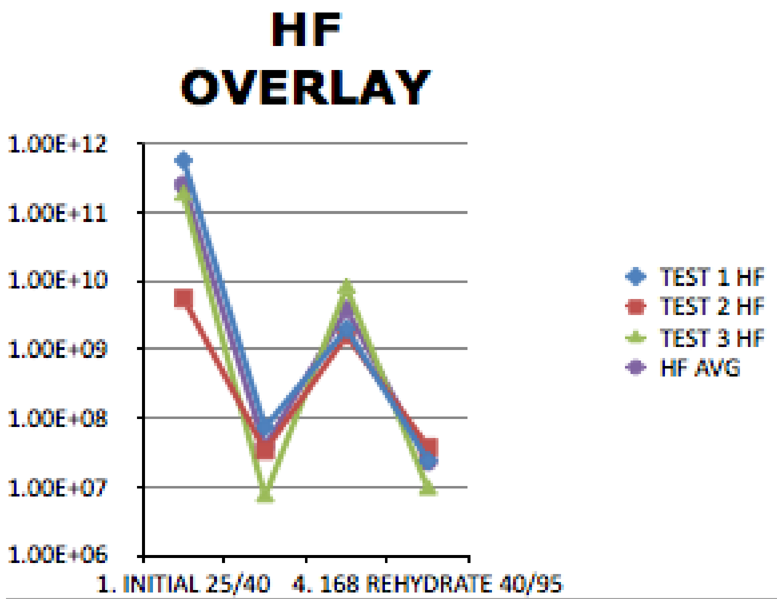
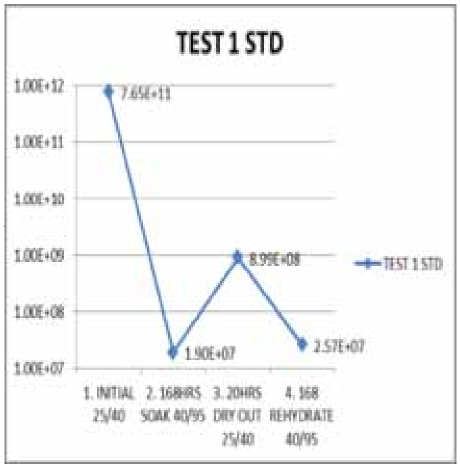
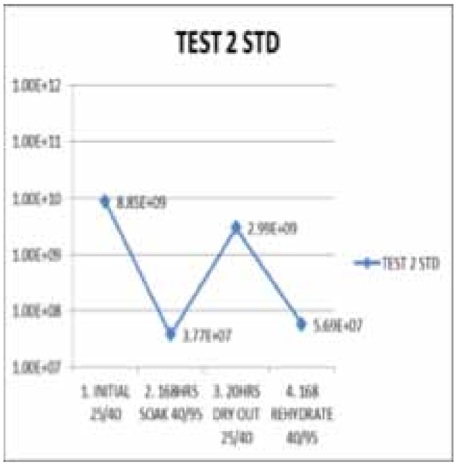



*Figure 14: HALOGEN FREE HF FLUX HF Overlay comparison of Test 1 thru 3 with STD AVG.*



