AUGUST 2018

I-Connect007

SMT007 MAGAZINE

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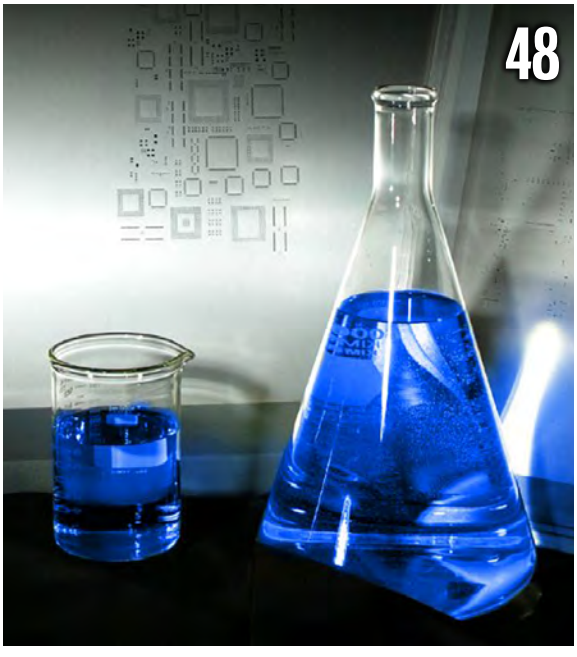

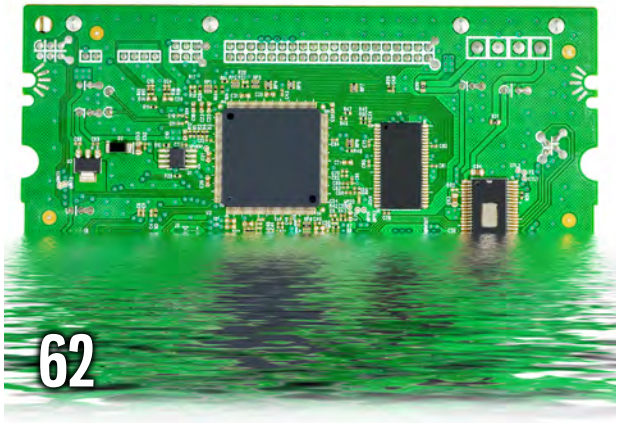

To Clean or Not To Clean

That is the question…whether tis nobler in the mind to suffer outrageous field failures, or take arms against a sea of particles! Alas, cleaning PCB assemblies raises many pros and cons. This issue of *SMT007 Magazine* features the challenges, latest developments, and strategies for cleaning, and will help you decide whether to clean, or not clean your PCB assemblies.

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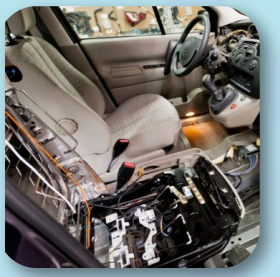

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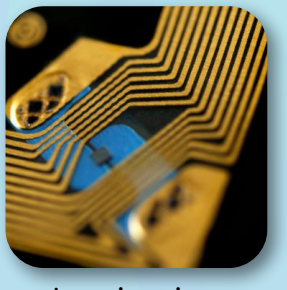

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Why Clean?

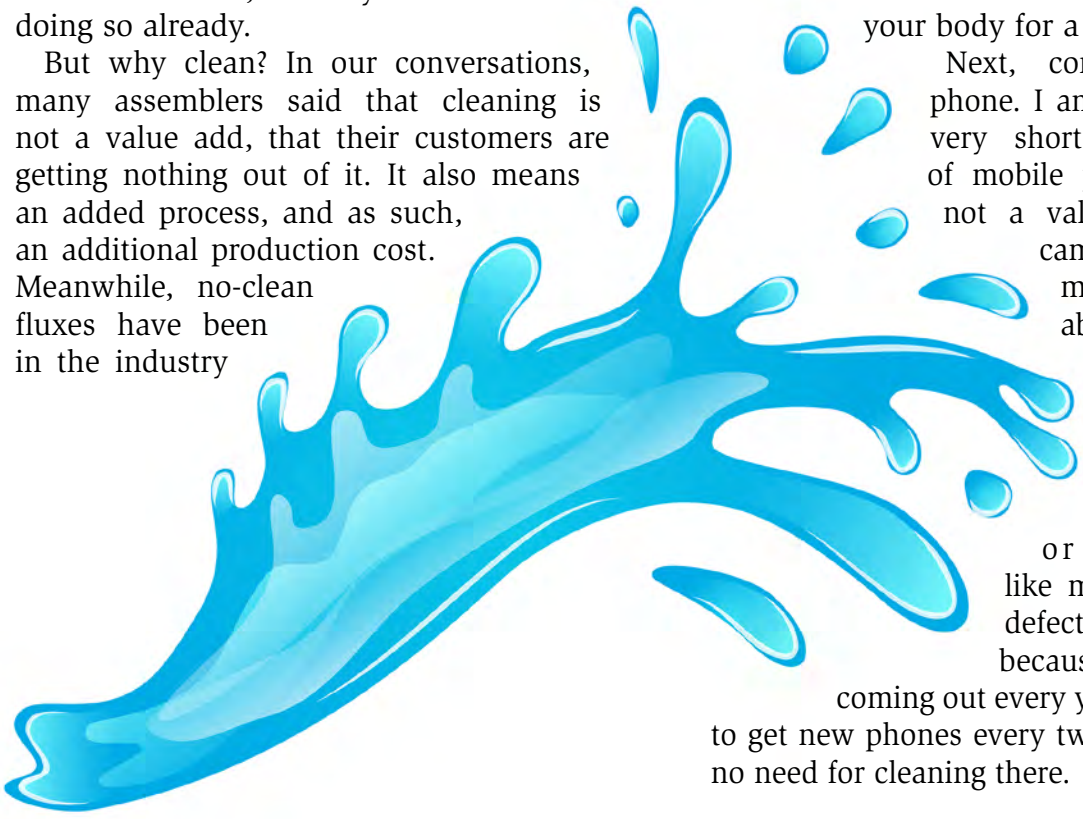
Editor's Note

by Stephen Las Marias, I-CONNECT007

Without sounding like a broken record, the continuing trend of miniaturization in electronics devices remains to be among the key issues that assemblers must grapple with when it comes to electronics assembly. From paste printing, to the pick-and-place, and all the way to the reflow process and inspection, these smaller and smaller PCB assemblies—with their increasingly shrinking components and packages, not to mention board real estates—can have a very big impact in every step of the manufacturing process.

For this month's issue of *SMT007 Magazine,* our focus is on cleaning: the challenges, key considerations, and strategies to improve the cleaning process—and why every manufacturer should start considering cleaning their assemblies now, if they haven't been doing so already.

But why clean? In our conversations, many assemblers said that cleaning is not a value add, that their customers are getting nothing out of it. It also means an added process, and as such, an additional production cost. Meanwhile, no-clean fluxes have been in the industry for over 20 years now. So why do we even have an issue about cleaning the no-cleans?



Perhaps, clean is in the eye of the beholder. Yeah, it does sound corny. But consider this example/explanation given to me by Kyzen's Tom Forsythe during an interview: Imagine you are going to have a pacemaker—an electronic device—installed in your body. Now, I am pretty sure that you would want to have a pacemaker that has undergone a cleaning process to remove whatever contaminant may have come in contact with it during its assembly process. Granted, such electronics are being assembled in cleanrooms anyway. But it still must be cleaned, as it will undergo the soldering/reflow process perhaps, and you want to make sure that it is in the most pristine condition before being put inside your body for a very long time.

Next, consider the mobile phone. I am sure that with the very short product lifecycles of mobile phones, cleaning is not a value add. I recently came across an article mentioning something about 'time-delayed' effect, wherein defects will not show up until a product has been used for a year or two. In products like mobile phones, such defects won't show up because newer models are coming out every year, and people tend to get new phones every two years anyway. So, no need for cleaning there.

Therefore, I would say cleaning depends on the application. In mission-critical systems, contamination of boards could result in massive, even life-threatening issues later, if not dealt with early on. Reliability is a must, so cleaning the assemblies is important. These are just a few simple things I can come up with, as I am no cleaning expert.

Luckily, our contributors to *SMT007 Magazine* this month are experts on clean. First, we have Eric Camden and Paco Solis of Foresite Inc., and Greg Smith of BlueRing Stencils discussing cleaning challenges, testing the cleanliness of boards and assemblies, their experiences with cleaning issues in PCBAs, and possible solutions.

Jason Fullerton of Alpha Assembly Solutions provided an article on an investigation and comparison of the performance of no-clean liquid wave soldering fluxes using a commercially available localized extraction and cleanliness testing system, and surface insulation resistance (SIR) testing.

In an interview with Kyzen's Tom Forsythe, he discusses the developments in cleaning strategies and the benefits of having a data-driven approach.

Joe Russeau of Precision Analytical Laboratory Inc. and Mark Northrup of IEC Electronics summarized their presentation at SMTA International last year, which compares component cleanliness results from the Resistivity of Solvent Extract (ROSE) test against ion chromatography (IC) test results.

In a second interview on cleaning, I spoke with Zestron's Dr. Harald Wack, during the recent opening of their facility in Taiwan. He talked about cleaning in general, the need to clean no-cleans, and the future of cleaning.

Finally, Eric Camden—our newest columnist—offers the reasons to clean a no-clean flux.

Surely, there are pros and cons of cleaning your PCBAs. I hope this issue of *SMT007 Magazine* helps to clarify whether cleaning is the best strategy for you.

Stay tuned next month as we highlight some of the megatrends happening in our world today and their impact on the electronics assembly industry. **SMT007**

Stephen Las Marias is managing editor of *SMT007 Magazine*. He has been a technology editor for more than 14 years covering electronics, components, and industrial automation systems.

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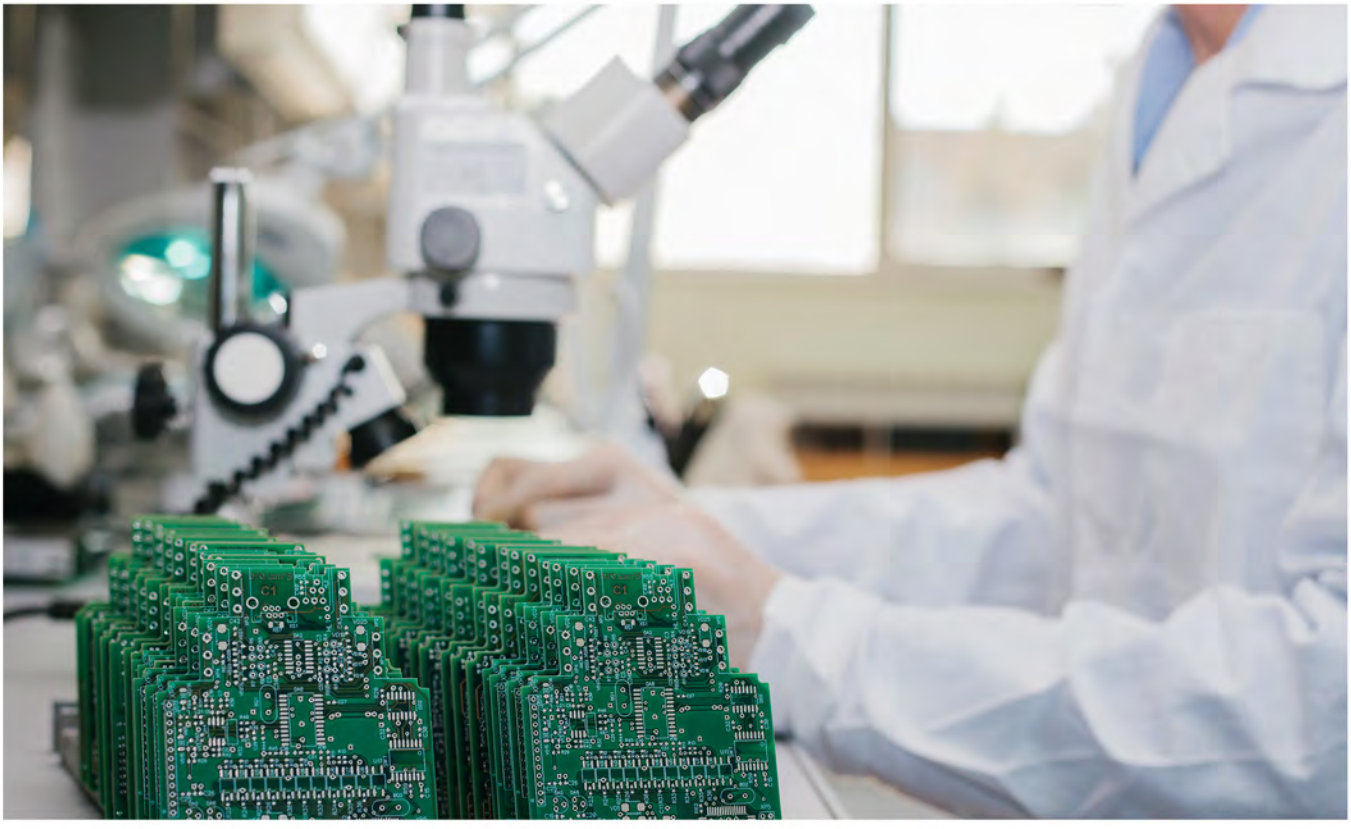

Getting More with Cleaning

Feature by the I-Connect007 Editorial Team

The continuing growth of the electronics industry, driven by the rapid expansion of electronics into areas such as automotive and medical, is creating a new mindset with regard to cleaning, mainly due to quality and reliability issues. Historically considered a non-value-add, cleaning is now being increasingly relied upon by manufacturers to mitigate potential board defects.

For this month's issue of *SMT007 Magazine,* we invited failure analysis experts Eric Camden and Paco Solis, both lead investigators at Foresite Inc., and industry veteran Greg Smith, manager of stencil technology at BlueRing Stencils, to share their experiences with cleaning challenges in PCBAs and possible solutions.

Stephen Las Marias: What are the most critical challenges when it comes to cleaning?

Eric Camden: The critical points for cleaning these days are the bottom-terminated components in general, but with a focus on QFNs because of their low standoff height—which are very difficult to process either with water-soluble or no-clean flux.

If you are trying to clean a no-clean flux from underneath a QFN, you are going to struggle, there's no doubt about it. And I am talking about the best cleaning equipment that you can find. You still need to have a fine eye and be able to tune your cleaning process to address the QFNs. And if you can do that in general, you can say that other components will be very clean because you can effectively clean the hardest part on the board. So, from a failure analysis point, from a process reliability standpoint, from what we do in the analytical world, we see lots of issues in QFN during a wash process.

It's very difficult to outgas the flux activators when you are starting at half a mil or 1 mil

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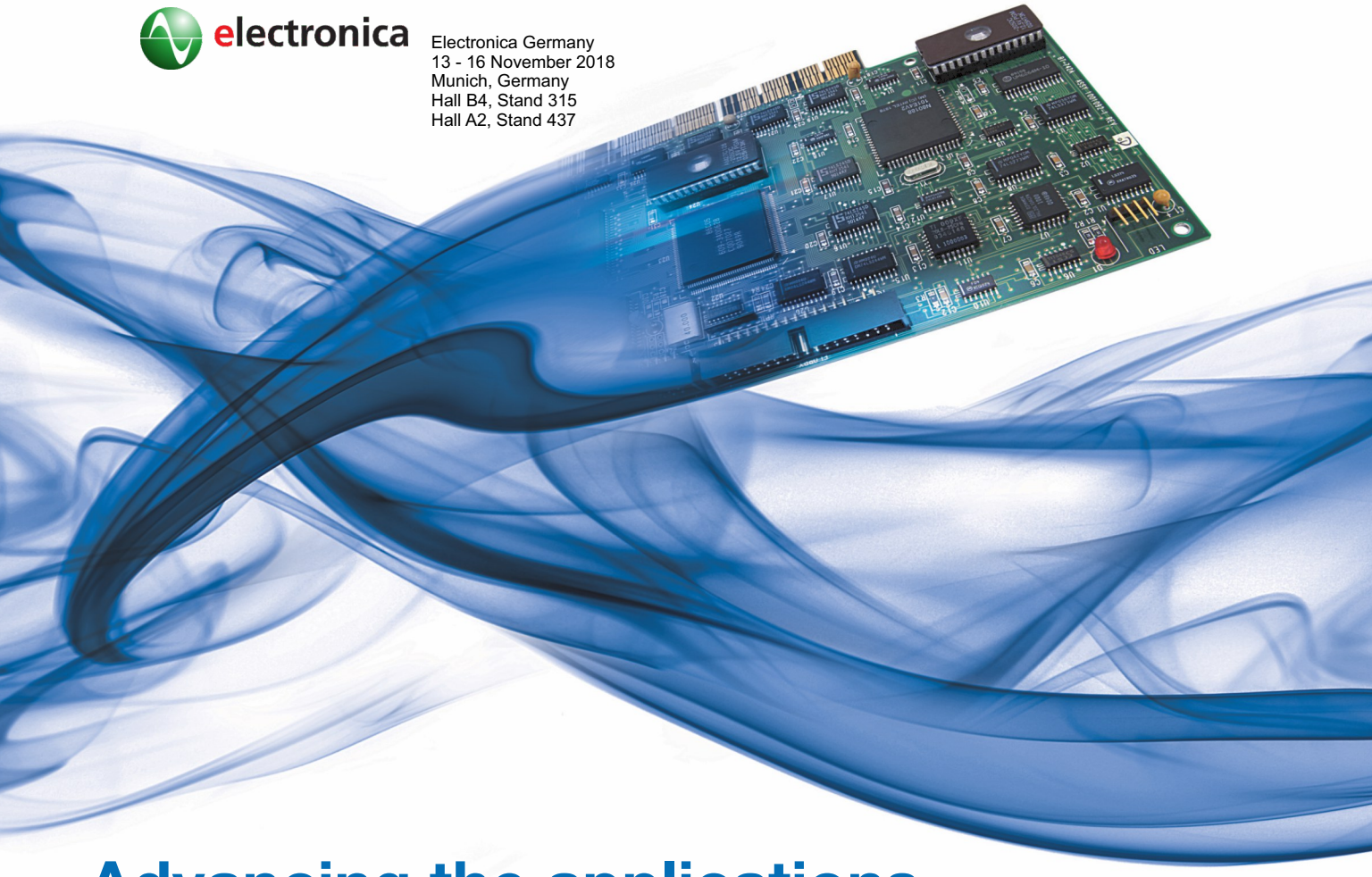

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standoff height. So, really the QFNs are probably the most critical part that we see when it comes to optimizing a wash process.

Paco Solis: When it comes down to the cleaning part of it, the hydrodynamics—the flow dynamics—of the cleaning process itself, it's one thing to have a QFN on its own without a lot of high aspect ratio architectures around it. But now, every PCBA is going to be a different, unique architecture and it may have specific requirements that impede flow dynamics. So, you just can't put every board through in the same way. Sometimes, you have to change your orientation, your flow nozzles, or direction, to increase the flow dynamics and contact time. It's a challenging part on its own. But the collateral architecture around it or adjacent to it can also make your issue a bit more difficult just to get chemistry or water at it.

Paco Solis, Foresite Inc.

Las Marias: Is there still a misconception when it comes to no-clean?

Solis: It depends on circuit sensitivity and architecture. And then in defense of the flux suppliers, they don't know how and what design layout engineers and electrical engineers are going to throw at, at their products, so it's really a little difficult sometimes to predict what's necessary for sensitive architectures.

Las Marias: One of the issues we always hear when speaking to industry experts is the need for communication between the designers and assemblers. Is the cleaning process another issue that they should be talking about when it comes to discussions on their design and assembly?

Camden: There's a term—design for cleanability—that's been out there for a few years now because of some of these same issues. Some thoughts fit in to the final step of cleaning during the design process, but I think it is seen as low-value input when it comes to design, because those who design don't always clean. Design for cleanability is something that's out there, and it should be considered absolutely when you plan on cleaning it, because what you're doing upfront have a negative impact on the cleaning process.

Andy Shaughnessy: What are some things that designers should do to make the cleaning process go more smoothly?

Solis: There are some architecture layers that you stuck down your trace even. We see some mistakes where layout persons are putting their legends down underneath the QFN. They are doing more and more interconnects; now you have architectures that will start impeding or there are architectures where packages are touching directly. I have some cross-section areas that show these QFNs staying at 6 microns away from the solder mask area. Basically, the core of the part is cordoned off by these architectures, so the layout engineers need to understand what the challenges are for

the cleanliness and for sensitive electronics. That is something that typically they are not involved with. Just those architectures and having to lay out those signals and the I/Os can make it more difficult just to clean.

Shaughnessy: So, they need to be in communication from the start. Because I don't think they put this thought in the cleaning process; I don't hear many designers talking about that.

Camden: You'll see a group of four or five supercaps right next to four or five QFNs. You a disruption of the water flow where it can't get repeatably underneath those QFNs, which are already hard to clean. So, those types of things just aren't thought of. This is the circuit that needs to go on, but when you look at the placements—that's something that needs to be thought of if you're going to clean your boards.

Solis: Layout is extremely important. Here's an example. There are QFNs very close to plated through-hole. Now, in our analysis, we were able to detect the through-hole flux that's flowing underneath the via under the QFN. Because the organic acids are so different in the surface mount versus the through-hole flux, we were able to detect and verify that they are getting cross contamination from the through-hole process into the surface-mount QFN.

Shaughnessy: That's interesting. I am sure people will be surprised to read that because I really don't think they put a whole lot of effort into designing for cleaning.

Barry Matties: You guys focus on reliability, training, process audits. What typical problems you encounter in your audits as you go into these facilities?

Solis: There's one interesting thing that pops out on, let's say, a few times that I have walked the line: the conception that brush cleaning for solder balls is a positive, a value-added step. I've seen operators dry brushing at the flux in the final architectures. They are taking large paint brushes and dipping them in bowls of alcohol. The problem with that is the flux that is already benign, just because it had the look that there's a little residue there, they start scrubbing it, and they have no idea that they are breaking down and solubilizing fluxes. We call it contamination relocation. They are making it much worse, but it is perceived that alcohol cleans things, that alcohol dissolves things. But they just relocate what was good flux, now they basically shove it to the nearest surface mount architecture, so now you have collateral contamination.

Camden: The spot you are working on is clean, and then half-an-inch square around it is extremely dirty.

Solis: Now, you have a super concentration of flux and resin from weeks and weeks, or days and days, of dipping it back and forth, and now they are spreading it on clean boards.

Matties: Why is this a prevalent problem?

Solis: I think a lot of people can't get to the thought of no-clean, and they just accept that it is a blanket term. In many factories, a lot of engineers really don't understand what no-clean really is and how it behaves. Often, they don't even go back and ask their flux suppliers on how they can learn more about this.

Camden: The problem is it is not a repeatable process. If you have a hundred boards and they all fail in the same manner a hundred times, that's an easy thing to diagnose. When you are looking at rework or repair, they are not part of standard assembly operations, and they aren't usually documented in the same manner.

It's really because rework is not always a repeatable process, and because you are not doing touch up on 100% of boards. Operator A may be doing a perfect job every time; Operator B may not be doing a perfect job every time; so, of the hundreds of boards that are touched up, even out of those, only a small percentage of failures will have that as the root

cause because environments still play a role; how effective Operator A is versus Operator B, how old the cleaning brush is, things like that. There are a lot of little things that come into play to avoid failure when it comes to cleaning.

Matties: When somebody has a need for high reliability, they just spec the cleaning process in, correct?

Camden: More times than not, yes.

Matties: For that very reason, you can never know that failures are going to happen, so it's an insurance policy.

Camden: The biggest problem we see with that now is the cleaning of no-clean flux and how to properly address the risk. Again, when an engineer hears the words no-clean, they assume the risk is very low when their residues are left behind after the wash process—when it is the opposite. In a nutshell, the residues left behind from an improper, ineffective wash process on a no-clean flux can be as detrimental as water soluble flux left behind.

Eric Camden, Foresite Inc.

Matties: So, if somebody wanted to really do an audit of their cleaning process, what are the steps that they should consider?

Solis: They should use the proper metrics. How are they cleaning? How are they measuring that their boards are clean? What internal or external standards are they trying to achieve?

Matties: I see that you do on-site offerings and classroom training. How many companies do take you up on that type of training at operator level?

Camden: I would say that from a cleaning side of things, we probably do trainings about 15 times a year. We don't schedule the classes; we are very reactionary when it comes to that. And usually, when it comes down to onsite audits, they are a reaction to a failed process. I have a handful of companies that I go onsite for annually, just to look at their line, look at their wash, the entire assembly process, but that's the minority of the cases. The majority have field problems, so they will call us in. We'll do some ion chromatography, we will look at some boards that have failed. We'll look at not just their parameters, but their maintenance records, how they are doing everything they should be doing, if they are maintaining their cleaning equipment properly, and at the right intervals. So, there's really no answer to how often we do that year-to-year, but I would say that for the most part, it's reactionary because the company has done something wrong, and they ask us to come in, look at their process, and optimize it.

Solis: We call that baptism by fire. Now, they have to try to put that into DFM, where they should be looking for opportunities for contamination introduction. And they are also rethinking what "optimized" means to their process, if they are really doing best practices, and if their process is really optimized. When we show up, we'll say "You didn't quite optimize those boards for this thermal mass. But if you do these couple of tweaks here, and you can validate in the lab, maybe you don't need to clean at all." That's always an option—if they are truly optimized for the no-clean, they may not even need to clean.

Matties: In terms of cost and time, what impact does that have on the order? How much cost or time are we adding to that? I've had people tell me it's just pennies and it's just a quick process.

Camden: Right. And we always like to compare

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that to the cost of doing it wrong. They may be pennies to do this process or use this analytical test versus this one, it's cheaper and faster, but the cost of failure is always going to be higher. It drives them to prove out to really qualify their wash process while they are doing their first article inspections.

Las Marias: Greg, in the PCBA industry, one major cause of defects is the paste printing process, and a part of that process is the stencils. From your perspective, are there critical challenges when it comes to the chemicals used for the stencil cleaning process?

Greg Smith: Yes, I see both in small and high-volume manufacturers where stencils are not properly cleaned when they are put back on the rack. Many times, I've seen stencils pulled from the shelves and put into production with inadequately cleaned apertures. Of course, this causes printing challenges. Over the years a lot of people just use IPA for stencil clean up. Today there are many really good cleaners on the market that are much more effective than IPA. As component miniaturization continues, stencil apertures continue to get smaller and smaller. It is extremely important that the correct cleaning chemistry is used in both the printer and the stencil wash equipment.

Greg Smith, BlueRing Stencils

Matties: That is an easy problem to resolve. Is it just a matter of having the discipline to follow the process that causes this?

Smith: I believe it is, especially for standard stainless-steel stencils. The more challenging issue now is the proper cleaning of nano-coated stencils. As more and more companies use nano-coated stencils, it is very critical that they change their cleaning processes to maximize the life of the coatings. Many of the current cleaners being used for standard stainless-steel stencils can attack these coatings and cause premature wear. Also, elevated temperatures can damage the coatings as well. Replacing current cleaners with new pH-neutral chemistry that work at ambient temperatures will help customers get maximum life from these coated stencils.

Matties: Right. It just seems like an elementary problem, that it is something that any good production manager would insist upon a solid process and verification.

Smith: Yes, it is very simple. Good inspection processes after the final cleaning cycle will make sure the stencil performs as it should the next time it is used.

Matties: Does your company sell the cleaning process as well or just the stencils?

Smith: One of our sister companies recently developed our own cleaning process. But there are several different chemistries out there now made specifically for coated stencils.

Camden: On the ceramic stencil side, you have to state the precautions because most people will just take their coated stencils and put it in their standard stencil wash. So, there can be issues.

Matties: What's interesting here is that the conversation between you, Greg, Paco and Eric, all are talking about discipline with the process, understanding the process, and utilizing the process correctly. And again, it just seems basic, but what do you think the struggle is for people to follow that process? Why is there a struggle?

Camden: I think the challenge becomes almost like a lost art form, for people to own their own process instead of like building Legos. They

know they need this on top of this and this and check these three boxes and everything's fine—which, contractually they are obligated to do—but if people will think more ownership, the quality manager, the production floor guys, if they really take more ownership in what they are doing, I think it will create a much higher quality product because you put that common sense thing back in the forefront instead of just checking a box. When we look at the brain drain from when they let go of the operators that make all the money and have all the experience, now they have to reset their learning curve. They hire new operators who weren't there when the old crew was there, so they are going to make the same mistakes many times.

Paco and I have been in the same facilities working on the exact same failures three, four, or five years apart, with 100% different people. So that knowledge gets taken with the people as they are turned over to save money—I assume that would be the impetus of letting some of these people go—and then they don't always leave behind the things that are important to remember when it comes to either processing or cleaning their process. I think there's a lot of different things that play together.

Solis: Tribal knowledge is a factor.

Matties: Right. Unless you are documenting the process, that is all you're left with.

Camden: Right, if it's not a work instruction, then you may not ever know that information.

Solis: You also must document your errata as much as documenting the process. Every time it goes wrong, that has to be part of your causal analysis. If something goes wrong in this line, can it go wrong on the other line?

Matties: Is there something that we haven't talked about that you think we should be discussing?

Camden: If I could just go back to what we were saying earlier—the designing for cleanability—I know there was a document that covers that. I was part of the task group that put together a lot of standalone documents, the IPC-CH-65B cleaning handbook. If you reference CH-65B Section 4, Designing Assemblies for Cleaning, there is some good information there from some of the leaders in the industry that are cleaning and are designing for cleaning. That's a good reference point.

Las Marias: Thank you. Our readers will find that interesting. Do you have any final comments?

Solis: I've got a couple. One thing that hasn't been done in the industry much right now is people really working with suppliers and having the technology relationship. I see a lot less collaboration between the production line and the suppliers. And I think a lot of it is education, and a lot of it is tribal knowledge, that could be caught if manufacturers have a better relationship with the supplier. They can circumvent some of these issues from happening if they really take time to understand what they are buying and what they are working with, and just talk to their suppliers.

Patty Goldman: Sounds easy!

Camden: Don't let industry standards and documents and tests keep you from making a quality product. Understand what you are doing and why you are doing it, especially when it comes to cleaning, because you know, cleanliness is really a hallmark to reliability depending on the end-user environment. So, understanding where your products are being used, and owning your own product, and not relying only on industry standards, will help you make that reliability.

Las Marias: Gentlemen, thank you very much for your time today.

Paco: Absolutely, thank you for having us. **SMT007**

MilAero007 Highlights

Elbit Systems Wins $17M Electronic Warfare Contract ▶

Elbit Systems Ltd was awarded an approximately $17 million contract from a European country to supply a range of advanced ground-based electronic warfare and signal intelligence systems.

Sanmina's Costa Mesa Facility Achieves AS9100D Certification ▶

Sanmina Corp. announced that its technology center in Costa Mesa, California, has earned AS9100D certification for defense and aerospace manufacturing.

Celestica Subsidiary Wins Raytheon Award ▶

AbelConn Electronics, a Celestica company, has been awarded a Raytheon Integrated Defense Systems 4-Star Supplier Excellence Award.

ERAPSCO Protests Exclusion from Sonobuoy Solicitation ▶

Sparton Corp. has announced the filing of a bid protest by ERAPSCO with the United States Government Accountability Office (GAO) challenging the recent competitive range exclusion of ERAPSCO under United States Navy Solicitation No. N00019-19-R-0002 for the GFY19-23 AN/SSQ-125A Production Sonobuoy.

Elbit Systems Gets Green Light for IMI Systems Acquisition ▶

Completion of the transaction is subject to the signing of the relevant documents and the receipt of the remaining applicable governmental approvals, including the approval of the Head of the Israeli Antitrust Authority.

STI Earns Recertification to IPC J-STD-001 and IPC-A-610 ▶

STI Electronics Inc. announces the recertification as a Qualified Manufacturer to IPC J-STD-001 and IPC-A-610.

Libra Industries Promotes Jim Zelina to Program Manager ▶

Libra Industries, a privately held electronics manufacturing services provider, has announced the promotion of Jim Zelina to the position of program manager.

Kitron Posts 3% Revenue Growth in Q2 2018 ▶

Kitron has reported a revenue of NOK 667 million in the second quarter, an increase of 3% compared to the same quarter last year.

AWS Electronics Appoints Godwin as Group Quotations Manager ▶

EMS firm AWS Electronics Group has appointed Amelia Godwin as new group quotations manager.

Neways Gears Up to Address Miniaturization Trend ▶

Neways is developing a technology to lithographically pattern printable noble metal pastes as a robust industrial solution for the miniaturization of electronic applications.

SMS Reports 30% Revenue Growth in FY2017 ▶

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Cleaning a No-clean Flux: The Worst Decision You've Ever Made?

Quest for Reliability

Feature Column by Eric Camden, FORESITE

Cleaning a no-clean flux is not a task for the uninitiated or uneducated; it is a task for those who like to run into brick walls with blindfolds on. It can be as fun as it sounds, or with the proper knowledge and a little experience, it can be merely terrible.

There are a few reasons to choose to clean a no-clean flux (and even fewer are actually good reasons). One good reason to clean is when the assembly requires conformal coating, especially when using Parylene. Another reason is when probes are required for testing. The flux residue can inhibit a good contact surface. Other than that, I struggle to think of another good reason to clean a no-clean flux.

From where I sit here in the failure analysis (FA) lab, the main reason for cleaning no-clean is that if flux residues are not fully removed, what is left behind will be of no concern since they were intended to be left fully intact to begin with. As an employee at an analytical test lab with kids to send to college, I couldn't agree more—no further research is necessary. As an objective observer, there are several problems with this theory (which we will touch on in this month's installment).

Let's start with a brief explanation of no-clean flux. Traditional water-soluble flux formulations have approximately 10–40% solids. Flux activators at these levels might burn through the containers they are shipped in if not used within a week or two after receiving them, so they need to be cleaned right away. These residues can be effectively removed with a standard in-line wash process using only high-quality deionized (DI) water, or with the addition of a saponifier to lower the surface tension to get under low-standoff components

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such as quad-flat no-leads (QFNs) and other bottom-terminated components (BTCs).

Some companies have made the switch to no-clean flux because they can use the same wash parameters as with water soluble. Let me reiterate that I have kids to send to college, so I won't argue too much with this position. The problem with this approach is the fact that no-clean flux formulations use either rosin or resin to help bind any oxides and contamination from the surface of the metallized surfaces to be soldered. The rosin also acts as a "poor man's coating" because it is a retardant for moisture ingression when properly processed. That last part is very important because if any of the chemistries are left in an active state, it is hygroscopic. Given enough time and available atmospheric moisture, it is possible to set up an electrical leakage path and eventually electrochemical migration.

That last part is very important because if any of the chemistries are left in an active state, it is hygroscopic.

When no-clean flux is not properly processed with sufficient thermal exposure to render it near benign, it remains active. If you ineffectively clean it, you open the active part directly to the atmosphere. I always equate this to ripping off a bandage and exposing a wound. I have seen a shift from the component manufacturers to assemble certain parts, like QFNs, with only no-clean flux because they are aware of the difficulty in cleaning under those.

Now that I've covered why it's a terrible idea to try and clean no-clean flux, let's discuss some of the most effective ways I have found to achieve this fool's errand. As previously mentioned, every effective wash process requires a high-quality DI water system. The minimum quality should be in the resistivity range of 10 megaohms—not 2-megaohm dummy light water—because as soon as the DI water hits the air, the resistivity drops, which isn't as good of a solvent. Many wash machines have an onboard resistivity measurement system so consider making 10 megaohms the lower end for acceptable wash water.

You will also need to introduce some sort of cleaning chemistry to your system. This will aid in reducing the surface tension and help to soften those residues that hardened after assembly—even more so with higher temperature lead-free processes. The higher the reflow/wave solder temperature, the more difficult the residues are to remove. There are a number of high-quality options for a saponifier. Consult your cleaning chemical supplier to determine the best chemistry for your specific flux and assembly process.

The next thing to think about is the wash parameters. The temperature of the wash and rinse solutions should be around 60°C. This will further lower the surface tension of the solution. The spray pressures shouldn't be so high because they atomize immediately and lose much of their energy. High volume, low pressure is a good rule to wash by. This means using larger openings on your spray nozzles—around 2.0 gpm is a good place to start—to soak the assemblies and create more of a horizontal flow pattern. This will keep the flux exposed to the chemistry and allow it to better soften and remove better than 400-PSI blasters. Spray nozzle impingement angles should be canted about 20° inward on both the entry and exit bars to help increase the horizontal flow of the wash and rinse solutions. This is necessary to help clean under those pesky BTCs.

Belt speed is another important consideration because if you have gone through all the trouble of increasing the nozzle flow and pressures, if you whip assemblies through at 5.0 FPM to increase throughput, you effectively negate all the other work. I have found that 2.0 FPM is about as fast as you want to push product through to give the chemistry time to do its job. It's all about exposure time to the thermal and chemical energy combination.

These are general recommendations, and as with all assembly materials, it may vary

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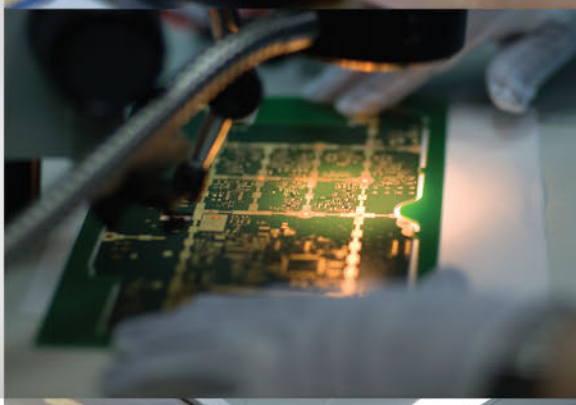

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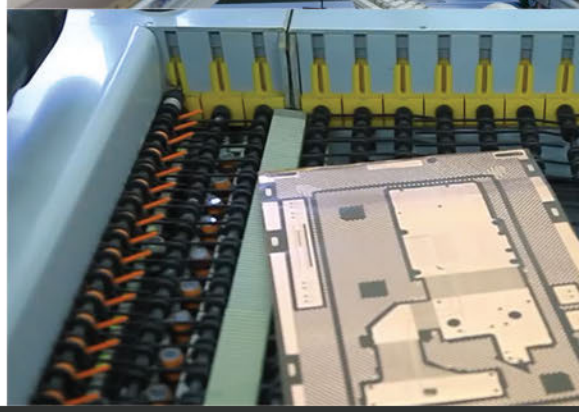

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depending on your actual product. It's important to remember that none of the material suppliers know exactly what you are building. When their tech data sheets show a recommended profile or application, it is just that—a recommendation. After cleaning no-clean flux processed assemblies, it is also important to do some destructive physical analysis. You will need to mechanically remove some parts to take a closer look at the interface between the pads and component bodies. This is where the vast majority of flux residue will remain if it is to be found. Removing a few QFNs on the actual product and instead of just testing the boards is a great place to start. I recommend focusing on these parts because they are so difficult to clean; if you are successful, the rest will most likely fall in line.

Further, it is highly recommended to use ion chromatography on the parts and pads to determine the amount of each specific ion used in the flux activator. You won't necessarily be able to see the residues; it may look fine but could still have a thin film invisible to the naked eye or someone looking through a microscope. You will most likely be able to see no-clean flux residue because it normally absorbs moisture from the wash process and will have a milky haze. If you see this hazy residue, go back and start optimizing your wash parameters, such as slowing the belt speed, increasing the percentage of chemistry, temperatures, etc. You will find the sweet spot, and once you do, remember it is most likely only going to be effective for that specific board style.

Much like swimwear, one size does not fit all. **SMT007**

Eric Camden is a lead investigator at Foresite, Inc. To read his past columns or to contact Camden, **click here.**

Nearing Retirement, Juki's Bob Black Reflects on a Long Career

After more than 40 years in the electronics manufacturing industry, Juki's Bob Black is nearing retirement. Bob sat down with I-Connect007 Publisher Barry Matties at the recent SMT Hybrid Packaging show in Nuremberg to reflect on his career and talk about the importance of strategic partnerships, even if that means playing nice with your competitors.

Black spoke about what started his career, what moved him to the electronics space, building his own company, and his advice he would give to those starting in this industry. He also discussed the challenges in the pick-and-place machine industry, and how to address those issues.

Read the full interview here.

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Whitepaper: Electronics Cleanliness Testing

Feature by Jason Fullerton
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Abstract

This study is an investigation and comparison of the performance of no-clean liquid wave soldering fluxes using a commercially available localized extraction and cleanliness testing system and surface insulation resistance (SIR) testing.

The flux test coupons for both tests were prepared in accordance with IPC TM-650 2.6.3.3. The IPC B-24 coupons used were manufactured using a lead-free wave solder process. Coupons were then tested for SIR per J-STD-004B using IPC TM-650 2.6.3.7 and tested with localized cleanliness testing.

The results for 15 no-clean fluxes are presented: three VOC-free rosin-free fluxes, two alcohol-based rosin-free fluxes, and 10 alcohol-based fluxes with rosin. The results with six of these fluxes were demonstrated in Part 1 of this study.[1]

A divergence in test results is observed between the J-STD-004B SIR pass/fail requirement of 100 MΩ minimum and the clean/dirty results provided by the cleanliness test system.

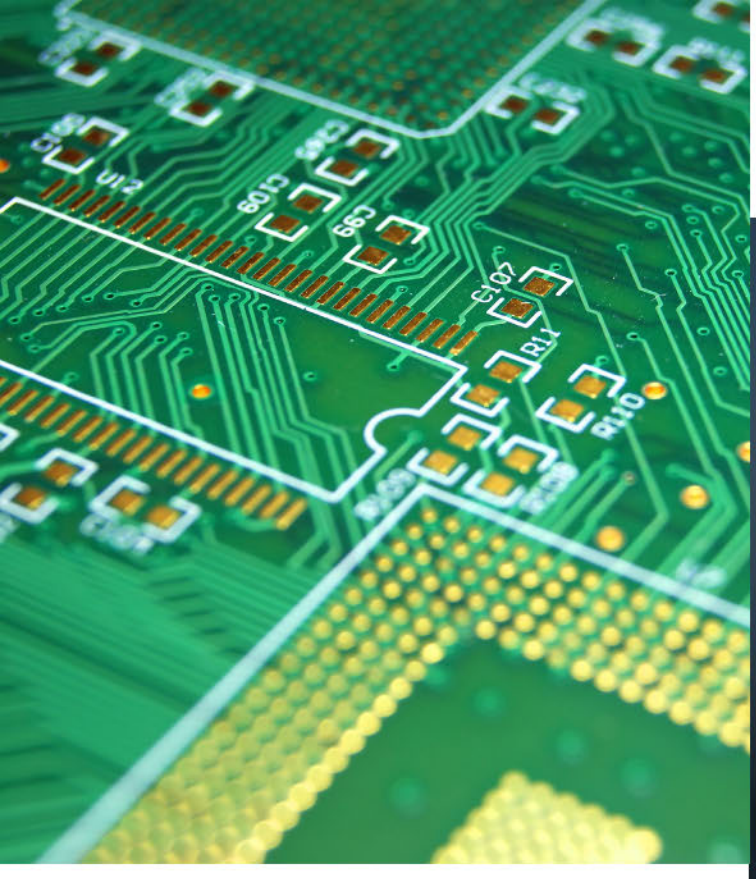
The SIR resistance/time graphs and cleanliness tester current/time graphs are compared. The Corrosivity Index (CI) calculated based on the result of localized cleanliness testing is compared with final SIR values for the fluxes.

Introduction

Surface Insulation Resistance Tests

There are various test methods available for assessing SIR properties of no-clean flux residues, including those published by IPC, Bellcore, and Japanese Industrial Standards organizations. All SIR tests are accelerated electrochemical reliability prediction tests for no-clean fluxes that incorporate manufacturing conditions and service environment factors in the test methods. Although specific conditions can vary across the test methods, each test incorporates the following characteristics:

1. Test coupons utilizing comb patterns with defined comb width and spacing
2. Sufficient flux loading applied to each comb pattern



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3. Coupons are processed in a wave solder system in both comb up (preheat without solder wave contact on the combs) and comb down (preheat and solder wave contact) orientations
4. Applied bias and exposure to accelerating fixed temperature and humidity environments
5. Quantified pass/fail minimum resistance criteria
6. Qualitative pass/fail inspection requirements after environmental conditioning

Localized Extraction and Cleanliness Testing

The commercially available cleanliness test system utilized in this study uses a novel localized extraction method to isolate the flux under test from a surface where flux has been applied. This system applies steam generated from deionized water and vacuum to extract a solution of flux residue and water. The steam head contains an integral PCB coupon that is immersed in the extracted solution. A bias is applied across a set of non-connected PCB lands and current across these lands is measured. The time for the current to reach a critical value called a "current leakage event" is measured. The system reports a clean result if the current remains below the critical value for a minimum specified time; otherwise, the test system reports a DIRTY result.