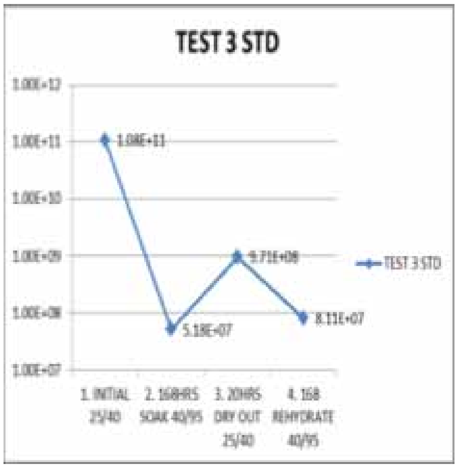




Figure 10 thru Figure 14 shows the test data for Halogen Free flux system used in this real time SIR test. Key points are the initial resistance before environmental testing is >1.00E+11 for sensor 1 and > 1.00E+9 for sensor 2 which has a lower gap distance between adjacent pads on the QFN component where sensor 1 was between the ground lug and an inner sensor trace. After the first 168 hour environmental test of 40 degrees C and 90 plus humidity, one can see a drop in resistance from a safe 1.00E+11/+9 to resistance readings in the 1.00E +7/+6. This drop in resistance in surface insulation is below industry thresholds of 1.00E+8 for safe operating surface insulation resistance (SIR) parameters. The next cycle shows a drying out period to see what happens when the humidity drops to below 50% and the test specimen dries out at the surface and below the components themselves. The surface insulation resistance increases back from a non- acceptable state back above 1.00E+8 industry threshold. Again if the test vehicle is rehydrated in a humid 40 degrees c/90% plus humidity then the surface insulation resistance will drop from acceptable back to non-acceptable SIR ranges in the 1.00E+7/+6 ohms. This confirms the need for a temperature and high humidity test that allows for ion mobility i.e. 40 degrees C and 90% plus Relative Humidity environmental test protocol.

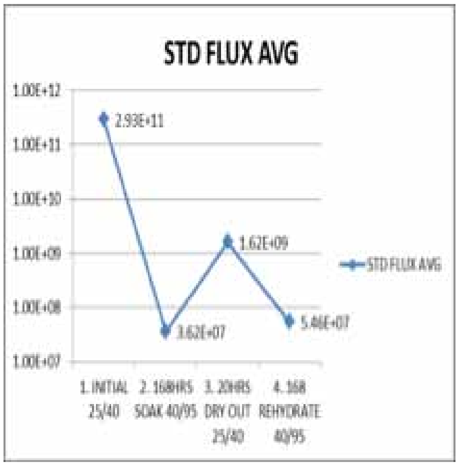



*Figure 18: STD FLUX AVG.*
*STD Halogen Flux Average Test 1 thru 3*

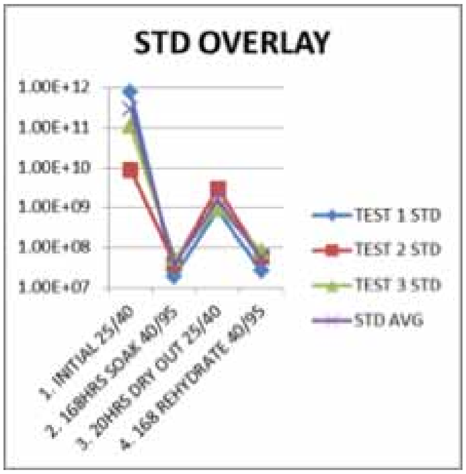



*Figure 19: STD HALOGEN FLUX*
*STD Halogen Flux overlay comparison of Test 1 thru 3 with STD average*

Figure 15 thru Figure 19 shows the test data for a STD Halide based flux system used in this real time SIR test. Key points are the initial resistance before environmental testing is >1.00E+11 for sensor 1 and > 1.00E+9 for sensor 2 which has a lower gap distance between adjacent pads on the QFN component where sensor 1 was between the ground lug and an inner sensor trace. After the first 168 hour environmental test of 40 degrees C and 90 plus humidity, one can see a drop in resistance from a safe 1.00E+11/+9 to resistance readings in the 1.00E +7/. This drop in resistance in surface insulation is below industry thresholds of 1.00E+8 for safe operating surface insulation resistance (SIR) parameters. The next cycle shows a drying out period to see what happens when the humidity drops to below 50% and the test specimen dries out at the surface and below the components themselves. The surface insulation resistance increases back from a non- acceptable state back above 1.00E+8 industry threshold. Again if the test vehicle is rehydrated in a humid 40 degrees c/90% plus humidity then the surface insulation resistance will drop from acceptable back to non-acceptable SIR ranges in the 1.00E+7 ohms. This confirms the need for a temperature and high humidity test that allows for ion mobility i.e. 40 degrees C and 90% plus Relative Humidity environmental test protocol.