Test Methods

SIR Testing According to IPC J-STD-004B (Requirements for Soldering Fluxes)

IPC J-STD-004B 3.4.1.4 provides SIR test requirements for manufacturers of no-clean fluxes. This standard refers to IPC TM-650-2.6.3.7 (Surface Insulation Resistance) for the specific conditions for performing this testing, requires a test duration of 7 days, and refers to IPC TM-650 2.6.3.3B (Surface Insulation Resistance, Fluxes) for preparation of the test coupons.

The above referenced test methods call for a number of conditions that are to be followed when performing SIR testing. The IPC B-24 test coupon is specified, with four comb patterns per coupon. Each individual comb pattern is unpreserved bare copper, with 0.4 mm width lines and 0.5 mm spacing between comb traces. The test coupons used in this study are a modified version of the B-24 coupon that maintain the key characteristics on a slightly different form factor PCB (Figure 1).

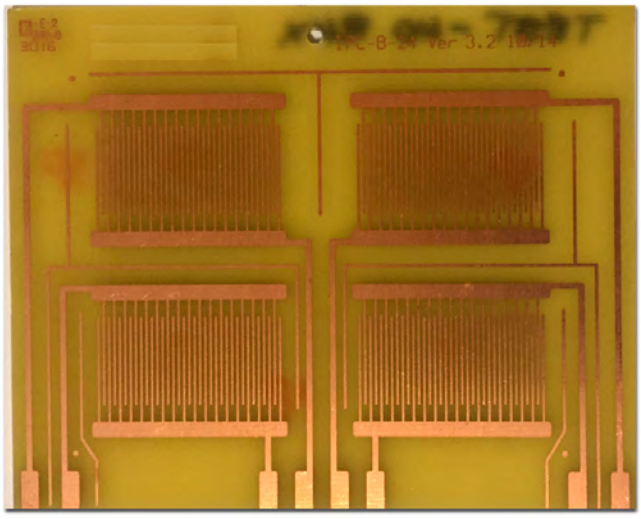

Figure 1: Modified B-24 test coupon.

The test conditions are specified as 40 ± 2°C and 90 ± 3% relative humidity. During the seven-day environmental conditioning exposure, a direct current bias of 25 ± 1 V/mm between adjacent parallel traces of the comb patterns is applied. This is equivalent to 12.5 ± 0.5 V on the B-24 coupon, having 0.5 mm comb spacing.

The key qualitative output of J-STD-004B SIR testing is the measurement of the resistance between adjacent comb patterns. These SIR measurements are taken at a maximum interval of 20 minutes over the environmental conditioning test duration.

The criteria for passing the SIR test are:

1. All SIR measurements between adjacent combs is no less than 100 MΩ (log SIR > 8) between hours 24 and 168 of the conditioning duration
2. There shall be no evidence of electrochemical migration that reduces conductor spacing by more than 20%
3. There shall not be corrosion of comb conductors

The visual inspections for electrochemical migration and corrosion after SIR testing are performed at 30–40X magnification in light field and dark field lighting.

Localized Extraction and Cleanliness Testing System

This test system utilizes a steam head (Figure 2) to extract a sample of deionized water and flux residue effluent from a localized region of approximately 0.1 in^2 (6.45 mm2). The test system is designed to extract the flux residue effluent by heating deionized water and delivering it to the test site (red arrow in Figure 2), followed by a vacuum aspiration of the solution into the collection reservoir (blue arrow in Figure 2). This cycle is performed nine times to produce a volume of effluent sufficient to fill the collection reservoir to a point where the exposed traces on the test coupon are covered. The test system applies a known bias (10 VDC) across the test coupon electrodes and measures the resulting current every 0.25 seconds.

The test system provides for two different acceptance criteria schemes. The more stringent criteria are recommended for use on IPC Class 2 and Class 3 assemblies and the less stringent criteria are recommended for use on IPC Class 1 assemblies. It should be noted that no IPC specification refers to this test, and the

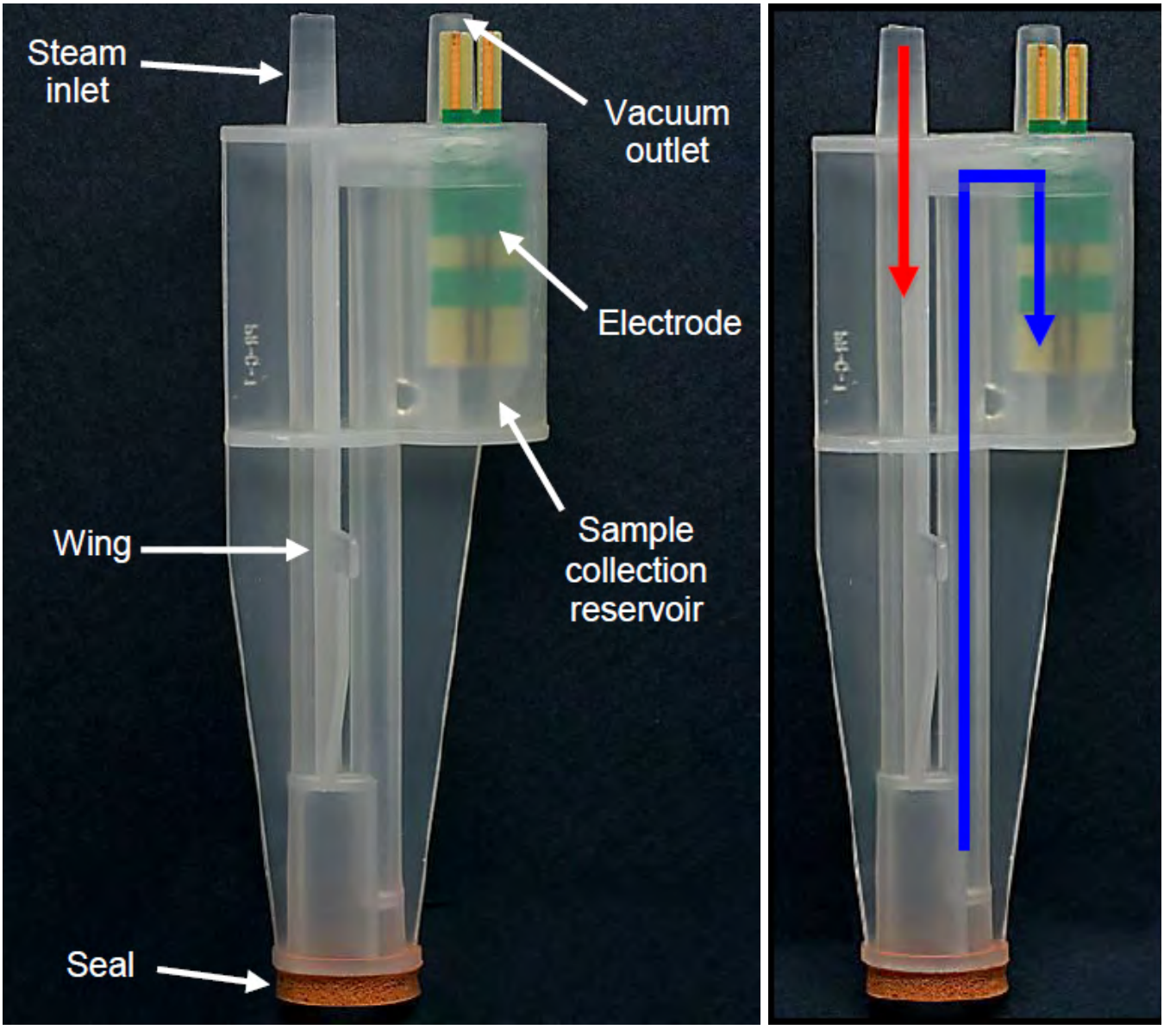

Figure 2: Localized extraction and cleanliness testing steam head.[2]

selection of IPC classes as representative of the two test limits is arbitrary.

The Class 2/3 acceptability limit is a measured current below 250 µA for a minimum of 120 seconds. The Class 1 acceptability limit is a measured current below 500 µA for at least 60 seconds. For both conditions, test cycles that meet the acceptance requirements are reported as CLEAN and test cycles that do not meet the acceptance requirements are reported as DIRTY.

In addition, the localized cleanliness test system reports a measure that is called the Corrosivity Index (CI). The index is calculated by dividing the maximum current seen during the test by the elapsed time of the test, or by dividing the maximum test current limit by the time required to reach the limit.[3]

The calculation for determining the CI for any test indicates that a lower CI is preferable. For reference, the Class 2/3 limit of 250 µA at 120 seconds can be converted to a CI of 2.08; this implies that a CI higher than 2.08 indicates a DIRTY test result for the Class 2/3 limit. The CI at the Class 1 limit of 500 µA at 60 seconds is 8.33.

Experimental Method for This Study

Test Coupon Preparation - Comb Down

The comb down orientation is designed to reproduce the wave soldering process as directly as possible prior to testing. The test coupons have 1–2 mL of liquid flux applied to each comb pattern, and the coupons are tilted vertically to allow the excess flux to drain from the board surface. The coupons are then processed comb-down through a wave solder system using a 5 ft/min (152.4 cm/min) conveyor speed to a topside preheat temperature of 220 ± 10°F (104.5 ± 5.5°C). The solder wave contained a tin-silver-copper alloy heated to 510°F (265.5°C) and each coupon contacted the wave for 4 seconds.

Test Coupon Preparation–Comb Up

The comb-up orientation is designed to simulate irregular conditions that can be encountered in a modern wave soldering process, such as topside flux overspray. In addition, assemblies that are processed in masking pallets can contain areas that contact flux, are heated during preheat, but do not directly contact the wave during the process. This results in flux residues that have a limited exposure to thermal energy and can have different electrochemical properties in the service environment of an assembly.

The comb-up coupons were prepared identically to the comb-down coupons with respect to flux application, conveyor speed, and preheat temperatures. These coupons are processed with the comb pattern facing up and without direct contact to the solder wave.

Test Quantities

For this study, three coupons soldered in the comb up orientation and three coupons in the comb down orientation were submitted to J-STD-004B SIR testing for each flux. For each test coupon there are a total of four comb patterns present but each coupon is considered a single test replicate (i.e., all four combs must meet the test acceptability requirements for a coupon to be considered to have passed the test. One coupon soldered in the comb up orientation and one coupon soldered in the comb down orientation was submitted to localized cleanliness testing for each flux. Each of the four comb patterns is considered an individual test for each coupon. This provides four replicates of the localized cleanliness test for each flux and soldering condition.

Fluxes Tested

VOC-Free Fluxes

Flux 1 is a legacy VOC-free formulation, originally characterized under the requirements of J-STD-004A. The flux is classified as ORL0 and contains 4.0% solids content.

Flux 2 is a VOC-free formulation that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified as ORL0 and contains 4.0% solids content.

Flux 3 is a VOC-free formulation that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified as ORL0 and contains 4.0% solids content.

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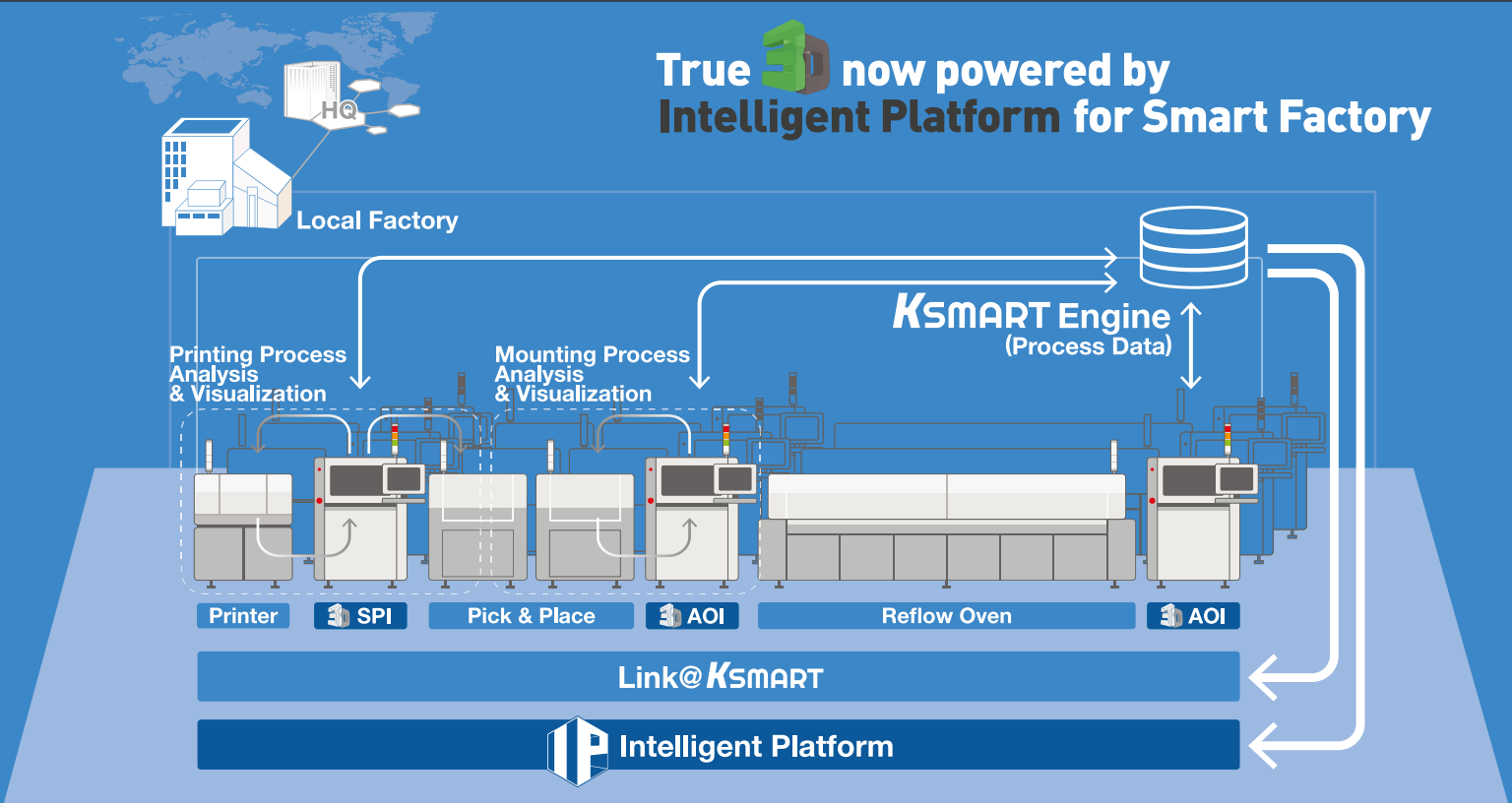

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Alcohol-based Rosin-free Fluxes

Flux 4 is a rosin-free alcohol-based flux originally developed when tin-lead wave soldering was the norm and the original revision of J-STD-004 was the current release. The flux is classified as ORL0 and contains 2.2% solids content.

Flux 5 is a rosin-free alcohol-based flux originally characterized under the requirements of J-STD-004A. The flux is classified as ORL0 and contains 2.2% solids content.

Flux	Solvent	Rosin?	Class	Solids %
Flux 1	Water	No	ORL0	4
Flux 2	Water	No	ORL0	4
Flux 3	Water	No	ORL0	4
Flux 4	Alcohol	No	ORL0	2.2
Flux 5	Alcohol	No	ORL0	2.2
Flux 6	Alcohol	Yes	ORL0	3.6
Flux 7	Alcohol	Yes	ORL0	4.3
Flux 8	Alcohol	Yes	ORL0	3.6
Flux 9	Alcohol	Yes	ORL0	6
Flux 10	Alcohol	Yes	ROL0	4
Flux 11	Alcohol	Yes	ROL0	4.1
Flux 12	Alcohol	Yes	ROL0	6
Flux 13	Alcohol	Yes	ROM1	7
Flux 14	Alcohol	Yes	ROL1	25
Flux 15	Alcohol	Yes	ROL1	25

Table 1: Summary of fluxes tested.

Alcohol-based Fluxes with Rosin, OR-class (Low Rosin)

Flux 6 is a rosin-bearing alcohol-based flux that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified ORL0 and contains 3.6% solids content.

Flux 7 is a rosin-bearing alcohol-based flux that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified ORL0 and contains 4.3% solids content.

Flux 8 is a rosin-bearing alcohol-based flux that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified ORL0 and contains 3.6% solids content.

Flux 9 is a rosin-bearing alcohol-based flux that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified ORL0 and contains 6.0% solids content.

Alcohol-based Fluxes with Rosin, RO-class (High Rosin)

Flux 10 is a halogen-free rosin-bearing alcohol-based flux that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified ROL0 and contains 4.0% solids content.

Flux 11 is a rosin-bearing alcohol-based flux that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified ROL0 and contains 4.1% solids content.

Flux 12 is a rosin-bearing alcohol-based flux that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified ROL0 and contains 6.0% solids content.

Flux 13 is a rosin-bearing alcohol-based flux that meets the requirements of J-STD-004B for a no-clean flux. The flux is classified ROM1 and contains 7.0% solids content.

RMA Fluxes

Flux 14 is a flux that was originally classified under the requirements of MIL-F-14256 as flux type RMA and contains 25% total solids. It is classified as ROL1 under J-STD-004B criteria.

Flux 15 meets the requirements of J-STD-002 and J-STD-003 solderability test flux #2. It is classified ROL1 under J-STD-004B and contains 25% total solids.

Results

SIR and Localized Cleanliness Testing Results

All fluxes passed the qualitative portion of SIR testing (no evidence of corrosion or electrochemical migration on any coupons after environmental conditioning under bias). The following discussion focuses on the quantitative output of the SIR and cleanliness testing and comparison of that data to the applied limits for each test.

The full plotted values for SIR vs. time and localized cleanliness testing current vs. time are provided in Appendix A.

	J-STD-004B SIR Test Results		Localized Cleanliness Test Class 1 (500/60)		Localized Cleanliness Test Class 2/3 (250/120)	
	Comb Up	Comb Down	Comb Up	Comb Down	Comb Up	Comb Down
Flux 1	FAIL	PASS	CLEAN	CLEAN	CLEAN	CLEAN
Flux 2	PASS	PASS	CLEAN	CLEAN	DIRTY	DIRTY
Flux 3	PASS	PASS	CLEAN	CLEAN	DIRTY	CLEAN

Table 2: VOC-free flux test results summary.

	J-STD-004B SIR Test Results		Localized Cleanliness Test Class 1 (500/60)		Localized Cleanliness Test Class 2/3 (250/120)	
	Comb Up	Comb Down	Comb Up	Comb Down	Comb Up	Comb Down
Flux 4	PASS	PASS	DIRTY	CLEAN	DIRTY	DIRTY
Flux 5	PASS	FAIL	CLEAN	CLEAN	CLEAN	CLEAN

Table 3: Alcohol-based rosin-free flux test results summary.

	J-STD-004B SIR Test Results		Localized Cleanliness Test Class 1 (500/60)		Localized Cleanliness Test Class 2/3 (250/120)	
	Comb Up	Comb Down	Comb Up	Comb Down	Comb Up	Comb Down
Flux 6	PASS	PASS	DIRTY	CLEAN	DIRTY	DIRTY
Flux 7	PASS	PASS	DIRTY	CLEAN	DIRTY	DIRTY
Flux 8	PASS	PASS	CLEAN	CLEAN	DIRTY	DIRTY
Flux 9	PASS	PASS	DIRTY	CLEAN	DIRTY	DIRTY

Table 4: Alcohol-based rosin-bearing flux test results summary, OR-class fluxes.

VOC-free Fluxes

Flux 1 failed J-STD004B SIR testing in the comb-up configuration, but the localized cleanliness testing reported a clean result.

Fluxes 2 and 3 both passed J-STD-004B SIR testing, but the localized cleanliness testing reported a dirty result for both fluxes in the comb-up configuration, and for Flux 3 in the comb-down configuration, under the Class 2/3 limit.

Alcohol-based Rosin-free Fluxes

Flux 4 passed J-STD-004B SIR testing. The localized testing reported a dirty result for the comb-up configuration and for the Class 2/3 limit in the comb-down configuration.

Flux 5 failed J-STD-004B SIR testing in the comb-down configuration, but the localized cleanliness testing reported a clean result.

Alcohol-based Fluxes with Rosin, OR-class (Low Rosin)

All of the fluxes in this category (Fluxes 6–9) passed J-STD-004B SIR testing. Localized cleanliness testing reports a dirty result for all fluxes to the Class 2/3 limit in both the comb-down and comb-up configuration, and a dirty result for the comb-up configuration to the Class 1 limit for Fluxes 6, 7, and 9.

	J-STD-004B SIR Test Results		Localized Cleanliness Test Class 1 (500/60)		Localized Cleanliness Test Class 2/3 (250/120)	
	Comb Up	Comb Down	Comb Up	Comb Down	Comb Up	Comb Down
Flux 10	PASS	PASS	CLEAN	CLEAN	CLEAN	DIRTY
Flux 11	PASS	PASS	CLEAN	CLEAN	DIRTY	DIRTY
Flux 12	PASS	PASS	CLEAN	CLEAN	CLEAN	DIRTY
Flux 13	PASS	PASS	CLEAN	CLEAN	CLEAN	DIRTY

Table 5: Alcohol-based rosin-bearing flux test results summary, RO-class fluxes.

	J-STD-004B SIR Test Results		Localized Cleanliness Test Class 1 (500/60)		Localized Cleanliness Test Class 2/3 (250/120)	
	Comb Up	Comb Down	Comb Up	Comb Down	Comb Up	Comb Down
Flux 14	PASS	PASS	CLEAN	CLEAN	CLEAN	CLEAN
Flux 15	PASS	PASS	CLEAN	CLEAN	CLEAN	CLEAN

Table 6: RMA flux test results summary.

Alcohol-based Fluxes with Rosin, RO-class (High Rosin)

All of the fluxes in this category (Fluxes 10–13) passed J-STD-004B SIR testing. Localized cleanliness testing reports a dirty result for all fluxes in the comb-down configuration, and for Flux 11 in the comb-up configuration, to the Class 2/3 limit provided by the test.

RMA Fluxes

Both of the RMA fluxes tested (Fluxes 14 and 15) pass J-STD-004B SIR testing. Localized cleanliness testing reports a clean result for both fluxes under all conditions.

Corrosivity Index

The CI values were calculated for each localized cleanliness test performed using the Class 2/3 limit of 250 µA. The values were averaged for the four tests performed for each combination of flux and comb configuration. The final log SIR values recorded at 168 h for each configuration of flux and comb configuration were averaged for each of the twelve combs tested. These values were plotted and are shown in Figure 3.

Note that CI values below 2.08 for an individual test indicate a clean condition and log SIR values above 8.0 for an individual comb would pass J-STD-004B SIR testing.

The values show a large grouping of data points in the upper left portion of the graph, with log SIR values above 9.5 and CI values below 2.08. These data points correlate well, since high SIR and low CI are the desired values.

However, there are three data points that present relatively low log SIR values (lower than 9) along with low CI values (below 2.08). These values tend to be contradictory, where a preferred low CI is reported by fluxes with marginal or failing SIR performance.

In addition, there are a number of data points with log SIR values above 9.0 that report CI values above 2.08. These SIR values are one or more orders of magnitude higher than the established minimum limits for SIR but show high, undesirable CI values. These values

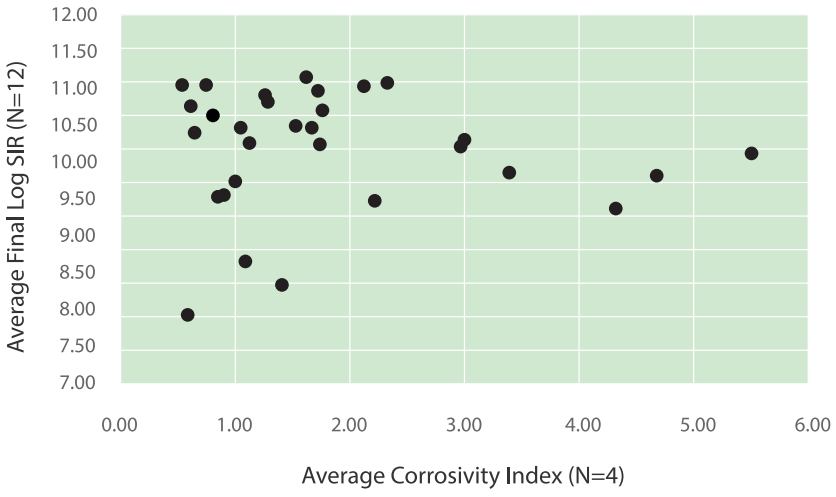

Figure 3: CI and final SIR values.

demonstrate cases where a high CI value is a poor indicator of SIR performance.

Conclusions

The design of the cleanliness test system assumes that the more corrosive or conductive the extracted residue, the quicker a current leakage event occurs.[4] In addition, the CI index is marketed as a predictor of product performance in that the lower the CI the less likely a tested product site will suffer performance problems due to the presence of a detrimental ionic residue.[5] However, a comparison to SIR testing results indicates that these assumptions do not hold true when testing no-clean liquid wave solder fluxes.

Recall that SIR testing requires no evidence of corrosion on comb patterns, no evidence of electrochemical migration that exceeds 20% of the distance between combs, and maintains 100 MΩ minimum resistance under controlled, elevated temperature and humidity conditions to receive a pass result.

In addition, all of the fluxes tested (with the exception of Flux 13) are classified as "L" activity per J-STD-004. This classification is derived from the results of corrosion testing on full-strength flux and indicates that the fluxes are non-corrosive to copper. Flux 13 is a special case, where it is rated "M" activity (which indicates it can be mildly corrosive to copper) but still meets all the requirements to be called a "no-clean" flux per J-STD-004B.

The localized cleanliness test system appears to be prone to a high rate false negative errors, with 11 fluxes reporting a dirty result where they pass SIR testing. These results show that users of the localized cleanliness test system could be rejecting useful fluxes based on the results of localized cleanliness testing. This is burdensome to users, as it tends to limit the available fluxes to select when developing new processes. This can also lead to situations where end users have localized cleanliness testing performed and require the assembler to respond to undesirable localized cleanliness testing results. This response can include additional product testing or implementation of a new assembly process in order to receive a desirable result of cleanliness testing, in cases where the original process was acceptable in its current condition.

Also, there were two fluxes tested that the localized cleanliness test system suffered false positive errors, reporting clean cleanliness results while they fail SIR testing. These results show that users could be accepting fluxes that will not provide the expected reliability performance in the product's service environment. This can be especially dangerous, as field returns due to poor reliability performance can be very damaging to an assembler's business.

The only fluxes that did not experience errors are fluxes 14 and 15, which are both very old technology formulations and are infrequently used for new applications and processes. In fact, Flux 15 is a flux designed for solderability testing and is not intended for assembly soldering.

The study of CI values and their relationship to final SIR values shows that there are a significant number of cases where the desirable results (low CI, high SIR) exist.

However, there are also cases where low CI values (desirable) are matched with low SIR

values (undesirable) and cases where high CI values (undesirable) are matched with high final SIR values (desirable). These results indicate that CI values and SIR values are not well correlated in all cases. SMT007

Acknowledgements

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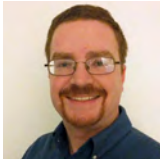


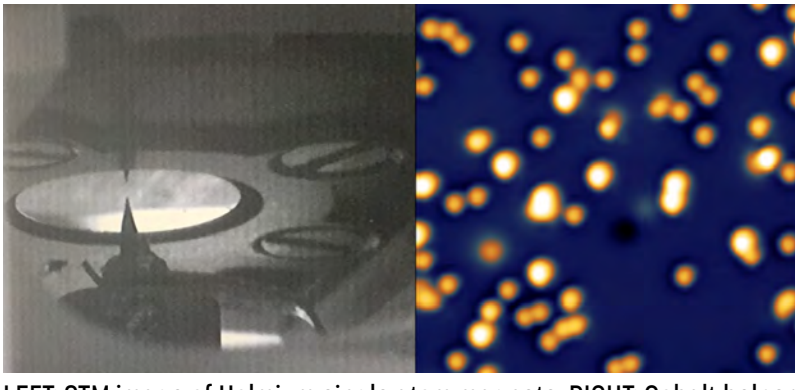
Jason Fullerton is a customer technical support engineer at Alpha Assembly Solutions.

A Step Closer to Single-Atom Data Storage

In a new study published in Physical Review Letters, physicists at EPFL's Institute of Physics have used scanning tunneling microscopy to demonstrate the stability of a magnet consisting of a single atom of holmium, an element they have been working with for years.

The scientists exposed the atom to extreme conditions that normally de-magnetize single-atom magnets, such as temperature and high magnetic fields, all of which would pose risks to future storage devices. Using a scanning tunneling microscope, the scientists found that the holmium atoms could retain their magnetization in a magnetic field exceeding 8 Tesla. The authors describe this as "record-breaking coercivity", a term that describes the ability of a magnet to withstand an external magnetic field without becoming demagnetized.

Next, the researchers exposed a series of Holmium single-atom magnets to temperatures of up to 45 Kelvin. The Holmium single-atom magnets remained stable up to a temperature of 35K. Only at around 45K, the magnets began to spontaneously align themselves to the applied magnetic field. This showed that they can withstand relatively high temperature perturbations and might point to the way forward for running single-atom magnets at more commercially viable temperatures.



LEFT: STM image of Holmium single atom magnets. RIGHT: Cobalt helper atoms on magnesium oxide. Credit: F. Natterer/EPFL

"We have demonstrated that the smallest bits can indeed be extremely stable, but next we need to learn how to write information to those bits more effectively to overcome the magnetic 'trilemma' of magnetic recording: stability, writability, and signal-to-noise ratio," says EPFL's Fabian Natterer who is the paper's first author.

Source: École Polytechnique Fédérale de Lausanne (EPFL)

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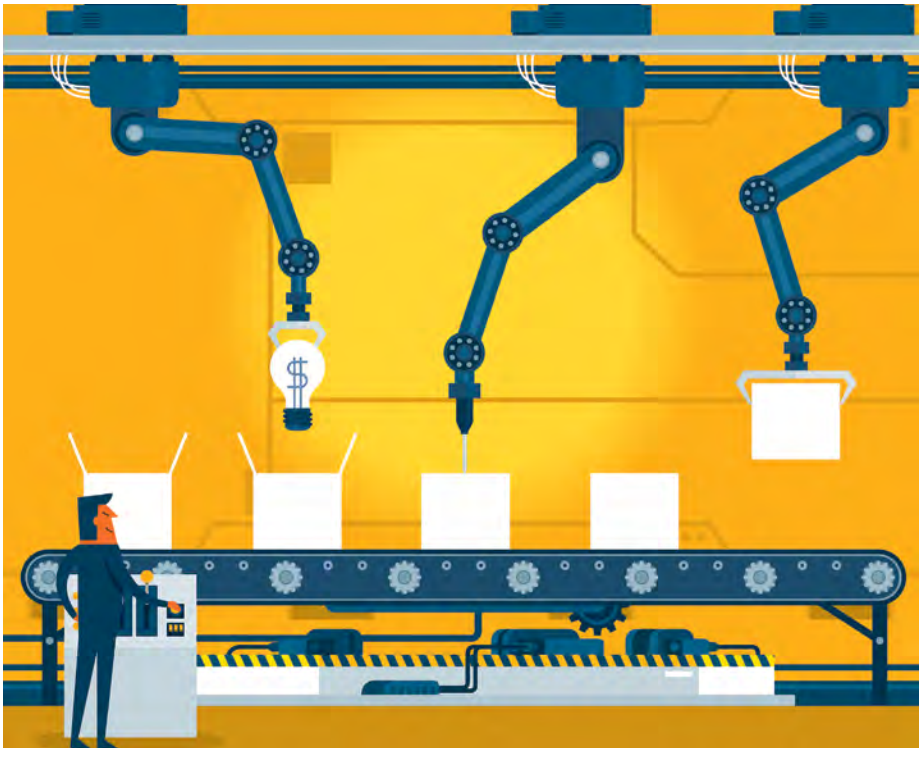
Advanced Digitalization Makes Best Practice, Part 2: Adaptive Planning

Accelerating Tech-Insights from the Smarter Factory

by Michael Ford, AEGIS SOFTWARE

In the first part of this series, I examined digital remastering, as it refers to the process of creating the digital product model from design and bill of materials (BOM) information, with conversion then, by digital engineering tools, into execution-ready engineering data. In our new digital MES environment, this process is not just to create a single execution instance for a pre-designated line configuration as was mandated in the past, but for all capable configurations, to provide choice at actual run-time. We now look towards the next step in our new digital factory best practices that digital remastering of engineering data has made possible: the software known as Adaptive Planning, created by Adaptive Insights.



The Challenge of Factory Planning

The dedication of production lines to products, or more recently, groups of products, has become a rather comfortable environment, with just one set of engineering data to support, a single supply-chain of materials, lined up hours in advance, so no concerns for production at all. The flaw in this plan is best illustrated by considering the simplest form of production and having a product running at high-volume on one such dedicated line. Many operations dream about the good ol' days where such high-volume lines were common and have forgotten that even the operation of those lines were hiding significant losses to the business overall.

Take the case where such a line would make 1,000 products per day, over many days. This is the most efficient example of how SMT equipment automation

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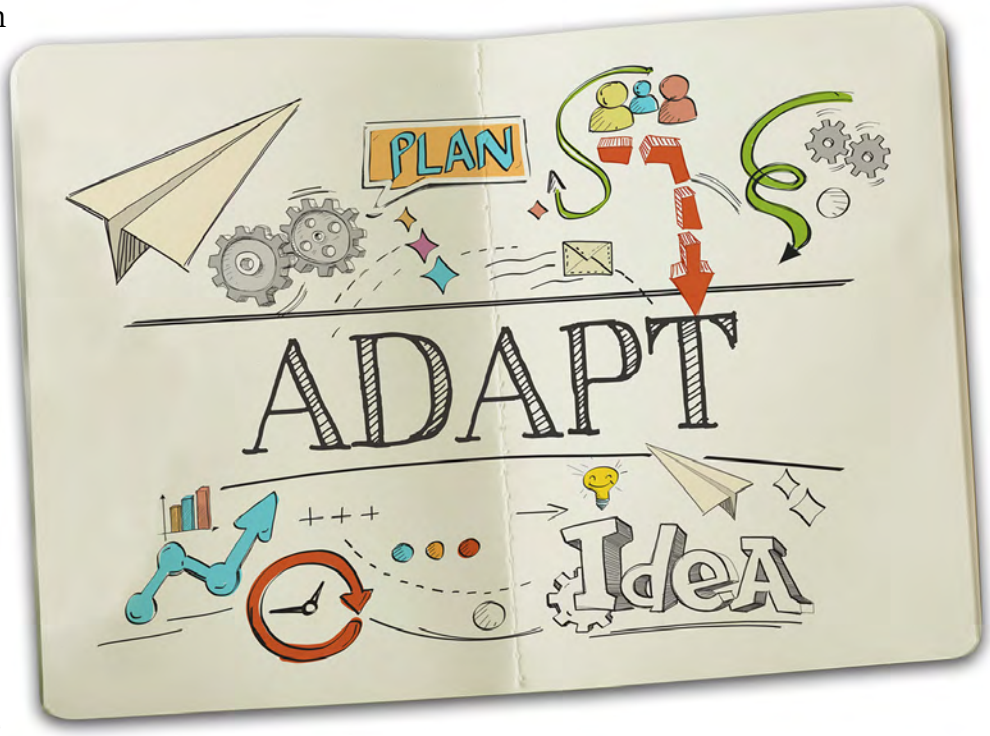
could be used. It consisted of extremely well-optimized machine programs and carefully balanced lines, where work was split as equally as possible over all machines to get to a single consistent takt time with no losses in between. The 1,000 products would be made, and then disappear into the warehouse. Job done, for SMT. From the business perspective however, unnecessary costs then start to accumulate. It is extremely unlikely that the optimal capacity of the line was exactly meeting the delivery need of the customer. If the customer would take only 900 per day, then 100 additional pieces would have to remain in stock in the factory warehouse. Without careful finished-goods management, the warehouse could soon fill to capacity. The 1,000 per day line capacity was necessary however, as the customer could take the full 1,000 per day or even slightly more. Whenever the assigned warehouse locations became overloaded, the SMT line would be told to stop. Though triggered by a physical threshold, the cost of storage of this "dead" inventory was the significant factor. Often, the SMT line had to stop for just a couple of hours here or there, when the time could be taken advantage of, performing routine maintenance for example, but often, the line would stop for a shift or even longer, getting progressively worse as the fluctuation in customer demand increased.

Customers were simultaneously reducing the stock in their whole supply-chain, as the stock held in their buffers became too expensive to maintain, especially considering the erosion in the value of the products. Pushing back on the factory to utilize storage which smoothed out the supply-chain has been a long-term increasing trend. This resultant lost production opportunity was rarely reported in performance reports however. When the SMT line was scheduled to run, it ran with extremely high performance, with completions being reported favorably against scheduled targets. When there was no schedule, there was no target, and therefore from the reporting aspect, no loss. This lead to the great phenomenon whereby visitors to a manufacturing site, would see glowing reports of productivity, but then see an ocean of red lights on inactive machines when scanning around the shop-floor, indicating that most machines were idle.



Even with today's more complex, high-mix production environments, the situation is the same. Products are usually now grouped in advance by engineering in a way that makes sense from the perspective of product commonality and is then assigned again to a line configuration that can satisfy the peak demand of the product group. This is especially true in the EMS world, where production for each customer is often ring-fenced from other customers. The essence of the line-rate matching customers demand issue is the same. Performance is again only measured against the schedule. This time, it is worse, as there is no measurement for the efficiency or of the now more complex schedule itself.

Changeover down-time between setups of different products are taken as a fact of life. Loss of machine program efficiency to support the grouping of materials between products to reduce change-over time, is an often-ignored consequence. These "hidden" additional costs, then appear on top of the line-rate issues, which incidentally have also now worsened, due to the increase in the number of different products being produced, each of which now needs their own separate buffer stock. Factories were always going to lose this battle against the customer's supply-chain, as stock held in the supply-chain is far more visible and is under the control of the customer in the EMS case, or by the sales organization in the OEM case.

Legacy Planning Solutions

To try to make sense of this whole situation, there are literally hundreds of commercial solutions available for factory planning. Earliest attempts at shop-floor planning solutions came from ERP, which were spectacularly poor in dealing with the complexities of PCB manufacturing machines, processes and steps. It is not possible for a simple time-per-product model definition to be an accurate representation. Consequently, as a next step, more complex, process simulation tools became popular, to analyze the performance of the machines and processes, in a connected line and across lines, to identify a more accurate timing model for products at each production configuration, which could then create better schedules, squeezing out more production performance. In performing fixed simulations of production requirement, these solutions completely missed the point that the most important losses were based on the growing customer demand fluctuation. Next came advanced planning and scheduling (APS) tools that focused on more complex scheduling requirements that came with higher mix production. Attempting to create a long-range, complex schedule became little more than a complete failure, since as soon as customer requirements changed, the whole remainder of the plan was obsolete. Another critical issue is that the APS software is trying to work with its hands tied behind its back, as without digital remastering of the product data, the legacy product to line configuration dedication gave very little flexibility, and no opportunity for APS algorithms to find alternatives. The resultant value of using APS tools, even in the best of cases, were significantly less than expected.

We then come to the most practical and established shop-floor planning solution, currently in use in the majority of electronics manufacturing, Excel. Sometimes simple, sometimes extraordinarily complex, Excel remains the practical tool of choice for real-world work-order scheduling. It is an intensively manual process to maintain, as expected performance data needs to be continuously updated, as does the progress of manufacturing as time passes. In the hands of the most expert, experienced and expensive shop-floor planning engineers, Excel shines over and above other legacy tools in keeping the factory running. Due to this ability of Excel to assist and support human decision-making in planning in the very near term, demand fluctuations become manageable, not easy, but possible, which is more than can be said for the other legacy solutions discussed. The losses incurred by legacy solutions on a routine basis may be as little as 20% of lost productivity, measured in real terms of factory and machine availability, but may also often be as high as 80% in higher mix and lower volume combination situations. The worst thing about this is that often, these losses are not reported, and nothing is done to eliminate them. Instead, it is thought that high degrees of flexibility, together with high productivity are

Sometimes simple, sometimes extraordinarily complex, Excel remains the practical tool of choice for real-world work-order scheduling.

simply not possible, which is clearly at odds with the concept of Industry 4.0.

Adaptive Planning

We need to look at the Excel solutions, with some well-earned respect for the people who have created those solutions and use them every day. There is no long-term planning here, they know it is pointless, as in an Industry 4.0 factory, customer demand fluctuates day by day. The effect of fluctuation and product mix will, however, only become more extreme going forward. Looking at how Excel and factory planning are now working separately, there is a clear difference between capacity planning and planning live and near-term production, which will need to continue as separate entities. The capacity plan is a high-level calculation, that provides an assurance that the factory capability can meet customer requirements in the medium and long term, without looking into details of processes. With confidence in the capacity plan, the focus of live planning can be placed on the immediate future only, making sure that current demands are met in the most efficient way. As the degree of flexibility expected for the factory grows more extreme, the capability of Excel becomes less effective, prompting the use of a next-generation digital live planning solution that expands upon the fundamentals of Excel, Adaptive Planning.

Adaptive Planning brings automation to the dynamic decision-making process of allocation of work-orders to production configurations. This is where the importance of Digitally Remastered engineering best practices plays a critical part. Now with the required information, it is possible to shift production from the 1,000 per day capable line in the previous example, to the 900 per day capable line, which then runs at 100% efficiency to meet actual customer demand, without dependence on bloated finished goods stock, in a process that also frees up the extra capacity of the faster line to meet other targets. In fact, Adaptive Planning will consider the rate of completion of every product on every possible line configuration to find the best possible combination for the period for which demand is accurately predicted. This is too much for the Excel tools to handle. Adaptive Planning works effectively as it has continuous, live data about the progress and performance of the shop-floor operations available, as well as the availability of materials and key resources such as feeders. With all this information, the Adaptive Planning algorithms provide the critical assistance in the decision-making process, allocate products to create demand-based product groups, and allocate product and groups to lines with the best fit. The Adaptive Planning tool therefore does not need to plan far ahead, managing short-term schedules with surgical precision. The reliance on excess levels of stock in the warehouse to enable the factory to appear responsive to demand changes, are a thing of the past. The factory, now made up of Lean processes, can "turn on a dime" to provide whatever delivery is required. Inherent losses built into long-term schedule planning are avoided, as the best available configuration for the job is continuously selected.

For Industry 4.0 operations, Adaptive Planning has the capability of replacing both legacy APS tools, simulations, and even Excel solutions. As time goes on, with increases in the scope, quality and reliability of live data coming from the shop-floor, using for example the Connected Factory Exchange standard (CFX), it is expected that Adaptive Planning solutions will become progressively smarter, offering greater guidance while managing constraints as well as optimization.

One major constraint, material availability, especially in these times of material shortages in the market, is a major challenge, and is the next area for our consideration where legacy factory practices need to change. This will be the subject of part three of our "Advanced Digitalization Makes Best Practice" series. **SMT007**

Michael Ford is the European marketing director for Aegis Software. To read past columns or to contact Ford, click here.