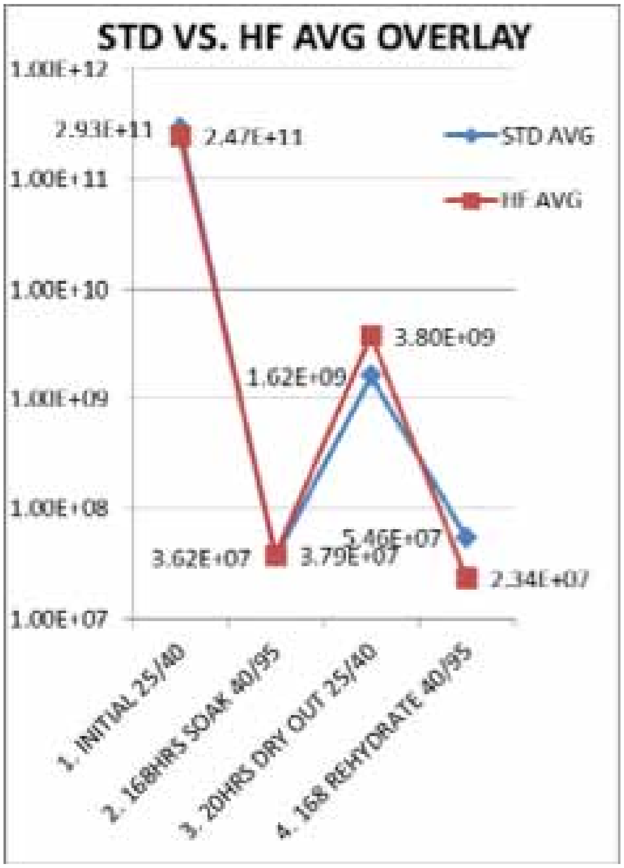



*Figure 20: STD HALIDE FLUX vs. HALOGEN FREE FLUX AVERAGE OVERLAY COMPARISON*

Figure 20 STD Halide Flux vs. Halogen Free Flux is an overlay of the average of each flux type system for a visual comparison. The averages allow us to normalize the data and draw trend analysis within the data and population. Note that we do not see a large discrepancy between these flux families when averaging the HF – Halogen Free Flux System vs. STD – Standard Halide Flux System. This comparison was using the same solder family from the same solder paste vendor with the difference being HF- Halogen Free vs.

STD. -Halide based. This data further shows that there is very little difference in SIR test results between environmental exposures initially and after a second rehydration exposure. Finally, 20 hours of drying out at 25 degrees C and 40% RH shows that it does not take very much time for ions to become non mobile and SIR test results recover back to safe SIR industry limits. This type of swing above and below the SIR Limit can explain why intermittent failure modes can be very difficult to find and verify.

## *Inferences from Data Findings:*

Though the sample size is limited, certain trends can be identified in the data. These trends relate to humidity, flux type, and outgassing design features for bottom termination parts and their corresponding relationships to resistance.

The most prevalent observation has been the need for humidity in order to coax electrochemical phenomenon to manifest in a measurable way. In fact, the absence of moisture in samples can mask the presence of flux residue by rendering it immobile, allowing potentially innocuous compounds to lay dormant until sufficiently hydrated. It is also important to note that pure water has a practical upper limit to its electrical resistance when it meets air. This limit is on the order of 106 (Mega) Ohms. Therefore, measurements above these values are attributed to causes other than water (i.e. flux residues).

Another observation that bears mentioning is the Test Vehicles/ Samples propensity to dry out and normalize at customarily acceptable SIR levels. After returning to a dry environment, the boards tend to dry out over the course of 20 hours, allowing SIR levels to generally return to above 108 (100 Mega) Ohms. This tendency to recover underscores the need for humidity for accurate measurements. Subsequent environmental exposure, however, induces a rapid return to less-than-acceptable SIR levels.

An interesting observation has also been made in the area of flux type, in that the Halogen-Free flux appears to be no better than Halide based flux systems in preventing a humidity-induced decrease in resistance; at least for the first and second round of environmental exposure. Subsequent exposure exhibited similar declines in resistance between halogen-free and standard halide flux types. This further infers that halide free substitutes in halogen free fluxes such as an organic amine structures if not properly activated/boiled off tend to have the same negative attribute of inducing voltage leakage via metal dissolution of the solder alloys and or pad plating that are present in and near the flux residue. Again the key attribute is the source of a mobilizing fluid such as water from humidity that helps promote the metal ion dissolution.

The data shows that both flux types if not properly outgassed due to component type and low z axis height attributes causes the residue to be active and mobile when presented an environment whereby the humidity is above 50 to 60% which seems to be floor for hydrating the active residue flux remaining on the underside of the BTC style components.