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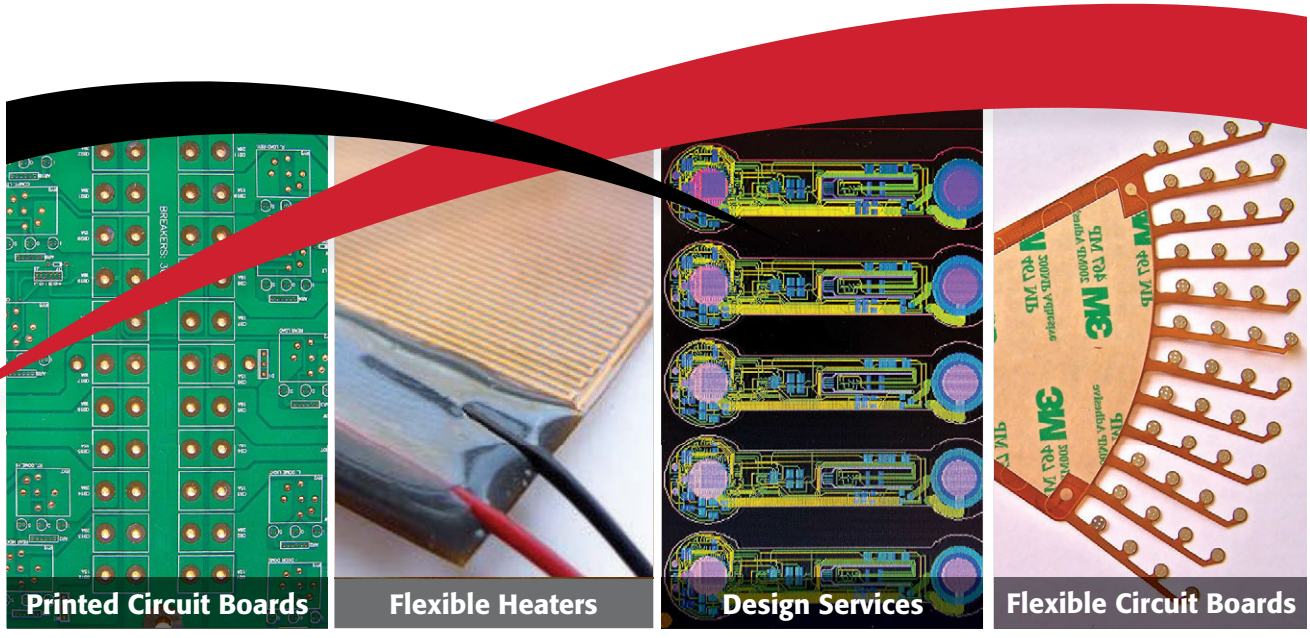

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Supplier Highlights

Aegis on CFX and Hermes Efforts ▶

The Connected Factory Exchange (CFX) specification is truly revolutionizing the PCB industry. Michael Ford, from Aegis Software, met with I-Connect007's Barry Matties for an interview during the SMT Hybrid Packaging show in Nuremberg, Germany, to discuss the impact of this collaborative effort, and how it differs from the Hermes Standard.

KYZEN Sees Growth in Asia and Expands Marketing Support ▶

KYZEN announced that Lina Ong has taken on an expanded role as marketing specialist at KYZEN's Southeast Asia Headquarters in Penang, Malaysia.

Rehm to Improve Blaubeuren Business Center ▶

Rehm Thermal Systems is continuing to invest in its headquarters in Blaubeuren.

Yxlon Installs Test Equipment at San Jose and Ohio Facilities ▶

Comet's Lab One in California, and Yxlon in Ohio now give customers direct access to testing and inspection services based on radioscopic, CT and X-ray and electron beam technology.

Rogers Venting Membranes Improves Electronics Enclosure Reliability ▶

Rogers Corp.'s DeWAL V-Series venting membranes is engineered to vent and protect a wide range of critical enclosure applications.

Alpha Intros Ultra-Low Voiding Solder Paste for Increased Reliability ▶

Alpha Assembly Solutions recently introduced ALPHA OM-358, a lead-free, zero-halogen solder paste designed to provide ultra-low voiding performance on all component types, including bottom terminated components.

Solder Paste Market to Grow on Rising EMS Demand Until 2022 ▶

The solder paste market has specially witnessed a bullish run in the last two decades and is anticipated to grow further with the diffusion of information technology and enabled services in human life globally.

Zestron Americas Names Raul Silva Regional Sales Manager ▶

Zestron is pleased to announce the addition of Raul Silva as the new North Mexico regional sales manager.

SMT Worldwide to Distribute AIM Solder Products in Spain and Portugal ▶

AIM Solder has added SMT Worldwide as a new distributor for its full line of solder products in Spain and Portugal.

Scienscope Expands Partnership with Restronics ▶

Scienscope International has partnered with Restronics as its newest manufacturers' representative.

Thermaltronics Sets Sights on Hand Soldering System Leadership ▶

Thermaltronics, a fast-growing manufacturer of precision hand soldering systems incorporating the unique Curie Point technology, is embarking on an aggressive marketing campaign in the US.

AIM Solder to Donate Solder Paste to CENALTEC High-Tech Training Center ▶

AIM Solder is pleased to announce their donation of solder paste materials for training at the CENALTEC High Technology Training Center in Chihuahua, Chih., Mexico.

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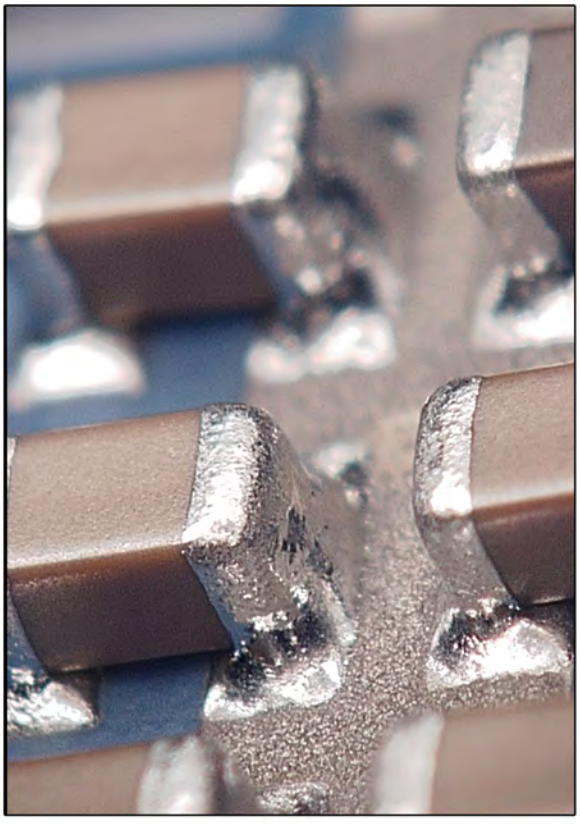

Towards a Data-driven Cleaning Environment

Feature Interview by Stephen Las Marias
I-CONNECT007

In an interview with *SMT007 Magazine,* Tom Forsythe, executive vice president at Kyzen Corp., discusses the most critical challenges of the cleaning process, a new approach to testing the cleanliness of PCB assemblies, and how Kyzen is helping customers develop a more data-driven approach to cleaning.

Stephen Las Marias: What are the critical challenges when it comes to cleaning?

Tom Forsythe: There are really two critical challenges today: The first is the evolution of our industry, in that bottom-termination components (BTCs) are becoming very popular for a host of performance reasons, and they present challenges both in cleaning, or in the case of no-clean components, reliability because of the challenges of ensuring that the no-cleans are fully cured underneath the BTCs. That's a big challenge these days because what's going on is that everyone doesn't respectfully recognize outside the high-reliability world, and the industry is sorting out just how it is we can solve this problem. I think over the next year or so, there will be changes that that will be generally accepted to try to improve that opportunity.

The second challenge is more on the confirmation, certification, or validation aspect. Historically, over the last 10 years anyway, the industry has largely relied on an operational basis on a particular test equipment known as Resistivity of Solvent Extract (ROSE). Last fall, the industry standards groups spoke out on the fact that ROSE is not very compatible with no-clean residues and has simply been relied upon as the only method for assuring cleanliness. Right now, the industry is trying to decide just what that means. Is there a new method that's necessary? So, there's a great deal of work going on. Over the next year or two, there will be very meaningful change in

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that test and validation space, which is a little bit unknown right now.

Las Marias: Is there still this confusion between no-clean and the regular fluxes?

Forsythe: It depends on the application. Here's a little bit of an extreme example. A doctor tells you, "You need a pacemaker." Should a pacemaker, an electronics device, be clean? Also, do you think that your pacemaker should be made with soldering technology that was invented in 1970? Then, consider—mind you, this is just an extreme example for the sake of discussion—if you want to use a modern soldering material, what type of modern soldering material has been developed over the last five, 10 or 15 years? Aren't they mostly no-clean?

Tom Forsythe

Remember, no-clean is really the wrong name. No-clean really means low residue, low reactivity. But whether it is low enough for any particular application is the decision of the person assembling the board. I don't have a percentage handy, but I can say a large majority of our customers have been running no-clean for 10 years.

Las Marias: Does that mean the question, "how clean is really clean?" depends upon the application?

Forsythe: There is a bit of that, to be sure. Over the last many years this ROSE testing has been around, and the old military standard for cleaning was 10 micrograms/in^2 of equivalent ionic residue level. Ten is a great number. We had very good customers who were happy with a 10 in those days.

But it wasn't a matter of how clean is clean enough; it was a matter of how clean could it get. Because those people who've wanted 1 instead of a 10, they weren't doing it because it was a good round number, they want it to be as clean as they could possibly get.

That cleanliness, surely, is helping them with reliability. Because if I am removing contaminants, I am certainly not hurting reliability. I think the whole idea here is what the performance profile is of the device. As we expect our devices to last longer and longer, cleaning and making sure these things are going to last that long becomes a valuable part of that equation. Therefore, we have a few customers saying, "Imagine going to the doctor and being asked, 'How surgically clean do you want us to make these cuts? Do you want really clean, or are you fine with so-so?'" I think I know the answer to that. Well, what about your car? "Well, so-so is okay. I am good if it will give me five or six years; I'll just get a new one."

The reality is, as consumers, we are quite fickle. We want things that are very inexpensive, and we want them to last forever.

The reality is, we have also been impacting this decision from the technology we put inside things for a long time. The BTCs, densities, line spacings and things like these are driving up the whole risk factor of the contaminates. These are the challenges that people are dealing with. While cleaning never completely went away, it kind of went over to the specialty area.

In general, and this has been coming gradually for some time, more people are cleaning. And we believe it is okay for the consumer. Because the incidental cost of cleaning is quite high. With a circuit card, we're talking pennies. From a production side, the incidental cost is very modest, yet the reward will be very successful. The assembly business is a business of pennies. Every penny counts. So, if we can help in reliability with a few cents a card, it's a gain.

Las Marias: Are there still some steps that people are doing incorrectly when it comes to cleaning?

Forsythe: The answer to that is mostly no. The people who are cleaning generally fall into the camp of people who never stopped cleaning. They've been cleaning for the past 20-30 years, and they've had time to improve and optimize and adjust things to match up to their needs. By and large, people do a very solid job using a very reliable process that is robust and works quite well.

One of the reasons there's a lot of education when it comes to cleaning is to help people who are doing cleaning for the first time, or in a very long time, to learn. It is kind of a standard operating stuff; while it is new and a little bit different, it is not really very different and not challenging to do a very good job, in a very efficient and low-cost way.

People are starting to do cleaning every day and they are experiencing that. They are seeing the yields, and they are seeing improved reliability and an improved risk profile for their operation. So, in general, I think most customers do a pretty good job and we are in the background and here to help, for small changes. Our industry often has a lot of people that come and go, and anyone can find themselves a bit short on the technical expertise. That's when the vendors step up and help train the new guys and help them come up to speed on things. That's part of our value proposition.

Las Marias: Are there still opportunities for optimizing the cleaning process?

Forsythe: There always is. For instance, if you are an EMS provider, your product portfolio changes all the time. Therefore, maybe their processes are lined up and matched with what their current uses are, but they might be different than they were a year ago. There's that piece of the puzzle. People tend to, by nature and by the talent in our industry, lean things out and run them as efficiently as possible.

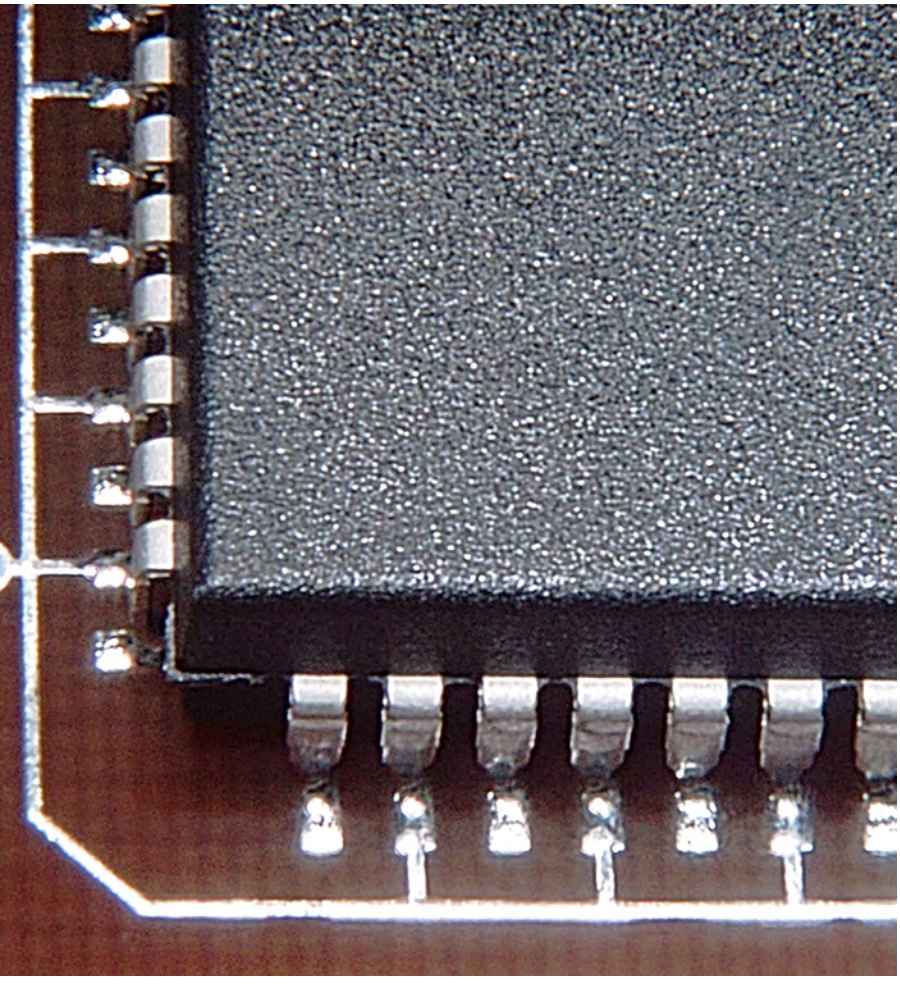
Las Marias: In our ongoing conversations within the industry, we've learned that communication is always key in the supply chain. Please give your comments on that.

Forsythe: If you're having a bad day, we're standing next to you tomorrow. And together, we will figure out how to make that go away. It's rarely something that's a quality issue with our stuff; it's usually something's changed in the operations environment. Is the equipment having a bad day? Did the product mix really change and have the needs changed?

Our customers live in a dynamic world. When things do change, our engineers and tech people they're busy fellows. We're here to help them. And I think that is a big deal and think that's a key part of what we bring, and what others try to bring to the marketplace.

Las Marias: What is Analyst, and what are the latest developments?

Forsythe: The Analyst is a monitoring system that we introduced two years ago, and the idea was really multidimensional. The world doesn't need another gauge or another horn. What the world needs is information. So, we brought a data-services approach where we delivered data through the cloud, through the phone, computer—wherever a customer wants it; triggers are set for warning and for red zones, and a text or email, in real-time, is delivered to that address. The data collection and curating has been popular and effective. Now that data is available digitally, they can be searched and in a very few minutes, touched—even if it's a few months old—one can go back to a particular day or time and grab the data. That curation tends to be very popular.



Now, we have taken the Analyst concept and brought it to our process control system. We've been selling what we call the Kyzen PCS for 20 years or so. These are tried and true machines out there doing their job, not only monitoring but controlling the water chemical balance of these aqueous systems. When we brought out this idea of data collection, curating and information, as well as a data-rich display locally to the PCS, it received tremendous acceptance; people are very pleased with it. It's been one of the very best introductions we've ever had.

Las Marias: This data-driven approach must offer a much more comprehensive and even continuous result, right?

Forsythe: Absolutely. Previously, when people check for the concentration once or twice a shift, it was difficult. Data that's virtually continuous is different from checking once or twice a shift. There are several parameters, not just the concentration. But when you bring the Analyst to the PCS, it monitors 30-40 different parameters, and that paints a complete picture. From an archival perspective, customers having an audit may need to go back and prove that the cleaning process was as it should be for that a shift or whatever time they need to audit. They can go back and within minutes, rather than days, touch that information and see a very clear picture of what was going on. And that is a tremendous value add because it's not just one number in a log book; it's dozens of different data points in and around that wash system that demonstrates, "Hey, we were doing our jobs!"

Las Marias: Even without incidents in the line, you can go home assured that your cleaning system will have a stable concentration throughout.

Forsythe: That's right—the beauty of it. What the PCS has brought for many years, with data services now, enhances this idea of a very robust and stable process that now has better documentation than ever before. The nuts and bolts of the process really aren't very different; but the world is data-driven today. And we have taken on the challenge of bringing cleaning into that data-driven, data-rich environment. And it's because everything is that way, I guess it's not all that surprising that people like it.

Las Marias: What advice can you give our readers when it comes to their cleaning process?

Forsythe: There are a couple of things. One is to make sure that it's meeting their needs. If you are already cleaning, is your process optimized? Do you have the rich data experience? Are you comfortable with your value equation—value not being deemed as a cost per gallon—

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in the sense of you have a robust process that runs day in and day out and just getting the job done, meeting your reliability needs, and helping you get your quality target.

If you are not cleaning, and you are considering it, the same questions apply: How can your process be helped by cleaning? Is operation meeting its goals and can cleaning be a value adder? Most of our customers believe that it is. No one's eager to clean, because the perception is that doing more is never easier than doing less. However, sometimes doing more delivers a great deal of value. That's how we view cleaning and how most of our customers view it.

Las Marias: Is there anything else you would like to add?

Forsythe: I think there's one thing that might be good to cover. Our philosophy focuses on where science and care converge. And we believe in pushing the science ahead. We do a lot of R&D, we do a lot of technical papers, and we're always working on new products and staying engaged with the industry. We help customers meet their technical needs because our industry changes the world every day. We're inventing new things that have new requirements.

The other important part of that concept is this idea of care about the outcomes for our customers. If someone's having a bad day today, we're standing next to them tomorrow to offer our expertise, as quickly as we can. Their success is our success.

Las Marias: Great! Tom, thank you very much again for your time.

Forsythe: Thank you. **SMT007**

Photos courtesy of Kyzen.

ASM Assembly Solutions on CFX

ASM Assembly Solutions was one of the 30+ companies participating in IPC's CFX (Connected Factory Exchange) showcase at the recent SMT Hybrid Packaging show in Nuremberg, Germany. In an inter-view with I-Connect007's Barry Matties, Thomas Marktscheffel, Director Product Management SW-Integration Platform, SMT Solutions, at ASM Assembly Systems, shared his perspective on CFX and its current challenges.

Marktscheffel also discussed what CFX will offer PCB fabricators and dispelled the notion that CFX might be a cookie-cutter approach to the smart factory.

Read the full interview here.

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Interview with a High School Robotics Team Mentor

Interview by Happy Holden
I-CONNECT007

On the floor of the recent Wisconsin SMTA Annual Tech Forum, I-Connect007 Technical Editor Happy Holden sat down with Aaron Denk, representing the local Cedarburg High School's robotics team.

Happy Holden: Aaron, how did you get involved with this activity?

Aaron Denk: I started on the robotics team as a freshman, just kind of absorbing the information, learning the techniques and tasks and things like that, and then I evolved into more of a leader, teaching the up-and-coming students as they came into the program. I was part of the program all four years of high school and I have continued being a mentor as I go through college, as well.

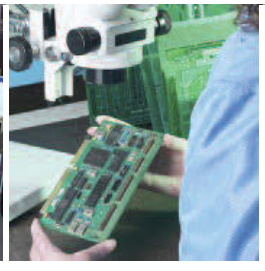
Holden: How did this affect what you chose to do in college?

Denk: As a high school freshman, I had no idea what I wanted to do. I knew that I enjoyed working with my hands, but I really had no clear direction as to what I wanted to do. Being a part of the high school robotics team really showed me that I had the love for mechanical engineering and it guided me to what I wanted to pursue in a degree and a career throughout the rest of my life. It taught me skills that other students in my classes did not have, putting me one step ahead of the others.

Holden: You mentioned that now you have the role of a mentor. What's that like on a team like this?

Denk: The high school robotics team is student-led and student-driven. The students make the



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decisions, but they work alongside industry professionals and a team of mentors that not only guide but teach and keep things rolling smoothly throughout the team. Students bounce ideas off mentors and take a second look at it. The mentors are there to guide and teach and to progress the students throughout the engineering process. We are a resource for the students as they run into design problems, and we help them as they brainstorm solutions.

We are a resource for the students as they run into design problems, and we help them as they brainstorm solutions.

Our robotics team is part of FIRST Robotics Competition, which is the highest and most advanced division of the robotics competitions through FIRST. FIRST is an acronym which stands for "For Inspiration and Recognition of Science and Technology." That is the parent organization of the different robotics competitions. Throughout the FIRST robotics competitions this season, our team competed in St. Louis and the Wisconsin regional. At the Wisconsin regional, we qualified to go to the world championships this year in Detroit.

Holden: How did you guys do and who won, do you remember?

Denk: We ran into a little programming issue at Worlds that set us back just a little bit, but we were competitive. We learned throughout the whole experience and it was a memory to last a lifetime for the entire team. It was the first time the team made it that far. The students put in long and hard hours, and seeing their robot compete at such an advanced level made it worth it.

Holden: What have you learned by being part of the team versus the more traditional high school activities?

Denk: The neat thing about the high school robotics team is that it requires the knowledge that you learn in school, and it lets you apply it to a problem-solving challenge; you can see your successes at the competition. By learning these additional skills and using those skills, I was one step ahead of all the other students that are in some of my classes at college. Advanced manufacturing techniques and industry-level CAD software are just some of the things that are taught in robotics and not in school.

Holden: Do the mentor and sponsors conduct classes in these new skills that might be needed to compete like this?

Denk: There are some engineering classes and things like that, but nothing to this level of application and this level of industry work. Some of the stuff we do isn't taught during the school day, for example TIG welding, SolidWorks, C++ programming. That kind of stuff isn't taught in school, but it is used in the industry, so being part of the team got students access to these skills and these programs and they'll be one step ahead of everybody else as they go into the industry or go into a career. When our students put on their resume that they have these experiences and have the knowledge of these advanced programs and skills, they are ahead of others coming out of high school.

Holden: I have taken a picture of their relatively large, complex robot. Was that designed, built and programmed by the students?

Denk: Yes, we have a team of about 20 to 25 students who participate in this after school club, totally student driven, student led, student designed. The team of mentors is there working alongside them, but if a student thinks that they want to make this change, they meet with their students and work through the pros and the cons of this design change and they work through all the situations that might occur and the alternate solutions, and they make the final decision as to what they want to pursue. So it is really a student-

based team and they teach themselves and they work with one another, but alongside mentors.

Holden: What school are you attending and what is your major?

Denk: I'm a sophomore at Milwaukee School of Engineering, majoring in mechanical engineering.

Holden: Do you think the experience in high school has helped you in engineering?

Denk: Most certainly! This program really guided me into mechanical engineering so that is the first way that it has helped me. But by teaching me leadership skills, working with a team, problem solving, all these things that the average student doesn't really get, set me up for great success. I can compare myself to my classmates and a lot of them don't have the knowledge and skills that I learned from the robotics team.

Holden: What software or what language is used in robotics?

Denk: The students program in a language called C++. It's a programming language that students can get their feet wet with before they go out into the industry.

Holden: As a mentor, what's your advice to others about how to get started or become involved by lending help?

Denk: I know teams all over are looking for mentors to help teach these students. FIRST Robotics teams are all over the world, odds are there is a team near your hometown! The teams also look for sponsorship because that is a big part of keeping these teams running for building the robots, entry fees, going to competitions and things like that. Teams always are looking for more mentors to help the engineers of tomorrow. For more information about FIRST Robotics you can go to firstinspires.org

Holden: Thank you, Aaron, for giving us your time and best of luck to the Cedarburg High School Robotics Team next year.

Denk: Thank you, Happy. SMT007

Hex Hounds 2018 Season Highlights: Testing, STL Regional and WI Regional.

Electronics Industry News and Market Highlights

5G Networks Have a Paramount Role in Autonomous Vehicle Connectivity ▶

5G networks may be as much as 10 times more efficient than 4G networks. With this new level of network capability, communications service providers can secure future market opportunities with manufacturers of autonomous vehicles in the fields of driver safety and data processing and management, according to Gartner Inc.

Global Electronic Warfare Market to See CAGR of 6.2% from 2017-2026 ▶

The global electronic warfare market is expected to reach $38.31 billion by 2026, growing at a CAGR of 6.2% during the 2017-2026 period.

Micro LED & Mini LED Market Expects Explosive Business Opportunities ▶

Micro LED displays and mini LED backlight technology have been the focus of spotlight in this year's exhibitions of consumer electronics and display technology.

Global Semiconductor Industry Down 3.4% to $115.8 Billion in Q1 2018 ▶

Global semiconductor industry revenue declined 3.4 percent in the first quarter of 2018 falling to $115.8 billion. Semiconductor industry performance was negatively affected by the declining sales and first-quarter seasonality in the wireless communications market. according to IHS Markit

Flexible Substrates Market Worth $775.8 Million by 2023 ▶

The flexible substrates market is projected to grow from $402.9 million in 2018 to $775.8 million by 2023, at a CAGR of 14% from 2018 to 2023, according to MarketsandMarkets.

Right to Internet Access in Malaysia to Positively Drive Digital Economy and Country GDP ▶

International Data Corp. (IDC) believes that the recent proposal in Malaysia to include the right to internet access in the Federal Constitution will create a positive impact in driving the digital economy and GDP of the country.

Traditional PC Market Grows 2.7% in Q2 of 2018 ▶

Preliminary results for the second quarter of 2018 showed shipments of traditional PCs—desktop, notebook, and workstation—totaled 62.3 million units, recording solid year-on-year growth of 2.7%, according to the International Data Corp. (IDC) Worldwide Quarterly Personal Computing Device Tracker.

Worldwide Smart Home Devices Market Forecast to Ship 549.5 Million Units in 2018 ▶

The worldwide smart home devices market, inclusive of smart speakers, digital media adapters, lighting, thermostats, is forecast to ship 549.5 million devices in 2018, growing 26.8% over the prior year.

Semiconductor Equipment Market to Reach $62.7 Billion in 2018 ▶

Releasing its mid-year forecast at the annual SEMICON West exposition, SEMI reported that worldwide sales of new semiconductor manufacturing equipment are projected to increase by 10.8% to $62.7 billion in 2018, exceeding the historic high of $56.6 billion set last year.

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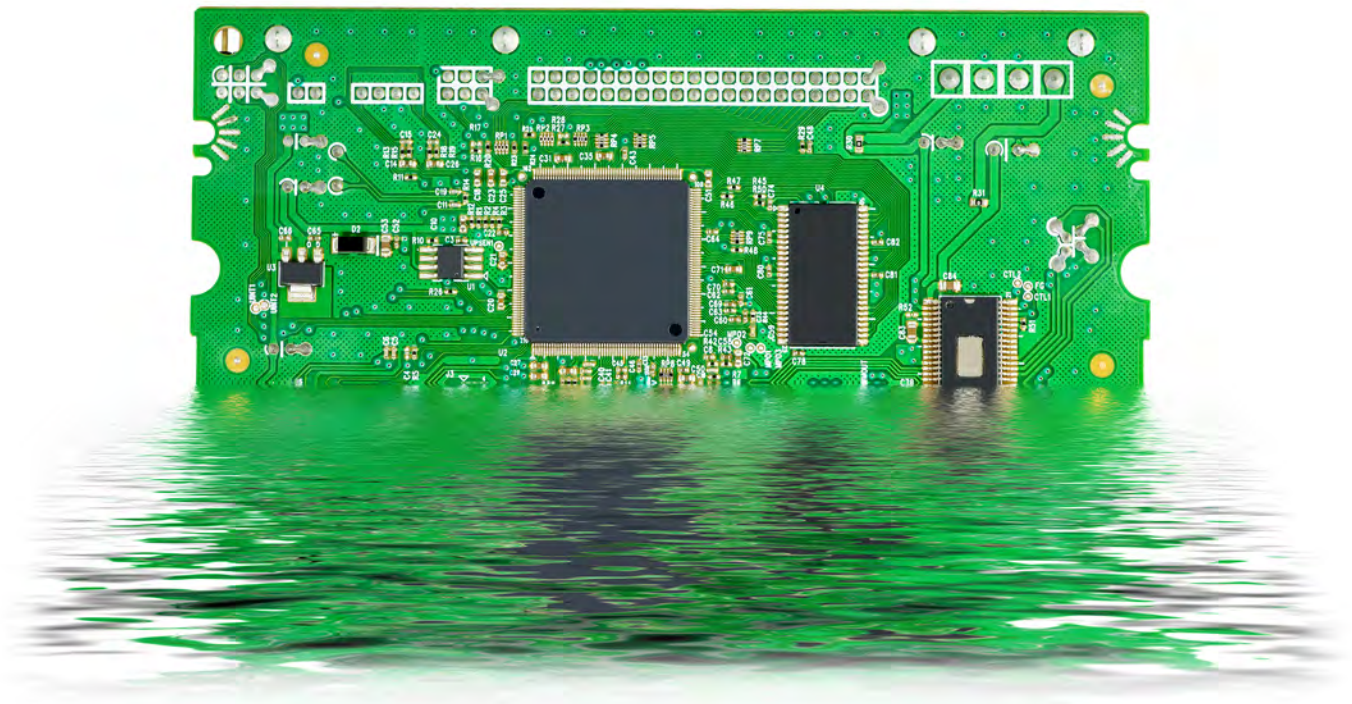

Is Component Testing Using ROSE Practical?

Feature by Joe Russeau
PRECISION ANALYTICAL LABORATORY,
and Mark Northrup
IEC ELECTRONICS

In a previous article, "It's Time to Retire ROSE Testing," we discussed the basis for why ROSE testing should be retired as an industry cleanliness or process control test. In this article, we reemphasize our position by highlighting some work we presented at the 2017 SMTA International Conference comparing component cleanliness results from the Resistivity of Solvent Extract (ROSE) against Ion Chromatography (IC) results. For those of you interested in reviewing that body of work, the working title was "PCBA Component Cleanliness Specifications Limits are Lacking."[1]

The ROSE test has been used in the electronics industry since the early 1970s. It was originally developed to estimate the amount of residual rosin flux remaining on a printed board. The predominant flux from that era contained greater than 30% rosin. So, it should go without saying that modern day flux technology and circuit designs are vastly different from those 70s-era predecessors. By that same token, our methods for assessing the ionic cleanliness of printed board assemblies are vastly different as well, right? Well, not exactly. The ROSE test is still the most predominantly used ionic cleanliness test in our industry and in truth, it has not been modified or changed since the early 1980s. In addition, ROSE testing is not only used for determining the ionic cleanliness of printed boards and printed board assemblies, but it is also being used for evaluating the cleanliness of components [2].

In the previous article, Mark and I indicated that there were two important attributes necessary for evaluating the ionic cleanliness of PCBs and PCBAs. These attributes would be considerably more crucial for evaluating components. We said that those two attributes were selectivity and sensitivity. To properly evaluate ionic cleanliness, it is important to use as little extraction solvent as possible (to concentrate the residues to the area being evaluated) and to have a system that can

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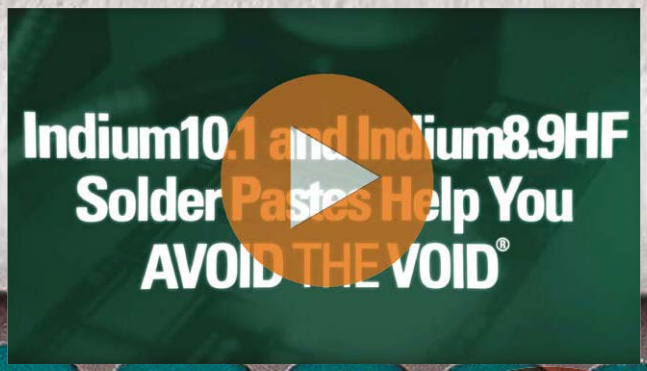

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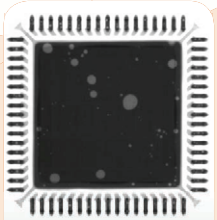

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Component Cleanliness IC/ROSE Data

Ion Name	Chemical ID	797-S29GL512P12FFIV2 (Sample Group #2)			
		1001-001-18	1001-001-19	Mean	Mean / Part
Lithium	Li^+	0.00	0.00	0.00	0.000
Sodium	Na^+	0.10	0.10	0.10	0.010
Ammonium	NH_4^+	0.15	0.16	0.16	0.016
Potassium	K^+	0.37	0.37	0.37	0.037
Magnesium	Mg^{2+}	0.02	0.02	0.02	0.002
Calcium	Ca^{2+}	0.00	0.00	0.00	0.000
Fluoride	F^-	0.00	0.00	0.00	0.000
Chloride	Cl^-	0.23	0.26	0.25	0.025
Nitrite	NO_2^-	0.00	0.00	0.00	0.000
Bromide	Br^-	0.16	0.16	0.16	0.016
Nitrate	NO_3^-	0.02	0.03	0.03	0.003
Phosphate	PO_4^{3-}	0.00	0.00	0.00	0.000
Sulfate	SO_4^{2-}	0.00	0.00	0.00	0.000
Acetate	$C_2H_3O_2^-$	0.00	0.00	0.00	0.000
Formate	CHO_2^-	0.22	0.25	0.24	0.024
Succinate	$C_4H_4O_4^{2-}$	0.07	0.16	0.12	0.012
Adipate	$C_6H_8O_4^{2-}$	0.00	0.00	0.00	0.000
Maleate	$C_4H_2O_4^{2-}$	0.00	0.00	0.00	0.000
Citrate	$C_6H_5O_7^{3-}$	0.00	0.00	0.00	0.000
		Total Measured Ions (µg/cm²) by IC		1.43	
		ROSE Results (µg NaCl eq / cm²)		0.01	
		IC Results Na and Cl ions (µg/cm²)		0.35	

1. Five parts tested per sample (2 samples total)

Figure 1: IC has considerably greater selectivity than does ROSE and can identify specific ion species from a sample extract.

identify each specific residue that is present. The ROSE test provides a single bulk value (not ion selective) and liters of solution are often used, which affects the sensitivity. Please consider the results in the following table taken from our 2017 SMTAi presentation.

Before I discuss the results in Figure 1, it would be prudent to first discuss what was done. First, the cleanliness of five different ball grid array (BGA) groups (i.e., size, ball count and pitch) was baselined using IC. We processed two replicates for each group because we had a limited number of parts to work with. The BGAs were then sent to be re-balled using a standard robotic reballing process. The ionic cleanliness of each group was then re-evaluated using the ROSE test as defined in the GEIA-STD-0006 and again with IC. The solvent volumes used for each test were five milliliters for the IC test and ninety-eight milliliters for the ROSE test.

A side-by-side overview of what was done for this testing is shown in Figure 2.

The different ions listed in Figure 1 are from the IC test. As we have indicated, IC has considerably greater selectivity than does ROSE and can identify specific ion species from a sample extract. At the bottom of the table is a red circle around the ROSE and IC results. The ROSE result is expressed as µg of NaCl equivalents per square centimeter. It is important to understand that this is neither a measurement of sodium nor chloride, but an expression of the result compared to a standardized solution of a NaCl salt, which is used to standardize the instrument. The IC results are given as micrograms of ion per square centimeter. The IC results are direct measurements made back to certified standards of specific ion species. Each ion species is calibrated separately.

In our example, we compared the ROSE result with the sodium and chloride ion results

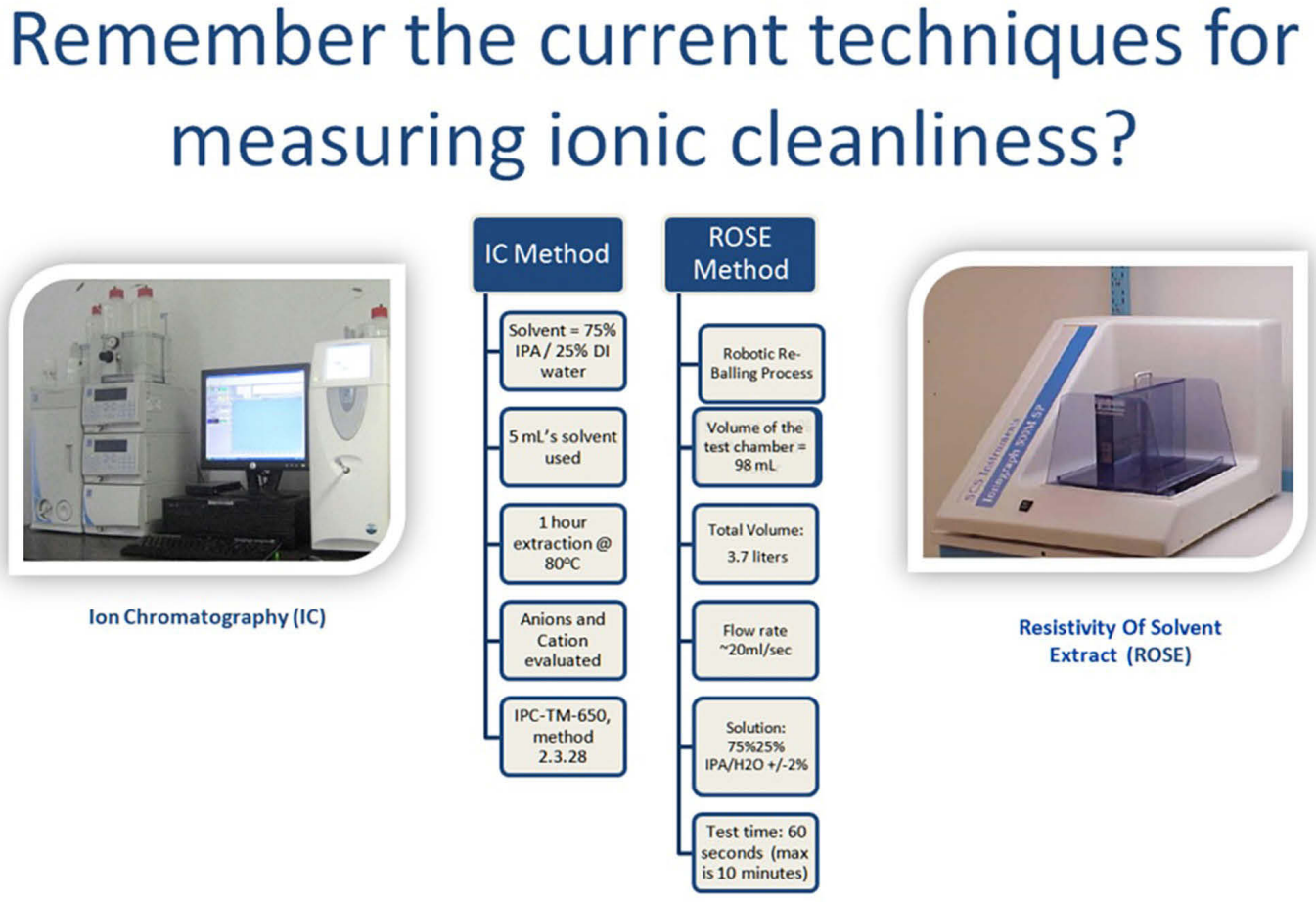


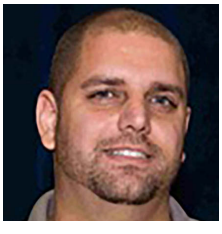
Figure 2: IC versus ROSE method.

from the IC test. The sodium and chloride ion results from the IC test were added together to be able to make the comparison to the ROSE results. Please be aware that this is not an exact comparison of the results from the two tests because of how their units are defined (µg of NaCl equivalents/cm^2 vs. µg/cm2).

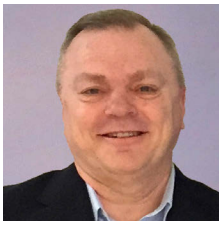
Comparing the ROSE results to the IC results, we found that the IC test gave a substantially higher response on four of the five tested BGA groups when comparing just two ions. If you consider all the ions that were measured by the IC compared to the ROSE results, there was no comparison. The IC test provided far more insight into the ionic cleanliness of all five BGA groups. Please be aware that we are not making a claim in this study about "how clean is clean enough?" We are showing that the ROSE test is an inadequate tool for low level evaluations of ionic residues as are needed for modern electronic products. **SMT007**

References

1. SMTA International 2017 Conference Proceedings, "PCBA Component Cleanliness Specifications Limits are Lacking."
2. GEIA-STD-0006



Joe Russeau is president and CEO of Precision Analytical Laboratory. To contact Russeau, click here.



Mark Northrup is VP of technology with IEC Electronics.

PCBAs: To Clean or Not to Clean

Feature Interview by Stephen Las Marias
I-CONNECT007

With the opening of its new technical facility in Hsinchu, Taiwan, Zestron now owns a total of eight globally linked technical support facilities throughout the world. The new facility includes an analytical lab, a technical center, and office space, and it will enable the company to deliver comprehensive cleaning trials with various cleaning machines and cleaning agents right to the doorsteps of its customers in Taiwan.

In an interview with *SMT007 Magazine,* Dr. Harald Wack, president of Zestron, explains the challenges their customers face in cleaning, the increasing need to clean PCB assemblies, and the role of automation in the cleaning process.

Stephen Las Marias: First, tell us more about Zestron, including how business was last year, and your outlook for this year.

Dr. Harald Wack: Most of our products are water-based products. The last 10 years, we have developed a lot of very innovative green chemistries—pH-neutral products to clean flux residues and with concentration levels of between five to 10%, sometimes 15%. So very green, with a lot of DI (deionized) water being the rest of it.

We've had a tremendous amount of success in the last 10 to 15 years. The last year has been double-digit growth, mostly higher double-digit growth in Asia. In the U.S. and Europe, it's more of a mature market, but I think it must be probably between 10 and 20%. Overall, we've seen very satisfactory results, and we've been humbled by this success. We continuously try to get better and work on what we can improve in our company. The first couple of months this year had been also very positive.

Las Marias: What are some of the major drivers of growth for the company?

Wack: Numerous markets are employing more and more electronics devices, including automotive, Industry 4.0—with the machines talking to each other—and the consumer

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	Development:	12 plus Layers
Rigid Flex Technology	Standard:	4 - 14 Layers
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world. There's a lot of positive changes towards cleaning because all these electronics are not only increasing in number but are also getting more complicated. Overall, it's become challenging to clean and provide value, and that's what we are good at. We like challenges.

Las Marias: What are the greatest challenges that your customers face when it comes to cleaning?

Wack: Well, none of our customers would want to pay for cleaning if they wouldn't have to. So, customers will come to us with their challenges, and they come to us to look for solutions and help. Like I said, they don't do it voluntarily because that's an added cost. You don't see a cleaning agent on the component or circuit board afterwards, but it adds value because it removes contamination. So, when customers come to us or to the competition, they know they need help. But at least when we talk to them it's a clear understanding and expectation they have of us to help them solve their problems. Typically, people come to us for cleaning challenges, environmental challenges, and a lot of them have come from the no-clean world and haven't cleaned before; they're looking for education and general understanding of how to set up a process.

You don't see a cleaning agent on the component or circuit board afterwards, but it adds value because it removes contamination.

It's a varying degree of things that they asked us for, but in the end, it all centers around support, education, helping them set up processes, improve processes, cut the cost, go greener, and look for more environmentally sound products; sometimes they come to us because they look for new products. Every year, our innovation index is very high—the number of new products relative to current products. So, a lot of customers are interested in testing the new products; if there's something like a new set up, it spurs a lot of general interest from the customers. I think most come to us because they have cleaning challenges—sometimes new cleaning challenges that they haven't had before.

Las Marias: You mentioned there are also companies that aren't really cleaning their assemblies.

Wack: In the 1990s when the no-cleans came out, we thought we would go out of business. But as it turned out, no-clean is not no residue, it's low residue. And for some high-end applications, military or aerospace or medical, even automotive, that little residue is still too much. However, there is still a big contingency of customers who are not cleaning. They are just using no-clean and coating over it, and so far, for those applications, it seems to be good enough; maybe in the future, that will change and give us an opportunity to help them as well.

Las Marias: There seems to have this misconception when it comes to no-clean flux. Some still think that when you say no-clean, there's no need for cleaning.

Wack: Some customers will try as much and will go as far as they can in terms of reliability, if it is for whatever product lifespan is acceptable, and if they can get away with not cleaning, they will. As soon as it begins to fail, and they see issues—and that's across all industries—they come to us and say, "I am at the point that I have to start cleaning no-clean." And a vast number of our customers clean the no-clean because they have reached that point already.