Further research is ongoing with halogen free and halide based flux systems to better define test methodologies that better quantify and identify their key attributes that affect long term reliability. Real time SIR testing along the manufacturing process and material introductions allows for the identification of material and processes that negatively impact SIR thresholds. The key is SIR data that defines which material set and/or manufacturing processes that induce negative SIR data results which helps define and quantify the negative SIR results below the industry acceptable standard of 1.00 to the 8th ohms.

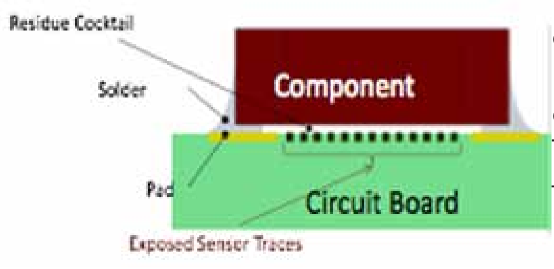



*Figure 22: Real Time SIR Sensor*

## *Conclusions*

Highly dense and low profile interconnects and environmental factors speed the mean time to failure. To build in quality, definition of the finished product performance expectations is the starting point. What are the performance objectives in relation to size, speed, cost, mass, style and efficiency? By first screening in reliability the product can be designed for the end use environment. It is critical to plan for the environment in which the device will be used.

When ions are mobilized, the corrosion process is initiated through oxidation and reduction of metal ions. Ionic residues are mobilized based on the strength of the ion-dipole forces of attraction with water. The intermolecular bond with water creates an electrolytic solution, which can be acidic or basic but can be neutral as well. When the electrolyte solution comes in contact with solder alloy, component metallization and pad plating, metal oxides can dissolve into the electrolyte. The metals mobilized within the electrolyte can plate out in the form of dendrites. The leakage current from these dendrites reduces resistivity.

Real Time Surface Insulation Resistance (RT SIR) test vehicles can be used to evaluate the cleanliness levels under bottom termination components. Humidity is needed in order to coax electrochemical phenomenon to manifest in a measurable way. The absence of moisture in samples can mask the presence of flux residue by rendering it immobile, allowing potentially innocuous compounds to lay dormant until sufficiently hydrated. Outgassing flux residues under bottom terminations provides a channel to reduce active residues under the bottom termination. The challenge is in the creation of outgassing pathways via thru hole- vias and increasing the z-axis height of the component off the printed circuit board surface. One such method being used today is solder mask removal under low profile parts to help with the z-axis height limitations.

The paper and its research is outlining the need for a more detailed industry test protocol which addresses the different electronic assemblies failure modes that are entering and effecting Highly Critical Electronic assemblies and their corresponding industries that need design guidance in how to make long term reliable electronic hardware that can meet warranty expectations of 10 to 25 years. This is a tall order but the need for identification and assessment of material choices along with the manufacturing guidelines/ processes which together can be used to insure warranty objectives in excess of 10 year life. STI and Kyzen believes the future to miniaturization revolves around having test protocols capable of testing for cleanliness levels under critical components and critical circuitry such as high frequency RF and low voltage control circuitry. Real Time SIR measurements under key component types and high density layouts allows for the verification of material choices and their interrelationships with manufacturing processes to insure the material choice along with processes does not create a flux concoction/mixture residue that is not benign and is thus detrimental to long term reliability.

### *Future Tests Protocols*

STI is designing a test vehicle with 8 to 10 different component types/family of parts that can have real time SIR Sensors under them which will allow for future tests to evaluate material choices and manufacturing processes to insure cleanliness under components to insure electronic manufacturers can verify their processes as well as flux and material choices. The QFN/LGA style component was chosen first due to its complexity and difficulty for cleaning and thus it is an ideal candidate for showing the problems with long term reliability and how real time SIR measurements can help design/system engineers understand the importance of designing circuit boards that address cleanliness from the beginning of the design process. This approach also allows the design engineer a test protocol that can help them gather data on their material choices for solder alloys and its corresponding flux system as well as an outline for defining manufacturing processes and their control process guidelines to insure a clean electronic assembly that meets its long term warranty expectation. There are a number of material choices and manufacturing processes that influence board cleanliness levels and having a new test standard and protocol is a necessary tool for future designers designing miniaturized high density electronic assemblies.