Las Marias: Where does Zestron come in? How are you helping customers address their cleaning issues?

Dr. Harald Wack

Wack: Typically, what we do is when we see new trends happening in the industry, we set up technical studies—we try to be proactive and communicating the challenges. Some customers are also proactive—they read and inform themselves, they understand problems that we have described, and how to go about resolving those. We pride ourselves in being proactive when it comes to creating technical educational content and informing the customers up front, and being very innovative and bringing out new products, be that on the chemistry side or auxiliary product. We are very strong in this aspect with our educational arm, Zestron Academy. We don't sell chemistry products per se, but we sell information. We try to educate customers.

Las Marias: How clean is clean?

Wack: There are a lot of different standards in the U.S. and in Europe; different organizations have certain industry standards, be that IPC or the SMTA. It's different in Germany and Japan has their own; every industry has different associations, and there's no right answer to that.

Despite the industry association limits or recommendations, every customer has their own limitations and experiences. If the contamination value, however you measure it, reaches certain limits, then you can associate that to reliability. It typically turns to how long this result is good for my product quality or reliability, depending on what environment it is in.

So, the answer is complicated because it depends on what industry you are in, your requirements, what instruments or measurements you do want to use, and then what standard do you set yourself to. Do you go by an industry standard, or by individual experiences? There's just no one answer.

Las Marias: Are you seeing a strategy shift when it comes to cleaning?

Wack: Because everything's getting smaller, the trend is turning into more cleaning, as it has been in the last 10 years. It just continues because the space becomes exponentially less; now they are starting with systems and packaging, they are moving some of the semiconductor aspects into the SMT market. The things are moving

together and merging and suddenly it becomes even more complicated. And if you look at the growth of these components, which are now going vertical, you have 3D substrates. The customers are expected to clean in between each while you are assembling those or during the assembly process. In the past, we've cleaned under one component; now we must clean under many components. That's just one example of how things are getting more complicated.

Then, it's getting smaller and smaller—so the low-residue, no-clean, is enough residue for them to cause failures. The trend towards cleaning continues to grow, and I think the amount of people that are cleaning, therefore, increases.

Las Marias: Are you still seeing instances where the operators are making mistakes when it comes to their cleaning processes?

Wack: I think we all make mistakes every day; but yes, we do see a lot, and most of the time, that's because the responsibilities in companies are not very clear. In a very few companies you'll find individuals who are designated for cleaning. In most companies, you go in and ask who's responsible for cleaning—usually the answer is it's a shared responsibility. A lot of customers don't have individuals for just one equipment responsibility. They share. And when you share, you have a little knowledge of each, but not a high knowledge of one. So, that's part of the reason we started the academy because we realize a lot of customers need teaching. Sometimes, when new engineers come in and have no experience about cleaning, we train them for a couple of days if they are interested in that. We offer it for a reason—because we realized that a lot of young engineers simply don't have the experience in cleaning. With cleaning, you look at the process; you can teach people for weeks just about the cleaning process. A lot of information, a lot of aspects needed to be considered, based on the experience we've gained over the years. So, we look forward to customers who we know need cleaning; it's probably one of the reasons we're set up the way we are, even the technical center we opened today offers possibilities and facilities to further the educational effort we're now doing here locally with our local engineers.

In most companies, you go in and ask who's responsible for cleaning—usually the answer is it's a shared responsibility.

For big companies, we have written handbooks on cleaning to help them disseminate information or we come in and give customized seminars for those companies who can't come to us. We are proactive, and we see that as a competitive advantage, that we can offer such seminars.

Las Marias: How does automation factor in when it comes to the cleaning process?

Wack: Here's an example: The cleaning process includes, among other things, a cleaning reservoir where the cleaning agent is put in. The cleaning agent needs to be mixed at a certain percentage. That's one good example where human error comes into play—we have an operator that misreads information, isn't trained on how to correctly measure the concentration, and then assumes that it's a certain concentration, and doesn't measure it often enough—there are variations in the cleaning process because you are dragging in contamination. This cleaning agent being dragged out because the conveyor or the batch process—whatever machine you have—changes constantly, and you have to be on top of it to understand at what point and how quickly it changes and how to adjust for it.

Just the simple aspect of maintaining a certain concentration correctly is not as trivial as it sounds, so we have devised certain tools to automate that piece of it through a unit,

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Dr. Harald Wack (third from right), president of Zestron, and Dr. Oskar K. Wack (second from right), founder of Dr. O.K. Wack Chemie GmbH–the parent company of Zestron–during the opening ceremony of their Taiwan technical center.

which is an ultrasonic that measures the concentration correctly. It takes that human factor out, or completely automates it with a system we call Zestron CM, which douses the water and the chemistry in the wash tank. It not only measures it, but adjusts for the volume loss in the cleaning tank.

That helps overall by providing data in whatever other system integrates data; that's sort of our most recent endeavor to help in Industry 4.0—providing data and automating it to avoid human error.

Las Marias: And you can rest assured that the cleaning bath for your system has this some sort of stability control.

Wack: What a customer assumes, and their customer, in turn, is a certain product quality. And the product quality is easily affected by two or three percent below concentration limit or specified concentration of it. So, if you say you need to be 10%, then for some reason, the machine puts a little bit more DI water to sometimes adjust for low-level alarms, you go down to 5% and it might not clean anymore. And you keep running, and some of these machines—called inline machines—are big, they clean thousands of boards. So a certain batch of these boards were just cleaned at 5%. Then you have to re-run them. It's a lot of extra work, maybe it is more difficult because you run it a second time; there are just unnecessary things that you can easily avoid by using automated aspects in the process.

Everybody wants to be automated and digitally connected to suppliers and customers and so on, to make less of a human aspect of it because we all make mistakes.

Las Marias: Manufacturers tell us that today, communication and collaboration are critical factors to success. Is that your experience as well?

Wack: We have had longstanding relationships with all the equipment manufacturers who do want to collaborate with us. Most of them do, because they see the benefit. Here's one example: A customer buys a new machine thinks that's the greatest machine ever. And then he stands in front of it and says, "I think I need to use chemistry in there," versus, maybe before, using only DI water, which didn't clean. The machine may or may not be suitable for chemistry in the first place, so he might have to retrofit it or buy a new machine, and then he realizes he made a big mistake.

Collaboration usually helps the customer win because they can proactively inform themselves as to what combination, what budget or throughput, what aspects of the overall cleaning process work for them in the best way.

We see ourselves as a facilitator. The tech centers we have are showrooms in a way, but they are also process specification rooms, so

that you can see the machines and you can compare. The other thing is you can try them out, you can bring substrates and you can see; and at that point, you begin to understand the many aspects of the cleaning process. You go from cleanliness to material compatibility to process settings to chemistries that are out there. We, obviously being one of the suppliers, have to make certain decisions. So, it helps us, the customers, and everybody in the value chain to talk to each other. These technical centers are typically equipped by our equipment partners because they see the benefits of putting their machines in. Then the customers come in and use it; we have no financial benefit in it because we don't see it as a value add. But we want to be an objective platform to recommend certain processes. Typically, when the customers ask us for advice, we give them two or three recommendations just to stay neutral. But it's relevant for us to have our own engineers understand the equipment and the cleaning equipment manufacturers understand our products.

Las Marias: What factors should users consider when selecting their cleaning process?

Wack: Every customer has a different requirement, a different substrate, and a different specification in terms of cleanliness. There's not one product that we recommend. So, we use the tech centers to run the trials and the machines and the cleaning product. We have extensive knowledge of cleaning all the solder pastes that are currently used in the semiconductor or SMT industry. We have an internal cleaning platform where we keep track of all the data, so that when the customers come in and say they are using solder paste one or two, we know roughly what process we've cleaned this with before, what machines we've cleaned it with, so we can conduct a fairly easy first trial and see if we're going the right direction. Then there might be optimization or other aspects, from water generation to water disposal, that the customers may be interested in. There are so many facets to the cleaning process that it's first a discussion when they come, then it turns to the trials and continues. But overall, general customer process or project probably takes on the order of six to 12 months before implementation. It's not something you can do overnight or over the weekend.

Las Marias: What can you say about the future of the cleaning industry?

Wack: I think it's very bright; we have benefitted from the increase in cleaning demands over the last 10 years. I just don't see an end to it because as I've mentioned earlier, everything's becoming more integrated and smaller, and more difficult to clean. It will probably move more people to clean either with water or with DI water, for organic acid (OA) or no clean fluxes, and they will turn into probably potential and future customers of ours. Now that we have more or a presence in Taiwan, I think they will help us to capture more market share; and because we are here, we can demonstrate and show customers what they gain by working with us. We'll only win if the customer wins, that's usually our motto.

We'll only win if the customer wins, that's usually our motto.

But in general, I think the future of cleaning is bright—it's across all industries, in automotive, in consumer electronics, or maybe higher-end products as well.

The other thing is that, generally, more electronics are being produced, new innovations are coming out, so if there is no replacement to the solder paste, I think customers will continue to merge towards more cleaning in the future.

Las Marias: What are the challenges for your company?

Wack: The challenge is getting to the people before they realize that they have a problem.

We try to do that proactively with studies and communication. We find out that a lot of cost is generated by waiting for the failures to happen, so we try to educate customers. There are many challenges. We continue to be highly self-driven, we bring products that relevant to the market, and we see ourselves as a standard to improve upon. On the physical challenges, if the components become too flash mounted on the surface, at some point, there's a physical barrier that needs to be overcome, that will be some sort of a challenge for us, and we have to see how we can manage and overcome that. But other than that, I see only opportunities. I don't see too many challenges.

Infrastructure-wise, we are well positioned, I think, to handle all of Asia. There are certain internal organizational developments that we try to grow within the company in order to establish global procedures, but we are already addressing those, and we recognize that needs to be done. Growing bigger comes with more facilities, so you have to make sure you are organized in product development and other globally linked processes are in place. But I think we are on a good track. And yes, there will be challenges, but so far, we've had the humbleness and the self-awareness to recognize them and work on them and be systematic about finding solutions.

Las Marias: Do you have any final words?

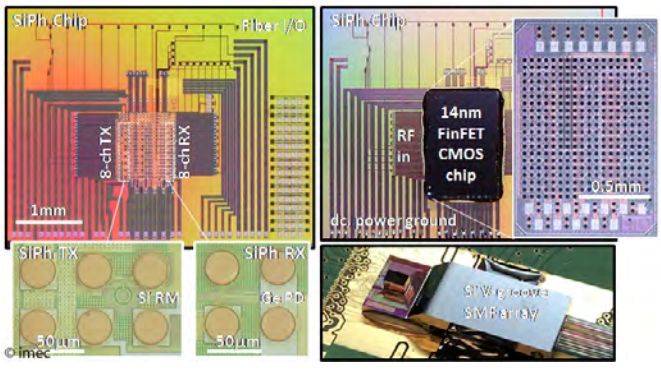
Wack: I appreciate the opportunity you've given us to talk to you and express some of our thoughts and opportunities and future outlooks. I am satisfied with the time I've had the pleasure of spending with you. Thank you for the opportunity.

Las Marias: Thank you very much. **SMT007**

Hybrid FinFET-Silicon Photonics Technology for Ultra-low Power Optical I/O

Imec has demonstrated ultra-low power, high-bandwidth optical transceivers through hybrid integration of silicon photonics and FinFET CMOS technologies.

In the presented work, a differential FinFET driver was co-designed with a silicon photonics ring modulator, achieving a 40Gb/s NRZ optical modulation at 154fJ/bit dynamic power consumption. The receiver included a FinFET trans-impedance amplifier (TIA) optimized for operation with a Ge waveguide photodiode, enabling 40Gb/s NRZ photodetection with an estimated sensitivity of -10dBm at 75fJ/bit power consumption. High-quality data transmission and reception was also demonstrated in a loop-back experiment at 1330nm wavelength over standard single mode fiber (SMF) with 2dB link margin. Finally, a 4x40Gb/s, 0.1mm2 wavelength-division multiplexing (WDM) transmitter with integrated thermal control was demonstrated, enabling bandwidth scaling beyond 100Gb/s per fiber.



"The demonstrated hybrid FinFET-silicon photonics platform integrates high-performance 14nm FinFET CMOS circuits with imec's 300mm silicon photonics technology through dense, low-capacitance Cu micro-bumps. Careful co-design in this combined platform has enabled us to demonstrate 40Gb/s NRZ optical transceivers with extremely low power consumption and high bandwidth density," says Joris Van Campenhout, director of the Optical I/O R&D program at imec.

This work has been carried out as part of imec's industrial affiliation R&D program on Optical I/O and was presented at the 2018 Symposia on VLSI Technology and Circuits (June 2018) in a "late news" paper.

Source: Imec

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3D Printing: Enabling a New Manufacturing Landscape

Source: Stratasys.com

Interview By Happy Holden
I-CONNECT007

Scott Schwarz, senior sales representative for rapid technology at Fisher Unitech, sat down with I-Connect007 Technical Editor Happy Holden at the recent Michigan SMTA Tech Forum to discuss advanced 3D printing applications.

Happy Holden: Scott, please tell our readers something about your company.

Scott Schwarz: I've worked with Fisher Unitech for 10 years and I started from the field service/technician side and transitioned into sales. Fisher Unitech deals primarily with Stratasys 3D printing as well as Artec 3D scanning. We are also involved with 3D CAD on the SolidWorks side and Mastercam. We're a product-driven company and we are heavily involved in customer applications. My territory is primarily focused in the southeast Michigan area. My customers range from automotive suppliers to OEM groups.


CUDA 3D Printed Underwater Jetpack
Source: Archie O'Brien

Holden: What are some of the highlights of your technical talk?

Schwarz: What we talked about were some of the advanced applications that have made some of the biggest impacts in the automotive manufacturing arena. Applications such as injection molding to conceptual modeling, and as far as die cast components and structural mock-ups. We've done a lot of different applications with a lot of different industries, and we wanted to just bring that to the forefront and inform people of the magic going on behind the scenes. All of these advanced applications were designed by our customers, not by Fisher Unitech or Stratasys, we only aided in making the application successful. We've developed this with our strategic partners, and we've perfected all these applications over time.

Holden: What interests do people have for the diversity of some of the projects you've seen?

Schwarz: I primarily deal with a lot of automotive. The introduction of 3D scanning has also made it possible for us to penetrate into the medical market.


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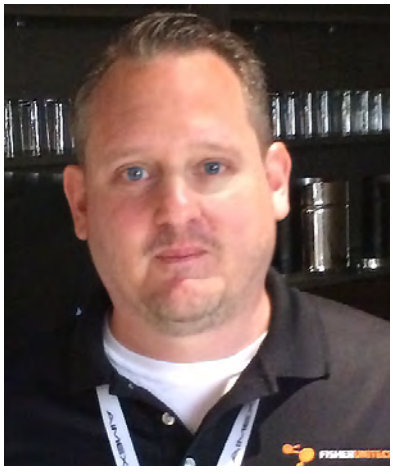
Low volume and complexity is our world in the 3D printing market, it's what we call the additive sweet spot. Obviously no two people are the same, so it lends itself very well to additive manufacturing or 3D printing. A lot of this customization will come into play when discussing prosthetics for individuals or pre-planned surgery/ surgical guides. There are other companies that we are not directly involved with, that are getting into what they call bioprinting. This is where we're taking man made T-cells and introducing DNA into the cells to create tissue samples of individuals. It's an ever-changing market and just the diversity from the medical side to aerospace, to consumer goods and automotive—it's all different in every single facet.



Scott Schwarz

Holden: Are some of these plastics suitable in the prototype or short-term to replace metal castings or things like that?

Schwarz: Castings would be a little tricky. I would say the jig/fixture applications are where we've made a very, very big impact. Areas like assembly fixturing, weldment fixturing, where some of our higher heat, chemically resistant materials have replaced a lot of traditional metal tooling. Where that makes the biggest impact is usually from a time and cost standpoint for our customers. Traditionally, making metal tooling for either pre-production or actual production can be very costly, especially from the pre-production side just for proof of concept. We have a big impact there because our tooling is a fraction of the cost and the turnaround time is extremely quick. That's where we see the biggest impact on the manufacturing side: in the fixturing market for replacing metal tooling.

Holden: From a financial point of view, does 3D printing make sense in today's market where time to market is so important?

Schwarz: Yes, for sure. What we're doing with 3D printing that makes sense from a time standpoint is catching the design flaws early on that prolongs going to production. We can make many different reiterations much quicker, which helps with the cycle product lifeline. It also helps with being able to have parts in hand before we move into production. Not only are we catching design flaws, but we're testing our form, fit and function, and we're able to prove the concept out much earlier on. Traditionally, waiting for the tool to show up or creating our in-house tooling and ultimately a product that we still need to prove out has been a downside in pre-production

Holden: Are some of these materials flexibles?

Schwarz: Yes, we do have materials that are flexible in both sides of the technology. Traditionally, our PolyJet materials were the ones that have been flexible. On the PolyJet side, we use a type of printing style that allows multiple materials within the same build. We can take what they call rubber-like materials and rigid materials and blend them in a physical model, where I can have a rigid component with a rubber overmold around the outside of it. On the FDM side, we are getting into actual elastomeric materials that will be extruded through our FDM process.

Holden: I was watching you demonstrate, and the machine was switching to a material that was soluble. Later, I guess it would be moveable or freed up from other parts that were printed?

Schwarz: That's correct. On both our FDM and PolyJet technology, our secondary support structure not only adds as scaffolding to our part for any areas that go beyond a 45-degree angle, but it also works as a material to separate moveable components in an assembly. Because were growing the part from the ground up and

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introducing that support structure mid-build, we can wash that component away from the actual model and have a full working assembly without having to assemble it after the fact.

Holden: With all of this, where do you see this technology heading? I think it's probably just in its infancy right now.

Schwarz: Well, ironically, the technology has been around for 30 years. Stratasys just celebrated their 30th anniversary of its inception by Scott Crump, in 1988. All the applications have been customer-driven, so we've seen it blossom on the customer side more so than our side. Where we do see it is with the advancements of materials getting stronger and higher temp. We're getting into higher-end advanced applications than we have ever thought possible. We've broken into the aerospace industry for end use parts. Ultimately, the goal for 3D printing is to one day be able to produce production parts from 3D printing. We're seeing that on the medical side, we're seeing that on the aerospace side, and we're seeing that in the racing industry. We'll take a little while to get there on the automotive side and the consumer good side, but I think it's right around the corner.

Ultimately, the goal for 3D printing is to one day be able to produce production parts from 3D printing.

Holden: What other information or viewpoints would you like to leave for customers?

Schwarz: I would say a lot of people are reluctant to break status quo in a lot of industries, especially when we talk to the supplier groups in automotive. It's hard for them to take something that they've always done out of metal and reconfigure their mindset to take on and try a plastic component, especially something that might have no reason to be a metal part. What we like to do is we like to go in and evaluate, start at the bottom, and then work our way up with our customers. We want to start out with the stuff we know will work, the easy stuff, prove it out, and then we want to push the limits to see how far we can take it. We will come to the facility and we will go through a thorough evaluation of how it's traditionally done, how we see it could be done, where that savings is, and how far we can push it. That's the actual trial process.

Holden: Have you ever started with a printed circuit board or flexible circuit and then 3D printed that where it became an integral part of the finished 3D printed part?

Schwarz: We have done a little bit with that. We have a material called ABS-ESD7. That's an electrostatic dissipative material. It's essentially an ABS material with nanoparticles of carbon in it, so it's static dissipative. We did partner with a company primarily to print circuit boards into the 3D printed ABS components; however, it was still only good from a prototyping level just because our ESD7 wasn't certified to go into production for automotive components at that level yet. I still say that from a material standpoint we're in our infancy, but as we grow, and these materials grow, we get closer and closer to that production level of our materials. You'll see those types of applications come back through as materials advance, and we'll see wiring removed from your automotive components and more electrical lines being physically printed into the 3D printed parts and going into vehicles.

Holden: There is a growing industry of printed electronics in which what's being printed is insulators or conductors. Are those materials compatible with your machines so that this could be a planar multilevel printed electronic?

Schwarz: They probably will be in the long run. I'd say right now we don't have many materials

dedicated to the electrical side of the business yet. We do have some metal materials that we are involved with, with a second vendor, Desktop Metal. We're still very early on in that relationship. Desktop Metal was just founded a year and a half ago. They're replacing the MIM, a metal injection molding technology, with a 3D printed version of that, which will be very interesting to see where their metals compare to traditional MIM technology. Currently with Stratasys, we only have the ESD7. I think as time goes on we'll develop more materials that have that nanocomposite inside, which should open doors in those areas.

Holden: We'll continue to watch this. 3D printing has a lot of potentials and we all will look forward to its rapid deployments and developments. Thanks, Scott.

Schwarz: Thank you. SMT007

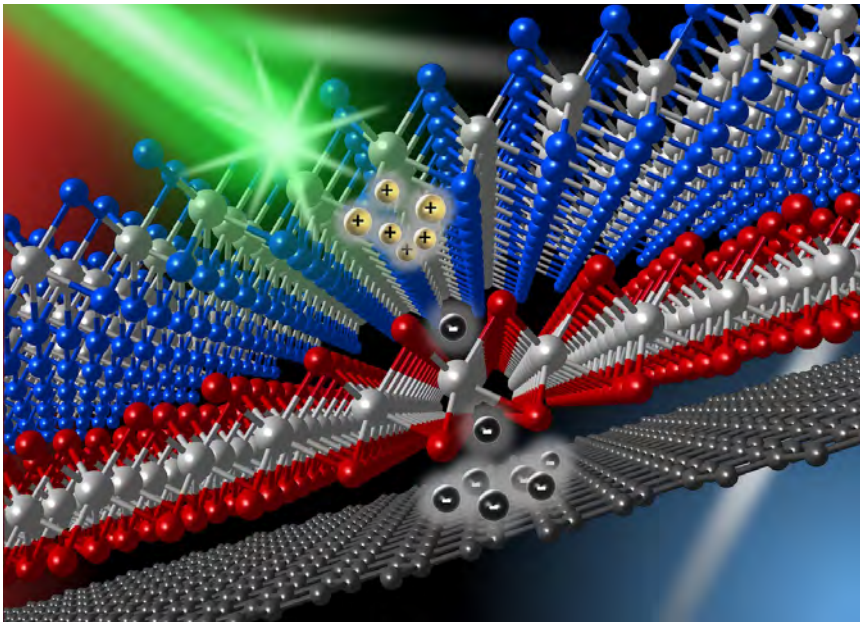
Researchers Improve Conductive Property of Graphene, Advancing Promise of Solar Technology

Two researchers from the University of Kansas, Professor Hui Zhao and graduate student Samuel Lane, both of the Department of Physics & Astronomy, have connected a graphene layer with two other atomic layers (molybdenum diselenide and tungsten disulfide) thereby extending the lifetime of excited electrons in graphene by several hundred times.

For electronic and optoelectronic applications, graphene has excellent charge transport property. But it has a major drawback that hinders such applications - its ultrashort lifetime of excited electronsof only about one picosecond.

The KU researcher said one of the biggest challenges to achieving high efficiency in solar cells with graphene as the working material is that liberated electrons – or, the standing students – have a strong tendency to losing their energy and become immobile. In their new paper, Zhao and Lane report this issue could be solved by using the so-called van der Waals materials. To achieve this goalthey designed a tri-layer material by putting single layers of MoSe2, WS2 and graphene on top of each other.

To demonstrate that the idea works, the KU researchers used an ultrashort laser pulse (0.1 picosecond) to liberate some of the electrons in MoSe2. By using another ultrashort laser pulse, they were able to monitor these electrons as they move to graphene. They found that these electrons move through the "hallway" in about 0.5 picosecond on average. They then stay mobile for about 400 picoseconds – a 400-fold improvement than a single layer of graphene, which they also measured in the same study.



The work at KU may speed development of ultrathin and flexible solar cells with high efficiency.

The findings will be published on Nano Futures, a newly launched and highly selective journal. The research was funded by National Science Foundation. Lane is supported by Self Graduate Fellowship.

Source: University of Kansas

Newly Re-branded Optel Software Lays Down China Strategy

Interview by Stephen Las Marias
I-CONNECT007

Optimal Electronics Corp., a provider of smart software solutions for electronics assembly, recently rebranded globally as Optel Software, as it starts its venture in China. In a recent interview with *SMT007 Magazine,* Dr. Ranko Vujosevic, CEO and CTO, updates on the latest developments from the company and discusses their plans in China and Asia this year.

Stephen Las Marias: Dr. Vujosevic, from the last time we spoke, you mentioned a lot of plans in China. How has it been so far?

Dr. Ranko Vujosevic: When we met in August 2017, we were exploring our entrance into the China market to start selling our software solutions that we had been developing for 19 years. I came to Shenzhen to meet potential partners, specifically WKK. We talked about it and they took me to their plant in Dongguan. They showed interest in partnering with us, but they have some preconditions: hire the right people; translate our software into Chinese; and establish a local presence.

They were reasonable requirements, of course, and we were planning to do all those things anyway. So, we jumped on that opportunity, and we first hired a person who has been in the industry for over 15 years to become our China Sales Manager in December of last year. Then we started the registration of our company in China. As soon as we hired him, we had a lucky break which happens when you are in the right place at the right time. On a hint from a WKK salesman, we learned that a Shenzhen company was looking for a complete MES solution and we were able to close a large deal with that customer that has 26 assembly lines within a few weeks. That was very surprising to me because in the U.S., to close a six-figure deal, it takes six months to a year, sometimes up to two years. We were able to close our first deal in China within two to three weeks.

Then we started preparing for our installation, while at the same time developing the business. We proceeded with the company registration and hired an application engineer with 20 years

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of experience in industry. We needed somebody to train customers and provide support locally. At the same time, we hired a marketing company from Houston to do a complete rebranding of our software.

We wanted to have a fresh international start. We already had a good reputation—people know us in the United States, but here, nobody knew us. So, we started with our new logo, brochure in English and Chinese, trade show banner in Chinese, and web site redesign. We attended NEPCON Shanghai in April 2018 as part of the WKK booth and we showcased our new marketing materials there.

We met all the main requirements that WKK wanted us to do and in February of 2018 we signed our formal representative agreement with WKK. We work very closely with WKK and I am extremely happy with our relationships and initial results. WKK is a major factor in our sales efforts, but we are also closing sales on our own.

Dr. Ranko Vujosevic

Las Marias: What was your experience dealing with your first China customer?

Vujosevic: After we hired our China Sales and China Application Managers, I sat down with them and we established our 3 main objectives for success in China: work hard to implement the best and the most complete solution possible, make sure our customers are better businesses after we are done with our project, and deal with customers and partners in the most honest way possible. Our first customer turned out to be an unbelievable positive experience. I did not know what to expect when we started the project, but what we discovered is a group of good and smart people, very hard working, and very open to any suggestions that can make their company better. We worked hard and we worked together to put in place a complex system that improved every operation in their plant. We developed a number of innovative solutions and actually are working now on applying for a patent together with our customer. The way they took care of us during implementation was outstanding and we are very grateful to them for that. Out staff on the other hand worked extremely hard to justify customer's confidence in us. There is no week when our first customer does not host our prospects and showcases our solutions. That is a significant component in our customer base growth and helping us close sales.

Las Marias: How has the situation been evolving in China?

Vujosevic: The fact that we are able to close deals much faster than in the U.S. is big for us. Because, we can plan our growth better. It is very difficult to sell something new in the United States now. China is the place where people want to try new things. China, and some other countries in South East Asia, are investing in AI and smart factory solutions. I am very excited about how things are developing in China. In my opinion, this is the place to be now for companies like ours. We are able to close large deals much faster than we could have ever done in USA, some of them with large international corporations with plants in many countries.

Las Marias: Are you limiting your presence in Asia to China only at this point?

Vujosevic: Not at all. We are also partnering with SIP Technology, a manufacturer's representative from Penang, Malaysia, with presence in Thailand, Vietnam, Singapore, and most of South East Asia. With their help, we just closed a large deal to help a company in Vietnam establish a smart factory for manufacturing of smart phones. SIP technology will deliver machines and hardware and Optel Software will deliver smart factory solutions. We will build a plant from "scratch" to be a smart factory. I

am very exciting about that project. We are now working on closing a number of large projects in Vietnam and plan to open a branch office in Hanoi in early Fall of this year.

Las Marias: From Optimal Electronics, you rebranded to Optel Software. What's the rationale behind this?

Vujosevic: Our software's been called Optel for a long time, but Optimal Electronics Corporation was a little bit confusing for people. Some people are thinking we are doing PCB assembly, while some people are thinking bareboard manufacturing—we want to just let people know right away that we are a software company. So, we rebranded ourselves as Optel Software in China and the U.S., so everything now is branded as Optel Software, including our brochures and marketing materials.

Las Marias: While you were on your mission last year, what challenges did you encounter?

Vujosevic: Finding the right people. Even now, where we are growing, finding the right people is the most important thing. It is easy to find a customer and promise solutions, but if we fail because we did not hire the right people and we did not deliver on our promises, we will be out of business very quickly. Sales are going so well for us now that my main focus is to build up our organization in Asia and hire right people. We are hiring three more people in August for our Shenzhen office.

We are not going to oversell and under-deliver; whatever we can sell, we are going to implement successfully, and that will allow us to grow. We cannot have a single, unhappy customer and that is not easy to do. That is the biggest challenge for us. Chinese companies had not been treated well by our competition and there are a lot of unhappy Chinese customers with failed MES projects. We will not leave such customers behind us and we are now trying to educate them that there is a better alternative, there is a company that will work together with them to make them a better business.

Las Marias: So far this year, have you experienced any significant challenges?

Vujosevic: Our Chinese company is wholly owned by our American company, so we are not in partnership, and we do not have to disclose software secrets to anybody. We own our company in China. On the other hand, we will have to protect our IP and we are taking steps in that direction, using patents and trademarks, as much as we can. And we are introducing other types of protection for our software in different customer sites. So we are not seeing any obstacles. The company registration process has been slow, but bureaucracy is slow everywhere.

We are even finding people interested in investing in our company. We will see how much money we are going to need to grow, and we might even get investments from Chinese investors.

Overall, we have had great experience doing business in China. Our customers, prospects, contacts, relationships, Chinese people in general, as well as Sichuan and Hunan cuisines, are highlights of these past seven months. We love it here!

Las Marias: What has changed since our conversation last year, when you mentioned that you considered in the past establishing in China, but at the time you did not pursue it?

Vujosevic: In my opinion, China did not appreciate software 10-15 years ago. China wanted to buy the hardware; the software they thought could get some other ways. And I did not want any part of it. So, I left and did not come back for 12 years or so. Now, things are different. The owner of our first customer company told me, 'I need to reduce overhead by 40% to stay in business because the labor is getting more expensive.' Customers are demanding more cost cuts. Software will allow him to do that and provide better solutions. So, they are willing to invest in software where they were not willing to invest before. They were just throwing more people into any problem. That does not work in China, anymore.

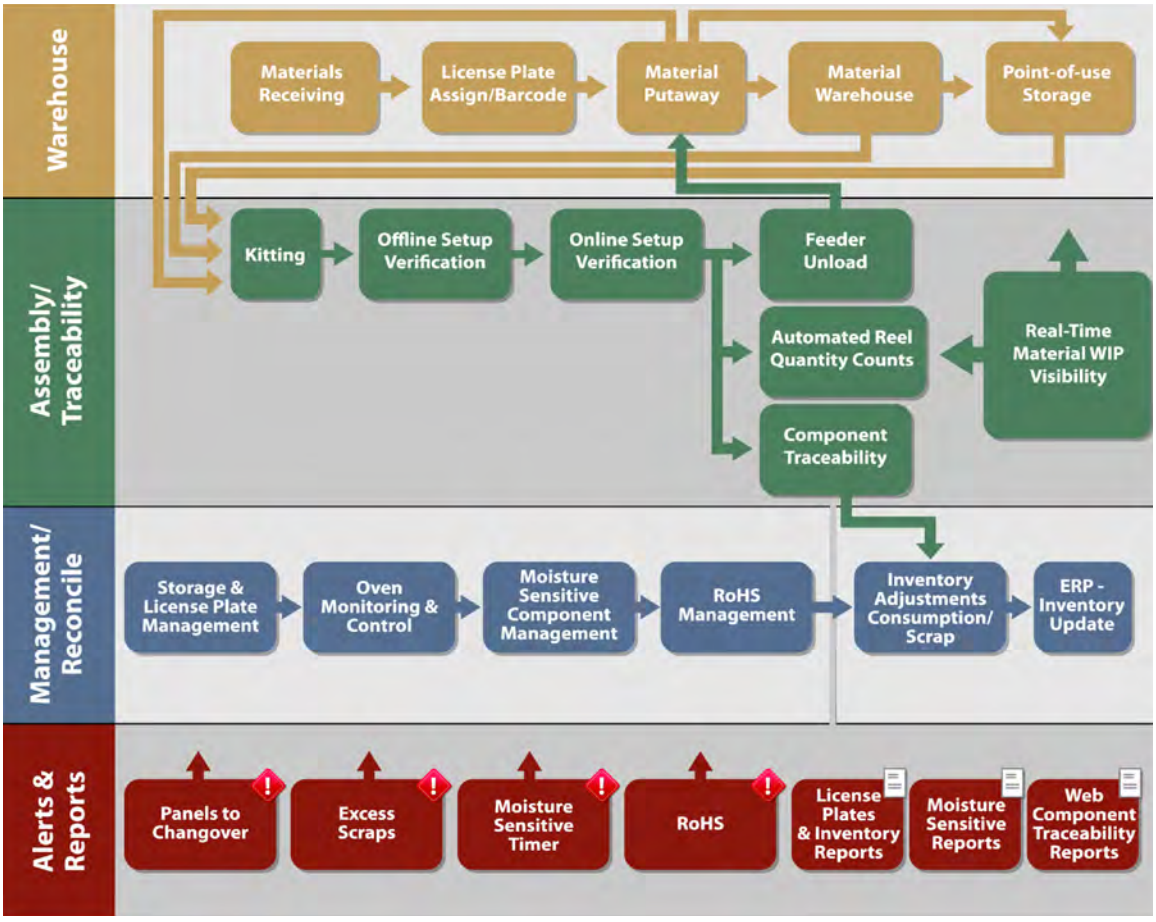

Figure 1: Optel's Materials Storage Management system provides a more granular control over materials inventory prior to the production process.

Las Marias: Last year, we talked about the lights-out electronics assembly facility. This year, we are seeing an increasing push towards Industry 4.0 and smart factories. Where is the industry now on this front?

Vujosevic: We have some big players that are investing in these technologies, such as Koh Young and ASM Assembly Systems, to name a few. We continue working on smart solutions. Our focus right now is in three directions: (1) intelligent production scheduling and real time performance monitoring; (2) self-correcting automated assembly lines with an intelligent process control, that will be able to self-correct process parameters before defects or down times actually occur; and (3) automated material delivery based on our intelligent scheduling and using latest in material storage, robots and automated guided vehicles. Our Vietnam projects will have all of these three solutions. You can say that we are pretty much following the blueprint I described in my "Lights Out Electronics Assembly" paper.

But, globally, it is still the same situation as last year. The pick-and-place systems are not there yet. They still need to have operators, and everything else can be pretty much automated. Until they solve that component placement problem, we will not have a completely automated line. But things can be done—not only to eliminate the operators, but to take them out of the decision-making loop if they must be present.

Las Marias: What other issues do you think needed ironing out for this smart-factory vision?

Vujosevic: Everything will start and finish with the software. The two components, in my opinion, are the pick-and-place equipment and the software. Pick-and-place equipment, if we

are still doing with the reels and feeders, that is not going to be automated anytime soon. But the software is also the problem. I am not a big believer that AI will create some emerging groundbreaking solutions in electronics manufacturing. I believe in human intelligence more than I believe in AI. Humans will develop better software, but fundamental science and better designs are needed, not gimmicks. For pick-and-place vendors, to completely redesign everything is a major undertaking on their side. I do not know if they are willing to do that. And I do not know if they have ideas how to do that. Without them doing that, we are not going to get to a completely automated line.

Las Marias: How are you helping companies begin their journey towards smarter manufacturing?

Vujosevic: That is what we are trying to provide globally—smart factory software solutions.

For example, we just developed a vision-based system for receiving materials, where there is no operator typing in and scanning the date code, lot code, etc., to create the material label. We just let cameras scan everything, then create and print the label, without the possibility for error. Our customers report that just at the receiving side, there are a lot of mislabeling issues that are happening. They are placing the wrong parts. We are eliminating that using a vision-based labeling system.

We also put in production an interface with SAP that allows us to download a finished goods BOM with all data and dependencies to be able to collect and report traceability data on multi work order level in SMT and backend operations. We can now model the largest electronics assembly operations and allow our customers to meet the toughest traceability requirements. Two themes that we hear over and over in our sales meetings from our prospects: help us reduce material and overhead cost, and help us meet traceability requirements.

And we will also continue to use AI solutions everywhere.

Everything we are doing has one goal: help our customers be better businesses.

Las Marias: What are some of the market trends that will drive the growth of the electronics manufacturing industry here in the region?

Vujosevic: Last year, we talked about the absence of new products. This year, there are still no new products. We are just recycling cellphones. We need some new electronics products, something that will make people excited, that will make people go out and buy. I have a phone that is five years old, and I am not going to change it because it works fine for me.

People want to be part of something exciting. And we do not have anything exciting now unless you include flying toys, or drones. What else is exciting these days? Maybe going to Mars will be exciting because it will involve a lot of electronics, but not on an enough large scale. I am not going to live long enough to see that. But, if there is a sign up list to go to Mars tomorrow, even if it is a one way trip, I would sign up. People want to be inspired. People want to be part of something big. But something extraordinary that will excite people to go out and buy more electronic products, that will drive the electronics manufacturing growth - we do not have much these days.

Las Marias: What about autonomous vehicles?

Vujosevic: That is going to eliminate drivers, but we will see what impact that will have on growth of the electronics manufacturing industry. It is going to be a long time to get to that point, especially with some of its drawbacks. But that is expected with anything new. There is an infrastructure that is needed for that to be in place, in addition to the cars.

Las Marias: Alright, thank you very much, Dr. Vujosevic. It was great speaking with you again.

Vujosevic: Thank you very much. **SMT007**

1 Seeing Clearly: XR Headsets and Flex's Reference Design at AWE ▶


Dan Feinberg

At this year's CES, they announced the launch of an extended reality (XR) reference design for the next generation of XR headsets.

2 Raising the Capability Ceiling: SMTA Upper Midwest Chapter Expo ▶

An energetic and engaged crowd filled the recent SMTA Upper Midwest Expo & Tech Forum. The event, held in June 14 in Minneapolis, Minnesota, hosted 57 exhibiting companies and had over 100 pre-registered attendees. The underlying theme for the technical presentations was "Raising the Capability Ceiling!" Here's a wrap-up of the event.

3 Is There an End in Sight to the Electronic Components Crisis? ▶


Neil Sharp

As new and innovative technology continues to evolve on a daily basis, the need for electronic components has reached unprecedented levels, with passive manufacturers in particular among those struggling to cope with demand. Electronic component shortages are now such an issue that many OEMs are predicting their forecasted growth for 2018-2019 will be thwarted if they are unable to source the parts they need.

4 DFM: Top Ten PCB Concerns ▶

DFM—design for manufacturability—is a critically important but often ignored aspect of the PCB design process that directly impacts product quality and reliability. This article will discuss the top 10 DFM concerns that should be part of any design review process.

5 President Trump Announces 25% Tariff Imposition on Chinese Imports ▶

President Donald Trump announced that he will impose 25% tariffs on Chinese imports worth roughly $50 billion. The tariffs, first proposed in April, are the result of a Section 301 investigation that found China's technology transfer policies had harmed U.S. companies.

6 Dave Bergman on IPC and CFX ▶


David Bergman

The recent SMT Hybrid Packaging show in Nuremberg, Germany, marked the second opportunity for IPC to showcase its new Connected Factory Exchange (CFX) initiative. In this interview, David Bergman, VP for international relations at IPC, tells us more on the overall reception of CFX and the benefits users are seeing thus far. He also provides an update on what's next for the open source standard.

7 Jabil's Geoffrey Doyle to Keynote SMTA Capital Chapter Expo and Tech Forum ▶

The SMTA Capital Chapter is pleased to announce Geoffrey Doyle of Jabil Circuit Inc. as keynote speaker for the upcoming Capital Expo and Tech Forum at Johns Hopkins University/Applied Physics Lab, Kossiakoff Center, on Thursday, August 23.

8 Sanmina Wins Award from Fujitsu Network Communications ▶

Sanmina received this award for its close collaboration with Fujitsu on the design and engineering of a wide range of printed circuit board solutions. Sanmina has been providing Fujitsu with advanced PCB technology for more than 20 years.

9 SMTA Capital Chapter's Expo and Tech Forum Set for August 23 ▶

The SMTA Capital Chapter is pleased to invite you to its upcoming Capital Expo and Tech Forum at Johns Hopkins University/Applied Physics Lab, Kossiakoff Center, 11100 Johns Hopkins Road, Laurel, MD 20723, on Thursday, August 23.

10 Flex Receives Lenovo Diamond Award ▶

Flex recently received the Diamond Award, the highest recognition Lenovo presents to select global suppliers and partners, for the delivery of high quality, on time, innovative support and outstanding services.

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- Located in Mexico
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- 3+ years of sales experience
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- Produce service reports
- Cooperate with technical team and share information across the organization
- Assist with the crating and uncrating of equipment

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Job Qualifications:
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- Strong writing and editing skills with experience in PCB design technologies
- Desktop publishing skills (InDesign) using project templates and knowledge of online publications and social media
- A technical background (B.S. in electrical engineering or computer science preferred; this role works closely with the PCB division's technical marketing engineers and managers
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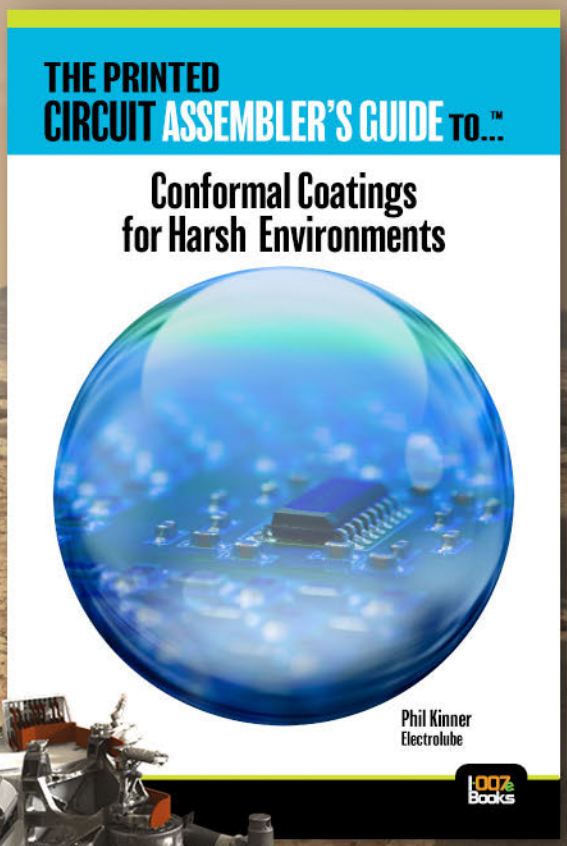

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Events Calendar

SMTA Capital Expo & Tech Forum ▶
August 23, 2018
Laurel, Maryland, USA

IPC Southeast Asia High Reliability Conferences 2018 ▶
August 26, 2018 – Ho Chi Minh, Vietnam
August 31, 2018 – Bangkok, Thailand

NEPCON South China 2018 ▶
August 28–30, 2018
Shenzhen, China

PCB West 2018 ▶
September 11–13, 2018
Santa Clara, California, USA

IPC E-Textiles 2018 Workshop ▶
September 13, 2018
Des Plaines, Illinois, USA

electronica India 2018 & productronica India 2018 ▶
September 26–28, 2018
Bangalore, India

IPC Southeast Asia High Reliability Conferences 2018 ▶
September 26, 2018 – Singapore
November 1, 2018 – Penang, Malaysia

18th Annual NW Electronics Design & Manufacturing Expo ▶
October 3, 2018
Tektronix, Beaverton, Oregon, USA

SMTA International ▶
October 14–18, 2018
Rosemont, Illinois, USA

International Wafer-Level Packaging Conference Exhibition ▶
October 23–24, 2018
San Jose, California, USA

IPC/SMTA High-Reliability Cleaning and Conformal Coating Conference ▶
November 13–15, 2018
Schaumburg, Illinois, USA

Additional Event Calendars

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