### ACKNOWLEDGEMENTS

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| | | | |
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| October 13-14 | October 31-November 1 | March 3-4<br>April 14-15<br>June 1-2<br>June 20-21 | July 7-8<br>September 15-16<br>October 10-11<br>December 8-9 |

## IPC-A-600 " ACCEPTABILITY OF PRINTED BOARDS"

| IPC-A-600 CERTIFIED IPC TRAINER (CIT) CERTIFICATION/RECERTIFICATION | IPC-A-600 CERTIFIED IPC APPLICATION SPECIALIST (CIS) CERTIFICATION/RECERTIFICATION | |
|---|---|---|
| Course available upon request | August 24-26 | |

## IPC-7711/7721 "REWORK, REPAIR AND MODIFICATION OF ELECTRONIC ASSEMBLIES"

| IPC-7711/7721 CERTIFIED IPC TRAINER (CIT) CERTIFICATION | | IPC-7711/7721 CERTIFIED IPC APPLICATION SPECIALIST (CIS)CERTIFICATION (Mods 1-9) | |
|---|---|---|---|
| Course available upon request | | April 4-12<br>September 6-14 | November 28 - December 6 |
| **IPC-7711/7721CERTIFIED IPC TRAINER (CIT) RECERTIFICATION** | | **IPC-7711/7721 CERTIFIED IPC APPLICATION SPECIALIST (CIS) RECERTIFICATION** | |
| July 21-22 | October 20-21 | July 18-19 | |

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# STI's Training Services - Houston, TX
# 2016 Schedule

## IPC-A-610 "THE ACCEPTABIITY OF ELECTRONIC ASSEMBLIES"

| IPC-A-610 CERTIFIED IPC TRAINER (CIT) CERTIFICATION | | IPC-A-610 CERTIFIED IPC APPLICATION SPECIALIST (CIS) CERTIFICATION/RECERTIFICATION | |
|---|---|---|---|
| May 10-13<br>June 27-30 | August 9-12<br>October 4-7 | March 29 - April 1<br>May 23-26 | September 20-23<br>November 15-18 |

| IPC-A-610 CERTIFIED IPC TRAINER (CIT) RECERTIFICATION | |
|---|---|
| August 22-23 | November 2-3 |

## IPC/WHMA-A-620 "REQUIREMENTS AND ACCEPTANCE FOR CABLE AND WIRE HARNESS ASSEMBLIES"

| IPC/WHMA-A-620 CERTIFIED IPC TRAINER (CIT) CERTIFICATION | | IPC/WHMA-A-620 CIS CERTIFICATION/ RECERTIFICATION | |
|---|---|---|---|
| August 16-20 | October 25-29 | April 19-22 | |

| IPC/WHMA-A-620 CERTIFIED IPC TRAINER (CIT) RECERTIFICATION | |
|---|---|
| June 23-24 | October 17-18 |

## CUSTOMIZED TRAINING COURSES

| BASIC SOLDERING | | Shop Floor Series - Print Reading | |
|---|---|---|---|
| March 7-11<br>April 25-29<br>May 2-6 | July 11-15<br>August 29-September 2<br>December 12-16 | April 26 | |

| Shop Floor Series - Problem Solving | | Shop Floor Series - Supervisor 1 | |
|---|---|---|---|
| April 27 | | April 28 | |

**Course dates subject to change based on class capacity and demand.*

**Click here for Class Registration**

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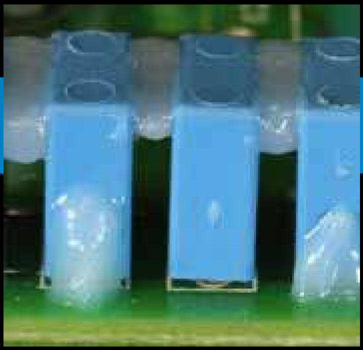

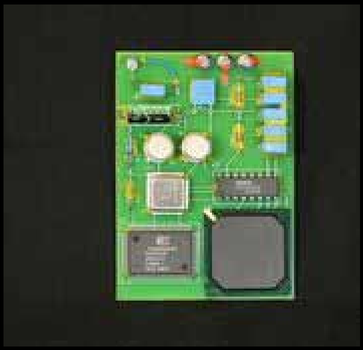

*Thank you for your interest in STI*

**Stay Tuned for our Summer Newsletter**